Quality deterioration kinetics and shelf-life estimation of fish koya

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Abstract: This study aimed to determine the quality deterioration kinetics of fish Koya and to estimate its shelf-life. Koya is a savory powder and usually added to traditional Indonesian foods such as Soto and noodles. In general, Koya is made from crushed shrimp crackers and fried garlic. In this study, Koya was made from red tilapia and tempeh flour, then packed in metalized plastic. The three formulas in this study were N1 (60% tempeh flour : 40% red tilapia fillets), N2 (50% tempeh flour : 50% red tilapia fillets), and N3 (40% tempeh flour : 60% red tilapia fillets). The Koya then stored at 35°C, 45°C, and 55°C for 28 days. Sensory quality and Thiobarbituric Acid (TBA) values during storage were observed every seven days. The sensory evaluation was conducted using multiple comparisons test. Shelf-life of fish Koya was determined at 30°C (room temperature) using Accelerated Shelf Life Test (ASLT) with the Arrhenius model. The results showed that aroma was the first parameter that decreased compared to other parameters. The zero-order equations were suitable to describe the decreased aroma quality of N1, N2, and N3. The activation energy of decreased quality for N1, N2, and N3 were 29.64 kJ/mol.K, 24.79 kJ/mol.K, and 22.43 kJ/mol.K, respectively. The shelf-life estimation for N1, N2, and N3 at room temperature was 131 days, 109 days, and 108 days, respectively.

1. Introduction

Nowadays, powder seasoning is much developed in Indonesia. It can be added during cooking or directly onto food to enhance the flavor. One of the powder seasonings that can be added directly to food is Koya. Koya is a powder seasoning made from crushed shrimp crackers and fried garlic. Koya is usually used to enhance savory flavor, especially in Soto. The common raw materials for Koya in the market just consist of shrimp crackers and fried garlic, so we encourage the development of Koya with high nutrients content.

The nutrient value of Koya can be enhanced by modifying its raw material by changing it with high and complete nutrient value. Fish is one of the food sources that contain a high nutrient value, especially omega-3 fatty acid, protein, vitamin, and mineral [1]. Tilapia is a fish that rich in protein, low fat, and easy to be cultured in Indonesia. Tilapia contains 1.7% fat of monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA), EPA, and DHA, also 17% protein with complete amino acid essentials [2,3]. Even though Tilapia contains the whole kind of high nutrient value, the addition
of Tilapia on *Koya* delivers a strong fishy smell. It needs to add other ingredients in order to cover the fishy smell. Tempeh is authentic Indonesian food, easy to find, and affordable [4]. Tempeh is a soybean fermented product or from other kinds of soy, and it provides a specific aroma component. The aroma components depend on the fermentation process, such as 2-acetyl-1-pyrroline, 2-methyl propanal, dan 2-ethyl-3,5-dimethyl pyrazine [5]. The aroma component in Tempeh is expected to cover the fishy smell of Tilapia. Besides, tempeh is rich in protein (17.5%), fat (9.2%), and isoflavone [6].

The high nutrient content in *Koya* makes it easily deteriorated during storage. Before it can be consumed, foodstuff undergoes processing like drying, salting, and other processes to extend the shelf life. The stored foodstuff can deteriorate because of humidity, temperature, and microorganism growth, which lead to food spoilage [7]. Those factors can affect the protein and fat contents of foodstuff — for instance, protein denaturation by the proteolytic enzyme and fat oxidation during the processing. The oxidizing process will continue if oxygen and light are present during storage [8]. The damage during storage can decrease the quality of the product that leads to a decrease in consumer acceptance. The decreasing of the quality found on aroma, flavor, texture, and nutrient value [9]. The prolonged shelf life depends on the reaction rate that leads to the damage of the product. It is necessary to identify the reaction rate to the nutritional components of fish *Koya*. This study aimed to determine the rate of reaction kinetics on fish *Koya* according to panellist acceptance and predict its shelf life.

### 2. Methods

#### 2.1. Material

The main ingredient was tilapia fish from Waduk Kedung Ombo, Central Java, Indonesia. Tempeh was obtained from UKM Tempeh Samudra, Mojosongo, Surakarta, Central Java, Indonesia. The spices bought from the local market in Surakarta, Central Java, Indonesia.

#### 2.2. Fish Koya Processing

A milled tilapia and tempeh flour were mixed until homogenous. The milled spices such as shallot, garlic, candlenut, and coriander were sautéed with crushed ginger, galangal, lemongrass, bay leaf, and lime leaf until fragrant. Then coconut milk, palm sugar, and salt were added. After the coconut milk becomes a little dry, ground Tilapia was added to the spices and stirred. Next, discharged the ginger, galangal, lemongrass, bay leaf, and lime leaf from the mixture and then added tempeh flour, mixed until it became brownish color. After that, *Koya* was grinded using a blender and kept inside a metalized plastic. The formulas of fish *Koya* are presented in Table 1.

#### 2.3. Quality Deterioration Kinetics

The quality deterioration on *Koya* was performed by the sensory analysis method with multiple comparison test [10]. The three formulas of *Koya* were stored in three different temperatures, such as 35°C, 45°C, and 55°C for 28 days. The observation was going for five weeks, aimed to determine the rate of quality deterioration during storage. The observation performed on days 0, 7, 14, 21, and 28. Panellists performed the sensory observation with five parameters, including colour, aroma, taste, texture, and overall. The score ranged from 1-7, with the critical limit of 3 determined a little bit worse than the referent. The higher score indicated a better product than the corresponding sample. The score ranged as follows: (1) worst, (2) worse, (3) somewhat bad, (4) no different, (5) somewhat good, (6) better, and (7) best. Then, the results were processed into the Arrhenius plot to define the reaction rate constant as a temperature function.
Table 1. Formulation of Fish Koya

| Ingredients          | N1    | N2    | N3    |
|----------------------|-------|-------|-------|
| Red Tilapia Fillet (g)/ (%) | 108 (40%) | 135 (50%) | 162 (60%) |
| Tempeh Flour (g)/ (%)    | 162 (60%) | 135 (50%) | 108 (40%) |
| Shallot (g)            | 40    | 40    | 40    |
| Garlic (g)             | 55    | 55    | 55    |
| Candlenut (g)          | 5     | 5     | 5     |
| Coriander (g)          | 2     | 2     | 2     |
| Coconut Milk (ml)      | 200   | 200   | 200   |
| Ginger (g)             | 3     | 3     | 3     |
| Galangal (g)           | 6     | 6     | 6     |
| Lemongrass (g)         | 8     | 8     | 8     |
| Bay leaves             | 2     | 2     | 2     |
| Lime leaves            | 4     | 4     | 4     |
| Palm Sugar (g)         | 25    | 25    | 25    |
| Salt (g)               | 3     | 3     | 3     |

2.4. Thiobarbituric acid
In the TBA analysis, 2-thiobarbituric acid would react to malonaldehyde in the sample and created a yellowish red color. The color intensity measured by spectrophotometer [11].

2.5. Shelf Life Estimation
The shelf-life calculated using the ASLT method of the Arrhenius model [12].
Zero-order
\[ t = \frac{(Q_0 - Q)}{k} \]  
First-order
\[ t = \frac{\ln(Q_0/Q)}{k} \]
Notes:
- \( Q_0 \): Value of Quality at the Beginning of Storage
- \( Q \): Value of Quality at the End of Storage
- \( k \): Reaction Rate Constant
- \( t \): Storage Duration (in days, month, or year)

3. Results and Discussions
3.1 Quality Deterioration Kinetics During Storage
The physical changes of fish Koya quality during storage were observed by sensory analysis, including color, aroma, taste, texture, and overall, while for the chemical properties by TBA value.
Table 2. Sensory Score of Fish Koya During Storage at Different Temperatures

| Parameters | Formula | Duration | (days) | Sensory Score | 35°C | 45°C | 55°C |
|------------|---------|----------|--------|---------------|------|------|------|
|            |         |          |        |               | 0.00 | 0.00 | 0.00 |
| Color      | N1      | 0        | 14.00  | 3.80          | 13.86| 13.76| 13.60|
|            |         | 7        | 21.00  | 3.76          | 13.76| 13.60| 13.40|
|            |         | 14       | 28.00  | 3.72          | 13.60| 13.40| 13.20|
|            |         | 21       | 0.00   | 4.14          | 13.40| 13.20| 13.00|
|            |         | 28       | 7.00   | 4.07          | 13.20| 13.00| 12.80|
| Aroma      | N2      | 0        | 14.00  | 3.80          | 13.86| 13.76| 13.60|
|            |         | 7        | 21.00  | 3.76          | 13.76| 13.60| 13.40|
|            |         | 14       | 28.00  | 3.72          | 13.60| 13.40| 13.20|
|            |         | 21       | 0.00   | 4.14          | 13.40| 13.20| 13.00|
|            |         | 28       | 7.00   | 4.07          | 13.20| 13.00| 12.80|
| Taste      | N2      | 0        | 14.00  | 3.80          | 13.86| 13.76| 13.60|
|            |         | 7        | 21.00  | 3.76          | 13.76| 13.60| 13.40|
|            |         | 14       | 28.00  | 3.72          | 13.60| 13.40| 13.20|
|            |         | 21       | 0.00   | 4.14          | 13.40| 13.20| 13.00|
|            |         | 28       | 7.00   | 4.07          | 13.20| 13.00| 12.80|
| Texture    | N2      | 0        | 14.00  | 3.80          | 13.86| 13.76| 13.60|
|            |         | 7        | 21.00  | 3.76          | 13.76| 13.60| 13.40|
|            |         | 14       | 28.00  | 3.72          | 13.60| 13.40| 13.20|
|            |         | 21       | 0.00   | 4.14          | 13.40| 13.20| 13.00|
|            |         | 28       | 7.00   | 4.07          | 13.20| 13.00| 12.80|
| Attributes | Formula | Temp (°C) | Temp (°K) | I/T | k | ln k | Arrhenius Equation | Ea (J/mol.K) |
|------------|---------|-----------|-----------|-----|---|-----|-------------------|--------------|
| **Taste**  |         |           |           |     |   |     |                   |              |
|            | N1      | 35        | 308       | 0.003| 0.014 | -4.241 | y = -4988.6x + 12.068 | 41470.23     |
|            |         | 45        | 318       | 0.003| 0.034 | -3.393 | R² = 0.8622        |              |
|            | N2      | 35        | 308       | 0.003| 0.013 | -4.313 | y = -5073.6x + 12.29 | 42181.91     |
|            |         | 45        | 318       | 0.003| 0.033 | -3.402 | R² = 0.8278        |              |
|            | N3      | 35        | 308       | 0.003| 0.017 | -4.080 | y = -3905.7x + 8.6986 | 32471.99     |
|            |         | 45        | 318       | 0.003| 0.034 | -3.384 | R² = 0.8322        |              |
|            |         | 55        | 328       | 0.003| 0.036 | -3.316 |                   |              |
| **Aroma**  |         |           |           |     |   |     |                   |              |
|            | N1      | 35        | 308       | 0.003| 0.014 | -4.262 | y = -4829.5x + 11.545 | 40152.46     |
|            |         | 45        | 318       | 0.003| 0.034 | -3.744 | R² = 0.8196        |              |
|            | N2      | 35        | 308       | 0.003| 0.005 | -5.404 | y = -3752.4x + 6.8816 | 31197.45     |
|            |         | 45        | 318       | 0.003| 0.009 | -4.711 | R² = 0.8081        |              |
|            | N3      | 35        | 308       | 0.003| 0.018 | -4.034 | y = -3565.6x + 7.6139 | 29644.40     |
|            |         | 45        | 318       | 0.003| 0.032 | -3.455 | R² = 0.8871        |              |
|            |         | 55        | 328       | 0.003| 0.036 | -3.333 |                   |              |
| **Color**  |         |           |           |     |   |     |                   |              |
|            | N1      | 35        | 308       | 0.003| 0.026 | -3.882 | y = -2982.2x + 5.8781 | 24794.01     |
|            |         | 45        | 318       | 0.003| 0.035 | -3.341 | R² = 0.8199        |              |
|            | N2      | 35        | 308       | 0.003| 0.027 | -3.844 | y = -2698.1x + 4.9648 | 22432.00     |
|            |         | 45        | 318       | 0.003| 0.032 | -3.420 | R² = 0.9045        |              |
|            |         | 55        | 328       | 0.003| 0.036 | -3.313 |                   |              |
| **Overall**|         |           |           |     |   |     |                   |              |
|            | N2      | 35        | 308       | 0.003| 0.014 | -4.241 | y = -4988.6x + 12.068 | 41470.23     |
|            |         | 45        | 318       | 0.003| 0.034 | -3.393 | R² = 0.8622        |              |
|            | N3      | 35        | 308       | 0.003| 0.013 | -4.313 | y = -5073.6x + 12.29 | 42181.91     |
|            |         | 45        | 318       | 0.003| 0.033 | -3.402 | R² = 0.8278        |              |
|            |         | 55        | 328       | 0.003| 0.036 | -3.316 |                   |              |
more sensitive to degrade ilapia and during the storage, the aroma of types of amino acids, such as aspartic acid, y a changing of 0.23 J/mol.K confirmed that the makes ion influenced the e occurrence of 3.1.1. Color
Fish Koya had a brownish yellow color, and during storage, the color changed to a darker color. The kinetics of the color are presented in Table 3. Based on the linear regression of zero and first order confirmed that the color degradation was following the zero-order. The prolonged storage and temperature could damage the color. The higher temperature and prolonged storage led to darker color changes due to the maillard reaction. Maillard reaction occurred between reducing sugars and primary amine groups in the material. Maillard reaction occurred during processing and affected the color and sensory characteristics of the product [13]. Maillard reaction occurred in fish Koya was caused by the ingredients and processing. Tilapia contained various types of amino acids, such as aspartic acid, leucine, and lysine [14]. Tempeh flour contained a high lysine that could affect the color of the product [15].

The Arrhenius plot for the color attribute created a linear regression and activation energy. The activation energy is the minimum energy needed for certain chemical reactions to occur. The activation energy can influence how fast or slow the reaction takes place [16]. Based on the Arrhenius plot, the activation energy values for N1, N2, and N3 were 41470.23 J/mol.K, 42181.91 J/mol.K, and 32471.99 J/mol.K, respectively. It indicated that the color on N3 was more sensitive to degrade compared to N1 and N2.

3.1.2. Aroma
Fish Koya had a fishy smell from the tilapia and during the storage, the aroma of fish Koya changed from a distinctive fish smell into an off-flavor. It happened due to the fat oxidation during storage. The fat oxidation caused quality deterioration in the product. The fat oxidation influenced the formation of volatile components that contributed to the occurrence of off-flavor (rancidity) [17]. The kinetics of the aroma degradation are presented in Table 3. Based on the linear regression of zero and first order, it showed that the aroma degradation was following the first order. Arrhenius plot showed that N3 produced the lowest activation energy of 31197.45 J/mol.K compared to other samples. It indicated that the aroma on N3 was easily degraded during storage.

3.1.3. Flavor
Fish Koya had a savoury flavor due to its two main ingredients, tilapia and tempeh flour. The savory flavor was derived from the peptides and glutamate. Glutamic acid is an amino acid that played an essential role in neurotransmission, which gave umami or savory flavor [18]. The flavour of Koya had decreased during storage, identified by a changing of flavor from savory to bitter. The kinetics of the flavor degradation of fish Koya are presented in Table 3. Based on the linear regression of zero and first order, it showed that the flavor degradation was following the zero-order. The bitter flavour in

| Texture | N2     | 35 | 0.003 | 0.017 | -5.279 | y = -3865.8x + 7.368 | 32140.26 |
|---------|--------|----|-------|-------|--------|---------------------|----------|
|         | 45     |    | 0.003 | 0.010 | -4.595 | R² = 0.8375          |          |
|         | 55     |    | 0.003 | 0.011 | -4.519 |                      |          |
| N3      | 35     |    | 0.003 | 0.005 | -5.382 | y = -4438.6x + 9.1428 | 36902.52 |
|         | 45     |    | 0.003 | 0.010 | -4.855 | R² = 0.8278          |          |
|         | 55     |    | 0.003 | 0.011 | -4.510 |                      |          |
| N1      | 35     |    | 0.003 | 0.015 | -4.180 | y = -4413x + 10.255  | 36689.68 |
|         | 45     |    | 0.003 | 0.033 | -3.402 | R² = 0.8397          |          |
|         | 55     |    | 0.003 | 0.036 | -3.313 |                      |          |
| Overall | N2     | 35 | 0.003 | 0.017 | -4.051 | y = -3690.4x + 8.0123 | 30681.99 |
|         | 45     |    | 0.003 | 0.033 | -3.423 | R² = 0.8611          |          |
|         | 55     |    | 0.003 | 0.036 | -3.327 |                      |          |
| N3      | 35     |    | 0.003 | 0.005 | -5.319 | y = -5468.2x + 12.588 | 45462.61 |
|         | 45     |    | 0.003 | 0.014 | -4.290 | R² = 0.7954          |          |
|         | 55     |    | 0.003 | 0.014 | -4.248 |                      |          |
fish Koya caused by Maillard reactions of hydrophobic amino acids that last until storage [19]. The Arrhenius plot showed that N3 produced the lowest activation energy of 22432 J/mol.K compared to other samples. It indicated that the flavor of N3 was easily degraded during storage.

3.1.4. Texture

Fish Koya is a powder with a grainy texture. During storage, the texture of fish Koya changed to hard and dry due to the water loss. Dry products experienced water loss during storage due to temperature treatment [20]. Based on the linear regression of zero and first order, it showed that the texture degradation was following the zero-order. Arrhenius plot showed that N2 produced the lowest activation energy of 32140.26 J/mol.K compared to other samples. It indicated that the texture of N2 was easily degraded during storage.

3.1.5. Overall

Fish Koya had decreased in overall attributes. On day-0 of storage at different temperatures, the average sensory score of N1, N2, and N3 was above 4. It indicated that the sample was not significantly different from the reference sample. While at the end of the storage, days-28 at different temperatures, the average sensory scores of N1, N2, and N3 were above 2 and 3. These values indicated a variation in fish Koya samples after being stored for 28 days. Panelist gave K values that following zero-order, with the reaction kinetics are presented in Table 3.

The quality degradation of the overall parameter was linear to the reduction in color, flavor, and texture. Based on the overall parameters, N2 produced the lowest activation energy of 30681.99 J/mol.K compared to other samples. It indicated that N2 was easily damaged during storage.

3.1.6. TBA

The TBA test was a specific test for the result of unsaturated fatty acids oxidation and formed in foodstuff with low unsaturated fatty acids. Fish Koya gave increasing TBA values during storage. The TBA value of fish Koya during storage are presented in Table 4.

### Table 4. TBA Value of Fish Koya During Storage

| Formula | Duration (day) | TBA (mg malonaldehyde/kg) |
|---------|----------------|---------------------------|
|         | 35°C | 45°C | 55°C |
| N1      | 0    | 0.288 | 0.288 | 0.288 |
|         | 7    | 0.358 | 0.821 | 1.289 |
|         | 14   | 0.548 | 1.011 | 1.460 |
|         | 21   | 0.592 | 1.065 | 1.526 |
|         | 28   | 0.814 | 1.257 | 1.683 |
| N2      | 0    | 0.564 | 0.564 | 0.564 |
|         | 7    | 0.590 | 1.060 | 1.533 |
|         | 14   | 0.784 | 1.219 | 1.671 |
|         | 21   | 0.821 | 1.294 | 1.762 |
|         | 28   | 0.999 | 1.432 | 1.933 |
| N3      | 0    | 0.732 | 0.732 | 0.732 |
|         | 7    | 0.824 | 1.296 | 1.774 |
|         | 14   | 0.992 | 1.477 | 1.926 |
|         | 21   | 1.065 | 1.540 | 1.991 |
|         | 28   | 1.226 | 1.673 | 2.232 |

The TBA value on storage day-0 for N1, N2, and N3 were less than 1 mg MDA/kg. While at the end of the storage, days-28, the TBA values of N1, N2, and N3 were between 0.99 to more than 2 mg malonaldehyde/kg. The increasing number indicated a quality degradation of fish Koya during storage.
The TBA values during storage created k values that following zero-order with the kinetics presented in Table 5.

| Formula | Temp (°C) | Temp (°K) | I/T | k   | ln k | Arrhenius Equation | Ea (J/mol.K) |
|---------|-----------|-----------|-----|-----|------|--------------------|--------------|
| N1      | 35        | 308       | 0.003 | 0.018 | -3.995 | y = -4320.5x + 10.06 | 35920.64     |
|         | 45        | 318       | 0.003 | 0.031 | -3.467 | R² = 0.9861         |              |
|         | 55        | 328       | 0.003 | 0.043 | -3.142 |                     |              |
| N2      | 35        | 308       | 0.003 | 0.016 | -4.154 | y = -5025.7x + 12.186 | 41783.67     |
|         | 45        | 318       | 0.003 | 0.028 | -3.572 | R² = 0.9935         |              |
|         | 55        | 328       | 0.003 | 0.042 | -3.161 |                     |              |
| N3      | 35        | 308       | 0.003 | 0.018 | -4.040 | y = -5850.1x + 14.937 | 48637.73     |
|         | 45        | 318       | 0.003 | 0.030 | -3.493 | R² = 0.9974         |              |
|         | 55        | 328       | 0.003 | 0.056 | -2.881 |                     |              |

TBA value indicated the rancidity level of a product. Rancidity occurred when TBA values ranged more than 3.0 mg MDA/kg. Good quality foodstuff had TBA values less than 3 mg MDA/kg [21]. It showed that fish Koya stored for 28 days at different temperatures were still suitable for consumption. Rancidity in food is related to fat oxidation. In fish Koya, the fat content could trigger the rancidity of the product during storage. The fat content in tilapia fillets was 1.01% [22], while in tempeh flour was 24.7% [23].

The increased temperature and prolonged storage influenced the rancidity of fish Koya. Rancidity occurred due to the presence of malonaldehyde compounds from oxidation during the storage. Malonaldehyde derived from incomplete aldehyde and a result of the hydroperoxides breakdown. It also caused the deterioration of the products, the higher the malonaldehyde content, the higher the TBA value. If the TBA value was high, then the quality decreased or the level of rancidity would be higher. Storage temperature was an essential factor in the oxidation process. TBA value would increase with the increasing storage duration and temperature [24]. The fat oxidation rate would increase with an increase in temperature and would decrease along with a decrease in temperature [25].

3.2 Shelf-life Estimation

The shelf-life on foodstuff is the interval time between production to consumption and when the product is in satisfactory condition based on the appearance, flavor, aroma, texture, and nutritional value [26]. Shelf life was calculated based on the reaction kinetics that occurred on quality attributes. The kinetics of deterioration occurred in fish Koya according to sensory attributes and TBA value is presented in Table 6.

| Formula | Parameter | Equation | R²  | Slope (k) | Ea (J/mol.K) |
|---------|-----------|----------|-----|-----------|--------------|
| N1      | Color     | y = -4988.6x + 12.068 | 0.862 | 4988.0 | 41470.23    |
|         | Aroma     | y = -4829.5x + 11.545 | 0.820 | 4829.5 | 40152.46    |
|         | Taste     | y = -3565.6x + 7.6139 | 0.887 | 3565.6 | 29644.40    |
|         | Texture   | y = -4570.8x + 10.827 | 0.838 | 4570.8 | 38026.57    |
|         | Overall   | y = -4413x + 10.255 | 0.840 | 4413.0 | 36869.68    |
|         | TBA       | y = -4320.5x + 10.06 | 0.986 | 4320.5 | 35920.64    |
| N2      | Color     | y = -5073.6x + 12.29 | 0.828 | 5073.6 | 42181.91    |
|         | Aroma     | y = -4506.6x + 9.2151 | 0.853 | 4506.6 | 37467.87    |
|         | Taste     | y = -2982.2x + 5.8781 | 0.820 | 2982.2 | 24794.01    |
|         | Texture   | y = -3865.8x + 7.368 | 0.838 | 3865.8 | 32140.26    |
|         | Overall   | y = -3690.4x + 8.0123 | 0.861 | 3690.4 | 30681.99    |
|         | TBA       | y = -5025.7x + 12.186 | 0.994 | 5025.7 | 41783.67    |
Based on the table, it found that the three fish Koya formulas for flavor attributes had the lowest activation energy. It indicated that flavor was the first attribute that quickly degraded. The parameter with the lowest activation energy was calculated by projecting it under three different room temperature (30°C). The prediction of shelf life is presented in Table 7.

| Formula | Temp (°C) | Temp (°K) | 1/T | K | Shelf life (days) | Shelf life (months) |
|---------|-----------|-----------|-----|---|------------------|---------------------|
| N1      | 30        | 303       | 0.0033 | 0.016 | 130.53 | 4.35 |
| N2      | 30        | 303       | 0.0033 | 0.085 | 108.51 | 3.61 |
| N3      | 30        | 303       | 0.0033 | 0.088 | 107.45 | 3.58 |

Table 7 shows that the estimated shelf life of N1, N2, and N3 was 131 days, 109 days, and 108 days, respectively. This result was lower compared to high-protein beef meat bone meal packed in PET, with the expected shelf life of 12 months [27]. This different result was due to the different packaging materials used.

4. Conclusion

It can be concluded that all three fish Koya formulas have decreased quality during storage at different temperatures. The flavor attribute exhibits the smallest activation energy among all the three formulas. Based on the calculation, the estimated shelf life of fish Koya N1, N2, and N3 were 131 days, 109 days, and 108 days, respectively.

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