



## **Shelf Life of Nori from *Gracilaria* sp. with Polypropylene (PP) 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 SN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EL and IN managed the analyses of the study. Author EA managed the literature searches. All authors read and approved the final manuscript.*

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### **ABSTRACT**

This research was conducted at the Laboratory of Fisheries Products Processing, Faculty of Fisheries and Marine Sciences, Padjadjaran University, Jatinangor, West Java, Indonesia. The purpose of this research was to determine the shelf life of Nori from *Gracilaria* sp. with the Accelerated Shelf Life Test (ASLT) method Arrhenius Model using Polypropylene (PP) packaging. *Gracilaria* is a genus of red algae (Rhodophyta) used as a food for humans and various species of shellfish. Polypropylene (PP) is a shiny, clear plastic with good optical properties and tensile resistance. The determination of the shelf life of the ASLT method is carried out using parameters of environmental conditions that can accelerate the process of product quality degradation, namely by storing the product at several temperatures above normal storage temperature. The observations used in determining the shelf life of *Gracilaria* sp. using a sensory test and a water content test with storage for 35 days, at a temperature of 25°C and 35°C. The calculation results of the Arrhenius model used texture parameters as critical parameters because those had the lowest Activation Energy (Ea) in determining the shelf life of *Gracilaria* sp. which is packaged using PP plastic. The results showed the value used for determining the shelf life of nori *Gracilaria* sp.

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namely texture parameters based on the order 0 reaction with the Arrhenius plot  $\ln K = -2.0381 - 214.63 (1 / T)$  and  $E_a$  of 1784.6485. The shelf life of nori *Gracilaria* sp. was found to be elongated if stored at room temperature of (25°C) which was around 94 days.

**Keywords:** Arrhenius; ASLT; *Gracilaria* sp.; nori; polypropylene; shelf life.

## 1. INTRODUCTION

Japanese food has become a lifestyle for several people in Indonesia. One of the favorite Japanese foods is sushi. Sushi is a food filling consisting of rice, watercress, seafood, kyuri and then rolled coated using dried seaweed sheets or what we usually know as nori. Nori is the main ingredient in sushi making. Nori is the name in Japanese for food in the form of dried seaweed sheets [1].

Seaweed is one of the marine plants belonging to the benthic macroalgae that lives attached to the bottom of the waters [2]. According to the Indonesian Seaweed Association (ARLI), of the 555 types of seaweed found in Indonesia, only 3 types can only be cultivated, including *Gracilaria*, *Eucheuma Cotonii*, and *Eucheuma Spinosum* [1]. It is one of the seaweed species which has an important economic value in Indonesia, namely *Gracilaria* sp. from the Rhodophyceae class, this seaweed is widely used as raw material for making agar [3].

*Gracilaria* sp. is widely used in the industrial sector, one of which is the food and beverage industry such as ice cream, cheese, candy, jelly, and chocolate milk, as well as fish and meat canning [4]. Apart from these preparations, one of the efforts to utilize the resources of *Gracilaria* sp. another is by processing it into nori products [5].

Nori *Gracilaria* sp. is a new processed seaweed product, so it is necessary to know the nutritional content and shelf life of the product. One way to maintain and extend the shelf life of a product is by using packaging. Packaging can provide protection for food that has been produced either in packaging or placing the product into a container [6]. Nori which is dry but easily becomes damp and so requires an airtight packaging for long shelf life [5]. Polypropylene packaging has permeability to water, gas, and odors [7], making it suitable for packaging nori which has dry characteristics and easily becomes moist so that its quality is maintained. Polypropylene (PP) is a shiny and clear plastic with good optical properties and tensile

resistance, making it easy to handle and distribute [8].

The Arrhenius model of Accelerated Shelf Life Test (ASLT) method is a method of estimating the shelf life of a product by using an acceleration temperature so that it can accelerate the reaction that causes damage to the product [9]. This method is generally applied to all types of food products, especially those that have decreased quality due to the effects of chemical deterioration [10]. Based on this background, research is needed to determine the shelf life of Nori products made from *Gracilaria* sp. with the Accelerated Shelf Life Test (ASLT) method Arrhenius model.

## 2. LITERATURE REVIEW

*Gracilaria* sp. is one type of red seaweed (Rhodophyta) which has a very wide geographical distribution [2]. In Indonesia *Gracilaria* sp. Has been developed in Bali, NTB, NTT, South Sulawesi, East Kalimantan, Maluku, and Irian Jaya, through cultivation with a total production of *Gracilaria* sp. reaching 1.1 million tonnes [11]. Resources *Gracilaria* sp. widely used in the food industry. Utilization of *Gracilaria* sp. being a nori product is one of the nori innovations in Indonesia [5].

Nori is dried seaweed sheet and used as a decoration and flavoring for various Japanese dishes. There are two types of nori on the market, namely nori as a snack and nori as a coating which is commonly used as a wrapper for sushi. There is no big difference with coating nori, snack nori has a delicious taste and is addictive [1]. Generally, coating nori has a bland taste which is used to roll temakisushi and makisushi [5].

Nori as a coating has the property of being easily dampened and requires airtight packaging. Plastic packaging such as PP has good water and gas molecular migration barrier properties [7], making it suitable for packaging nori which has dry characteristics and easily becomes moist so that product quality is maintained.

Polypropylene (PP) packaging is a shiny and clear plastic, has good tensile strength and is tear resistant. The advantages of polypropylene are polymers of propylene with the main properties of being light and easy to form, tensile strength is easier than the type of polyethylene, not easily torn so it is easy to handle and distribution, resistant to strong acids, bases and oil [8]. In general, the function of packaging is to maintain and extend the shelf life of a product [6].

The shelf life is the period of time for food products starting from production and packaging to their use by consumers, provided that product quality can still be maintained and accepted both organoleptically and at the level of safety [6]. The Arrhenius model ASLT method is generally used to estimate the shelf life of food products that are easily damaged by chemical reactions. In general, the rate of chemical reactions will be faster at higher temperatures, which means that the decline in product quality will occur [6].

### 3. MATERIALS AND METHODS

#### 3.1 Tools and Materials

The tools used in this research are a basin, blender, baking sheet (15 x 20 cm), scale, oven, measuring cup, spoon, pan, label, polypropylene (0.6 mm thickness), incubator and sealer.

The materials used in this research are dried seaweed (*Gracilaria* sp.), rice water, clean water, salt, sugar and ground pepper, flavorings, sesame oil, olive oil and fish sauce.

#### 3.2 Methods

This research uses the ASLT method Arrhenius model by means of nori products made from *Gracilaria* sp. packed into polypropylene packaging. The packaged products were stored at 25°C and 35°C as a determination of acceleration temperature. Observations were made on days 1, 7, 14, 21, 28 and 35. The parameters tested for estimating the shelf life of the Arrhenius model ASLT method were using water content test data and sensory evaluation (appearance, aroma, texture, taste) tested by standard panelist.

#### 3.3 Data Analysis

Determination of the shelf life of nori *Gracilaria* sp. was based on the value of the smallest activation energy.  $E_a$  (activation energy) can provide an idea of the magnitude of the effect of

temperature on the reaction. The formula for determining shelf life is as follows [12]:

But in case of using the zero-order kinetics rate model the formula is as follows [12]:

$$C_t - C_0 = K_T t$$

Furthermore, if the reaction rate follows order one the formula is as follows [12]:

$$\ln C_t = \ln C_0 + K \times t$$

## 4. RESULTS AND DISCUSSION

### 4.1 Organoleptic Characteristics of Nori *Gracilaria* sp.

#### 4.1.1 Appearance

Appearance assessment aims to determine the panelists' acceptance as assessed from the surface appearance and nori color made from *Gracilaria* sp. Product appearance is the most important attribute in a product. In choosing a product, consumers will consider the appearance of the product first and ignore other sensory attributes [13]. The level of acceptance of food products from appearance can be influenced by color changes, this is because changes in color can indicate changes in nutritional value, so that color changes are used as indicators of quality degradation [12].

**Table 1. Average Value of the Appearance Parameters of Nori from *Gracilaria* sp.**

Day storage to-	Appearance parameters	
	25°C	35°C
1	7.57	7.57
7	7.57	6.43
14	7.57	6.43
21	6.43	5.57
28	5.00	4.43
35	4.71	4.71

The average value of the appearance parameters of nori made from *Gracilaria* sp. (Table 1) packaged using polypropylene (PP). shows a decrease in appearance quality along with the length of the storage period both at 25°C and 35°C. The high and low average appearance values are influenced by several factors including pigments, caramelization reactions, Maillard reactions (reactions between amino groups and reducing sugar groups), reactions of organic compounds with air and the addition of dyes [14].

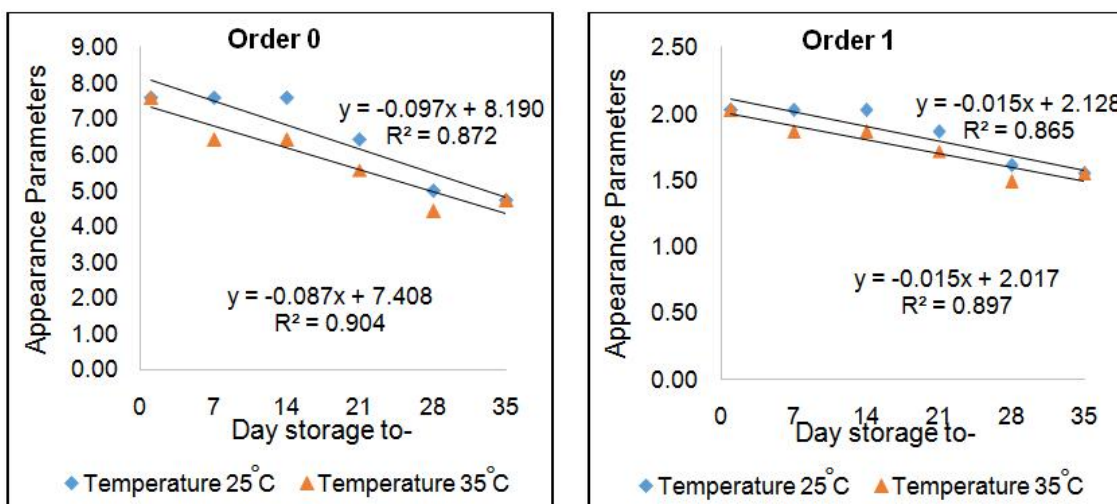


Fig. 1. Graph of the decrease in appearance value against time

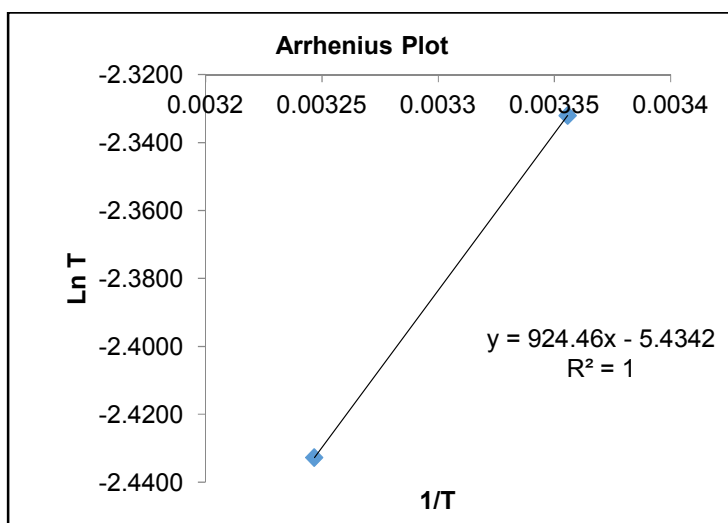


Fig. 2. Graph of arrhenius plot parameters appearance of nori *Gracilaria* sp.

From the Fig. 1, it can be seen that the value of  $R^2$  for both temperature order 0 (0.904) is greater than order 1 (0.8971) in the graph of the decrease in the appearance score against time, so order 0 is selected to determine the Arrhenius plot.

Based on the graph of the Arrhenius plot, the appearance parameter (Fig. 2), the slope value is obtained, which is a linear amalgamation of the two temperatures used in Nori storage made from *Gracilaria* sp. The results of linear regression analysis of the  $1/T$  and  $\ln K$  plots on the decrease in the appearance produce the plot  $\ln K = -5.4342 + 924.46 (1/T)$ .

#### 4.1.2 Aroma

Aroma or odor can be produced due to the presence of volatile compounds (volatile) in food is carried by air and then enter the nasal cavity [15]. Aromatic compounds are volatile, so they easily reach the olfactory system at the top of the nose, and need sufficient concentration to interact with one or more olfactory receptors [13]. The aroma parameter determines consumer acceptance because aroma or odor stimuli become impulses that will go to the olfactory nerve and describe the characteristics of a product [12].

**Table 2. Average value of the aroma parameters of Nori from *Gracilaria* sp.**

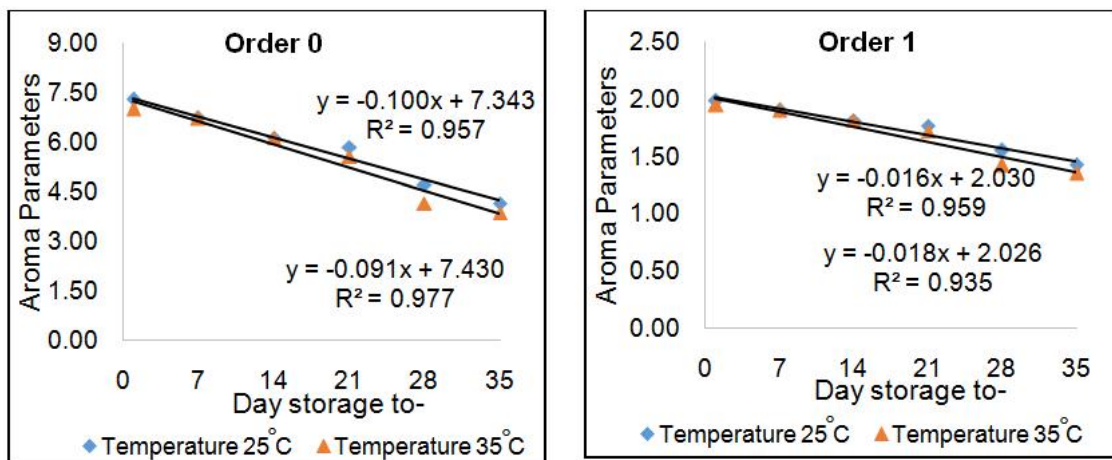
Day storage to-	Aroma parameters	
	25°C	35°C
1	7.29	7.00
7	6.71	6.71
14	6.14	6.14
21	5.86	5.57
28	4.71	4.14
35	4.14	3.86

The average value of nori aroma parameters made from *Gracilaria* sp. (Table 2) which was packaged using polypropylene (PP) showed a decrease in the quality of the aroma along with the long storage period both at 25°C and 35°C. The quality degradation is caused by the evaporation process of volatile compounds in

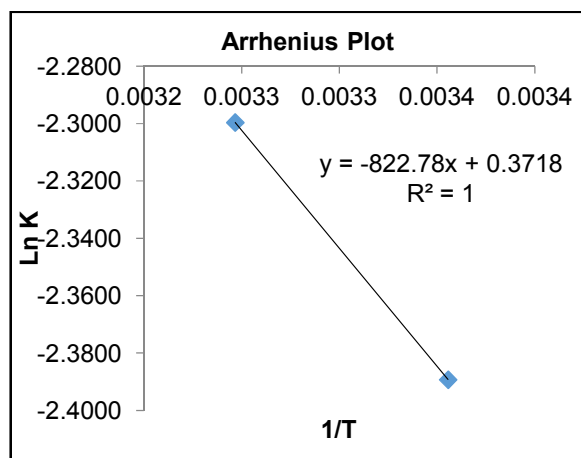
nori made from *Gracilaria* sp. The longer the storage time and temperature, the greater the evaporation rate of volatile compounds in the product [16].

In the Fig. 3, it can be seen that the value of R<sup>2</sup> for both temperature order 0 (0.9773) is greater than order 1 (0.9592) in the graph of the decrease in aroma score against time, so order 0 is selected to determine the Arrhenius plot.

Based on the graph of the Arrhenius plot, aroma parameters (Fig. 4), the slope value is obtained which is a linear amalgamation of the two temperatures used in storage of nori made from *Gracilaria* sp. The results of linear regression analysis of the 1 / T and Ln K plots on the decrease in aroma resulted in the plot Ln K = 0.3718 - 822.78 (1 / T).



**Fig. 3. Graph of the decrease in the value of aroma against time**



**Fig. 4. Graph of arrhenius plot parameters of aroma nori *Gracilaria* sp.**

### 4.1.3 Texture

The acceptance rate of food products from the nori texture made from *Gracilaria* sp. influenced by the moisture content of a product. Texture is a characteristic of a material as a result of a combination of several physical properties including size, shape, quantity and the elements forming the material that can be felt by the sense of touch and taste, including the sense of mouth and sight [12].

**Table 3. Average value of the texture parameters of Nori from *Gracilaria* sp.**

Day storage to-	Texture parameters	
	25°C	35°C
1	7.29	7.00
7	7.29	7.00
14	6.71	7.29
21	6.43	6.71
28	6.14	5.86
35	5.00	4.71

The average value of nori texture parameters made from *Gracilaria* sp. (Table 3) which was packaged using polypropylene (PP) showed a decrease in texture quality along with the length of the storage period both at 25°C and 35°C. The texture of nori as a coating or wrapper for sushi is dominant in a crunchy texture and does not break easily if the nori is still in good quality [17]. The longer and higher the temperature wherein the sample is stored, the lower the average score for the scoring test will be. Indirectly, changes in texture are influenced by storage time and storage temperature [12].

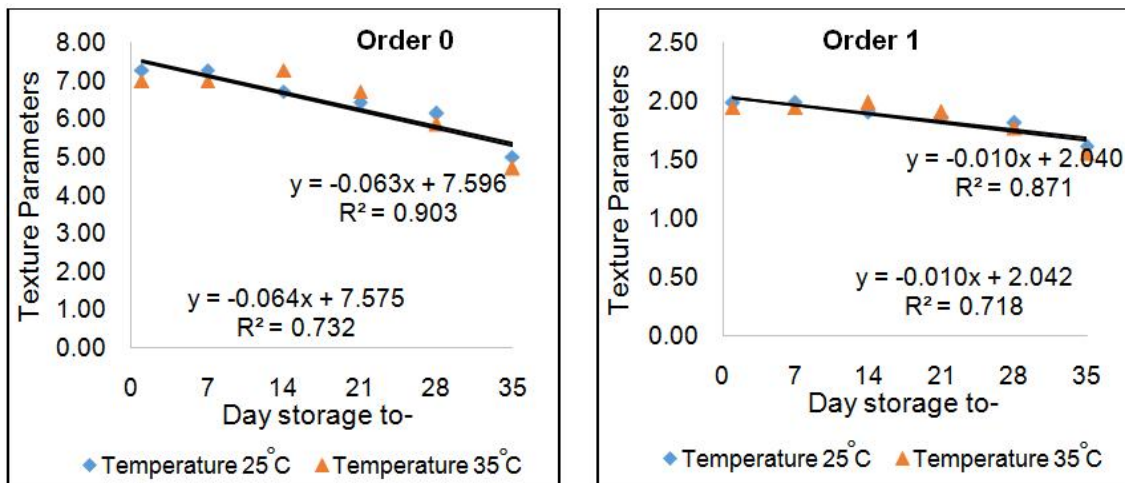
In the Fig. 5, it is seen that the value of  $R^2$  for both temperature order 0 (0.9039) is greater than order 1 (0.8719) that is, in decreasing trend which can be observed in this graph expressing the decrease in texture score against time, so order 0 is selected to determine the Arrhenius plot.

Based on the texture parameter Arrhenius plot graph (Fig. 6), the slope value is obtained which is a linear combination of the two temperatures used in storage of Nori made from *Gracilaria* sp. The results of linear regression analysis of the  $1/T$  and  $\ln K$  plots on the reduction of the textures produce the equation  $\ln K = -2.0381 - 214.63 (1/T)$ .

### 4.1.4 Taste

Taste is an important factor of food products in addition to texture, appearance and consistency of ingredients that will affect the taste caused by these food ingredients. The taste of an ingredient can come from the nature of the food itself or because of the presence of other substances added to the processing process [18].

The average value of nori flavor parameters made from *Gracilaria* sp. (Table 4) which was obtained when packaged using polypropylene (PP) showed a decrease in taste quality along with the length of the storage period both at 25°C and 35°C. The decreasing quality of nori made from *Gracilaria* sp. can be influenced by several factors. These factors are chemical compounds, temperature, concentration, and interactions with other taste components [13].



**Fig. 5. Graph of the decrease in texture value against**

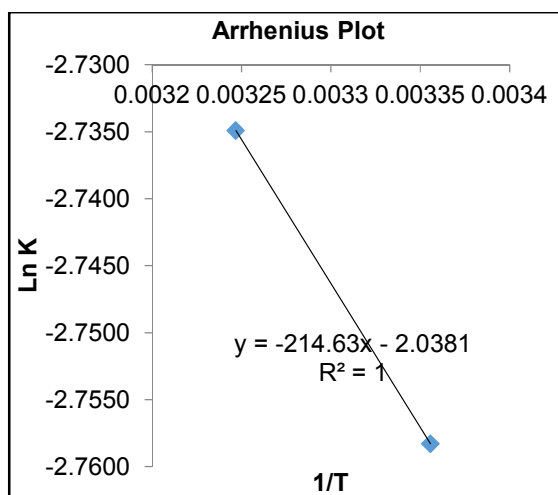


Fig 6. Graph of arrhenius plot texture parameters for nori *Gracilaria* sp.

Table 4. Average value of the taste parameters of nori from *Gracilaria* sp.

Day storage to-	Taste parameters	
	25°C	35°C
1	7.86	7.29
7	6.71	6.71
14	6.14	6.43
21	5.29	5.57
28	5.29	4.71
35	4.43	4.14

From the Fig. 7, it can be observed that the value of  $R^2$  for both temperature order 0 (0.9844) is greater than order 1 (0.9707) as can be seen in the graph showing the relationship between the decrease in taste score against time, so order 0 is selected to determine the Arrhenius plot.

Based on the graph of the Arrhenius plot showing, the taste parameters (Fig. 8), the slope value is obtained which is a linear amalgamation of the two temperatures used in storage of Nori made from *Gracilaria* sp. The results of linear regression analysis of the  $1/T$  and  $\ln K$  plots on the decrease in taste resulted in the plot  $\ln K = 69.132 - 21311 (1/T)$ .

#### 4.2 Water Content

Durability of processed products is related to water content because it can affect the development of microorganisms in the product [14]. Testing the moisture content in a food product needs to be determined, because higher the water content in the food, more the possibility in the food of being spoiled that will not last long [12].

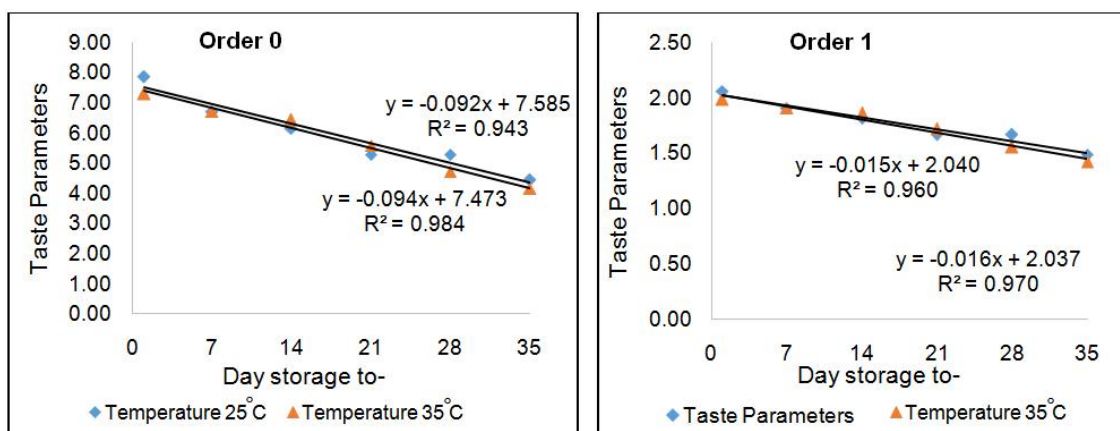


Fig. 7. Graph of the relationship of decreased taste value against time

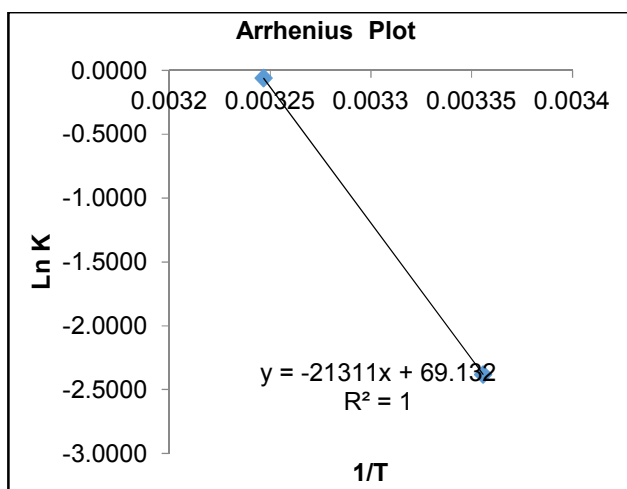


Fig. 8. Graph of arrhenius plot parameters for taste of Nori *Gracilaria* sp.

Table 5. Nori water content values from *Gracilaria* sp.

Day storage to-	Water content parameters	
	25°C	35°C
1	16.82%	16.67%
7	16.88%	16.50%
14	16.99%	16.44%
21	16.89%	16.67%
28	16.79%	16.55%
35	17.02%	16.97%

The value of water content of nori made from *Gracilaria* sp. (Table 5) which was packaged using polypropylene (PP) showed an increase in water content concentration along with the length of the storage period both at 25°C and 35°C. The

increase in water content concentration is caused by high temperature and air velocity that will accelerate the evaporation process on the surface and particle parts due to differences in water vapor pressure [19]. Increasing water content through absorption of moisture from the environment causes these food products to decline in quality [20]. The value of water content of nori made from *Gracilaria* sp. there is a range of 15.20 - 17.17% [5].

From the Fig. 9, it can be observed that the value of  $R^2$  for both temperature order 0 (0.2985) is greater than order 1 (0.2968) in the graph (Fig. 9) of the relationship between the decrease in taste score against time, so order 0 is selected to determine the Arrhenius equation.

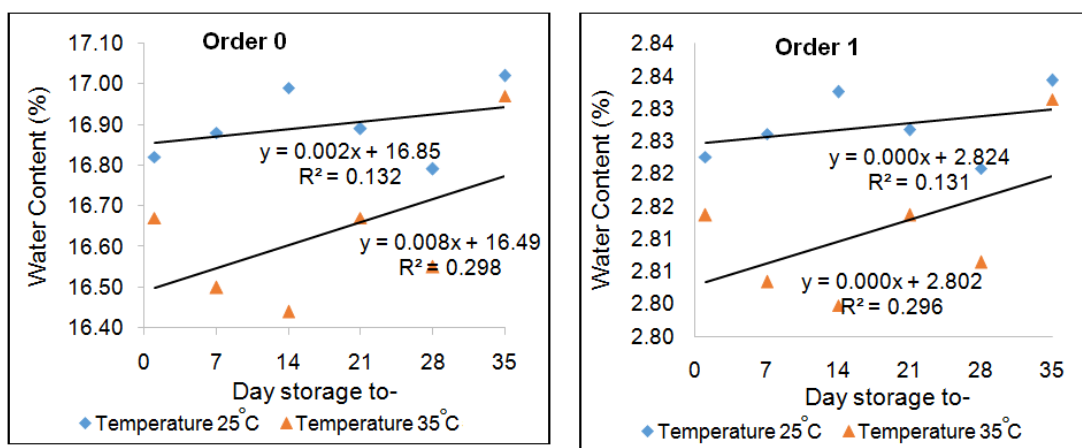


Fig. 9. Graph of relationship between increase in water content value against time



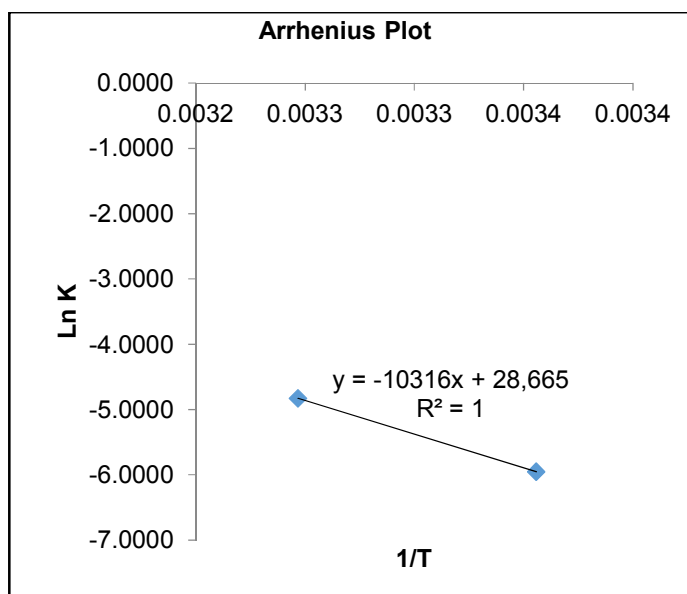


Fig. 10. Graph of arrhenius plot water content of nori *Gracilaria* sp.

Based on the graph of the Arrhenius plot water content (Fig. 10), the slope value is obtained is a linear amalgamation both for the two temperatures used in storage of Nori made from *Gracilaria* sp. The results of linear regression analysis of the  $1 / T$  and  $\text{Ln K}$  plots on the increase in the moisture content result in the plot  $\text{Ln K} = -28,665 - 10316 (1 / T)$ .

### 4.3 Determination of Shelf Life

Shelf life is the time until the product experiences a certain level of quality degradation so that it is not fit for consumption or is no longer in accordance with the criteria stated on the packaging (the quality is no longer in accordance with the quality level promised), due to the deterioration reaction that takes place. The deterioration reaction causes quality degradation and delivers the product to a low quality condition so

that it is not suitable for consumption [10].

This deterioration reaction will cause changes to the Nori product made from *Gracilaria* sp. in terms of appearance, aroma, texture, taste and moisture content of the product. Determination of the critical value of nori made from *Gracilaria* sp. based on the parameter that has the smallest activation energy ( $E_a$ ). This is in accordance with the Arrhenius theory that to produce a product in a chemical reaction, the molecule must have a certain amount of energy to react, or in other words it can produce product molecules, so the bonds in the reactants must be broken. The breaking of a chemical bond requires an energy called the activation energy ( $E_a$ ) [21]. The value of  $E_a$  also interprets the minimum energy required by a reaction. A large  $E_a$  value indicates that the energy of the interaction between molecules is strong, so starting a reaction requires a large amount of energy.

Table 6. Activation energy value ( $E_a$ ) of each parameter

Parameters	$E_a$ (Kj/mol)	Arrhenius Plot
Appearance	7686.8849	$\text{Ln K} = -5.4342 + 924.46 (1/T)$
Aroma	6841.4157	$\text{Ln K} = 0.3718 - 822.78 (1/T)$
Texture	1784.6485	$\text{Ln K} = -2.0381 - 214.63 (1/T)$
Taste	177200.965	$\text{Ln K} = 69.132 - 21311 (1/T)$
Water Content	85777.54	$\text{Ln K} = -28.665 - 10316 (1/T)$

The results of Ea calculations in Table 6 show that the parameter that has the smallest Ea is the texture parameter. After the Ea value is known, the shelf life of *Gracilaria* sp. can be calculated using the order 0 reaction kinetics, namely  $\ln C_t = \ln C_0 + K \times t$ . Shelf life of nori *Gracilaria* sp. If it is assumed that the temperature during distribution and storage is room temperature of 25°C or 298 K, by using PP packaging, the shelf life is 94.641 days (3 months 4 days 15 hours) with the activation energy of changes in texture parameters of 1784.6485 KJ / mol. Although almost the same as the type of polyethylene, polypropylene has more complex molecular structure, this causes polypropylene to have better permeability to water, gas, and odor when compared to plastic types [7].

## 5. CONCLUSION

The shelf life of nori from *Gracilaria* sp. stored in polypropylene (PP) packaging at a storage temperature of 25°C or 298 K is 94.641 days (3 months 4 days 15 hours) with the activation energy of changes in texture parameters of 1784.6485 KJ / mol, which means that to start the appearance change, energy is required is 1784.6485 KJ / mol.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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