Shelf Life of Nori from *Eucheuma cottonii* with Aluminum Foil Packaging Based on the Accelerated Shelf Life Test Method

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Authors' contributions

This work was carried out in collaboration among all authors. Author SAM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EL and ER managed the analyses of the study. Author EA managed the literature searches. All authors read and approved the final manuscript.

ABSTRACT

This research aims to determine the shelf life of Nori from *Eucheuma cottonii* in aluminum foil packaging using the Accelerated Shelf Life Test (ASLT) method with the Arrhenius approach model. This research was conducted using aluminum foil packaging to package *Eucheuma cottonii* nori products in 2 different storage temperatures, namely 25°C and 35°C. Observations were made on the 35th day with a countdown method which included sensory testing and moisture content testing. The data from the observations had analyzed the estimation of shelf life using the Arrhenius approach model. The results showed that the taste quality parameter is a critical parameter that determines the shelf life of *Eucheuma cottonii* nori using aluminum foil packaging. The shelf life of nori from *Eucheuma cottonii* using aluminum foil packaging has a shelf life of 2 months 14 days 17 hours.

Keywords: Aluminum foil; Arrhenius; packaging; nori Eucheuma cottonii; shelf life.

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1. INTRODUCTION

Seaweed or sea algae (seaweed) is one of the main commodities of aquaculture in Indonesia. Seaweed can be used as a food ingredient, used in the pharmaceutical, cosmetic and textile industries [1]. The total production of Indonesian seaweed in 2016 reached 11 million tons or an increase of almost 4 (four) times compared to 2010, namely 3.9 million tons [2].

One of the foods made from seaweed is nori. Nori is a traditional Japanese food made from *Porphyra* red seaweed, in the form of thin sheets that are consumed after drying and roasting [3]. However, this seaweed is difficult to cultivate in tropical climates. Therefore, it is necessary to look for alternatives to other types of seaweed that are easily cultivated in Indonesia as a raw material for nori.

One type of seaweed that is often cultivated in Indonesia and used as raw material for making nori is *Eucheuma cottonii*. *Eucheuma cottonii* is a type of red seaweed (*Rhodophyceae*) known as *Kappaphycus alvarezii*. *Eucheuma cottonii* as a carrageenan product can be used as industrial raw material and can be processed into food that can be consumed directly [4].

Nori has properties that easily lose its crunchy taste and easily becomes moist. To prevent this from happening, an effort is made, one of which is the packaging. The packaging is an important requirement to maintain the quality of food ingredients the packaging plays a role in protecting the ingredients from microbial growth and pollution from outside as well as preventing the entry of foreign objects, that quality is maintained and the shelf life of packaged food is longer [5].

The packaging of the right form, type and a good packaging process is very important to determine the expiration period of the packaged food product. Therefore we need a method of estimating shelf life that is the fastest, easiest, closer to the actual shelf life, and following the characteristics of the food product concerned [6]. The *Arrhenius Model Accelerated Shelf Life Test* (ASLT) method is a method of estimating the shelf life of a product using accelerated temperatures so that it can accelerate reactions that cause damage to products [7].

The packaging used to package nori in this study is aluminum foil packaging. Aluminum foil packaging can maintain product quality, that product protection from dirt, contamination, physical damage, can withstand gas and water vapor transfer. Also can prevent from damage due to lighting and oxidation to extend product shelf life (Rohima 2010). This packaging is expected to be able to prevent the degradation of *Eucheuma cottonii* nori and reduce damage to nori by preventing the entry of air so that the amount of moisture content in the nori does not increase during storage. Therefore, it is necessary to research on the shelf life of nori using *Eucheuma cottonii* aluminum foil packaging with the Arrhenius Model ASLT Method.

2. MATERIALS AND METHODS

2.1 Tools

The tools used for the manufacture of nori in this research were aluminum foil packaging, an electric scale with an accuracy of 500 g and 0.01 g, basin, blender, measuring cup, spatula, pan, gas stove, 17 x 27 cm baking sheet, oven, label sticker, incubator, and sealer.

2.2 Materials

The ingredients used to make nori [8] were dried *Eucheuma cottonii* seaweed, rice water, clean water, salt, sugar, pepper, flavorings, fish sauce, olive oil, and sesame oil.

2.3 Methods

This research was carried out at the Fisheries Product Processing Laboratory of the Faculty of Fisheries and Marine Sciences, Padjadjaran University from January to March 2020. This research used the *Accelerated Shelf Life Test* (ASLT) method of the Arrhenius model, testing is carried out using of Nori products made from *Eucheuma cottonii* as a material in aluminum foil packaging which is stored at 25°C and 35°C for 35 days. Observations were made on 1, 7, 14, 21, 28, and 35 days for each treatment. The parameters tested for estimating the shelf life of the Arrhenius ASLT method were using sensory data (appearance, aroma, texture, taste) and water content test. Determination of the shelf life of *Eucheuma cottonii* nori is determined based on the smallest activation energy among sensory parameters (appearance, aroma, texture, and taste) and moisture content. The formula for determining shelf life is as follows:

If you follow the zero-order kinetic rate model the formula is as follows [9] :

$$C_t - C_0 = KT_t$$

Information:

K_t = Damage reaction rate
C_t = Concentration at time t in zero order
C_0 = Initial concentration in zero order

Furthermore, if the reaction rate follows order one the formula is as follows:

$$L_n C_t = L_n C_O + K \times t$$

Information:

$L_n C_t$ = Concentration at time t in order one
$L_n C_o$ = Initial concentration in order one

3. RESULTS AND DISCUSSION

3.1 Appearance

Appearance is the first parameter that consumers assess a product. The level of acceptance of food products from appearance is influenced by color changes color chanches will also indicate changes in nutritional value, so that color changes are used as indicators of quality degradation. The observation results of nori made from *Eucheuma cottonii* packaged in aluminum foil were based on the appearance parameters at 25°C and 35°C storage (Table 1).

Table 1. Average value of appearance of nori during storage

Code	Temperature (°C)	Appearance parameters					
		1	7	14	21	28	35
Aluminum Foil	25	8.71	8.71	7.57	7.29	6.43	5.86
Alumunum Foil	35	8.71	8.71	8.14	7.29	6.71	6.14

The change in appearance pattern of the nori product, a linear regression equation and correlation (R^2) were obtained for the zero order reaction (Fig. 1) for each treatment by comparing R^2 in the first order reaction equation in the same figure. The comparison of the R^2 value on aluminum foil packaging (at 25°C and 35°C) which has the highest R^2 value, namely zero order in the graph of the decrease in appearance score against time, so that in determining the Arrhenius equation, zero order is chosen for aluminum foil packaging.
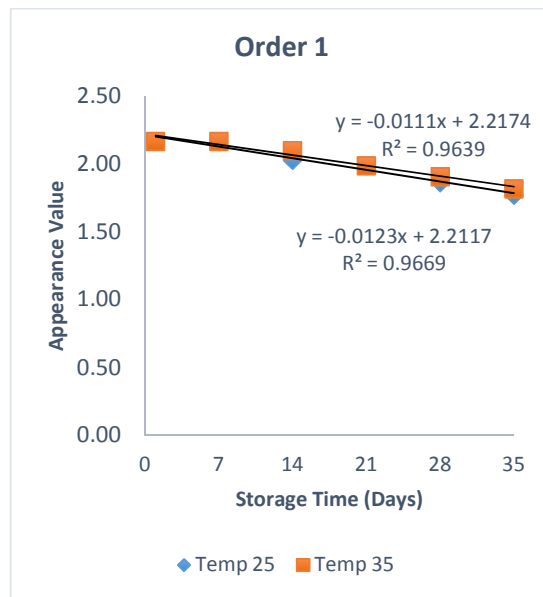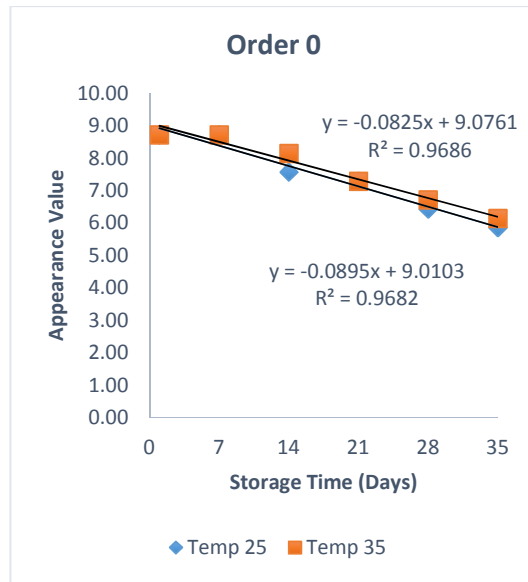

Fig. 1. Graphics of the decreased appearance score relationship using aluminum foil packaging against time

The comparison of the R^2 value Fig. 1 the aluminum foil packaging (at 25°C and 35°C) which has the greatest R^2 value, which is zero order so that in determining the Arrhenius equation, zero order is chosen for aluminum foil packaging. The slope value of the two equations, the K value for each treatment is plotted into the Arrhenius model by looking at the relationship between 1 / T to Ln K, so that the Arrhenius graph is shown in Fig. 2.
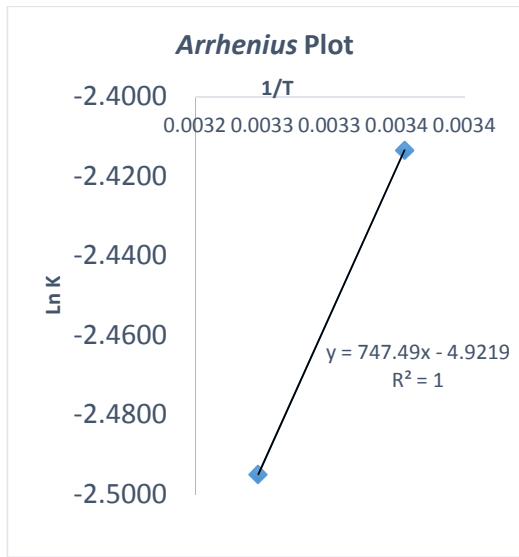
Fig. 2. The arrhenius appearance plot graph on aluminum foil packaging

The correlation between appearance and time of product in aluminum foil packaging with storage at 25°C and 35°C forms a regression equation, namely y = 747.49x - 4.9219 (R² = 1). This equation in the analysis of the model is then used to determine the value of the Arrhenius deterioration rate.

3.2 Aroma

Aroma is an odor caused by chemical stimulation that is smelled by olfactory nerves in the nasal cavity when food enters the mouth [10]. The results of the aroma sensory test on nori made from *Eucheuma cottonii* during storage can be seen in Table 2.

Table 2. Average value of nori aroma during storage

Code	Temperature (°C)	Aroma parameters					
		1	7	14	21	28	35
Aluminum Foil	25	8.43	8.71	7.86	7.29	5.86	5.86
Aluminum Foil	35	8.43	8.43	7.29	7.00	6.43	6.14

The comparison of the R² value on aluminum foil packaging (at 25°C and 35°C) which has the highest R² value, namely zero order in the graph of the decrease in aroma score against time, so order 0 is selected to determine the Arrhenius equation for aluminum packaging.
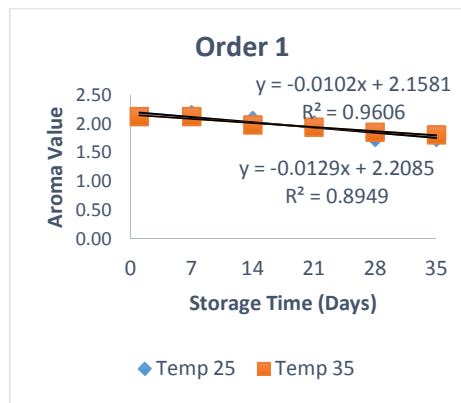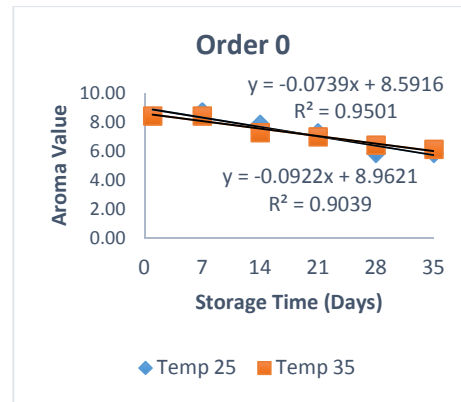

Fig. 3. Graphics of the decreased aroma score relationshipusing aluminum foil packaging against time

The slope value of the two equations is the K value on the aluminum foil packaging. Then an Arrhenius plot was made with the value of Ln K as the ordinate and the value of 1 / T as the abscissa. The Arrhenius plot of a nori product can be seen in Fig. 4.
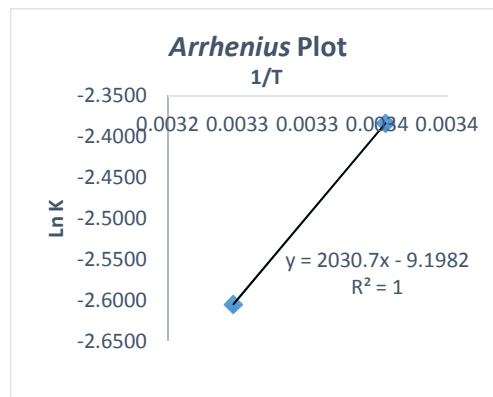

Fig. 4. Arrhenius aroma plot graph on aluminum foil packaging

From the results of linear regression at 25°C and 35°C storage temperatures on aluminum foil packaging, the equation for the line y = 2030.7x - 9.1982 (R² = 1). This equation in the analysis of the model is used to determine the value of the Arrhenius deterioration rate.

3.3 Texture

The texture is one of the attributes of food quality [11]. The texture is also one that changes frequently during storage. The level of acceptance of food products from the nori texture made from *Eucheuma cottonii* is influenced by the moisture content of the product, so that changes in texture are indirectly influenced by storage time and storage temperature. The results of the sensory test for nori texture made from *Eucheuma cottonii* seaweed during storage can be seen in Table 3.

Table 3. Nori texture average value during storage

Code	Temperature (°C)	Texture parameters					
		1	7	14	21	28	35
Aluminum Foil	25	9.00	8.14	7.57	7.29	6.71	5.86
Aluminum Foil	35	8.71	8.14	7.57	7.29	6.71	6.43

From the observations of changes in the texture of the nori product, a linear regression equation from R^2 for a zero - reaction can be seen in Fig. 5 comparing R^2 in the first order reaction equation in the same figure. It was found that the determination of the shelf life of nori products used order one.

Order 0

y = -0.0665x + 8.6512
R² = 0.9842

y = -0.0843x + 8.9183
R² = 0.9758

◆ Temp 25   ■ Temp 35

Order 1

y = -0.0089x + 2.1634
R² = 0.9909

y = -0.0115x + 2.1994
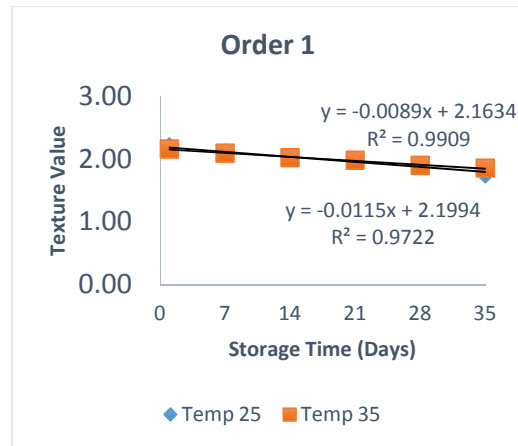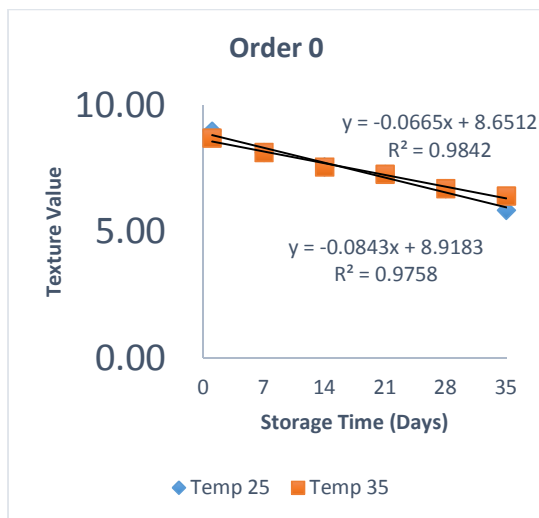R² = 0.9722

◆ Temp 25   ■ Temp 35

Fig. 5.Graph of the decrease in texture score relationship using aluminum foil packaging against time

Furthermore, by connecting each one per storage temperature (1 / T) expressed in degrees Kelvin (^{0}K) with the k (slope) value which is natural logged to be ln k from each linear regression equation, the Arrhenius equation for future treatment is obtained (Fig. 6).
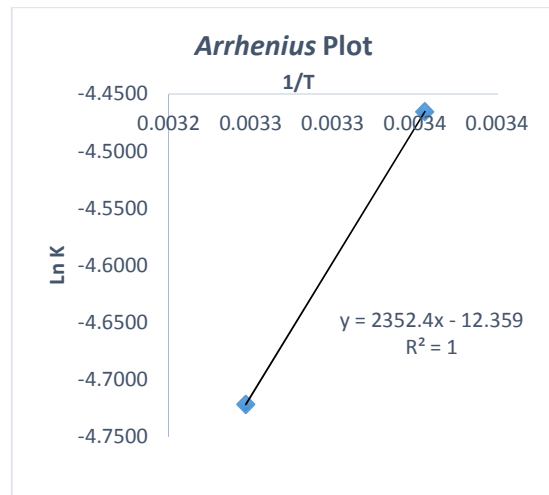

Arrhenius Plot

1/T

y = 2352.4x - 12.359
R² = 1

Fig. 6. The arrhenius texture plot graph on aluminum foil packaging

The correlation between texture and observation time of nori made from *Eucheuma cottonii* in aluminum foil packaging with storage at 25°C and 35°C forms a regression equation, namely y = 2352.4x - 12,359 (R² = 1) (Fig. 6). This equation in the analysis of the model is then used to determine the value of the Arrhenius deterioration rate.

3.4 Taste

Taste is a very important factor in determining the level of consumer acceptance of a product, because taste determines consumer tastes before eating a product in large quantities [10]. The value of the taste of nori products packaging during storage at temperature 25°C and 35°C can be seen in Table 4.

Table 4. Average value of nori taste during storage

Code	Temperature (°C)	Taste parameters					
		1	7	14	21	28	35
Alumimum Foil	25	8.43	8.43	8.43	7.29	6.71	5.86
Alumunium Foil	35	8.43	8.43	8.14	7.57	7.00	5.86

The results of the analysis of the nori scoring test can determine the Arrhenius plot from the graph of the relationship between the decrease in taste scores and time, by comparing R^2 in order 0 and order 1 (Fig. 7).

It can be seen that the value of R^2 (Fig. 7) of the two temperatures (25°C and 35°C) order 0 is greater than order 1 on the graph of the relationship between the decrease in taste scores using aluminum foil packaging against time, so that in determining the Arrhenius equation, order 0. The slope value of the three equations is the K value at each storage temperature. After obtaining the K value at each storage temperature, an Arrhenius plot was made with the Ln K value as the ordinate and the 1 / T value as the abscissa.
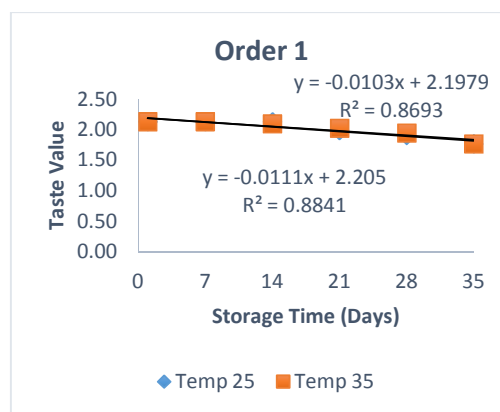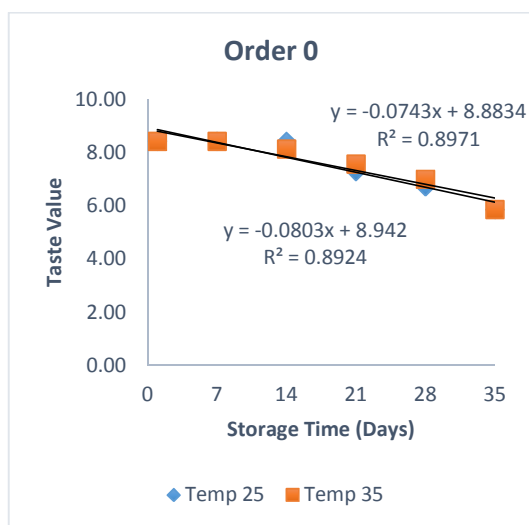

Order 0

$y = -0.0743x + 8.8834$
$R^2 = 0.8971$

$y = -0.0803x + 8.942$
$R^2 = 0.8924$

Order 1

$y = -0.0103x + 2.1979$
$R^2 = 0.8693$

$y = -0.0111x + 2.205$
$R^2 = 0.8841$

Fig. 7. Graphics of the decrease in the taste score relationship using aluminum foil packaging against time

From the results of linear regression at storage temperatures of 25°C and 35°C on aluminum foil packaging, the equation for the line y = 712.78x - 4.9139 is obtained with a correlation coefficient of $R^2 = 1$. This equation in the subsequent model analysis is used to determine the value of the Arrhenius deterioration Fig. 8.
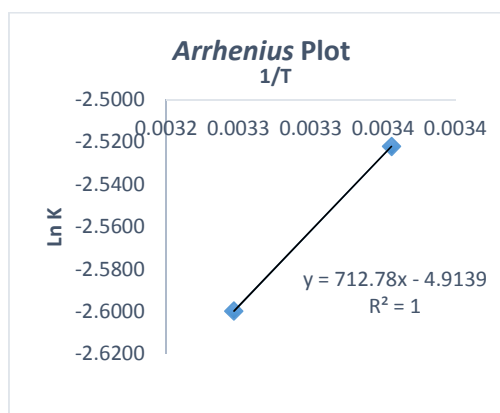

Arrhenius Plot
1/T

$y = 712.78x - 4.9139$
$R^2 = 1$

Fig. 8. The arrhenius taste plot graph on aluminum foil packaging

3.5 Water Content

The water content in a food ingredient needs to be determined, because the higher water content in the food cause the food will spoilage and not last long. [12] states that the increase in water content of food in packaging is influenced by water vapor permeability, water vapor absorption properties of food ingredients and relative humidity around the packaging. The results of the average value of the water content using aluminum foil packaging with a temperature of 25°C and 35°C can be seen in Table 5.

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Table 5. The average value of nori moisture content during storage

Code	Temperature (°C)	Water content parameters					
		1	7	14	21	28	35
Aluminum Foil	25	17.73	17.58	17.62	17.86	17.97	18.25
Aluminum Foil	35	17.50	17.67	17.86	17.71	17.73	18.19

From the observations of the pattern of changes in water content of nori products, a linear regression equation and correlation (R^2) are obtained for zero-order reactions as can be seen in Fig. 9 of the treatment by comparing R^2 in the first order reaction equation in the same figure. The determination of the shelf life of nori products made from *Eucheuma cottonii* seaweed uses order one for aluminum foil Fig. 9.
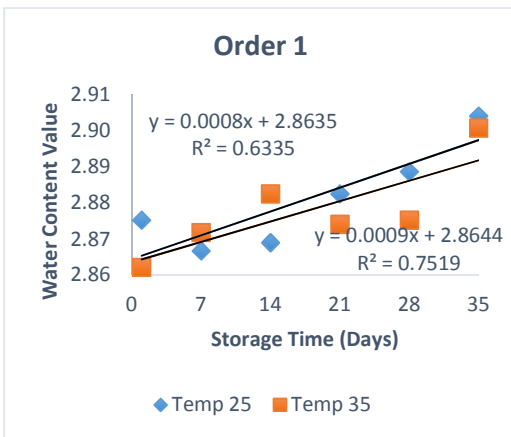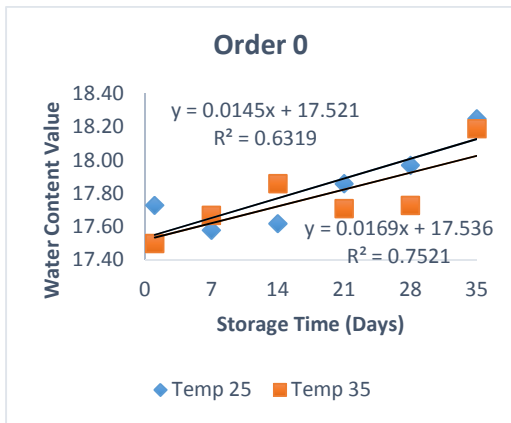

Fig. 9. Graphics relationship to decrease in water content score using aluminum foil packaging against time

The slope value of the two equations is the K value at each storage temperature. After obtaining the K value at each storage temperature, an Arrhenius plot was made with the Ln K value as the ordinate and the 1 / T value as the abscissa. The Arrhenius plot of the nori product is presented in Fig. 10.
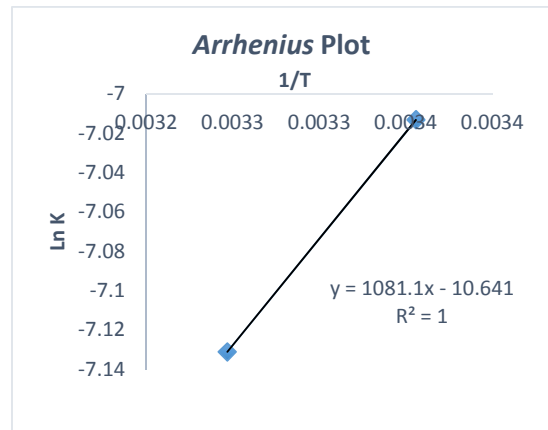

Fig. 10. Arrhenius water content plot graph on aluminum foil packaging

From the results of linear regression at storage temperatures of 25°C and 35°C using aluminum foil packaging, the equation for the line y = 1081.1x - 10,641 with a correlation coefficient of R^2 = 1. This equation is used in the analysis of the model to determine the value of the Arrhenius deterioration rate.

3.6 Shelf Life

The shelf life of a food product is an interval of production and consumption time where the product is in a satisfactory condition in terms of appearance, aroma, texture, taste and nutritional value [13]. In determining the rate of deterioration reactions using temperature as one of the parameters to accelerate the deterioration, the rate of deterioration can be determined based on the energy of activation. The parameter used is the parameter that has the lowest activation energy value because the lower the energy needed to start the damage reaction is lower so that the damage reaction will last longer. If the activation energy is high, the energy needed to initiate the damage reaction is higher and the damage reaction will take place faster [14]. The results of calculating the shelf life of nori products from *Eucheuma cottonii* at temperatures of 25°C and 35°C using aluminum foil packaging can be seen in Table 6.

Table 6. Shelf life of *eucheuma cottonii* nori on aluminum foil packaging

Parameters	Arrhenius equation	Ea (kJ/mol)	Shelf life
Appearance	y = 747.49x - 4.9219 R² = 1	1485,262	2 months 7 days 9 hours
Aroma	y = 2030.7x - 9.1982 R² = 1	4035,0009	2 months 5 days 1 hours
Texture	y = 2352.4x - 12.359 R² = 1	4674,218	3 months 5 days 11 hours
Taste	y = 712.78x - 4.9139 R² = 1	1416,293	2 months 14 days 17 hours
Water Content	y = 1081.1x - 10.641 R² = 1	2148,145	1 months 16 days 15 hours

Based on the appearance, aroma, texture, taste and water content parameters that have the smallest activation energy on aluminum foil packaging is the taste parameter with a value of 1416.293 kJ / mol. So that the critical quality parameter shelf life of nori made from *Eucheuma cottonii* using aluminum foil packaging is a parameter of taste. Based on the taste parameters it shows that the aluminum foil packaging has a shelf life of 2 months 14 days 17 hours (Table 6). Aluminum foil packaging can increase protection against packaged materials from moisture, gas, light and odors compared to other plastic packaging [15].

4. CONCLUSIONS

Based on the results of the research, it can be concluded that the shelf life of products from *Eucheuma cottonii* which is packaged using aluminum foil packaging can last about 2 months 14 days 17 hours. This can be seen from changes in taste quality and shelf life.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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