Effect of cooking oil on the characteristics and shelf life of shredded catfish (Clarias sp)

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Abstract. The purpose of this research is to identify the characteristics of shredded catfish (Clarias sp) processed with and without cooking oil and determine the shelf life by using the Arrhenius method. The shredded catfish was made by filleting the fish and soaking in a 2% vinegar solution for 10 minutes, and boiling the fillets for 15 minutes in a 2% salt solution mixed with 2% bay leaves and 2% lemongrass with the ratio of fillet: solution (1:2 (w/v)). The cooked fillets were then pressed, shredded into small pieces, and added with spices (2% red onion, 3% garlic, 15% granulated sugar, 1% coriander, 1% galangal, and 0.5% flavoring powder) and 20% coconut milk, then cooked until it dried. The shredded catfish was observed for its proximate values, while the shelf life was determined using the acceleration method (Arrhenius) at three different storage temperatures and day of observation, i.e. at 25°C was for 0, 10, 20, 30, 40 days; at 35°C was for 0, 7, 14, 21, 28 days and at 45°C was for 0, 3, 6, 9, 12 days. The parameters of observation for shredded catfish’s shelf life were peroxide value, Aw, total plate count (TPC), and sensory test (hedonic). The result of proximate value showed that the protein content of shredded catfish with oil was lower than without oil, while moisture content was higher for treatment using oil. The shelf life of shredded catfish with cooking oil was shorter than without cooking oil, estimated for 83 days at 25°C, 55 days at 35°C, 47 days at 45°C, compared to 155 days at 25°C, 103 days at 35°C, and 62 days at 45°C, respectively. This was supported by the panelist’s preferences for shredded catfish without oil at the end of the observation. These results indicate that the use of cooking oil during the cooking process of shredded catfish greatly affects the product’s shelf life.

1. Introduction
Catfish is one of the most popular freshwater fish in Indonesia due to its tasty taste, high nutritional value, and ease of cultivation. The high potential of catfish has led to the encouragement of the Ministry of Maritime Affairs and Fisheries of Indonesia to increase the fish production through an environmentally friendly system called bio-floc technology. The technology has increased the national catfish production by 21.31% per year within five-year periods, from 337.5 tons in 2011 to 722.6 tons in 2015 [1]. Efforts in the form of product diversification are needed to balance the high production of catfish. One of them is to process the catfish into dried and ready-to-eat foods.

Catfish is the potential to substitute beef as a raw material since it also has high nutritional content, reported as 12-22 % of protein and 0.5- 4.7 % of fat content depending on the species. Catfish from Clarias gariepinus species contains saturated fatty acids (SFA) of 32.9%, monounsaturated fatty acids...
(MUFA) of 43.3%, and polyunsaturated fatty acids (PUFA) of 20.9%. The importance of long-chain polyunsaturated fatty acids has a protective effect on human health as anti-inflammatory and cytoprotective properties, including omega-6 (ω-6) of 11.2%, omega-3 (ω-3) of 9.5%, EPA of 1.2% and DHA of 2.0% [2]. The high nutritional content in catfish can be used as raw material for shredded products to substitute shredded meat, which is generally from beef.

Shredded meat is one of the traditional ready-to-eat food products in dry form and is usually consumed as a side dish. The most popular raw material for shredded meat was beef, mainly because of its coarse texture, which is preferred by consumers. The product also contains spices which are not only function as a flavor enhancer but also as the product’s preservative. Processing catfish into dried foods such as shredded meat also possess benefits in term of longer shelf life, which reported still acceptable after 50 days of storage at room temperature [3].

A shelf-life test is required for the production of food products. The shelf life of a food product can define as the time during for food product will remain safe, which is certain to retain desired sensory, chemical, physical, and microbiological properties and be acceptable to the consumer [4]. Accelerated shelf-life testing (ASLT) with the Arrhenius model is popular in estimation for the shelf life of food products. It uses a method capable of evaluating product stability, based on data observation in deterioration processes (chemical, physical, biochemical, or microbial) which obtained in a shorter period and some certain temperature [5]. Observation parameters for deterioration of food product quality during storage are known through the oxidation of fatty acid analysis, microbiology analysis, and sensory analysis.

The shelf life of shredded meat products mainly depends on the ingredient and processing steps. The use of cooking oil, which is generally applied by producers, can reduce the cooking time and produces a richer taste. However, the use of cooking oil can accelerate the occurrence of rancidity and result in a shorter product’s shelf life. Generally, the food frying process uses commercial palm oil. Palm oil can change its physicochemical properties after the frying process at a temperature of 180°C, which is indicated by an increase in the acid value of palm oil. This is caused by the cleavage of the double bond oxidation in palm oil molecules to form carbonyl compounds. Furthermore, oxidation occurs to low molecular weight fatty acids during frying. The palm oil oxidation reaction can also produce a dark color in the frying as the frying time increases [6]. As an alternative, we can remove the use of cooking oil during the processing of shredded catfish. The present study investigates the characteristics and shelf life of shredded made from catfish meat which was processed with and without the addition of cooking oil at temperature < 100 °C. So that there is no rapid oxidation of cooking oil or fat in the shredded material and the resulting color is not dark.

The purpose of this research is to analyze the characteristics of shredded catfish meat with and without cooking oil and determine its shelf-life by using the Arrhenius method. The shredded catfish characteristics were observed for their proximate values. The determination of shredded catfish shelf life was performed by using the acceleration method (Arrhenius) which parameters of observation during storage at 3 different storage temperatures (25°C, 35°C, and 45°C) were peroxide value analysis, Aω, microbiology analysis (total plate count) and sensory analysis (hedonic test).

2. Material and methods

2.1. Materials
The materials used in this study were fresh catfish (Clarias batracus) (500g - 1 kg/head) obtained from fish farming ponds in Bogor, West Java, Indonesia. Other ingredients used for shredded meat were crushed ice, salt, granulated sugar, commercial palm oil, coconut milk, seasoning, commercial spices (shallots, garlic, coriander, galangal, bay leaves, and lemongrass), and polypropylene plastic.

2.2. Methods
Fresh catfish were stunned by immersing in cold water (±5°C) for 15 minutes, then filleted, washed thoroughly, and soaked in a 2% vinegar solution for 10 minutes. After soaking, the fillets were boiled
in 5% salt solution for 15 minutes with a ratio of fillet: solution (1:2 (w/v)) and added with 2% bay leaves and 2% lemongrass. In order to get dry cooked meat, the fillet was pressed, and the coarse fillet fibers were separated using a fork. The meat was then added to a mixture of spices (red onion 2%, garlic 3%, granulated sugar 15%, coriander 1%, galangal 1%, and seasoning 0.5%) that have gone through a cooking process (sangria). Finally, 20% of coconut milk was added, and the mixture was heated until a thick liquid was formed. Following this, the meat fibers were fried using cooking oil for 20 minutes. The resulting shredded catfish product was then centrifuged using a spinner for 30 minutes to remove the oil content [3]. As a control, the frying process was done without cooking oil. The shredded catfish were packed in polypropylene plastic, sealed, and stored for further analysis.

2.2.1. Proximate analysis. The parameters for proximate analysis observed in the study included moisture, protein, fat, and ash contents [7]. Moisture content analysis was done by drying a porcelain dishes for 1 hour at 105°C, cooling them down in a desiccator for 30 minutes, and weighing them to constant weight. Following that, 2 g of sample was weighed and placed in the porcelain cup, then dried in 105°C oven for 5 hours. When the drying was completed, the cup containing the sample was cooled in a desiccator until it is obtained a constant weight. The moisture content was calculated using the following formula:

\[
\text{Moisture content} \, (\%) = 100 \times \frac{\text{initial weight} - \text{final weight} \, (g)}{\text{sample weight} \, (g)}
\]

Ash content analysis was carried out by weighing 2 g of samples into dried porcelain dishes and burned over a burner until it became charcoal. Then the cup containing the charcoal sample was put into a muffle furnace and burned at 600°C for 6 hours until it became whitish ash. The sample was then cooled by putting it in a desiccator until it is obtained a constant weight. The ash content was calculated using the following formula:

\[
\text{Ash content} \, (\%) = 100 \times \frac{\text{ash weight} \, (g)}{\text{dry sample weight} \, (g)}
\]

The protein content analysis was done by three steps, namely destruction, distillation, and titration. The destruction process was conducted by weighing the samples 5 g and put into a Kjeldahl flask, added with selenium Kjeldahl tab and 10 ml H2SO4. Destruction was done at 400°C until the solution became clear. The product was then cooled and made up to 100 ml solution. Following this, 10 ml of resulted solution was pipetted into the distillation flask. In doing so, 25 ml boric acid solution and 2-4 indicator drops (contains 2 parts of methyl red 0.1% and 1 part of Brown Cresol Green 0.1% in alcohol) were placed in the condenser before distillation started. 8-10 ml NaOH was added into the samples, and they were distilled until bluish-green color appeared. In the end, the distilled solution was titrated using 0.01N HCl until the solution was changed in color. The protein content is calculated based on the following formula:

\[
\text{Nitrogen content} \, (\%) = \frac{\text{titration volume} \times N \, \text{HCl} \times \text{BM} \, N}{\text{sample weight} \, (mg)} \times 100 \%
\]

\[
\text{Protein content} \, (\%) = \text{nitrogen content} \times 6.25
\]
Fat content (%) = \[ \frac{\text{final volumetric flask weight} - \text{initial volumetric flask weight (g)}}{\text{sample weight (g)}} \times 100 \% \] (5)

2.2.2. Determination of shelf life. Determination of the shelf life of shredded catfish with and without oil was carried out using the acceleration method (Arrhenius) [4] with modification. The samples were stored in at three different storage temperatures, i.e., 25°C, 35°C, and 45°C and observed at designed observation time, which were 0, 10, 20, 30, 40 days for 25°C, 0, 7, 14, 21, 28 days for 35°C and 0, 3, 6, 9, 12 days for 45°C. Parameters observed were analysis of peroxide value, Aw, total microorganism content, and sensory (hedonic).

2.2.3. Peroxide value analysis. Peroxide value was measured by weighing 0.2 g of samples into 250 Erlenmeyer flasks; and added with 30 ml of acetic acid/chloroform (3:2, v/v) and 0.5 ml of saturated potassium iodide (KI). The mixture was mixed vigorously for a minute and added with 30 ml of water and 0.5 ml aliquot of 1% (w/v) starch indicator. The mixture was then titrated using 0.001 N sodium thiosulfate (Na\textsubscript{2}SO\textsubscript{3}) until the purple color disappeared. The peroxide value (PV) was calculated [8] as:

\[ \text{PV} = \frac{(S-B) \times N \times 1000}{W} \] (6)

Where,  
\( S \) = volume of Na\textsubscript{2}SO\textsubscript{3} add to the sample (mL)  
\( B \) = volume of Na\textsubscript{2}SO\textsubscript{3} of the blank (mL)  
\( N \) = normality of Na\textsubscript{2}SO\textsubscript{3} solution  
\( W \) = sample weight

2.2.4. Water activity analysis. The water activity of shredded catfish was measured by an electronic dew-point water activity meter, Aqualab Series 3 model TE (Decagon Devices, Pullman, Washington, USA), equipped with a temperature-controlled system. Three replicates were performed for each sample to obtain a valid result.

2.2.5. Total plate count analysis. Total Plate Count (TPC) analysis was performed using the Total Plate Count Agar (PCA) (OXOID, Hampshire, United Kingdom). A total of 25 g of samples was placed in a sterile stomacher bag with 225 ml of 0.1% peptone water (OXOID, Hampshire, United Kingdom) and homogenized for 1 minute. A series of dilutions (10\textsuperscript{-1} to 10\textsuperscript{-3}) were made and spread into the media agar. The media were then incubated at 37°C for 48 hours before being observed. The logarithm numbers of colony-forming units per grams (CFU/g) of samples were enumerated after incubation [9]. All the microbial analyses were performed in triplicates for each sample.

2.2.6. Sensory analysis. Sensory analysis of shredded catfish was carried out by using the hedonic test for overall acceptability. In this sensory test by semi-trained panelists from Research Center for Marine and Fisheries Product Processing and Biotechnology. For the hedonic scale method was used a 5-point score to evaluate the sample product, which ranged from 1; very dislike, 2; dislike, 3; neutral, 4: like, and 5; very like [10].

3. Results and discussion

3.1. Proximate composition of shredded catfish
The proximate composition represents the nutritional content of shredded catfish, which is observed for moisture, ash, fat, protein, and carbohydrate content of the products. Table 1 shows the proximate composition of shredded catfish with oil and without oil. Shredded catfish treated with oil possessed lower water content (2.76% (w/v)) compared to shredded catfish treated without oil (7.03% (w/v)).
This is due to a higher temperature during the processing of shredded catfish which is enhanced by the addition of oil. The temperature while frying the shredded catfish with oil was recorded, ranging from 90 to 95°C, while the one without the added oil only reached a temperature of 80 - 85°C. The cooking temperature of shredded was set below 100°C in order to brighter color of shredded and homogeneously ripe. The higher the processing temperature of the shredded catfish leads to a higher rate of water evaporation within the fish meat, hence, produced drier shredded catfish.

The ash content of shredded meat processed with and without oil was not significantly different, namely 5.23% and 5.83%, respectively. Meanwhile, the addition of oil resulted in shredded catfish with a higher value of fat content (22.76%) compared to the one without oil (17.77%). However, both treatments considered produced high-fat content due to the use of coconut milk as an additional ingredient which contains quite high fat. Coconut milk generally contains 24.54% fat with a high saturated fatty acid content, namely lauric fatty acid 52.92% and myristic fatty acid 13.22% [11]. On the contrary, the use of oil in the processing of shredded catfish reduced the protein content. The protein content of shredded catfish processed with oil was 32.50%, lower than the one without oil addition (35.23%). The high temperature used in processing the shredded catfish can contribute to the damage of the protein molecular structure [13]. In addition, higher carbohydrate content was obtained from shredded catfish processed with oil (36.74%) than without oil (34.13%). Carbohydrate content is presumed to obtain from added sugar which breaks down into reducing sugars at high temperatures.

Table 1. The proximate composition of shredded catfish.

| Sample  | Moisture content (%) | Ash content (%) | Fat content (%) | Protein content (%) | Carbohydrate content (%) |
|---------|----------------------|-----------------|-----------------|--------------------|------------------------|
| SO      | 2.77 ± 0.21<sup>a</sup> | 5.23 ± 0.21<sup>a</sup> | 22.76 ± 0.25<sup>a</sup> | 32.50 ± 0.50<sup>a</sup> | 36.74                  |
| SWO     | 7.03 ± 0.55<sup>b</sup> | 5.83 ± 0.29<sup>a</sup> | 17.77 ± 0.68<sup>b</sup> | 35.23 ± 0.68<sup>b</sup> | 34.13                  |

Note: SO : shredded with oil, SWO : shredded without oil
*carbohydrate content (by different %)
**different of alphabet means significantly different (P < 0.05)

3.2. Observation of shredded catfish during storage

The observation of shredded catfish during storage at 3 temperature (25°C, 35°C, and 45°C) involve peroxide number, A<sub>n</sub>, Total Plate Count (TPC) and sensory (hedonic test) presented in the figure below. The observation time at temperature of 25 °C on 0, 10, 20, 30, 40 days; at temperature of 35°C on 0, 7, 14, 21, 28 days; temperature of 45 °C on of 0, 3, 6, 9, 12 days.

The peroxide value of shredded catfish processed with and without oil during storage are presented in Figure 2. Peroxide number is an important parameter to determine the quality of the oil, where the higher the peroxide number, the closer the oil is to rancidity. Figure 1 shows the peroxide value of shredded catfish with cooking oil increased significantly compared to shredded catfish without oil. Higher storage temperature also appears to increase the peroxide value. Correlation between storage temperature and peroxide value of shredded catfish is indicated by the value of R$^2$ > 0.80, which means that the correlation is positive that influencing the quality of shredded. This suggests that at a higher storage temperatures, the oxidation reaction runs faster, especially in the early stage of fat oxidation reactions, where the fatty acids react with oxygen to produce peroxide compounds [8].

The number of peroxides in fishery products that contain lots of unsaturated fatty acids will increase during storage along with the increase in the formation of free radicals, and after reaching the maximum value, it will tend to decrease due to the peroxide degradation process, which produces aldehydes, alcohols, hydrocarbons and volatile compounds [8]. Therefore, in estimating the shelf life of food products that contain a lot of oil, it needed oil quality parameters are also important to observe in order to obtain more accurate data as peroxide number.
Figure 1. Change of peroxide number value of shredded catfish during storage (Note: SO: shredded with oil, SWO: shredded without oil).

Therefore, parameters $a_w$ becomes one of our observations in the study. $a_w$ values of shredded catfish processed with and without oil during storage are shown in Figure 2. The $a_w$ value is one of the observation parameters that play a role in determining the deterioration of the quality of food products in dry conditions. Microbial growth began to grow at the value of $a_w = 0.6$. Figure 3 shows the $a_w < 0.6$ for all sample shredded catfish, indicating the shredded catfish have a low risk of bacterial contaminant [13]. The shredded catfish with oil shows the $a_w$ value is lower than without oil, although the $a_w$ value is not significantly different at the time of observation. Even though the mapping of the $a_w$ value of shredded catfish during storage in the graph does not show a positive correlation between the $a_w$ value and the time of observation. It is also related to under certain conditions during storage there can be influenced of air humidity which is sometimes unstable in a storage room at 25°C. Figure 2 indicated a correlation negative between storage temperature and $a_w$ of shredded catfish. It is shown by the value of $R^2 < 0.80$. It did not significantly affect the storage temperature of shredded catfish on the value of $A_w$ shredded.

Figure 2. Change of $A_w$ value of shredded catfish during storage (Note: SO: shredded with oil, SWO: shredded without oil).

Another essential parameters for estimating shelf life are the total microorganism. For this purpose, we conducted a Total Plate Count of the shredded catfish samples. The results of TPC are presented in Figure 3. The figure shows that the TPC values increased with storage time, reached the peak, and then they decreased until the end of observation. TPC values calculated mathematically with a linear graph do not provide a positive correlation.
The other parameter for estimating the shredded catfish is a sensory test. Sensory test of shredded catfish using a hedonic test showed that the panelists preferred shredded catfish processed with oil compared to processed without oil. The score of hedonic tests on the attribute of appearance, smell, taste, and texture of shredded catfish can be seen in Figure 4. The result of the initial hedonic test assessment showed that the panelist scored with a higher value to the shredded catfish processed with cooking oil compared to the one without cooking oil. The appearance of both shredded catfishes showed brown color, which suggests the Maillard reaction occurs due to the binding between reducing sugars from the seasoning and nitrogen-containing compounds, especially catfish protein. The brown color is not only caused by the Maillard reaction but also due to the caramelization process contributed by the use of high sugar content (15%). The heating process will cause degradation, fragmentation, and polymerization of polyhydroxy carbonyl compounds from sugar due to the heating process. It also raises an aroma that produces a savory smell and specific taste that is more found in shredded catfish with cooking oil. Therefore score value panelist is higher for shredded catfish processed with cooking oil. Oil will produce aromatic compounds such as furfural aldehyde, carbonyl, etc. which is associated with good smells. The texture of shredded catfish processed with oil was fibrous, like the texture of shredded beef. The characteristic flavor of cooked meat is volatiles generated during heating as a result of a process of Maillard reaction, lipid oxidation, interactions between Maillard reaction products and lipid oxidation products. Volatile compounds are generated to various chemical classes like hydrocarbons, alcohols, aldehydes, ketones, carboxylic acids, esters, lactones, furans, pyrans, pyrroles, pyrazines, pyridines, phenols, thiophenes, thiazoles, thiazolines, oxazole’s, and other nitrogen or sulfuric compounds [14].

Meanwhile, shredded catfish processed without cooking oil produces uneven brown color, a less savory smell and finer texture. When shredded catfish is fried without cooking oil, the sugar which is contained in the seasoning causes the surface of the fish meat to be covered by a sugar solution, forming a rigid and hard structure. During the heating process, this structure will be easily destroyed when exposed to mechanical frying in the shredded processing machine. Shredded catfish fried without cooking oil produces a softer product like a coarse flour. This characteristic is the opposite to the consumer preference, which are preferably lighter texture, visible fibers, and can form a network. However, the shredded catfish fried without cooking oil produces a less savory taste compared to cooking oil.

The mapping of hedonic values in a linear graph gives a positive correlation, with $R^2 > 0.8$, which means that the parameters are suitable for estimating the shelf life of shredded catfish using the Arrhenius method. Estimation of the shelf life using the Arrhenius model is based on critical parameters that indicate a deterioration in the quality of a product under extreme temperature conditions. In food products, a zero-order reaction equation is generally used in the quality of deterioration that constantly occurs at the same temperature. Sensory analysis is very needed for food product development and shelf-life determination. Changes in the sensory characteristics of a food
product are strongly influenced by the ingredients contained in the food and the physical treatment, which interact chemically with each other. Chemical reactions that indicate a deterioration in the quality of food products are (1) enzymatic degradation (in fresh fruit and vegetables, frozen food ingredients/products), (2) non-enzymatic browning, (3) fat oxidation (development of rancidity in snack food, dry food and frozen food) [4] [5]. So, the changes in chemical reactions in food product should be correlated to the results of sensory tests, especially hedonic tests, in order to determine the acceptance of the product by the panelists.

![Figure 4](image-url) Change of sensory test (hedonic) during storage (Note: SO: shredded with oil, SWO: shredded without oil).

Based on the results of the hedonic test data plot of shredded catfish shown in Figure 4, is obtained the k value of each equation on the zero order will be used in calculating the shelf life of catfish floss using the Arrhenius method. The tabulation of k value data of zero order is presented in Table 2.

**Table 2.** The value of the slope k of the zero-order equation from shredded catfish.

| Temperature (°C) | Shredded catfish with oil (SO) | Shredded catfish without oil (SWO) |
|------------------|-------------------------------|----------------------------------|
|                  | Equation                      | Slope k | R² | Equation                      | Slope k | R² |
| 25               | \( y = -0.050x + 5.38 \)     | 0.05    | 0.89 | \( y = -0.016x + 5.08 \)     | 0.016   | 0.88 |
| 35               | \( y = -0.060x + 5.38 \)     | 0.06    | 0.90 | \( y = -0.031x + 5.16 \)     | 0.031   | 0.92 |
| 45               | \( y = -0.070x + 5.37 \)     | 0.07    | 0.94 | \( y = -0.080x + 5.22 \)     | 0.080   | 0.94 |

The estimation of shelf life at a certain temperature can be determined using the Arrhenius equation which describes the relationship between the value of k and the storage temperature in Kelvin (1/T) [4] as follows:

\[
k = k_o \ e^{-\frac{[E_a/R]}{T}} \quad \text{or} \quad \ln k = \ln k_o - \frac{[E_a/R]}{T}
\]

(7)

The graph is obtained from the relationship ln k (y-axis) with 1/T (x-axis), which will give a linear equation: \( y = a + bx \), where the slope of b = \( (E_a/R) \) which is the slope of the regression line, and the intercept a = ln k_o. The value of k used in the Arrhenius equation is obtained from the zero-order equation which will then be used to calculate shelf life. The data tabulation of the Arrhenius equation on the order of zero obtained from the table above is as follows.

**Table 3.** Tabulation of the parameters of the Arrhenius equation on the order of zero.

| Temperature (°C) | With Oil (SO) | Without Oil (SWO) |
|------------------|---------------|-------------------|
|                  | (K)           | 1/T               | Slope k | Ln k | 1/T | Slope k | Ln k |
| 25               | 298           | 0.0034             | 0.050   | -2.996 | 0.0034 | 0.016 | -4.135 |
| 35               | 308           | 0.0032             | 0.060   | -2.813 | 0.0032 | 0.031 | -3.474 |
| 45               | 318           | 0.0031             | 0.070   | -2.659 | 0.0031 | 0.080 | -2.530 |
From the tabulation of the data above, then obtained a graph of the relationship between the value of \( \ln k \) and \( 1/T \) is made a linear equation will be obtained as follows.

\[\text{Figure 5. Arrhenius plot graph on zero-order of shredded catfish with oil (SO) and without oil (SWO).}\]

Figure 5 indicates a correlation positive between slope \( k (\ln k) \) from the hedonic test data in linear graph and each storage temperature \( (1/T) \) (K) which showed R-value > 0.90. These results obtained Arrhenius equation for shredded catfish with cooking oil is \( y = -1091.6x + 0.7066 \) with a value of \( R^2 = 0.98 \), while for the shredded catfish without oil the equation is \( y = -5057.9x + 12.974 \) with \( R^2 = 0.92 \). This reveals to the Arrhenius equation are \( \ln k = -0.702 - 1090 (1/T) \) for shredded catfish with cooking oil and \( \ln k = 12.974 - 5057(1/T) \) for shredded catfish without cooking oil. From the Arrhenius equation, we calculate the shelf life of the shredded catfish at the desired temperature using the following formula equation.

\[
t_s = \frac{Q_o - Q_s}{k}
\]

Where:
- \( ts \) = shelf life
- \( Q_s \) = the limit for the deterioration of the sensory value of the hedonic test is 2
- \( Q_o \) = initial hedonic value which is 5.3 (for shredded with oil)
- \( Q_o \) = initial hedonic value 5.1 (for shredded without oil)

The Arrhenius equation from Figure 5 and the equation for estimating the shelf life will reveal the \( k \) value at each temperature, which reflects the shelf life of shredded catfish at different temperatures of observation (Table 4).

**Table 4. Shelf life of shredded catfish with oil on the order of zero.**

| (°C) | (K)   | I/T   | ln k   | k    | Qo  | Qs  | Shelf life (day) |
|------|-------|-------|--------|------|-----|-----|------------------|
| 25   | 298   | 0.00336| -3.22  | 0.04 | 5.3 | 2   | 83               |
| 35   | 308   | 0.00325| -2.84  | 0.06 | 5.3 | 2   | 55               |
| 45   | 318   | 0.00314| -2.72  | 0.07 | 5.3 | 2   | 47               |

Based on the calculation, the shredded catfish without oil was predicted to have longer shelf life than that of shredded catfish with oil. The calculation revealed the shelf life of shredded catfish with oil is 83 days at 25°C, 55 days at 35°C and 47 days at 45°C. Meanwhile, the predicted shelf-life for shredded catfish without oil is 155 days at 25°C, 103 days at 35°C and 62 days at 45°C.
Table 5. Shelf life of shredded catfish without oil is on the order of zero.

| (°C) | (K) | 1/T  | ln k | k   | Qo  | Qs  | Shelf life (day) |
|------|-----|------|------|-----|-----|-----|-----------------|
| 25   | 298 | 0.00336 | -4.02 | 0.02 | 5.1 | 2   | 155             |
| 35   | 308 | 0.00325 | -3.46 | 0.03 | 5.1 | 2   | 103             |
| 45   | 318 | 0.00314 | -2.91 | 0.05 | 5.1 | 2   | 62              |

4. Conclusions
Processing shredded catfish using cooking oil was significantly affect the characteristics and shelf life of final products. Shredded catfish with cooking oil was preferred by panelists due to its better appearance, texture and taste. Shredded catfish with oil has moisture (2.77%) and fat content (22.76%) was higher compared to without oil (17.77%), but protein content in shredded with oil (32.50%) was lower. Estimation of the shredded catfish’s shelf life was performed using a parameter of peroxide number, sensory test, aw value and TPC value. However, it was identified that the hedonic test was the significant parameter for predicting the product’s shelf life based on the regression value. Based on the calculation, the shredded catfish without oil was predicted to have longer shelf life than shredded catfish with oil. Shelf life for shredded catfish with oil is 83 days at 25°C, 55 days at 35°C and 47 days at 45°C, while shelf life for shredded catfish without oil is 155 days at 25°C, 103 days at 35°C and 62 days at 45°C. These calculations of product shelf-life, indicate that the use of cooking oil in the cooking process of shredded catfish greatly affects its shelf life. Therefore, the processing of shredded catfish can also not use cooking oil to increase its shelf life.

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