Drying Kinetics and Study of Physical Characteristic Using Image Analysis of Dried Salted Striped Catfish (*Pangasius hypophthalmus*)

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Abstract. Dried salted striped catfish (*Pangasius hypophthalmus*) is one of dried fish produced by salt fermentation and drying process. Drying temperature, time, and methods cause specific characteristic of the product. Human visualization is limited and the conventional method to analyze the characteristic of the product is time consuming so that accurate method is needed with digital image analysis or image processing. The study aimed to determine mathematic model which show the characteristics of dried salted striped catfish cause by different drying process and to observe the visual transformations which is stated in image parameter of RGB, L*a*b, hue, saturation, intensity, area, and texture (entropy, energy, contrast, and homogeneity). This research did by using the temperature settings of 40, 50, and 60°C for 12 hours. Moisture content was carried out every two hours. The images were taken per hour for accurate results. The mathematical models used are Lewis, Henderson and Pabis, and Page. The mathematical models were obtained from the regression analysis. The research showed that the drying constant (k) was directly proportional to temperature increase. Model Page is more suitable than the other mathematical models because it has the highest $R^2$ value and the lowest value of SEE (Standard Error of Estimate). The result of diffusivity effective for each temperature with the value of $8.776 \times 10^{-3}$; $31.922 \times 10^{-3}$; $48.389 \times 10^{-3}$, with the activation energy of 74.34 kJ/g mol. The digital image has a strong correlation with moisture content reduction with $R^2 > 0.8$. The results of entropy and energy on textures were continued with Multiple Linear Regression (MLR) analysis produce equation of Moisture Content (%) = 188.721 + (Energy x 40.249) + (Entropy x (-25.801)).

1. Introduction
Striped catfish is one of the most popular commodities in Indonesia and widely consumed in the community. It has thick flesh and high-fat content. The nutritional content of striped catfish includes 16.08% protein, 5.75% fat, 1.5% carbohydrate, 0.97% ash, and 75.7% moisture content [1]. Fish is highly perishable food because it contains high protein and water. Therefore, handling by processing is needed to maintain the quality of fish [2].

Striped catfish are mainly processed by drying or salting which is called “jambal” [3] or dried catfish [4]. Drying catfish is usually done traditionally with the help of sunlight, which made it very dependent on the weather. The factors that influence the processing are the type of salt, salting and drying method [5].

The drying process can affect product characteristics. Drying is a process that combines heat and mass transfer. A mathematical model can explain a drying process so that it can design a drying suitable for striped catfish. The drying constant in the modeling can also be used further to predict the moisture content of the material.
In processing, the quality of the product should be the main focus. Human visualization and testing are conventional to analyze changes during and after drying risks are less accurate and requires a lot of time. Therefore, a quick method is needed by analyzing digital images. The purpose of digital image processing is to obtain information from images so the results are more convenient to read [6]. Information obtained from these images can be analyzed to determine product characteristics after drying without destructive testing, so the process is more effective and efficient. Image processing has been widely applied in the field of fisheries and agriculture such as the identification the effect of drying on the parameters of color and texture quality of sardine [7], visual changes of onion due to drying [6], and image analysis on drying ginger [8].

2. Methods
2.1. Sample preparation
Striped catfish (Pangasius hypophthalmus) were obtained from Rejomulyo market, Semarang. The samples were taken to the Laboratory by using a coolbox. The fish were cleaned from the head and entrails. After being washed thoroughly, the salting was done with 30% of salt for 24 hours. The salted fish was cut into a small square shape with ± 8 gr weight and dried to reduce the water content.

2.2. The experimental procedure
The drying process was carried out using an electric oven. The samples were placed on a rack so the heat is distributed evenly to all samples. The temperatures were set to 40, 50, 60°C for 12 hours. The samples were measured during the drying process every hour. The shrinkage of weight was measured using analytical scales. The image was taken every hour by using a webcam on a fiber box and visual observations with organoleptic tests on the sample. The 2 LED lights of 5-watt were placed for lighting. The moisture content test was carried out every 2 hours with the gravimetric method to determine the pattern of the decrease. Other tests carried out were salt content tests and aw. The temperature and humidity test were also carried out in the oven using a hygrometer [8].

2.3. Drying Kinetics
2.3.1. Drying rate
Equation used as follows [9],

\[ L_{pi} = (MC(i) - 1) / (t(i) - t(i-1)) \]

which MC represent moisture content (%) and t represent time (hour)

2.3.2. Moisture Ratio (MR)
MR calculated with following equation [10],

\[ MR = (Mt - Me) / (M0 - Me) \]

On oven drying, air humidity is inconstant where Me assumed to be ignored, so the equation is simplified to,

\[ MR = Mt / M0 \]

2.3.3. Drying Kinetics Models
Non-linear regression analysis was performed using Microsoft Excel. The matching results between experimental data and mathematical models were evaluated by the coefficient of determination (R²) and the Standard Error of Estimate (SEE). The best possible matching are those with the greatest R² value and the smallest SEE. Equation mathematical model used is as follows:

| Mathematical Models | Equation                                                                 | References |
|---------------------|--------------------------------------------------------------------------|------------|
| Lewis               | MR = exp(-kt)                                                            | [11]       |
|                     | ln (MR) = -kt                                                            |            |
| Page                | MR = exp(- km)                                                           | [12]       |
|                     | ln (-ln (MR)) = ln(k)+nln (t)                                            |            |
| Henderson and Pabis | MR = a exp(-kt)                                                          | [13]       |
|                     | ln MR = -kt + ln (a)                                                     |            |

Notes: MR = Moisture Ratio
k, a, n = drying constant
**Lewis Model**
This model assumes negligible internal resistance, which means there is no resistance to moisture movement from within the material to the surface. This model was used in many drying processes because it is simple. But, this model has deficiency, that it tended to over predict at the early stages and under predict at the later stages of the drying curve [19] [36].

**Henderson and Pabis Model**
This model has been used to model thin layer drying characteristic. The slope of this model is related to effective diffusivity when the drying process takes place only in the falling rate period and the diffusion controls the process [19] [37].

**Page Model**
[38] suggested a two constant empirical modification of the exponential model to correct for its shortcomings. The Page model modified the Lewis model by adding “n” as an empiric constant. The value of n varies for each material. This model has produced good fits to describe drying of many agricultural products and also more convenient to use compared with other equations which take more time in computing data [19] [27].

### 2.3.4 Evaluation of Effectiveness of Diffusion

The characteristics of drying in falling rate period can be explained by using Fick's diffusion law [14] in the following equation,

\[ MR = \frac{8}{\pi^2} \exp \left( \frac{D_{eff}}{4L^2} \right) \]

Where \( D_{eff} \) is the effective diffusivity (m\(^2\)/s); \( L \) is half the thickness of the material (m). Equation 4 can be changed in logarithmic form as follows:

\[ \ln (MR) = \ln \frac{8}{\pi^2} - \frac{D_{eff}}{4L^2} t \]

### 2.3.5 Calculation of Activation Energy with Arrhenius

Activation energy can be obtained from the slope calculation of the relationship \( \ln (D) \) vs \( 1/T \). The relationship between the effectiveness of moisture diffusion and temperature can be calculated with the Arrhenius equation as follows [15],

\[ D_{eff} = D_0 \exp \left( \frac{-E_a}{RT} \right) \]

Where \( D_{eff} \) is the effective diffusivity (m\(^2\)/s); \( D_0 \) is the effective diffusivity constant at high temperatures (m\(^2\)/s); \( E_a \) is the activation energy, \( R \) is the gas constant (8.314 J / mol K), and \( T \) is the absolute temperature (K).

### 2.4 Color Kinetics

The image during the drying process processed with MATLAB R2014b. The image was processed by image segmentation to obtain an RGB image. Conversion of RGB images was carried out to produce color parameters \( L \ast a \ast b \), HSI (Hue, Saturation, and Intensity), and grayscale. The detected grayscale image at the edge used to count the number of pixel dots to produce the Area of the image object. Besides, from the grayscale image, the results of the Texture Features (energy, contrast, homogeneity, and entropy) obtained from the image using a gray-level co-occurrence matrix (GLCM) method. The RGB color index is obtained from the following equation [16],

\[ r = \frac{R}{R + G + B} \]
\[ g = \frac{G}{R + G + B} \]
\[ b = \frac{B}{R + G + B} \]

Where \( r \), \( g \), \( b \) are the respective indices red, blue and green respectively.
3. Results and Discussion

3.1. Drying Fish

3.1.1. Moisture Content

Samples that dried at temperatures of 40, 50, and 60 at the 0 hour drying had moisture content of 57.11%; 61.50%; and 60.44% respectively. The moisture content measured after fish was salted for 24 hours. At 12 hours of drying, moisture content became 47.68%; 44.76%; and 41.98% respectively.

The decrease of moisture content at these temperature variations occurred because the water has evaporated by heat energy during the drying process. Water from inside the material will move to the surface of the product, which then evaporates into the air. This is in accordance to [17], which stated that the process of evaporation from a material involves five stages, namely the release of water bonds from the material, the diffusion of water and the water vapor from the material to the surface, the phase change to water vapor, the transfer of water vapor from the surface material into the surrounding air, and the transfer of water vapor in the air.

In the process of drying dried catfish, the fastest decrease in water content is drying at 60°C. This is because the higher the drying temperature the faster the process of evaporation of water. This is reinforced by [18], that moisture content was significantly affected by drying time, drying temperature, and a time-temperature interaction. Increasing the temperature resulted in a higher decline in moisture content and drying time.

3.1.2. Shrinkage of Weight

Initial sample weights for each temperature 40, 50, and 60°C are 7.44; 7.49; and 7.28 grams. After drying for 12 hours each sample weight shrinked to 5.79; 5.27; and 4; 27 grams. At 60°C, the largest weight loss was 3.01 grams. The highest drying reaction speed can be seen in Table 2 at a temperature of 60°C at $6.18 \times 10^5$ gr/s. Based on research [8], the drying process causes post-harvest losses such as physical losses measured by weight. The lowest weight reduction occurs on the bottom shelf drying. This is due to the proximity of the material to the furnace as a heating source, so the water in the material continues to evaporate quickly which causes weight reduction of the material.
Weight loss occurred due to the process of transpiration of water from materials caused by high temperatures. The loss of water during this process caused a reduction in weight and moisture content in the material. A higher temperature would make the meat shrinkage go faster. According to [19], the increase in the drying air temperature consequently increased drying rate and decreased drying time. Water content decreases because the water on the material was transported to the surface and then evaporated. The higher the temperature, the mass transfer on the material becomes faster. This also relates to relative humidity. If the drying temperature was increased, so the relative humidity decreases. The lower relative humidity of the air increases the difference between water vapor pressure on the surface of the fish and the air, so the drying process goes faster [9].

3.1.3. Salt Content

![Figure 3. The salt content value changes in dried salted striped catfish](image)

The initial salt content ranged between 35.6 - 41.51% db. Evaporation of water content in the product during the drying process caused the salt content to increase. In Figure 3, the highest salt content after drying at 60°C was 44.21% DB and the lowest at 40°C was 37.61% DB. This due to a higher temperature, which made moisture content decrease, making the value of the salt content increase. According to [20], in the study of dried milkfish (Chanos chanos), the salt content in dried fish was influenced by salt penetration during the salting process, the quality of fish and the high-fat content in the fish. These factors caused the salt penetration fast into the fish. Based on research [21] about stingray drying, the sun drying gives the highest hedonic taste value. This was due to the drying temperature is not too high, so the saltiness in the meat is too weak. While the lowest hedonic value was on the microwave treatment caused by high temperatures, so it forms caramelizing on the surface of the meat. This shows that the temperature affects the salt content in a material.

3.1.4. Water activity ($a_w$)

![Figure 4. The $a_w$ value changes in dried salted striped catfish](image)
The initial value of water activity \( (a_w) \) was between 0.74 - 0.76. Water activity \( (a_w) \) decreased after drying for 12 hours, which was around 0.72. According to [22], the value of water activity \( (a_w) \) influenced by salt concentration and soaking time. This happened because of osmosis, which caused the water level to decrease. Salt would bind easily to water, making the free water in the material decreased. Also, the water activity \( (a_w) \) decrease if there is drying treatment. This was confirmed by research [23], stated that low \( a_w \) value occurred because of high drying temperature. Low water \( (a_w) \) activity caused by high heating temperature. Different values of water activity on heating and drying time on the orange turmeric sample produce different result.

The decrease in water activity is free water that can be used by microbes for growth due to changes in salt, sugar, and the drying process [24]. Based on research by [25], the decrease of temperature during storage can increase the amount of bound water that will be followed by increased water activity \( (a_w) \). According to the theory of moisture sorption isotherms that a decrease in temperature is following by an increase in water content at the same humidity or in other words increased water vapor absorption capacity. This show that temperature can affect the value of water activity in a material.

### 3.1.5. Organoleptic Properties

| Time (hours) | Appearance | Texture |
|--------------|------------|---------|
| 0            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 1            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 2            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 3            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 4            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 5            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 6            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 7            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 8            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 9            | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 10           | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 11           | 3.0 ± 0.00 | 9.0 ± 0.00 |
| 12           | 3.0 ± 0.00 | 9.0 ± 0.00 |

At the temperature of 40°C, the organoleptic value on appearance has above seven at 10 hours of drying, while at the temperature of 50° and 60°C organoleptic have above 7 at 9 hours of drying. The value fit the standard in SNI 8376: 2017 for dried “jambal”, which at least 7. The appearance changed quickly as the temperature rose higher. According to [26], in the drying process, the appearance is related to the moisture content in the ingredients. Moisture content is an important component in food because it can affect the appearance value of the product.

Organoleptic values of texture parameters differed in each temperature variation. At 40°C, organoleptic values have a value above 7 at 11 hours after drying time, while at 50°C and 60°C the organoleptic value reached seven at 9 hours after drying time. This showed that higher drying temperature fastens the texture changes in dried catfish. According to [24], the addition of salt caused denaturation in fish protein, caused it lost weight and the water content oozed out. Protein denaturation would continue with coagulation (clumping), making the meat texture more compact. When associated with drying, the meat was denser than when it was fresh.

### 3.2. Drying Kinetics

#### 3.2.1. Drying Rate

Based on the figure 5, the drying rate of dried catfish decreased. This is because the longer the time, the less water is evaporated. The highest drying rate occurs at 60°C and the lowest at 40°C. Figure 5 shows that the pattern of the drying temperature at 40°C was different on its own. At the end of the drying process, the rate was higher than in the beginning.
This was possible because at the time with the temperature of 40°C variable, the oven door was often opened for practical sampling due to device limitations. This affected the fluctuation of the oven drying room temperature at the beginning of the drying process so that the drying rate was lower than at the end of the process. According to [9], the drying rate in the drying of mackerel thin films increased with increasing temperature, so the drying rate was directly proportional to the drying temperature used. In the initial drying stage, the drying rate was higher than the final drying stage. This was due to the initially water for evaporation comes from regions near the surface [19].

The drying rate is the amount of water that evaporated every unit of time and affected by the size, shape, composition of the material during the drying process, the temperature of the humidity, and the speed of the drying airflow. It showed strong dependence of drying rate with temperature. Drying rate increases when air temperature increases and moisture transfer occurs in the falling rate period of drying [27].

3.2.2. Drying Room Temperature and RH

Based on Figure 6, the initial RH at the temperature of 40°C, 50°C, and 60°C was 57.1%; 59.5%; and 58.1%. At the end of the final drying process, the RH was 34.8%; 25.1%; and 16.1%, respectively. The lowest RH value was 16.1% at 60°C and the highest was 34.8% at 40°C.

The difference in drying temperature affects the relative humidity (RH) value. The highest relative humidity value occurs at the initial process in all temperature variables. This was due to the initial drying temperature is relatively low so that the humidity is high. Moisture drying air affects the ability of air to absorb moisture from the dried material. The lower the moisture value of the drying air, the greater the moisture absorbed into the air from the dried fish. So, that the drying process becomes faster. According to [28], the higher temperature of the drying air, the lower of the RH on drying chamber. When the RH in the drying chamber is lower than the RH of the environment will result in a higher
drying rate. This is due to the temperature of the dryer. This is reinforced by [9], that the lower humidity of the air, the greater moisture that moves from the material to the air. This means that the drying rate will increase, so the drying process becomes fast. This capability decreases with increasing humidity in the drying air.

The controlled drying temperature is needed in the drying process so that the dried material quality is maintained. The controlled temperature in a certain range will affect the rate of heat transfer from the drying air to the dried material and the rate of water evaporation from the material to the drying air [29].

3.2.3. **Moisture Ratio (MR)**

Based on Figure 7, the pattern of MR reduction is in line with the pattern of decreasing moisture content of the material during drying. The moisture content decreases due to the increase in drying temperature.

![Figure 7. Effect of temperature on moisture ratio of dried salted striped catfish](image)

An increase in drying temperature causes increase the heat transfer process so that the increase in temperature reduces the time needed to reach each level of humidity ratio. The predictive MR pattern results from the calculation of the water content are then used to determine the best drying model in dried salted catfish. According to [30], the pattern of decreasing MR (moisture ratio) is in line with the pattern of decreasing water content in a material. This is because MR is calculated based on changes in water content.

3.2.4. **Drying Model**

The MR data were analyzed by Linear Regression using Microsoft Excel to find the values of drying constants and determine the mathematical model for drying catfish. The higher the temperature, the drying constant (k) was also greater, while the constants a and n were smaller. The a and n constant value is affected by the air humidity. In this research, the air humidity on the drying chamber decreases when the temperature rises, so the a and n constant values were also lower. The constant increases with increasing humidity and decreasing air velocity [31]. To determine the most suitable drying models and the characteristics of the material, it could be seen from the highest $R^2$. The highest value of $R^2$ was on the model Page $60^\circ C$, equal to 0.9848. The average value of SEE (Standard Error of Estimate) lowest is in the Page model that is equal to 0.014707. This value showed that the Page model is the most suitable model for drying of dried salted catfish in this study. The Page drying model is modified model of the Lewis model. This model was widely used for drying thin layer. The thin layer drying equation can be used to predict curves in drying process in general [32]. The Page model modified the Lewis model by adding “n” as an empiric constant. The value of n varies for each material. This model has produced good fits to describe drying of many agricultural products and also more convenient to use compared with other equations which take more time in computing data [27].

The predicted MR value was calculated from the model formula by entering the drying constants in the Page model equation to compare the actual MR value and the model. The model equation used $MR = \exp (-ktn)$. 

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8
Table 3. Model and constant drying in drying of dried salted striped catfish at various temperatures

| Model       | Temperature | K       | a      | n     | $R^2$  | SEE   |
|-------------|-------------|---------|--------|-------|--------|-------|
| Lewis       | 40          | 0.0129  |        |       | 0.8739 | 0.018206 |
|             | 50          | 0.0303  |        |       | 0.9517 | 0.018716 |
|             | 60          | 0.0345  |        |       | 0.9015 | 0.030547 |
| Hederson &  | 40          | 0.0153  | 1.020303 |  | 0.8919 | 0.021955 |
| Pabis       | 50          | 0.0287  | 0.986295 |  | 0.9594 | 0.017886 |
|             | 60          | 0.0293  | 0.955806 |  | 0.9446 | 0.026463 |
| Page        | 40          | 0.0087  |        | 1.0887 | 0.9056 | 0.012458 |
|             | 50          | 0.03172 |        | 0.9847 | 0.9553 | 0.019269 |
|             | 60          | 0.07189 |        | 0.6731 | 0.9848 | 0.008902 |

3.2.5. Effective Diffusivity

Figure 8. Relationship Between ln MR and Time in Drying of Dried Salted Striped Catfish at Various Temperature

The effective diffusivity value of drying dried salted striped catfish with the different temperature variables were obtained by plotting ln MR vs t in Figure 8. The plotting results was used to find the effective diffusivity value ($D_{eff}$). The $D_{eff}$ value was calculated by slope from linearization of the curve in Figure 7.

Table 4. Effective Diffusivity of Dry Salted Catfish at Various Temperature

| No | Temperature (°C) | $D_{eff}$ (m$^2$/s) |
|----|------------------|---------------------|
| 1  | 40               | 8.776 x 10$^{-3}$   |
| 2  | 50               | 31.922 x 10$^{-3}$  |
| 3  | 60               | 48.389 x 10$^{-3}$  |

From the results of these data can be seen that the diffusivity value will increase with increasing temperature. This happens because at higher temperatures, water evaporation will occur more quickly. Diffusivity is used to indicate the flow of moisture out of material during drying. In the falling rate period of drying, moisture is transfer mainly by molecular diffusion. Moisture diffusivity is influenced mainly by moisture content and temperature [30]. This is in accordance with the research conducted by [14] who states that diffusivity increases with increasing temperature. Evaporation was faster at higher temperatures, so the diffusivity will be even greater.

Effective diffusivity depends on the drying temperature. Variety, composition of material, and heat sorption within the food is another factor that affects effective diffusivity. Effect of temperature on effective diffusivity is generally described using Arrhenius to obtain the predicted curve of data experiment [19].
3.2.6. Application of Arrhenius Theory

![Graph showing effective diffusivity as a function of temperature](image)

Figure 9. Effective Diffusivity as a Function of Temperature

Figure 9 shows the relationship between Ln D vs 1/T expressed in Kelvin's absolute temperature (K). By adhering to the Arrhenius equation, the relationship of LN D vs 1/T is dilinierized and obtained the value of slope will be the value of Ea/R, so it can be calculated the activation energy is obtained at 74.34 kJ/gmol. This is in accordance with the research conducted by [14] regarding the drying of rosella flowers that follow the Arrhenius equation to obtain the energy value of its activations.

3.3. Kinetic

3.3.1. Changes in Area

Visually there is a change in the area and color of the fish samples shown in Table 5. The change in surface area occurs as the drying time increases. The longer the drying time, the surface area of the sample increasingly shrinks. The Area has a strong connection with the sample weight data obtained from weighing during drying. It is indicated by a coefficient of determination ($R^2$) value of 0.9788 in Figure 10. The Area decreases in line with the weight loss caused by water content in the material that evaporates.

![Graph showing relationship between area and weight loss](image)

Figure 10. Relationship Between Area and Weight Loss of Dried Salted Striped Catfish during Drying
Table 5. Visually changing color and sample size of dried salted striped catfish during 12 hours drying

| Drying Time (hours) | 40 | 50 | 60 |
|---------------------|----|----|----|
| 0                   | ![Image] | ![Image] | ![Image] |
| 1                   | ![Image] | ![Image] | ![Image] |
| 2                   | ![Image] | ![Image] | ![Image] |
| 3                   | ![Image] | ![Image] | ![Image] |
| 4                   | ![Image] | ![Image] | ![Image] |
| 5                   | ![Image] | ![Image] | ![Image] |
| 6                   | ![Image] | ![Image] | ![Image] |
| 7                   | ![Image] | ![Image] | ![Image] |
| 8                   | ![Image] | ![Image] | ![Image] |
| 9                   | ![Image] | ![Image] | ![Image] |
| 10                  | ![Image] | ![Image] | ![Image] |
| 11                  | ![Image] | ![Image] | ![Image] |
| 12                  | ![Image] | ![Image] | ![Image] |

Table 5 is indicate color changes in the sample occurred along with the drying time. The color changed due to chemical reactions caused by the drying heat. This trends in colour changes were attributed to reactions due to the high temperatures. When the drying temperature and time increased or the moisture content decreased, then more browning products were produced [7].
3.3.2. **Relationship of Water Content with Color Changes**

**Table 6. The Relationship of Color to Moisture Content at 60°C Drying**

| Water Content (%) | \( y \) equation | \( R^2 \) |
|-------------------|-------------------|----------|
| L                 | - 0.5607 \( x + 71.421 \) | 0.9512   |
| \( a \)           | 0.3375 \( x - 10.282 \) | 0.9626   |
| \( b \)           | 0.302 \( x + 2.572 \) | 0.9083   |
| Hue               | - 0.0009 \( x + 0.127 \) | 0.9024   |
| Saturation        | 0.0109 \( x - 0.1401 \) | 0.9943   |
| Intensity         | - 0.7023 \( x + 114.53 \) | 0.8952   |
| \( r \)           | 0.0011 \( x + 0.4594 \) | 0.9265   |
| \( g \)           | - 0.0031 \( x + 0.5644 \) | 0.9765   |
| \( b \)           | 0.002 \( x - 0.0238 \) | 0.9832   |

Based on Table 6, color is closely related to changes in sample moisture content during drying. Each color parameter has the coefficient of determination \( (R^2)>0.9 \), which means having a strong correlation with changes in moisture content.

In many cases, there is a correlation between color and other components such as moisture and fat content, hardness, and appearance is related to consumer acceptance. When the drying period increases, the water content decrease. Color changes are caused by physical and chemical reactions such as reducing water in the material. The presence of water in food affects the wavelength and the amount of light reflected from its surface [33] [16] [34].

3.3.3 **Relationship of Water Content with Texture**

Based on Table 7, it can be seen that the entropy value was tended to increase, while the energy and homogeneity values were decreased when observed in decreasing moisture content. For the contrast value, it was slightly decreased although at some time the drying value has risen. This is confirmed by research [35] regarding the drying of Tarkhineh (Iranian traditional food), the entropy parameter has an upward tendency while the homogeneity and energy parameters on the contrary tend to go down. For contrast parameters have another tendency. According to [6], the contrast has an increase tendency when the moisture content of the material decreased. This is indicating that there are a high of local variety in spatial distribution.

**Table 7. Some Image Texture of Dried Salted Striped Catfish During Drying (Temperature 60°C)**

| Time | Energy ± | Contrast ± | Homogeneity ± | Entropy ± |
|------|----------|------------|---------------|-----------|
| 0    | 0.48 ± 0.08 | 0.13 ± 0.04 | 0.95 ± 0.01 | 5.69 ± 0.34 |
| 1    | 0.45 ± 0.07 | 0.18 ± 0.02 | 0.94 ± 0.01 | 5.70 ± 0.27 |
| 2    | 0.42 ± 0.10 | 0.13 ± 0.03 | 0.94 ± 0.01 | 5.93 ± 0.37 |
| 3    | 0.40 ± 0.08 | 0.09 ± 0.02 | 0.94 ± 0.01 | 5.96 ± 0.21 |
| 4    | 0.40 ± 0.10 | 0.12 ± 0.04 | 0.94 ± 0.02 | 6.01 ± 0.35 |
| 5    | 0.40 ± 0.03 | 0.13 ± 0.03 | 0.94 ± 0.02 | 6.09 ± 0.11 |
| 6    | 0.39 ± 0.04 | 0.12 ± 0.02 | 0.94 ± 0.01 | 6.11 ± 0.00 |
| 7    | 0.38 ± 0.02 | 0.12 ± 0.02 | 0.94 ± 0.01 | 6.12 ± 0.11 |
| 8    | 0.37 ± 0.03 | 0.12 ± 0.03 | 0.94 ± 0.01 | 6.15 ± 0.00 |
| 9    | 0.37 ± 0.10 | 0.11 ± 0.02 | 0.94 ± 0.02 | 6.16 ± 0.18 |
| 10   | 0.37 ± 0.13 | 0.12 ± 0.03 | 0.94 ± 0.02 | 6.17 ± 0.06 |
| 11   | 0.36 ± 0.06 | 0.12 ± 0.03 | 0.93 ± 0.01 | 6.20 ± 0.11 |
| 12   | 0.33 ± 0.01 | 0.12 ± 0.02 | 0.92 ± 0.00 | 6.22 ± 0.12 |
The result obtained from the texture image of dried salted striped catfish showed that energy and entropy values changed significantly during the drying process. Figure 11 shows the correlation between entropy and energy features on the moisture content in dried striped catfish. Energy and entropy parameters have a strong correlation to moisture content decreases of dried striped catfish during drying. This is indicated by the coefficient of determination ($R^2$) each is equal to 0.9669 and 0.9843, while the correlation of moisture content with homogeneity and contrast features was not strong which indicated the $R$-value less than 0.9 (the graph is not displayed), so it can't be used to predict the moisture content of dried salted striped catfish. From these data then analyzed with Multiple Linear Regression (MLR) using Microsoft Excel. The equation obtained to find the amount of moisture content based on energy and entropy texture features, namely:

$\text{Moisture Content (\%)} = 188.721 + (\text{Energy} \times 40.249) + (\text{Entropy} \times (-25.801)) \ldots \ldots \ldots (10)$

Figure 12 shows the relationship between moisture content obtained from the image analysis (Y) with moisture content obtained from gravimetry method (X). The graph shows the coefficient of determination ($R^2$) of 0.983 which means to have a close correlation, so the equation (10) can be used to predict the moisture content of dried salted striped catfish. Also, the graph shows that the relationship between the moisture content obtained from the gravimetry method (X) and the moisture content obtained from image analysis (Y) is $Y = 0.9917X + 0.5542$.

Based on research by [35], the Multiple Linear Regression (MLR) method was successful predicts the water content of each “Tarkhineh” product.

4. Conclusion
Dried salted striped catfish drying rate indicates a falling rate of drying period. The most suitable model among the three models is the Page model because this model has the highest $R^2$ value and the lowest SEE (Standard Error of Estimate) average value. Effective diffusivity value at 3 variable temperature 40, 50, 60°C at 12 hours drying time in sequence of $8.776 \times 10^{-3}$; $31.922 \times 10^{-3}$; $48.389 \times 10^{-3}$ with its activation energy value of 74.34 kJ/Gmol.
Samples of dried salted striped catfish experienced a decrease in the value of \( a_i \) from those ranging from 0.74 – 0.76 to 0.72 and the increase in salt content from the range of 35.6 – 41.51% db became the highest at the temperature of 60\(^\circ\)C, i.e. 44.21% db. In addition, visually the dried samples underwent discoloration and texture. Once the digital image is analyzed and then analyzed by linear regression, it can be seen that the value of color parameters has a strong correlation with decreased moisture content. Each parameter has a value of \( R^2 \) above 0.8. From the energy and entropy data as texture features analyzed with Multiple linear Regression (MLR) by using Microsoft Excel obtained equations that can be used to predict the moisture content of dried salted striped catfish.

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