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Accelerated Shelf-life Testing of Balado Potato Chips Using Arrhenius Model Approach

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ABSTRACT

In order to assist food diversification initiatives, boost farmer incomes, provide non-oil and gas export commodities, and provide processed industrial raw materials, potatoes have the potential to be exploited as a commodity. Balado potato chips are one of the typical and well-liked processed potato items among Indonesians. The importance of product safety (food safety) in the form of shelf life information must obviously be taken into account since the product will ultimately be ingested. The incubator used to incubate the product samples has three storage temperatures: 25°C, 30°C, and 45°C. For a period of 28 days (days 0, 7, 14, 21, and 28), samples were examined for hedonic parameters, FFA levels, and water content every 7 days. The product shelf life at 25 °C, 30 °C and 45 °C respectively 37, 36 and 32 days. it is recommended that potato chip products be stored in closed packaging and stored in a cool place and avoid being stored in a place exposed to sunlight which will affect storage temperature and also free fatty acid levels which can cause rancidity.

Keywords: *ASLT; Potato; Chips; Shelf-life*

INTRODUCTION

Indonesia as a country with a tropical climate has a wealth of diverse natural resources and one of them is rich in agricultural commodities which are a source of carbohydrates. Indonesian people are very dependent on rice as a source of carbohydrates, but actually, there are many other commodities that can also be a source of carbohydrates and are quite popular among the people, one of which is potato. With roughly 5,000 different types globally, potatoes are the fourth most popular staple food in the world (Zaheer & Akhtar, 2016). Potatoes, which are high in carbohydrates, are also a good source of protein, fiber, vitamin C, vitamin E, vitamin B6, calcium, phosphorus, iron, magnesium, potassium, calcium, iodine, zinc, copper, and manganese (Kaplan et al., 2018). Additionally, it includes bioactive substances such tocopherols, tocotrienols, carotenoids, polyamines, phytonutrients, and phenols, polyphenols, and polyphenols. (Furrer et al., 2018).

Apart from being a source of carbohydrates, potatoes have the potential to be developed to support food diversification programs. Total potato production in 2020 reached 1.28 million tons and one of the provinces with the largest level of supply was West Java with a total of 196,856 tons (Kiloes et al., 2016).

Potatoes like other agricultural products after the harvest process will still experience metabolic processes such as respiration and transpiration processes. Besides that, chemically, potatoes have a high enough water content that makes them easily damaged during the post-harvest stage (Hana, 2022). Antibrowning agents, firming agents, stabilizers, antioxidants, and antimicrobials are just a few of the acidulants that slow down the physical degradation of the tissues in fruits and vegetables. (Sandarani et al., 2013). Processing into a ready-to-consume product is one of the efforts to avoid wasting potatoes and at the same time is one of the efforts to support the food diversification program.

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Processed potato products that are typical and popular with Indonesian people are balado potato chips. The stages of the potato chip production process include sorting, first washing, peeling, second washing, slicing, soaking, third washing, frying and packaging (Rosmeli et al., 2021).

Potatoes that have been processed into chips will have a relatively low water content and aw (water activity) so that the product will last longer. However, because this product is processed through a frying process, it will have a fairly high fat content. These properties cause potato chips to become rancid easily and their crispiness decreases when in direct contact with oxygen, light, or due to changes in temperature (Herawati et al., 2017).

The importance of product safety (food safety) in the form of shelf life information must obviously be taken into account since the product will ultimately be consumed and marketed (BPOM, 2018). Technically, the Accelerated Shelf Life Test (ASLT) method of the Arrhenius model involves estimating the shelf life by incubating the product at a high temperature for a predetermined amount of time. By accelerating the reaction that damages the product, this method can measure the shelf life more quickly and precisely. All sorts of food goods can use the Arrhenius model's Accelerated Shelf Life Test (ASLT) approach, especially those whose quality has declined as a result of chemical deterioration.. Shelf life estimation using the Arrhenius model can be described as the relationship between temperature and deterioration rate (Herawati et al., 2017). Another advantage of the shelf life analysis using this method is that it produces an equation that can be used to estimate the shelf life at various storage temperature conditions (Asiah et al., 2018).

METHODS

The research was conducted based on the Accelerated Shelf Life Test (ASLT) concept with the Arrhenius approach model and the parameters used were chemical parameters which included water content, Free Fatty Acid (FFA) and hedonic test to determine the value of the final quality characteristics.

Implementation of research on estimating shelf life is carried out with the following steps.

1. Initial stage of storage, a hedonic (favorite) test was carried out consisting of the parameters of color, aroma, crispness and taste which were tested on 10 semi-trained panelists and chemical analysis was carried out through testing for FFA and water content so that the value of the initial quality characteristics (A0) of chips could be obtained balado potatoes. The following are the assessment criteria for the preference test.

Table 1. Preference Test Assessment Criteria

Hedonic Scale	Numerical Scale
Very dislike	1
Dislike	2
Rather dislike	3
Neutral	4
Rather like	5
Like	6
Very like	7

2. The Accelerated Shelf Life Test (ASLT) method is the foundation for determining shelf life. Samples were incubated in an incubator at different temperatures of 25°C, 30°C, and 45°. Parameter analysis was carried out as in point number 1 (hedonics, FFA content, and water content) every 7 days for 28 days (days 0, 7, 14, 21, and 28).

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3. The value of the final quality characteristics (At) is determined by carrying out a hedonic test, namely when the preference score for each parameter in the Balado potato chip product shows a value of 3 (somewhat dislikes) from 50% of the panelists, it is assumed that the product is unacceptable by consumers. At the same time, tests for FFA and water content were carried out where the results of the analysis were the final quality characteristic values (At).
4. The test result data is then processed using the Accelerated Shelf Life Test (ASLT) method with the Arrhenius approach model.

Material

The Balado potato chip product used in this study was obtained from SMEs in the Cibeunying Kidul sub-district, Bandung City. Potato chip products are produced through stages consisting of sorting, first washing, peeling, second washing, slicing, soaking, third washing, frying, preparation and cooking of balado seasoning, mixing and packaging. The products were packaged in a plastic container made from PP thin wall which was covered with plastic wrap. The chemicals used were distilled water, NaOH Pro Analis Merck, Phenolphthalein Indicator Merck, and silica gel.

Tool

The tools used in this study included knife, gas stove, frying pan, plastic container, incubator, oven, Duran desiccator, crustang, KERN analytical balance capacity 210g and readability 0,1mg, Boshead clamp, Boshead stative, Iwaki Erlenmeyer flask, and Iwaki burette.

RESULT AND DISCUSSIONS

Product quality end point

A 28-day incubation period was used for the product samples, which were incubated in an incubator at three distinct temperatures: 25, 30, and 45 degrees Celsius.. Products with the most critical storage conditions (45°C) were hedonic tested on days 0, 7, 14, 21, and 28 with parameters of color, aroma, crispness and taste to determine the end point of the product being no longer accepted by consumers sensory or sensory. At each storage temperature and with the same storage time, the product is tested chemically with the parameters of water content and FFA (Free Fatty Acid). The results of hedonic testing during storage are presented in Table 2

Table 2. Hedonic Scale during Storage

Days-	Color	Aroma	Crispiness	Flavor	Average
0	6.8	6.7	6.7	7	6.8
7	6.3	6.7	6.5	6.6	6.5
14	5.6	6.3	5.9	6.1	5.9
21	4.2	4	3.9	3.5	3.9
28	3.8	3.2	2.3	3.0	3.0

Table 2 shows the results that the product after being stored until the 28th day received a score of 3 (rather disliked) so that the results of the analysis on the 28th day can be used as the value of the final quality characteristics of the product.

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Water content and Free Fatty Acid (FFA)

To determine the shelf life based on certain parameters, parameter values are needed during storage in the form of zero and first order reactions (Kusnandar & Adawiyah, 2010). The results of the analysis of water content and FFA at order zero and order one are summarized in Table 3 and Table 4 respectively.

Table 3. Water content during Storage

Days-	Ordo 0			Ordo 1		
	25°C	30°C	45°C	25°C	30°C	45°C
0	1.108 %	1.108 %	1.108 %	0.103	0.103	0.103
7	1.067 %	0.910 %	0.818 %	0.065	-0.094	-0.201
14	0.971 %	0.865 %	0.797 %	-0.029	-0.145	-0.227
21	0.993 %	0.794 %	0.562 %	-0.007	-0.231	-0.576
28	0.562 %	0.446 %	0.261 %	-0.576	-0.807	-1.343

Table 4. FFA during Storage

Days-	Ordo 0			Ordo 1		
	25°C	30°C	45°C	25°C	30°C	45°C
0	0.328 %	0.328 %	0.328 %	-1.115	-1.115	-1.115
7	0.338 %	0.340 %	0.397 %	-1.085	-1.079	-0.924
14	0.349 %	0.350 %	0.435 %	-1.053	-1.050	-0.832
21	0.402 %	0.410 %	0.439 %	-0.911	-0.892	-0.823
28	0.587 %	0.689 %	0.706 %	-0.533	-0.373	-0.348

Moisture value may decrease during incubation. The water content can be affected by temperature, with the higher the temperature as well as the longer the storage time causing greater evaporation of water from within the material (Wijayanti et al., 2011).FFA (Free Fatty Acid) are formed from the oxidation process and enzymatic hydrolysis in potatoes which are triggered by processing and storage processes. The FFA value of balado potato chips during storage ranges from 0.3% - 0.7%. When compared to regular potato chips, the FFA value ranges from 0.2% - 1.2% (Fajriyani et al., 2019) and for french fries it ranges from 0.2% - 0.7% (Mahmudan & Nisa, 2014). The FFA content will increase during storage. High FFA will simultaneously reduce product quality (Fajriyani et al., 2019).

Cooking oil is a medium in the frying process as well as being part of the food product itself. During the frying process, oil as the medium will easily experience oxidation. Cooking oil will decrease in quality along with the longer use. One of the damage caused is the increased levels of free fatty acids or FFA. The high free fatty acids will affect the quality of production. Rancidity and increased levels of cholesterol in the oil will be absorbed and become part of the product, this causes the product to experience a decrease in quality more easily (Maharani et al., 2012).

Rancidity occurs due to thermal oxidation which begins with the formation of free radicals in the product. Fat molecules which contain free radicals will oxidize unsaturated fatty acids and cause rancidity in the product (Moniharapon, 2018).

It is possible to delay the start of rancidity, but the product needs to be shielded from oxygen and light, both of which accelerate fat oxidation. Water influences the mechanical strength of the product by plasticizing and softening the starch/protein matrix, which changes the texture of the snack foods. Use of effective moisture barrier films can stop the loss of crispness. (Dunno et al., 2016) .

The order of reaction was determined by graphing the two orders by plotting the parameter data for each order with the length of storage, then creating a linear regression equation and determining the value of the coefficient of determination (R^2). The regression equation and the coefficient of determination on the parameters of water content and FFA can be observed in the following table.

Table 5. Regression Equation and R^2 Value of Water Content Parameters

Storage Temperature (°C/°K)	Regression Equation		R^2	
	Ordo 0	Ordo 1	Ordo 0	Ordo 1
25/298	y = -0.1166x + 1.29	y = -0.1429x + 0.3398	0.7118	0.6634
30/303	y = -0.144x + 1.2566	y = -0.1956x + 0.3519	0.888	0.8151
45/318	y = -0.195x + 1.2942	y = -0.3267x + 0.5311	0.9479	0.867

Table 6. Regression Equation and R^2 Value of FFA Parameters

Storage Temperature (°C/°K)	Regression Equation		R^2	
	Ordo 0	Ordo 1	Ordo 0	Ordo 1
25/298	y = 0.0582x + 0.2262	y = 0.1337x - 1.3405	0.7269	0.7748
30/303	y = 0.0792x + 0.1858	y = 0.1672x - 1.403	0.6806	0.7376
45/318	y = 0.0798x + 0.2216	y = 0.1634x - 1.2986	0.7675	0.8346

Based on Tables 5 and 6, the R^2 value for the water content parameter is higher at ordo 0, while the FFA parameter is higher at ordo 1. The next analysis stage was chosen based on the highest R^2.

Table 7. The value of k and ln k parameters of water content

Storage Temperature (°C)	k	ln k	T(°K)	1/T
25	0.1166	-2.149	298	0.00336
30	0.144	-1.937	303	0.0033
45	0.195	-1.634	318	0.00314

Table 8. The k and ln k values of the FFA parameters

Storage Temperature (°C)	k	ln k	T(°K)	1/T
25	0.1337	-2.012	298	0.00336
30	0.1672	-1.815	303	0.0033
45	0.1634	-1.811	318	0.00314

The slope value in the regression equation is the value of k or a constant which indicates the rate of change of water content and FFA (Puspitasari et al., 2020). When the k value is ln (natural logarithm) and plotted in graphical form with 1/T (in Kelvin units) at the three storage temperatures, the Arrhenius equation is obtained based on the regression equation (Asiah et al., 2018). The values of k, ln k, and 1/T of the two parameters can be observed in Table 7 and Table 8 respectively. Then the values of ln k and 1/T and the graph of the relationship between the two can be observed in the following figure.

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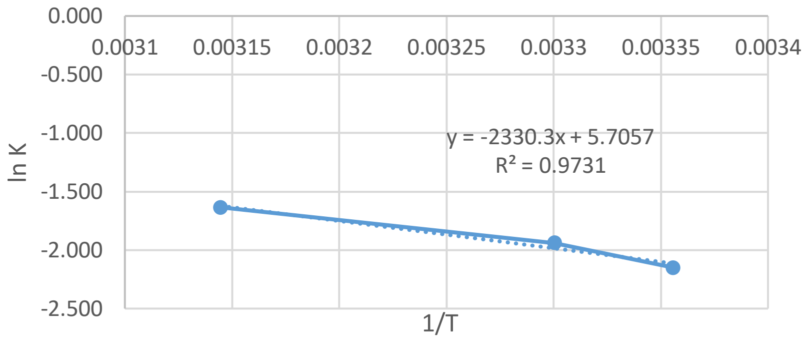

Figure 1. ln k to 1/T Water Content Parameters

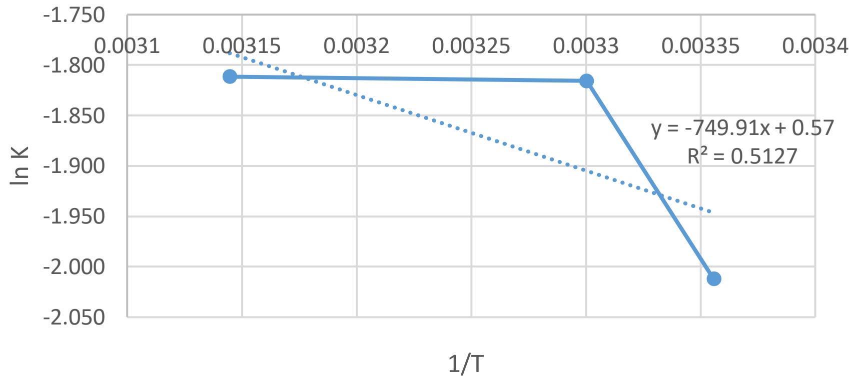

Figure 2. ln k to 1/T FFA Parameters

Based on the regression equation on the graph ln k to 1/T(°K) it can be seen that the Arrhenius equation generally has the equation formula ln k = -Ea/R (1/T) + ln ko. The Arrhenius equation and the parts of the equation are shown in Table 9

Table 9. Arrhenius Equation and Activation Energy Value of Water Content and FFA Parameters

Component Analysis Result	Analysis Component	
	Water Content	FFA
Regression Equation ln k vs 1/T(°K)	y = -2330.3x + 5.7057	y = -749.91x + 0.57
Coefficient of Determination (R^2)	0.9731	0.5127
Arrhenius Equation	ln k = -2330.3x + 5.7057	ln k = -749.91x + 0.57
Ea/R(K)	2330.3	749.91
R (Ideal Gas Constant) (cal/mol°K)	1.986	1.986
Ea (Energy activation) (cal/mol)	4627.976	1489.321
ln ko	5.7057	0.57

Activation energy can be interpreted as the energy value required to reduce product quality in certain parameters so that it will have a low value if it is easily damaged because reactions that cause damage will run faster (Asiah et al., 2018). The parameter for degradation of the quality of Balado potato chips which was determined to be the key parameter for determining the shelf life of the product was FFA with an activation energy of 1489.321 cal/mol.

Once determined, then it is necessary to know the value of k (degrade rate) at each storage temperature (25°C, 30°C, and 45°C) by using the Arrhenius FFA equation and paying attention to the initial formula of the Arrhenius equation, namely ln k = -Ea /R (1/T) + ln ko.

Table 10. Final Analysis Results and Product Shelf Life

Storage Temperature (°C)	k	Ao	At	In Ao	In At	t	Shelf life (days)
25	0.1427					5.369	37.58
30	0.1488	0.328	0.706	-1.115	-0.348	5.150	36.05
45	0.1672					4.583	32.08

Based on Table 10 above, it can be observed the final results of the product shelf life analysis based on the Accelerated Shelf Life Test (ASLT) principle of the Arrhenius model. If it is assumed that the product is conditioned at room temperature ±25°C, the shelf life of balado potato chips is 37 days. Compared to other products, namely regular potato chips, the shelf life is 28 days (Fajriyani et al., 2019), coconut chips have a shelf life of 18 days (Puspitasari et al., 2020), and tempeh chips 97 days (Kiloes et al., 2016).

Differences in the content of the material affect these differences. The starch content in the product has a role as the main part of the dry matter to improve quality, especially the texture of chips where a low starch content will result in less crunchiness chips or a higher water content. The type of packaging also affects the shelf life of the product because the different polymer components that make up the packaging will affect the permeability properties of the packaging which will affect the water absorption properties of the environment (Fajriyani et al., 2019).

CONCLUSION

The parameter for degradation of the quality of Balado potato chips which was determined to be the key parameter for determining the shelf life of the product was FFA with an activation energy of 1489.321 cal/mol. The final result of product shelf life analysis is based on the Accelerated Shelf Life Test (ASLT) principle of the Arrhenius model. The product shelf life at 25 °C, 30 °C and 45 °C respectively 37, 36 and 32 days. It is recommended that potato chip products be stored in closed packaging and stored in a cool place (25 °C) and avoid being stored in a place exposed to sunlight which will affect storage temperature and also free fatty acid levels which can cause rancidity.

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