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Estimating Shelf Life of Anchovy Savory Chips Based on Sensory and Microbes Data Using the Arrhenius ASLT Method

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ABSTRACT

Savory fish chip is one of the fish-based snacks with additional. One of the problems that often occur in chip products is that excessive oil absorption during the frying process can cause changes in texture and rancidity after storage. Based on these problems, it is necessary to test the shelf life of savory fish chip products as a preventive step to ensure they remain viable. Therefore, this study aims to estimate the shelf life of anchovy savory chip products using the ASLT Arrhenius method. Shelf-life testing was carried out by storing the product in polypropylene plastic and given vacuum and non-vacuum treatments then stored at three different temperatures, 30, 40, and 50℃ for 6 weeks. At each week, chemical (fat content, free fatty acids, moisture content), physical (crispness), sensory (taste, odor, appearance, texture), and microbiological were tested. After being tested, it was found that the shelf life of anchovy savory chips in non-vacuum polypropylene plastic packaging was 50 days at 30℃. Meanwhile, the shelf life in polypropylene plastic packaging under vacuum conditions is 82 days at 30℃. This information suggests anchovy savory chips should be stored in polypropylene plastic packaging with vacuum conditions.

1. INTRODUCTION

Fish is one of the highest protein and fatty acid foods, such as omega 3 and omega 6, which are very important for the human body. Even when compared between the quality of fish and meat, both are comparable because they have a good role in the human body [1]. One type of fish that contains many benefits and is easily available in Indonesian marine waters is anchovy. Anchovies are generally often utilized both in the form of fresh and dried fish. This potential anchovy resource in Indonesia is an opportunity for anchovy business development. Anchovy business development can be done through the anchovy preservation process by coating and frying to produce anchovy savory chips. With this process, it is expected to extend the durability and shelf life of anchovy products.

Savory fish chip is one type of snack innovation made from fish with other additives, which has a savory taste and crunchy texture. Crispness is the main characteristic of chip products [2]. Generally, savory fish chip products have a long shelf life but are still at risk of oxidation. One of the problems that often occurs in chip products is that excessive oil absorption during the frying process can cause changes in texture and rancidity after storage. In addition, marine products such as anchovies also contain a lot of unsaturated fatty acids which are very easy to cause oxidation, thus affecting product quality [3].

Based on these problems, information on the shelf life of anchovy savory chips products is needed as a preventive measure to ensure that the product remains viable and has not been damaged. Shelf life is a time for products that are still acceptable both in terms of sensory and nutrition. The process of estimating shelf life can be done by accelerated methods or Accelerated Shelf-life Tests (ASLT) and conventional methods or Extended Storage Studies (ESS). The most commonly used method to estimate shelf life is the Arrhenius approach ASLT method because this method can accelerate the reaction of food product quality decline until the storage time is found [4].

Estimation shelf life with the Arrhenius method is used to determine the accurate shelf life of products by accelerating quality deterioration through temperature differences in storage. The Arrhenius approach is generally applied to all types of food products, especially to products that experience quality loss due to chemical deterioration effects, such as fat oxidation, nutrient degradation, etc. The selection of temperatures 30, 40, and 50℃ in this study was carried out to accelerate the decline in product quality until the right correlation was found in determining the shelf life. Producers and consumers need this shelf-life information because it is closely related to product quality [5]. Therefore, this study aims to estimate the shelf life of anchovy savory chips products using the Arrhenius Accelerated Shelf-life Test (ASLT) method.

2. RESEARCH METHODOLOGY

2.1 Materials and tools

The main ingredient used is fresh anchovies from Pasaran Island, Bandar Lampung. Anchovies are selected that have bright or shiny colors, clear and clean eyes. Coating materials, auxiliary materials, seasoning, and polypropylene plastic 0.1 thickness are from Karang City, Bandar Lampung. The tools used for analysis were erlenmeyer, analytical balance, hot plate, measuring cup, fat flask, soxhlet, test tube, tweezers, vacuum machine, porcelain cup, oven, filter paper, stative clamp, burette, hardness tester, micropipette, petri dish, and incubator.

2.2 Research location

The research was conducted at KUB Melati Bahari Pulau Pasaran, Bandar Lampung, LPPMHP of Lampung Province Marine and Fisheries Office and Laboratory of Agricultural Product Technology of Lampung State Polytechnic from December 2016 to May 2017.

2.3 Procedure for making savory chips

The research on making savory chips was carried out in two stages. In the first stage, battered flour is made, which begins with the process of mixing rice flour (133 grams) with tapioca flour (67 grams). After mixing the flour, garlic powder (12 grams), salt (10 grams), pepper powder (9 grams), coriander powder (6 grams) and baking soda (3 grams) were added. After that, the mixing process is carried out until evenly distributed. In the second stage, savory chips are made by cleaning and draining 200 grams of anchovies. Next, anchovies are coated with egg white and then coated with coating flour (battered). After evenly coated, deep frying is done at 180℃ for 5 minutes. Anchovy savory chips are ready to be packaged.

2.4 Data collection method

Data collection is done descriptively from the results of product testing. Anchovy savory chips that have been packaged with polypropylene plastic in vacuum and non-vacuum conditions are then tested for shelf life. Polypropylene packaging is known to be quite good for use with dry foods due to its properties of being resistant to fats, moisture-proof, and stable at high temperatures compared to other types of packaging. A comparison between vacuum and non-vacuum packaging needs to be analyzed to consider the durability, safety, and practicality in selecting the best packaging for a product. Shelf-life testing on the product is carried out by the Arrhenius ASLT method which stores the product at three different temperatures, such as 30, 40, and 50℃ for 6 weeks. Each week, chemical testing (fat content, moisture content, free fatty acids), physical testing (crispiness), sensory testing (appearance, odor, texture, taste), and microbiological testing (ALT) were conducted. After obtaining all these data, a shelf-life calculation can be made to determine the appropriate shelf life and packaging of anchovy savory chips products.

2.5 Methods of analysis

2.5.1 Chemical test

Analysis of moisture content in anchovy savory chips is carried out using the gravimetric method. Analysis of fat content in anchovy savory chips was carried out using the soxhlet method. Analysis of free fatty acid content in anchovy savory chips was carried out using the alkalimetric titration method. Processing of the results of chemical testing is done descriptively.

2.5.2 Crispness test

The crispness test was conducted using a hardness tester. Anchovy savory chips are placed in the hardness tester, then the needle is inserted into the product for 5 seconds. The number indicated by the hardness tester is the crispness value, where the smaller the value obtained, the better crispness level. Processing of the results of the crispness test was done descriptively.

2.5.3 Sensory test

The savory chips anchovy sensory test was conducted on several parameters, including appearance, odor, taste, and texture. These criteria, also known as assessment attributes, are general criteria that make it easier for panelists to identify the sensors of each savory chips [6]. Sensory testing used in this product is a scoring test using an acceptance scale of 1 to 9. This assessment was carried out using 15 semi-trained panelists or students who have understood and received sensory testing courses. Data processing of sensory results is done descriptively.

2.5.4 Total plate number (ALT)

Microbiological testing in the form of total plate numbers is based on information from study [7]. The test was carried out using a Petri dish containing a sample solution and then added 12-15 ml of PCA (Plate Count Agar) and arranged upside down. Next, the dish was put into an incubator at 37℃ for 48 hours. After incubation was complete, the total number of bacteria that grew was counted using a colony counter. Data processing of ALT results is done descriptively.

2.5.5 Shelf-life testing

Shelf-life testing was carried out at temperatures of 30, 40, and 50℃ for 6 weeks. The observation results obtained were 6 observation points from each chemical, physical, sensory, and microbiological test and then plotted on the quality change curve and shelf life until a linear equation y=a+bx was obtained. After all the observations find the linear equation, then proceed with determining the order of the reaction by looking at the largest R^2 value. Next, the calculation with the Arrhenius equation is done by plotting the k curve or constant (ln k) with temperature (1/T) so that the equation y=a+bx or ln k=ln ko-(Ea/R) (1/T) is produced. Finally, the step in estimating the shelf life obtained from the change in quality before storage and after storage is divided by the value of k [5]. The formulas for determining shelf life is as follows:

$$t=(At-A0)/k, \text{ order } 0 \quad (1)$$

$$t=(\ln A0/\ln At)/k, 1^{st} \text{ order} \quad (2)$$

3. RESULT AND DISCUSSION

3.1 Quality characteristics of anchovy savory chips

Savory chips are one of the nutritious innovation products. Before storage, anchovy savory chips were first observed

regarding chemical tests (fat content, free fatty acid content, moisture content), physical tests (crispness), sensory tests (odor, appearance, texture, taste), and microbiological tests (ALT). The test results obtained data are presented in Table 1.

Table 1. Quality characteristics of anchovy savory chips before storage

Parameters	Analysis Result	Requirements
Moisture content	2.55%	Max 5% [8]
Fat	27.86%	Max 30% [8]
Free fatty acids	0.196%	Max 0.7% [9]
Crispness	0.27 kg/10^5 mm	1.90 kg/10^5 mm
Appearance	8.42	Min 7 [8]
Odor	8.33	Min 7 [8]
Flavor	8.33	Min 7 [8]
Texture	8.33	Min 7 [8]
ALT	0.5×10^1 colonies /g	Max 5.0×10^4 colonies /g

Based on the table, it can be seen that the moisture content of anchovy savory chips is 2.55%, based on study [8], the maximum moisture content of crispy fish is 5%. Furthermore, the results of the analysis of fat content of anchovy savory chips amounted to 27.86%, also still meeting the standards required by study [8], namely the maximum fat content of crispy fish is 30%. The results of the analysis of free fatty acids of savory chips amounted to 0.196% and met the quality standards based on study [9] which requires dry food products to have a maximum fatty acid content of 0.7%. The crispness of anchovy savory chips is 20.27 kg/10^5 mm, where the smaller the value of the analysis results, the better the crispness level. The results of sensory testing of anchovy savory chips, the appearance score is 8.42; the odor score is 8.33; the taste score is 8.33, and the texture score is 8.33. Study [8] sets the sensory quality requirements of each at a minimum of 7.00. Finally, the ALT test was conducted to determine the number of bacteria in anchovy savory chips and the ALT test result was 0.5×10^1 colonies / g. This result still meets the maximum quality standard for savory chips. This result still meets the maximum quality standard of anchovy savory chips which is 5.0×10^4 colonies/g [8].

3.2 Shelf-life estimation of anchovy savory chips

Shelf-life estimation is one way to identify the period a product is used between production and consumption. The storage time indicates that the product is still acceptable and safe for consumption [10].

3.2.1 Determination of reaction order

The ASLT method with the Arrhenius equation, generally applies kinetic theory and often uses reaction orders, namely reaction order zero (linear) and reaction order one (exponential) for food products. According to the zero-order reaction model, most types of deterioration are characterized by enzymatic degradation, non-enzymatic browning, and fat oxidation reactions. Meanwhile, first-order reactions generally include types of deterioration, such as rancidity in dried vegetables and salad oil, growth of microorganisms and death of microorganisms due to heat application, loss of vitamins, and loss of protein quality in dried foods [11]. Based on this information, the following process of determining the order of reaction in estimating the shelf life of anchovy savory chips can be seen in Table 2.

Table 2. Line equation of anchovy savory chips quality degradation and R^2

Quality Parameters	Packaging Treatment	Storage Temperature	Ordo 0			Ordo 1		
		(℃)	k	b	R^2	k	b	R^2
Water content	Non Vacuum	30	0.034	3.633	0.962	0.008	1.294	0.949
		40	0.025	3.588	0.981	0.006	1.280	0.975
		50	0.017	3.567	0.994	0.004	1.273	0.992
		Average	0.025	3.596	0.979	0.006	1.282	0.972
	Vacuum	30	0.022	3.510	0.988	0.006	1.260	0.991
		40	0.013	3.552	0.986	0.003	1.268	0.984
		50	0.011	3.508	0.857	0.003	1.257	0.857
		Average	0.015	3.523	0.944	0.004	1.262	0.944
Fat content	Non Vacuum	30	0.327	28.156	0.954	0.016	3.374	0.926
		40	0.375	27.943	0.972	0.020	3.384	0.933
		50	0.453	28.261	0.958	0.026	3.414	0.941
		Average	0.385	28.120	0.961	0.021	3.391	0.933
	Vacuum	30	0.240	27.828	0.998	0.011	3.314	0.993
		40	0.255	27.828	0.956	0.012	3.347	0.935
		50	0.287	27.265	0.999	0.014	3.328	0.990
		Average	0.261	27.640	0.984	0.012	3.330	0.973
Free fatty acids	Non Vacuum	30	0.010	0.188	0.989	0.027	1.537	0.989
		40	0.011	0.185	0.983	0.028	1.534	0.988
		50	0.012	0.187	0.990	0.030	1.515	0.983
		Average	0.011	0.187	0.987	0.028	1.529	0.987
	Vacuum	30	0.006	0.203	0.976	0.019	1.551	0.957
		40	0.007	0.194	0.995	0.022	1.570	0.986
		50	0.009	0.192	0.996	0.024	1.556	0.988
		Average	0.007	0.196	0.989	0.022	1.559	0.977
Crispness	Non Vacuum	30	0.040	0.548	0.906	0.041	0.686	0.738
		40	0.033	0.245	0.947	0.040	1.055	0.934
		50	0.025	0.356	0.945	0.035	0.992	0.845
		Average	0.033	0.383	0.933	0.039	0.911	0.839

	Vacuum	30	0.023	0.264	0.999	0.035	1.133	0.958
		40	0.019	0.260	0.999	0.032	1.185	0.972
		50	0.016	0.264	0.995	0.029	1.200	0.974
		Average	0.019	0.263	0.998	0.032	1.173	0.968
Appearance	Non Vacuum	30	0.032	8.415	0.998	0.004	2.132	0.998
		40	0.036	8.416	0.998	0.005	2.133	0.996
		50	0.035	8.398	0.998	0.005	2.130	0.998
		Average	0.034	8.410	0.998	0.005	2.132	0.997
	Vacuum	30	0.020	8.395	0.997	0.003	2.128	0.998
		40	0.027	8.405	0.984	0.003	2.130	0.983
		50	0.036	8.490	0.971	0.005	2.141	0.971
		Average	0.028	8.430	0.984	0.004	2.133	0.984
Bau	Non Vakum	30	0.029	8.364	0.993	0.004	2.126	0.993
		40	0.032	8.268	0.984	0.004	2.114	0.984
		50	0.038	8.307	0.980	0.005	2.120	0.980
		Rata-rata	0.033	8.313	0.986	0.004	2.120	0.986
	Vacuum	30	0.021	8.369	0.987	0.003	2.125	0.984
		40	0.033	8.388	0.990	0.004	2.129	0.988
		50	0.033	8.298	0.980	0.004	2.118	0.983
		Rata-rata	0.029	8.352	0.986	0.004	2.124	0.985
Odor	Non Vacuum	30	0.030	8.413	0.952	0.004	2.132	0.945
		40	0.042	8.480	0.888	0.005	2.131	0.690
		50	0.038	8.296	0.969	0.005	2.118	0.990
		Rata-rata	0.037	8.396	0.936	0.005	2.127	0.875
	Vacuum	30	0.020	8.363	0.984	0.003	2.125	0.982
		40	0.029	9.375	0.986	0.004	2.127	0.985
		50	0.039	8.383	0.990	0.005	2.129	0.990
		Rata-rata	0.029	8.707	0.987	0.004	2.127	0.986
Texture	Non Vacuum	30	0.029	8.411	0.979	0.004	2.132	0.975
		40	0.033	8.316	0.940	0.004	2.120	0.937
		50	0.038	8.294	0.980	0.005	2.118	0.983
		Rata-rata	0.033	8.340	0.966	0.004	2.123	0.965
	Vacuum	30	0.021	8.385	0.966	0.003	2.127	0.964
		40	0.030	8.369	0.992	0.004	2.127	0.989
		50	0.037	8.317	0.982	0.005	2.121	0.981
		Rata-rata	0.029	8.357	0.980	0.004	2.125	0.978

Based on Table 2, the largest regression value (R^2) on the quality parameters of anchovy savory chips occurs at the order 0 reaction rate and this product has a high-fat content due to the production process through frying so it is easy to experience fat oxidation. In addition, the determination of this reaction order is also based on the largest correlation value (R^2) [5]. This is following the opinion of Labuza [12] that food products that include order 0 are snack products and chips that are easily rancid due to fat oxidation reactions. Free fatty acid content is a critical parameter because the regression (R^2) is the largest, so it is used to estimate the shelf life of anchovy savory chips.

3.2.2 Arrhenius equation

After determining the reaction order, Arrhenius plotting is used to relate k to 1/T. The value of k is placed on the y-axis in logarithmic scale, k is the slope of the reaction order line equation, and the x-axis is 1/T in linear scale. The storage temperature is in units of kelvin (T). After Arrhenius plotting, the linear line and R^2 were established, and the Arrhenius equation was obtained, as shown in Table 3.

3.2.3 Critical limit determination

Determination of shelf life is determined by critical limits as criteria that separate something acceptable from something that is not acceptable. Anchovy savory chips are deep-fried products so the shelf life is related to rancidity due to oxidation reactions that occur in the product when stored. These are low molecular weight compounds that are responsible for unpleasant and undesirable flavors. The free fat number test is one of the parameters of rancidity. The higher ALB, the higher rancidity [13]. Free fatty acid in snack products is 0.70% [7]. Therefore, in this study, the shelf life was estimated using the parameter of free fatty acid content.

3.2.4 Estimated shelf life of non-vacuum packaged anchovy savory chips

The free fatty acid content of non-vacuum-packed anchovy savory chips during 6 weeks or 42 days of storage at 30, 40, and 50°C is presented in Table 4.

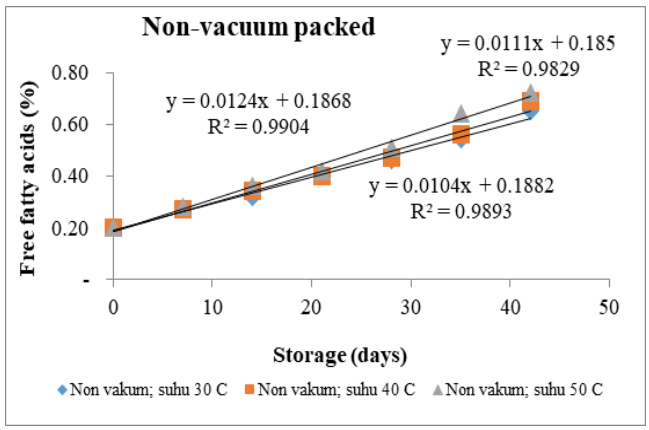

Figure 1. Graph of ALB increase rate of non-vacuum-packed anchovy chips savory chips

With the equation y=a+bx, a regression equation is obtained which shows the rate of decline in the quality of anchovy savory chips at each storage temperature. The trend of the rate of decline in the quality of anchovy savory chips based on free fatty acid content is presented in Figure 1.

The slope value of curve b is the reaction rate of quality deterioration of anchovy savory chips products or called k (quality deterioration reaction rate constant). The curve slope values of various temperatures (ln k) and storage temperatures (1/T) which is the Arrhenius equation are presented in Table 5.

Table 3. Arrhenius equation of quality reduction of anchovy savory chips from R^2

Parameters	Packaging Treatments	Persamaan Arrhenius	R^2
Moisture content	Non-vacuum	$ln\ k = -14.679e^{3427(1/T)}$	0.981
	Vacuum	$ln\ k = -14.639e^{3260.6(1/T)}$	0.888
Fat	Non-vacuum	$ln\ k = 4.099e^{-1583.4(1/T)}$	0.987
	Vacuum	$ln\ ln = 1.458e^{-877.844(1/T)}$	0.957
Free fatty acids	Non-vacuum	$ln\ k = -1.142e^{-1051(1/T)}$	0.993
	Vacuum	$ln\ k = 0.264e^{-1624.4(1/T)}$	0.999
Crispness	Non-vacuum	$ln\ k = -10.78e^{-2295.4(1/T)}$	0.974
	Vacuum	$ln\ k = -10.16e^{-1894.1(1/T)}$	0.992
Kenampakan	Non-vacuum	$ln\ k = 1.668e^{-533.6(1/T)}$	0.653
	Vacuum	$ln\ k = 5.479e^{-2842.5(1/T)}$	0.999
Bau	Non-vacuum	$ln\ k = 0.869e^{-1342.1(1/T)}$	0.941
	Vacuum	$ln\ k = 4.013e^{-2371.8(1/T)}$	0.803
Rasa	Non-vacuum	$ln\ k = 0.449e^{-1178.6(1/T)}$	0.442
	Vacuum	$ln\ k = 6.975e^{-3297(1/T)}$	0.993
Tekstur	Non-vacuum	$ln\ k = 1.070e^{-1402.3(1/T)}$	0.998
	Vacuum	$ln\ k = 5.45e^{-2816(1/T)}$	0.978

Table 4. Free fatty acid content of anchovy savory chips

Packaging Treatments	Storage Temperature	Storage (days)						
		0	7	14	21	28	35	42
Non-vacuum	30℃	0.20	0.27	0.32	0.40	0.46	0.54	0.65
	40℃	0.20	0.27	0.34	0.40	0.48	0.56	0.69
	50℃	0.20	0.28	0.36	0.42	0.51	0.64	0.72

Table 5. Slope value of non-vacuum-packed anchovy chips savory curve

Temperature (T)	Score 1/T	Score k	Score ln k
30°C or 303°K	0.0033	0.010	-4.605
40°C or 313°K	0.0032	0.011	-4.510
50°C or 323°K	0.0031	0.012	-4.390

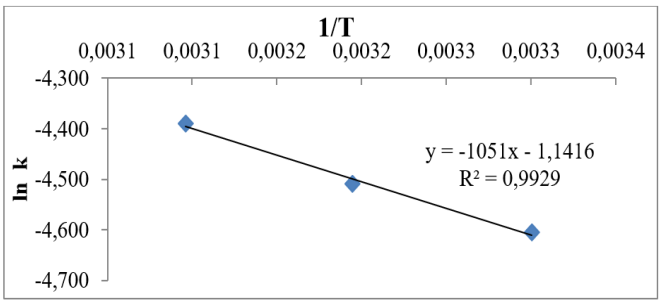

Figure 2. Kinetic rate equation graph estimating the shelf life of non-vacuum-packed anchovy savory chips

The slope value of the curve (ln k) was related to the storage temperature (1/T), which is presented in Figure 2 and a straight-line equation y=-1051.4x-1.1416 with R^2=0.9929 was obtained.

After the value of ln k is plotted against the value of 1/T, the intercept value (ln ko) and the slope of the linear regression equation are ln k=ln ko(E/R) (1/T), or ln k=-1.1416 e(-1051/T). The product parameter of the reaction speed equation model (k) is k=ko e(Ea/RT), with the constant value of k and the activation energy value of the product characteristic change (Ea=E). The minimum energy information required to activate the breakdown reaction is the activation energy, which can be calculated using the Arrhenius equation. The value of ln ko=-1.1416, and the value of ko=0.3193, so k=0.3193 e(-1051/T). The rancidity rate of anchovy savory chips can be calculated at various storage temperatures, as shown in Table 6 and Table 7, through the Arrhenius equation above.

Table 6. Rate of increase of free fatty acid in non-vacuum-packed anchovy chips

Temperature (T)	Equation	k (mg malonaldehyde/kg Sample)
30°C or 303°K	$k = 0.32e^{(-1051/303)}$	0.010
40°C or 313°K	$k = 0.32e^{(-1051/303)}$	0.011
50°C or 323°K	$k = 0.32e^{(-1051/303)}$	0.012

Table 7. Shelf life of non-vacuum-packed anchovy savory chips

Temperature (T)	Equation	Shelf-life
30°C or 303°K	$t = (0.7 - 0.20)/0.01$	50 days
40°C or 313°K	$t = (0.7 - 0.20)0.011$	45 days
50°C or 323°K	$t = (0.7 - 0.20)/0.0123$	41 days

Furthermore, the parameter in determining the shelf life is selected through the parameter that has the lowest activation energy value and then the shelf-life calculation is carried out using the order 0 equation. The selected parameter is a free fatty acid with a maximum standard of 0.7% [9] and the initial free fatty acid content of anchovy savory chips is 0.20%. After obtaining the rate of increase (k) of free fatty acid content, the shelf life of anchovy savory chips at different storage temperatures can be calculated by Eq. (1).

The shelf life of anchovy savory chips in polypropylene plastic packaging under non-vacuum conditions at storage temperatures of 30, 40, and 50°C is 50, 45, and 41 days. The best shelf life of anchovy savory chips in non-vacuum packaging is 50 days at room temperature (30°C).

3.2.5 Estimated shelf life of vacuum-packaged anchovy savory chips

The free fatty acid content of vacuum-packed anchovy savory chips during 42 days of storage at 30, 40, and 50°C is presented in Table 8.

With the equation y=a+bx, a regression equation is obtained which shows the rate of decline in the quality of anchovy savory chips at each storage temperature. The trend of the rate of decline in the quality of anchovy savory chips based on free fatty acid content is presented in Figure 3.

The slope value of curve b is the reaction rate of quality deterioration of anchovy savory chips products or called k (quality deterioration reaction rate constant). The curve slope values of various temperatures (ln k) and storage temperatures (1/T) which is the Arrhenius equation are presented in Table 9.

The slope value of the curve (ln k) was related to the storage temperature (1/T), which is presented in Figure 4, and a straight-line equation y=-1624.4x+0.2643 with R^2=0.9991 was obtained.

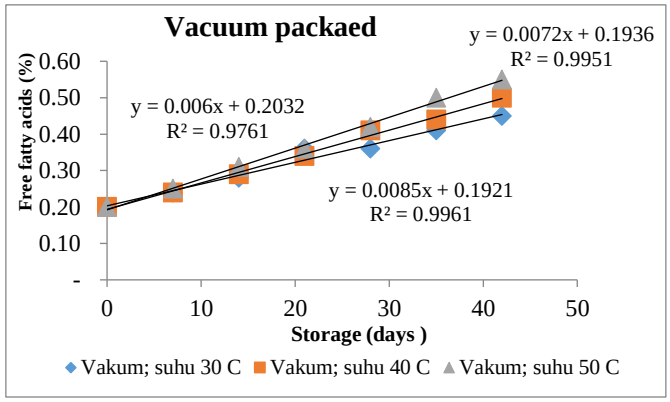

Figure 3. Graph of ALB increase rate of vacuum packed anchovy chips savory chips

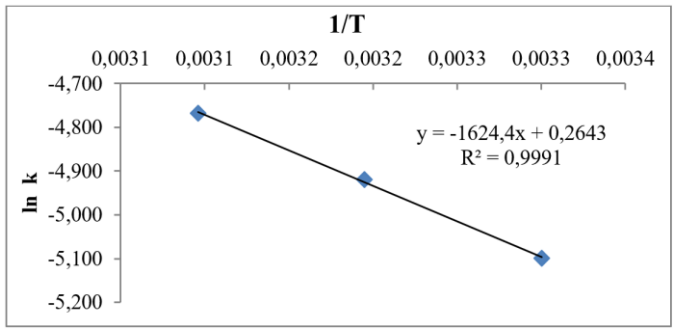

Figure 4. Kinetic rate equation graph estimating the shelf life of vacuum-packed anchovy savory chips

Table 8. Free fatty acid content of anchovy savory chips

Packaging Treatments	Storage Temperature	Storage (days)						
		0	7	14	21	28	35	42
Vacuum	30°C	0.20	0.24	0.28	0.36	0.36	0.41	0.45
	40°C	0.20	0.24	0.29	0.34	0.41	0.44	0.50
	50°C	0.20	0.25	0.31	0.36	0.42	0.50	0.55

Table 9. Shelf life of non-vacuum-packed anchovy savory chips

Temperature (T)	Score 1/T	Score k	Score ln k
30°C or 303°K	0.0033	0.006	-5.099
40°C or 313°K	0.0032	0.007	-4.920
50°C or 323°K	0.0031	0.009	-4.768

After the value of ln k is plotted against the value of 1/T, the intercept value (ln ko) and the slope of the linear regression equation are ln k = ln ko(E/R) (1/T), which means ln k = 0.2634 (-1624.4/T). The activation energy value of the change in product characteristics (Ea=E) and the constant value k were obtained from the equation. The value of the product parameter of the reaction speed equation (k) is k = ko e(Ea/RT), and the value of ln ko is 0.2634, so k = 1.303 e(-1624.4/T). The rancidity rate of anchovy savory chips can be calculated at various storage temperatures, as presented in Table 10 and Table 11 through the Arrhenius equation above.

Furthermore, the parameter in determining the shelf life is selected through the parameter that has the lowest activation energy value and then the shelf-life calculation is carried out using the order 0 equation. Free fatty acid levels became the selected parameter with an initial level of 0.20% and the highest free fatty acid level limit for food ingredients is 0.70% [7]. After obtaining the rate of increase (k) of free fatty acid content, the shelf life of anchovy savory chips at different storage temperatures can be calculated by Eq. (1).

The shelf life of anchovy savory chips packaged in polypropylene plastic vacuum conditions at storage temperatures of 30, 40, and 50°C are 82, 69, and 59 days. The best shelf life of non-vacuum-packed anchovy savory chips is 82 days at room temperature (30°C).

The results of testing the shelf life of anchovy savory chips show that products packaged in polypropylene plastic in non-vacuum conditions can last 50 days or 1.5 months at room temperature (30°C). Meanwhile, the shelf life of anchovy savory chips packaged in polypropylene plastic vacuum

conditions is 82 days or 2.4 months at room temperature (30℃). When compared with several similar studies, it is known that the results of testing the shelf life of anchovy savory chips are quite different, such as in pepetek fish chips packaged in polypropylene plastic which has a shelf life of 4.2 months at room temperature [14]. Then, the shelf life of beledang fish crackers in rigid polypropylene packaging at a storage temperature of 30℃ is 10 months and 3 days [15]. This difference in shelf life is possible given the differences in the production process and raw materials used. In addition, there are possibilities, such as the imperfect draining process that can cause the product to deteriorate quickly or have a short shelf life. This is following information from [2], that chip products are prone to rapid changes in texture and rancidity after storage as a result of excess oil absorption during the frying process.

Furthermore, through this discussion, it can be seen that anchovy savory chips packaged with vacuum polypropylene plastic packaging have a longer shelf life than products packaged using non-vacuum polypropylene plastic packaging. These results indicate that anchovy savory chips packaged using vacuum polypropylene plastic have a longer reaction rate so that the product does not deteriorate quickly [16-18]; although on the other hand, plastic also contaminated fishery products [19]. The use of vacuum polypropylene plastic, which can maintain product quality for a longer period, can enhance customer satisfaction and strengthen brand image. Additionally, the product becomes easier to store and requires less storage space.

In non-vacuum polypropylene packaging, the storage time of the product at 40 and 50℃ is shorter than the product stored at 30℃. This is because anchovy savory chips products packaged with non-vacuum polypropylene at 40 and 50℃ experience rancidity faster than anchovy savory chips stored at 30℃. The same results also occur in research conducted by Akbar et al. [17] and Sartika et al. [20], that the FFA content fluctuates at several points and increases over time. Contamination, packaging, poor storage of the final product, and heating temperature and heating duration are some of the causes of high free fatty acid levels. This fat hydrolysis process can cause an increase in free fatty acids because there is water in the fat [21]. Improper processing increased food waste [22]. Increasing food contamination also reduced food shelf life and increased food waste [23], so that integrated management was needed to extend food shelf life and food security.

Table 10. Rate of increase of free fatty acid in vacuum-packed anchovy chips

Temperature (T)	Equation	k (mg Malonaldehyde /kg Sample)
30℃ or 303°K	$k = 1.303\ e^{(-1624.4/303)}$	0.0061
40℃ or 313°K	$k = 1.303\ e^{(-1624.4/313)}$	0.0070
50℃ or 323°K	$k = 1.303\ e^{(-1624.4/323)}$	0.0090

Table 11. Shelf life of vacuum-packed anchovy savory chips

Temperature (T)	Equation	Shelf-Life
30℃ or 303°K	$t = (0.7 - 0.20)/0.006$	82 days
40℃ or 313°K	$t = (0.7 - 0.20)0.007$	69 days
50℃ or 323°K	$t = (0.7 - 0.20)/0.009$	59 days

4. CONCLUSIONS

This study concludes that the shelf life of anchovy savory chips in non-vacuum polypropylene plastic packaging is 50 days at room temperature (30℃). Meanwhile, the shelf life of anchovy savory chips in polypropylene plastic packaging under vacuum conditions is 82 days at room temperature (30℃). Based on this information, anchovy savory chips should be stored in polypropylene plastic packaging with vacuum conditions so that it has a long shelf life. By using vacuum polypropylene plastic, it can maintain product quality longer, improve customer satisfaction, and strengthen brand image. In addition, products are easier to store and require less storage space.

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