

Shelf Life of Combination Nori *Sargassum* sp. and *Eucheuma spinosum* with Alumunium 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. All authors read and approved the final manuscript.

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ABSTRACT

The purpose of this research was to determine the shelf life of Combination Nori *Sargassum* sp. and *Eucheuma spinosum* with the Accelerated Shelf Life Test (ASLT) method Arrhenius Model using Alumunium Foil packaging. This research was conducted at the Laboratory of Fisheries Product Processing, Faculty of Fisheries and Marine Sciences, Padjadjaran University from October to November 2020. *Sargassum* sp. is a genus of brown algae (Phaeophyta) used as in the food industry and non-food industry. *Sargassum* sp. cannot form nori sushi sheets because it lack carageenan. *Eucheuma spinosum* is a genus of red algae (Rhodophyta) used to complement the lack of carageenan in *Sargassum* sp. Alumunium foil is a metalized plastic package composed of hermetic, flexible and opaque metal that has high protection againsts light, water vapor and gas. The determination of the shelf life of the ASLT method is carried out using parameters of environmental conditions that can accelerate the product quality degradation by storing the product at high risk temperature. The observation used in determining the shelf life of Combination Nori *Sargassum* sp. and *Eucheuma spinosum* is a sensory test and water content test with 35 days in the storage at a temperature of 25°C and 35°C. The calculation results of the Arrhenius model used

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texture parameter as critical parameters that had the lowest Activation energy (Ea) in determining the shelf life of combination nori which packaged with aluminium foil. The results showed the value of texture parameters based on the order 0 reaction with the Arrhenius plot $\ln K = -2.8019$, $1/T = 97.596$ and $Ea = 193.92$. The shelf life of combination nori *Sargassum* sp. and *Eucheuma spinosum* that stored at room temperature (25°C) was around 137 days.

Keywords: Nori; shelf life; arrhenius; ASLT; alumunium foil.

1. INTRODUCTION

Nori is a processed product from one of the fishery products, namely seaweed. Nori in Indonesia is not a foreign ingredient because there have been many processed products derived from this seaweed that are sold in restaurants. The need for seaweed to be processed into nori in Indonesia has increased by 80% due to the development of Chinese and Japanese restaurants [1]. The need for nori in Indonesia increases the production of seaweed to be used as processed products for nori sushi sheets. Indonesia's total seaweed production in 2016 reached 11 million tons, an increase of almost 4 (four) times compared to 2010 which was 3.9 million tons [2].

Nori imported from Japan has raw materials derived from *Porphyra* seaweed, but *Porphyra* seaweed is difficult to cultivate in tropical climates such as Indonesia because it is more suitable to grow in subtropical climates. So far, nori has only been produced by Japan, South Korea and the People's Republic of China [3]. Alternative types of seaweed that are easy to cultivate in Indonesia need to be looked for as raw materials for making nori. One type of seaweed that is used as raw material for making nori is *Sargassum* sp. and *Eucheuma spinosum* [4].

Sargassum sp. is a type of brown seaweed (Phaeophyta) and *Eucheuma spinosum* is a type of red seaweed (Rhodophyta). This type of seaweed is cultivated because it is relatively easy to handle, in accordance with the tropical climate of Indonesia. The use of *Sargassum* sp. and *Eucheuma spinosum* which are combined to obtain alternative ingredients in the manufacture of nori sushi, thereby reducing imports of commercial nori sushi products. *Sargassum* sp. seaweed has little carrageenan content which requires other additives containing gel or carrageenan as a texture maker, so it is combined with *Eucheuma spinosum* seaweed as a carrageenan producer [4]. Carrageenan is used as a thickener, emulsifier and gelling agent

obtained from red seaweed which is important for food. The thickness and formation of nori are influenced by the presence of hydrocolloid compounds, namely carrageenan contained in red seaweed [5].

Nori combination *Sargassum* sp. and *Eucheuma spinosum* are new products processed by *Sargassum* sp. and *Eucheuma spinosum* so it is necessary to know the shelf life of the product. Packaging is one way to extend the shelf life of combined nori products. Nori as a dry product is also easy to lose its crunchy texture due to the rehydration process so that it easily becomes moist [1]. Packaging needs to be done so that nori quality degradation is inhibited so that it has a longer shelf life. Packaging can maintain and prevent food spoilage by blocking the entry of oxygen and air which contains many contaminants [6]. Aluminum foil packaging has zero water vapor and gas permeability and the highest density compared to other packaging [7], so it is the right packaging for packaging dry products such as nori and easily becomes moist. Aluminum foil packaging is a metalized plastic that has hermetic, flexible and opaque properties so that it can protect nori products from water vapor, gas and light [8].

Accelerated Shelf Life Test (ASLT) provides data on estimating shelf life under storage conditions that usually occur when products are sold with data obtained using accelerated storage conditions [9]. Decreasing quality and storage conditions can be predicted using the relationship between temperature and acceleration factor and the rate of deterioration from the Arrhenius equation [10]. The Arrhenius Model Accelerated Shelf Life Test (ASLT) method is a method of estimating the shelf life of a product by using an accelerated temperature so that it can accelerate the reaction that causes damage to the product [11]. The Arrhenius model ASLT method is generally applied to all types of food products, especially those that have decreased in quality due to chemical deterioration [12]. Based on this background, research is needed to determine the shelf life of

nori combination *Sargassum* sp. and *Eucheuma spinosum* using the Accelerated Shelf Life Test (ASLT) Arrhenius model.

2. MATERIALS AND METHODS

2.1 Tools and Materials

The tools used in this research are Blender, Baking sheet (size 15 x 20 cm inside), Basin, Digital Scale, Pan, Label, Aluminum Foil (0.6 mm thickness), Incubator, Sealer, Oven, Measuring Cup and Spoon.

The materials used in this research are dried *Sargassum* sp., dried *Eucheuma spinosum*, Rice Water, Clean Water, Salt, Flavorings, Sesame Oil, Olive Oil, Fish Sauce and Pepper Powder.

2.2 Methods

This research uses the ASLT method Arrhenius model that packed combination nori of *Sargassum* sp. and *Eucheuma spinosum* into alumunium foil packaging. The packaged products were stored at 25°C and 35°C as a determination of acceleration temperature. Observation of combination nori were made on the 35th day by counting down the observation every storage days 1, 7, 14, 21, 28 and 35 to see changes that occur during storage. The parameters tested for estimating the shelf life of the Arrhenius model ASLT method were using sensory evaluation (such as appereance, aroma, texture and taste) and water content test, tested by standard panelist.

2.3 Observed Parameters

2.3.1 Water content test

The water content in food greatly affects the quality of the product. Changes in water content in a food product will cause various damages such as the appearance of fungi and bacteria, hardening, softening and clumping, especially in dry products. Water content becomes a critical point and plays an important role in determining the physico-chemical, microbiological, and organoleptic characteristics during production and storage [13]. The formula for testing water content according to [14] is as follows:

$$\text{Water Content (\%)} = \frac{B - C}{B - A} \times 100\%$$

Information:

A = Weight of empty cup (grams).

B = Weight of the cup + initial sample (grams).

C = Weight of the cup + final/dry sample (grams).

2.3.2 Scoring test

The scoring test aims to determine the level of quality based on a scale of 1 as the lowest score and 9 as the highest score by using an assessment sheet [15]. The scoring test is carried out using the human senses as the main tool to assess the quality of fishery products. The scoring test on a numerical scale is expressed by a number indicating the score of the sensory attribute. Sensory attributes are a collection of words to describe the sensory characteristics of a food product, including appearance, aroma, texture and taste [16].

2.4 Data Analysis

Shelf life of nori combination *Sargassum* sp. and *Eucheuma spinosum* is calculated using the kinetic equation of the reaction based on the order of the reaction, if the reaction takes place on order zero and order one as follows [17]:

$$\text{Order Zero : } C_t - C_0 = K_t$$

$$\text{Order One : } \ln C_t = \ln C_0 + K_t$$

Information:

K_t = Damage reaction rate.

C_t = Concentration at time t on the order of zero.

C_0 = Initial concentration on the order of zero.

$\ln C_t$ = Concentration at time t on order one

$\ln C_0$ = Initial concentration of order one

3. RESULTS AND DISCUSSION

3.1 Appearance

Appearance is one of the first parameters judged by the panelists for the first time on a product in sensory evaluation. The assessment of appearance sensory attributes aims to see the color changes in the appearance of a product that affect the level of product acceptance by consumers or panelists. The level of product acceptance will decrease with the longer storage

of the product. The average results of combined nori appearance (Table 1) show a decrease in quality during storage at 25°C and 35°C. Changes in the average value of appearance parameters are influenced by product pigments, reactions of organic compounds with air and light [18]. The value of appearance on aluminum foil packaging provides good protection for food products due to the hermetic nature of the packaging so that the permeability of the packaging to light is low [19].

The results of the observation of the pattern of changes in the appearance of the combination of

nori *Sargassum* sp. and *Eucheuma spinosum* obtained linear regression equation and correlation (R^2). The zero order reactions of each treatment were compared with their correlations with the first order reaction equations in the same figure (Fig. 1). The reaction order used is the order with the largest R^2 value or close to one because it provides a more precise calculation of the nori expiration date. Comparison of R^2 values in the appearance parameter of aluminum foil packaging (25°C and 35°C) was chosen of order zero (0.8931) compared to order one (0.8895) (Fig. 1).

Table 1. Average value of the appearance parameter of combination nori

Temperature (°C)	Appearance parameter					
	1	7	14	21	28	35
25	9.00	8.60	8.20	6.60	6.80	6.40
35	8.60	8.80	8.40	7.00	6.00	6.20

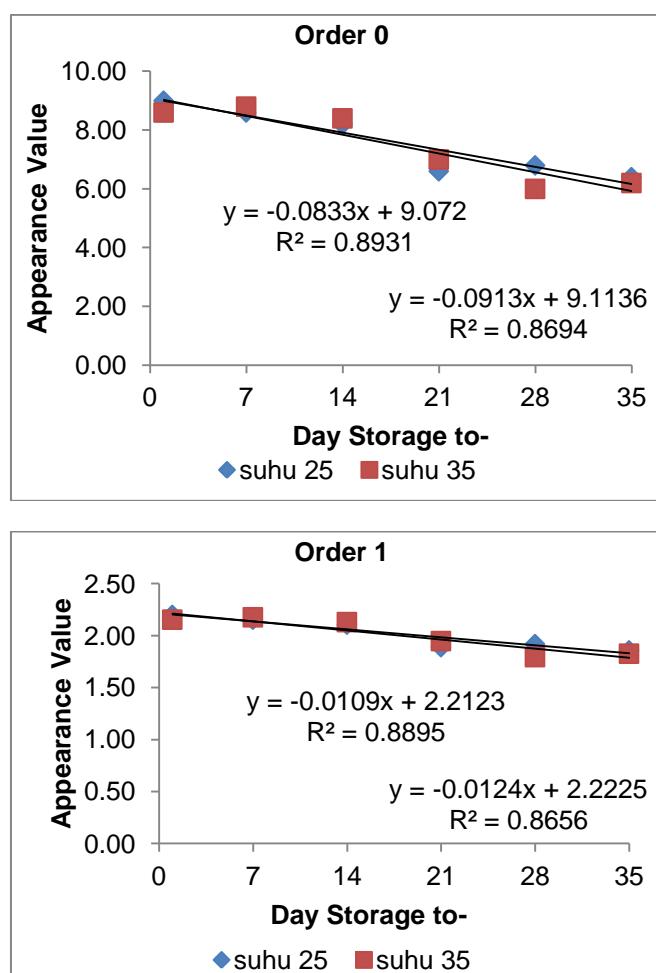


Fig. 1. Graph of correlation between impairment value on aluminum foil packaging and storage time

The correlation between appearance value and storage time forms a regression equation $y = -843.12x + 0.3442$, $R^2 = 1$. The equation obtained will be used to determine the rate of decline in Arrhenius quality.

3.2 Aroma

Aroma is an important quality trait in the sensory evaluation of a food product because aroma affects the level of consumer acceptance. Aroma value of nori combination *Sargassum* sp. and *Eucheuma spinosum* during storage decreased organoleptically (Table 2). The assessment of aroma parameters was carried out by panelists by assessing the aroma through chemical stimuli

that were smelled by the olfactory nerves in the nose. Decomposition of the properties of foodstuffs causes a decrease in the value of aroma, besides that air and light can accelerate the oxidation process, causing rancidity [20].

The zero order reaction of each treatment was compared with the correlation of the first order reaction equation in the same figure (Fig. 3). The reaction order used is the order with the largest R^2 value or close to one because it provides a more precise calculation of the nori expiration date. Comparison of R^2 values in the aroma parameter of aluminum foil packaging (25°C and 35°C) was chosen order one (0.9425) compared to zero order (0.9325) (Fig. 3).

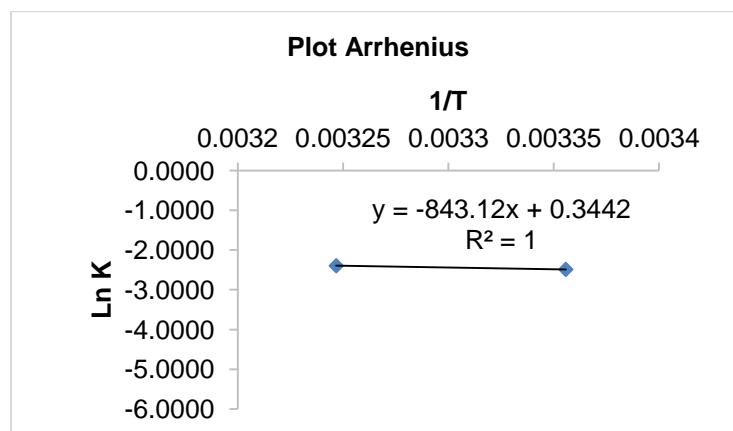
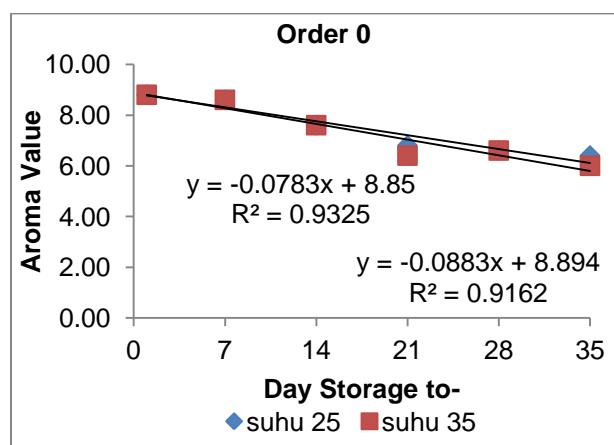


Fig. 2. Arrhenius plot graph appearance

Table 2. Average value of the aroma parameter of combination nori

Temperature (°C)	Aroma parameter					
	1	7	14	21	28	35
25	8.80	8.60	7.60	6.80	6.60	6.40
35	8.80	8.60	7.60	6.40	6.60	6.00



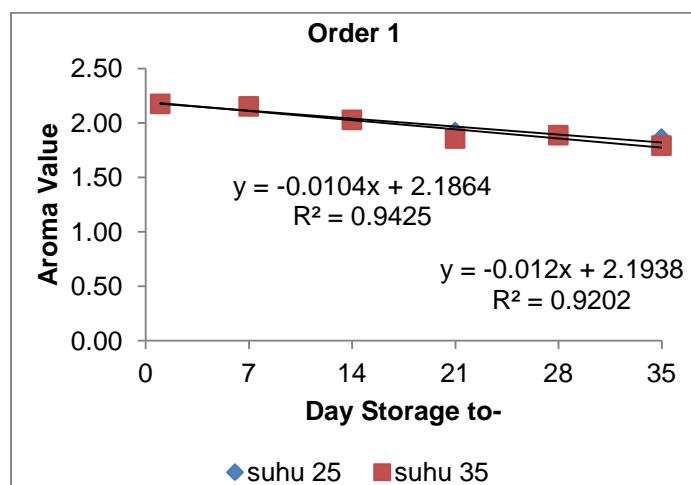


Fig. 3. Graph of correlation of decreasing aroma value on aluminum foil packaging against storage time

The correlation between aroma value and storage time forms a regression equation $y = -1315.7x - 0.1502$, $R^2 = 1$. The equation obtained will be used to determine the rate of decline in Arrhenius quality.

3.3 Texture

The texture has several types of shapes ranging from crunchy, chewy, mushy, liquid and others. The texture of nori coating or coating generally has a flexible texture but is still a bit crunchy. The texture parameter value of combination nori experienced a decrease in quality during storage (Table 3). The level of acceptance of the combined nori food product *Sargassum* sp. and *Eucheuma spinosum* in texture parameters are influenced by product moisture content and air, so that the storage time and storage temperature

of nori products will affect the texture. The water vapor and air permeability of aluminum foil packaging is equal to zero and is the packaging that has the highest density compared to other packaging and does not react with the material (inert) [7].

The zero-order reactions of each treatment were compared with the correlations of the first-order reaction equations in the same figure (Fig. 5). The reaction order used is the order with the largest R^2 value or close to one because it provides a more precise calculation of the nori expiration date. Comparison of the R^2 values on the texture parameters of aluminum foil packaging (25°C and 35°C) was chosen of order zero (0.6794) compared to order one (0.6464) (Fig. 5).

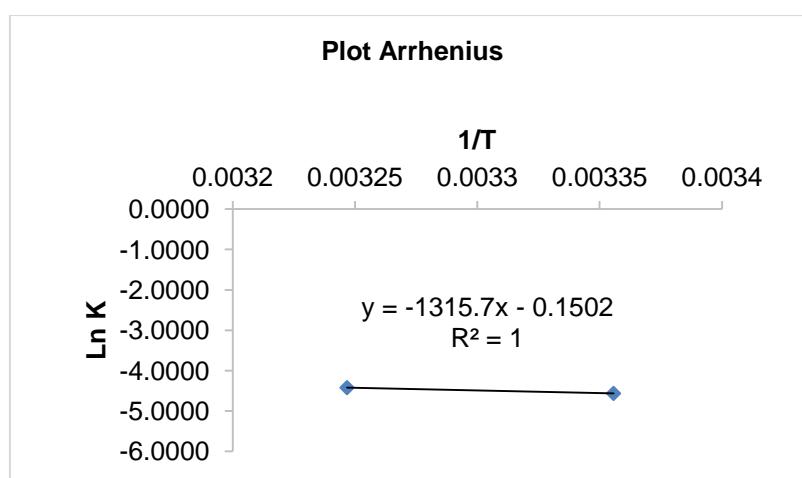
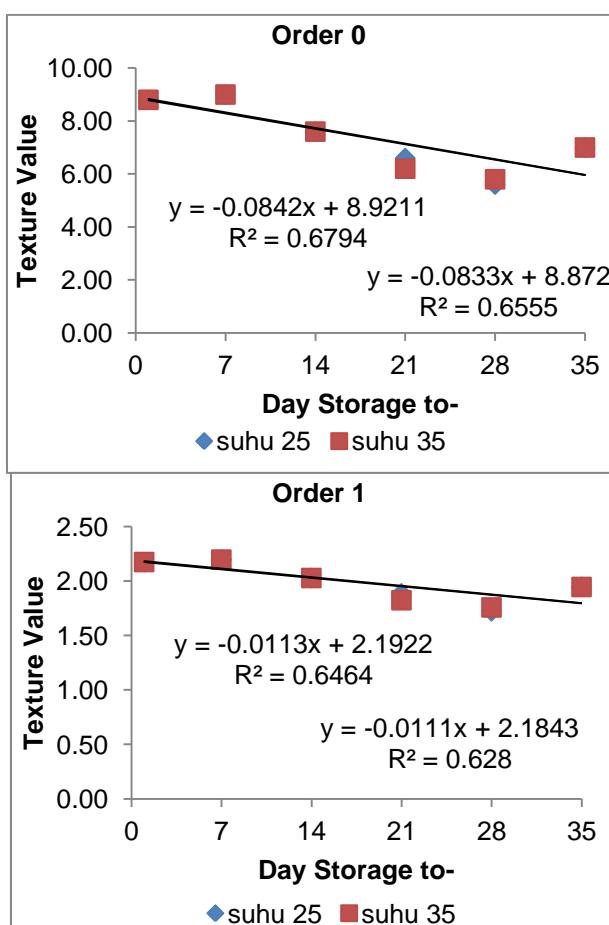


Fig. 4. Arrhenius aroma plot graph

Table 3. Average value of the texture parameter of combination nori

Temperature (°C)	Texture parameter					
	1	7	14	21	28	35
25	8.80	9.00	7.60	6.60	5.60	7.00
35	8.80	9.00	7.60	6.20	5.80	7.00

**Fig. 5. Graph of correlation between texture value decreasing on aluminum foil packaging and storage time**

The correlation of the texture value comparison with storage time forms a regression equation $y = 97.596x - 2.8019$, $R^2 = 1$. The obtained equation will be used to determine the Arrhenius rate of deterioration.

3.4 Taste

Taste is the last assessment in the scoring test which is also important in the level of consumer acceptance, if the assessment of other scoring test parameters is good but the taste parameters are not good it can make consumers reject the food product. Assessment of taste parameters is done by assessing taste through the sense of taste or tongue. Changes in the average value of

taste parameters during storage (Table 4) were caused by several factors. The decrease in taste quality is influenced by chemical compounds, temperature, concentration and other flavor components [18]. The taste of nori has a typical seaweed taste (it has a bitter after taste) and the taste of nori is formed by three amino acids in *Porphyra* seaweed such as alanine, glutamic acid and glycine [1]. *Eucheuma spinosum* contains amino acids that play a role in creating a good taste of nori (umami) [21].

The zero order reactions of each treatment were compared with the first order reaction equations in the same figure (Fig. 7). The reaction order used is the order with the largest R^2 value or

close to one because it provides a more precise calculation of the nori expiration date. Comparison of R^2 values on the taste parameters of aluminum foil packaging (25°C and 35°C) was chosen order one (0.7821) compared to order zero (0.7801) (Fig. 7).

The correlation between taste value and storage time forms a regression equation $y = -462.66x - 3.1578$, $R^2 = 1$. The equation obtained will be used to determine the rate of decline in Arrhenius quality.

3.5 Water Content

Food products such as nori, the longer they are stored, the higher the water content contained therein (Table 5). The increase in the water content of the food in the packaging is influenced by the water vapor permeability of the packaging, the moisture absorption properties of the food and the relative humidity around the packaging [22]. Nori combination *Sargassum* sp. and *Eucheuma spinosum* which have just been produced have a moisture content of 15.67% [4].

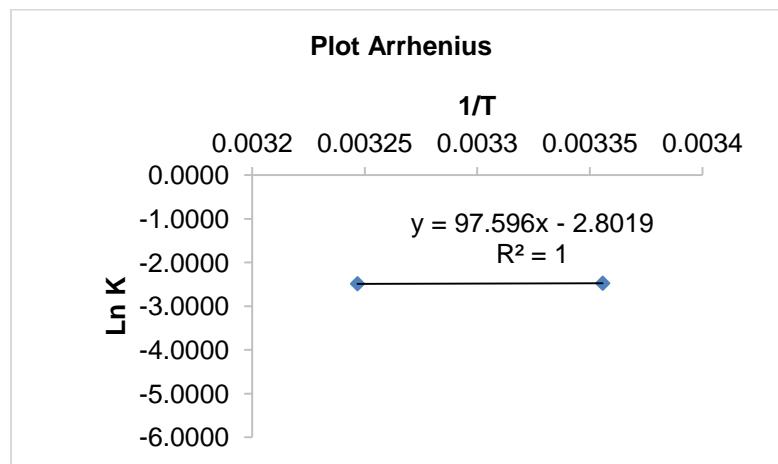


Fig. 6. Grafik plot Arrhenius tekstur

Table 4. Average value of the taste parameter of combination nori

Temperature (°C)	Taste parameter					
	1	7	14	21	28	35
25	8.60	9.00	7.60	6.60	6.80	6.80
35	8.80	9.00	7.60	6.60	6.80	6.80

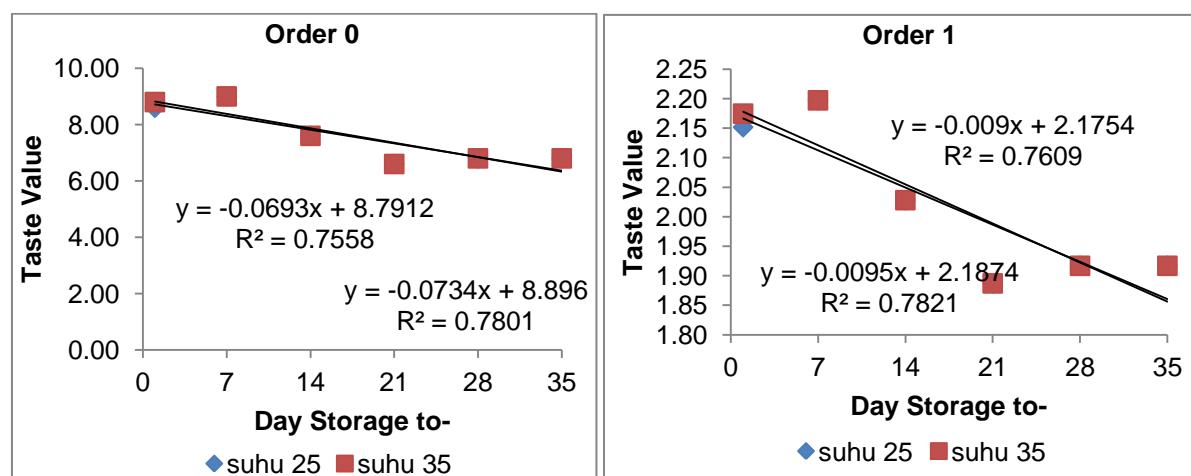
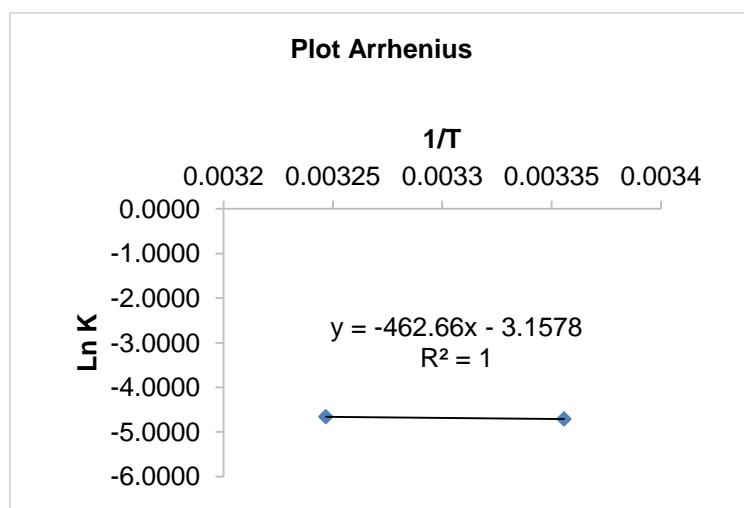


Fig. 7. Graph of the correlation of decreased taste value in aluminum foil packaging against storage time

**Fig. 8. Arrhenius taste plot chart****Table 5. Average value of the water content parameter of combination nori**

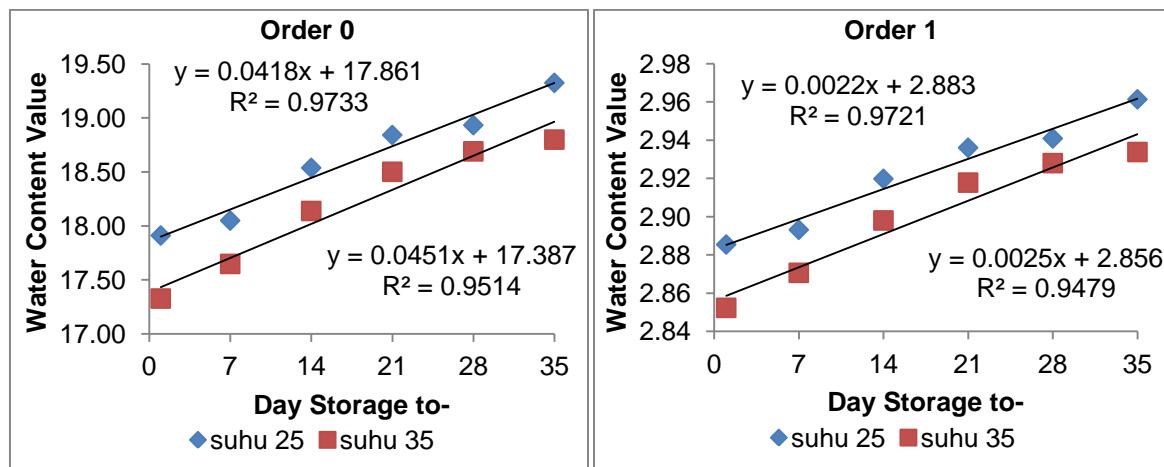
Temperature (°C)	Taste parameter					
	1	7	14	21	28	35
25	8.60	9.00	7.60	6.60	6.80	6.80
35	8.80	9.00	7.60	6.60	6.80	6.80

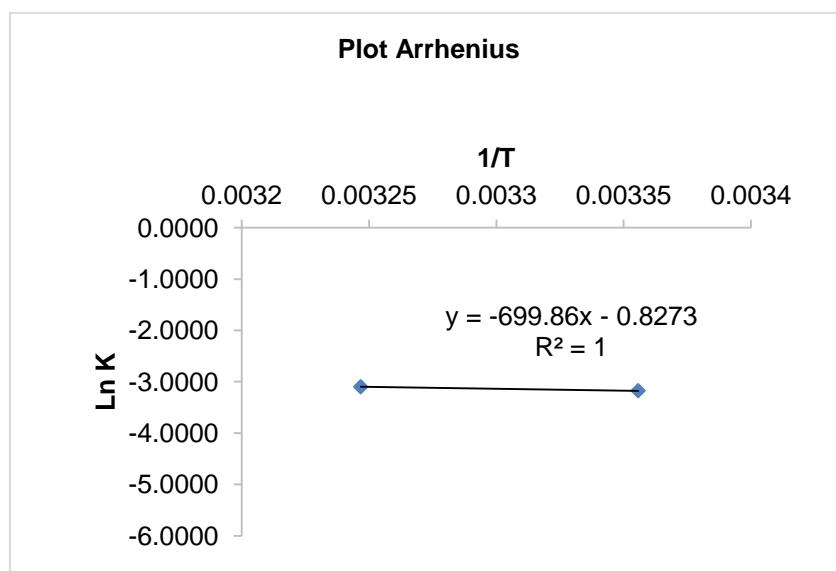
The resulting moisture content shown in Table 5. is higher, but closer to the moisture content of commercial nori prepared from *Porphyra*. Commercial nori made from *Porphyra* seaweed has a moisture content of 16.09% [23].

The zero-order reactions of each treatment were compared with the correlations of the first-order reaction equations in the same figure (Fig. 9). The reaction order used is the order with the largest R^2 value or close to one because it

provides a more precise calculation of the nori expiration date. Comparison of R^2 values on the taste parameters of aluminum foil packaging (25°C and 35°C) was chosen to be of order zero (0.9733) compared to order one (0.9721) (Fig. 9).

The correlation between the value of water content and storage time forms a regression equation $y = -699.86x - 0.8273$, $R^2 = 1$. The equation obtained will be used to determine the rate of decline in Arrhenius quality.

**Fig. 9. Graph of the relationship between the decreased water content value in aluminum foil packaging and storage time**

**Fig. 10. Arrhenius plot graph of water content**

3.6 Shelf Life

Determination of shelf life and sensory parameters in food products is very important in the development stage of food products. The shelf life of food products is the distance between the time of production and the time of consumption when the food product is in the best condition in terms of appearance, aroma, texture, taste and nutritional value [24].

The shelf life can be determined by looking at the critical factors that are most quickly damaged [25]. How to see critical factors in nori combination *Sargassum* sp. and *Eucheuma spinosum* by looking at the rate of deterioration caused by temperature as one of the parameters in accelerating the deterioration of food products based on activation energy (Table 6). Activation energy is the amount of energy needed to start a reaction [26]. The selection of critical quality parameters to be used as a calculation of the shelf life of food products is based on the lowest activation energy which greatly affects the

decline in the quality of food products during storage [27]. The greater the activation energy, the stronger the interaction, so to start a reaction, a large amount of energy is needed. The lower the activation energy value, the faster the reaction will run, so the faster it will contribute to product damage [28]. The lowest activation energy value indicates that the nori combination of *Sargassum* sp and *Eucheuma spinosum* in the package has been damaged in its sensory attribute parameters. Based on the parameters of appearance, aroma, texture, taste and water content (Table 6) after being compared with other parameters, aluminum foil packaging has the smallest activation energy in the texture parameter with a value of 193.92 kJ/mol. Based on the activity energy, it shows that the nori combination of *Sargassum* sp and *Eucheuma spinosum* packaged using aluminum foil has the longest shelf life of 137 days (Table 6). Barrier materials that make up aluminum foil packaging have the ability to protect products from the transfer of moisture, gases and other chemicals that affect shelf life [29].

Table 6. Shelf life of nori combination of *Sargassum* sp. and *Eucheuma spinosum* based on activation energy on aluminum foil packaging

Parameters	Arrhenius Equation	Ea (kJ/mol)	Shelf Life
Appearance	$y = -843.12x + 0.3442, R^2 = 1$	1675.27	72 Days
Aroma	$y = -1315.7x - 0.1502, R^2 = 1$	2614.23	105 Days
Texture	$y = 97.596x - 2.8019, R^2 = 1$	193.92	137 Days
Taste	$y = -462.66x - 3.1578, R^2 = 1$	919.31	122 Days
Water Content	$y = -699.86x - 0.8273, R^2 = 1$	1390.63	143 Days

4. CONCLUSION

Packaging that has the ability to withstand the movement of air and water vapor in the package during storage greatly affects the texture quality attribute parameters so that nori products combined with *Sargassum* sp. and *Eucheuma spinosum* do not quickly lose their characteristics to become moist. Aluminum foil packaging in packaging nori combination of *Sargassum* sp. and *Eucheuma spinosum* gave the results of the shelf life of nori combination of *Sargassum* sp. and *Eucheuma spinosum* 137 days based on the activation energy of texture parameters.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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