Evaluation on Moisture Content of *Eucheuma cottonii* Seaweed Variety using Statistical Quality Control Approach

*Evaluasi Kadar Air Rumput Laut Jenis Eucheuma cottonii dengan Pendekatan Statistical Quality Control*

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Abstract

Quality is a crucial factor of an industry. PT XYZ is an exporter and distributor company of seaweed in Makassar city. It exports various varieties of seaweed, one of them is *Eucheuma cottonii*. Quality must be maintained to preserve and increase company image or reputation and consumer satisfaction. The study aims to improve quality of seaweed through quality control by using Statistical Quality Control (SQC) method. Receiving data of *Eucheuma cottonii* seaweed obtained from 30 sample groups, each group contains three different samples. Analysis on the process capability then was carried out so that the obtained score of process capability ratio was 0.35<1 and the process capability index score was -0.12<0. It can be concluded that the receiving process of seaweed in this company was incapable and need improvement to increase receiving process capability of seaweed. Several factors caused this incapable process were the unskilled human resources on seaweed handling in material receiving process and during distribution process from the farmer, the limitation of reliable measuring instruments, and the lack of constructive partnership between farmers, suppliers, and industry. Hence, this study suggested to improve skills of the employee, supplier, and farmer regarding seaweed cultivation and handling, to provide more reliable measuring instruments, and to develop constructive partnership development among farmer, supplier, and industry as an improvement of seaweed quality on receiving process.

Keywords: Statistical Quality Control, quality control, *Eucheuma cottonii*, seaweed

INTRODUCTION

Seaweed is one of the superior commodities and can sustainably develop due to its relatively easy and cheap cultivation technique yet has high productivity. High basic selling price is a trigger factor people to cultivate it. Commonly, seaweed is developed in the form of; 1) dried seaweed, 2)
direct consumption product, and 3) hydrocolloid (alginate, jelly, and carrageenan). Around the world, 65% of seaweed is directly consumed, 15% is a hydrocolloid, and the rest 20% is for paper material, fertilizer, and biofuel (Dahuri, 2011).

One of the keys to success to outperform the upcoming seaweed industrial field in the globalization era is to notice the supply chain's quality entirely. The quality of seaweed is one of the crucial indicators of the agricultural product for the export market. It is influenced by three basic kinds of stuff such as cultivation, harvesting period, and drying process (Anggadiredja et al., 2006). Furthermore, the difference in cultivation place is another influential factor in its quality (Kumayanjati & Dwimayasanti, 2018). Another factor is quality seed selection and supply, which is cheap, easy, massive, and sustainable (Sarira & Pong-Masak, 2018). Those factors are crucial to ensure proper material quality for the production process.

Some elements or portions provided in supply chain management generally are supplier, industry/manufacture, product distribution, retail, and consumer. There is also a minor chain in the material supply process such as farmer, supplier, and distributor. In this matter, several kinds of essential things to be developed more deeply are on the seaweed collector and distributor chain. It is a susceptible area due to the new process, i.e., seaweed storage and drying. It certainly raises potential on the decreasing seaweed quality in the storage process, such as sorting process, storage durability, storage condition, and drying process and method being conducted. The initial result showed decreasing seaweed quality, especially in the receiving process of the industry.

The study regarding seaweed mostly still focused on matters that supported the success of seaweed cultivation to maximize the material quality of seaweed both of its internal and external factor (Anton, 2017; Yudistuti, Dharma, & Puspitha, 2018; Soenardjo, 2011; Valderrama et al., 2013; Triajie, 2010; Failu, Supriyono, & Suseno, 2016). It is also in the producing process chain of seaweed, as several studies conducted (Sedayu, Basmal, & Utomo, 2008; Setyadewi & Cakravastia, 2013; Fateha et al., 2019; Putri, et al., 2018). The quality in the cultivation area and producing process is relatively untouched and is still very limited. However, several different studies about seaweed contribute to the analysis of material quality towards certain kinds of material such as in food production and pharmacy (Rimantho & Mariani, 2017; Rimantho et al., 2017). Therefore, the study on the distribution process (among farmer and seaweed production industry) needs to be conducted to strengthen the supply chain of the seaweed production process of an industry.

Other than price, the quality of the product is an essential consideration for consumers. Consequently, quality must be a primary concern for the company to maintain and improve. Quality control is a phase to reduce defective products through process variation emphasis and meet the standard of product quality specification of a company or National Standardization Agency of Indonesia (BSN) and prevent the defective product received by consumers. Also, to reach a high quality on the production process, the company must carry out a step of quality control that aims to find out the occurred fault level so that improvement and perfection measure on the process and system can be developed. The process of quality control begins from the material receiving process to the final product.

The purposes of quality control are (Assauri, 2008) to ensure that the production result meets the quality standard; to achieve efficient inspection cost; to design the cost of the product and process on production quality as efficiently as possible; and to keep production cost as low as possible. The main goal of quality control is to obtain product and service quality assurance, set by economical and efficient cost.

Statistical Process Control (SPC) is a method that can be applied to carry out quality control. SPC is a problem-solving technique used to monitor, control, analyze, manage, and improve processes. It is expected by the company to produce goods and services that meet specifications through the beginning to the end of the process by applying several statistical methods (Ariani, 2004; Heizer & Render, 2013; Stevenson, 2009).

PT XYZ is one of the seaweed distribution and processing companies in Makassar municipality. One of the seaweed varieties distributed by PT XYZ, both for the domestic and non-domestic market, is Eucheuma cottonii. The company has several suppliers in various regions, namely Bantaeng Regency, Takalar, Pangkep, Mamuju, Nunukan, and Tarakan. The quality of seaweed in each region is different. Therefore, the company conducts seaweed product sorting of the supplier according to company standard or BSN by using the percentage of moisture content...
measurement. It is essential to the processing company because dried seaweed has high yield content, and it is relatively safe for a longer duration of storage. Seaweed is categorized as dried seaweed if it looks rigid, and salt grains stick to the seaweed surface with a moisture content of 31-35% for Eucheuma cottonii (Anggadiredja et al., 2006). Dried seaweed can easily be cleaned from the foreign object stick on its stems. If it is still wet (high moisture content), then the outer layer in the form of slime resulted in the dirt to stick. If seaweed is dried, bacteria that have the potential to damage the quality of seaweed cannot survive, so it is not easily damaged even for a longer duration of storage (Surata, Nindha, & Atmika, 2012). According to the observations, there is a difference with the relatively high gap between the results of each employee’s judgment in predicting the moisture content at the time of receipt of seaweed from the supplier and laboratory test results. Hence, an in-depth study is needed for mapping the quality of seaweed at the time of receiving from suppliers.

Based on the description, the study can be developed in four subjects; namely, 1) mapping control chart of Eucheuma cottonii; 2) calculating the process capability of Eucheuma cottonii; 3) identifying the factor of non-compatibility of seaweed quality according to BSN standard using fishbone diagram; 4) providing suggestion on the quality improvement of Eucheuma cottonii.

METHODS

The study was conducted at a distribution and processing company by using several phases.
1. Analysis of Moisture Content.
   In the process of moisture measurement conducted according to Indonesian National Standard (SNI 2690:2015) concerning dried seaweed threshold value of each criterion (Badan Standardisasi Nasional, 2015), particularly for the parameter regarding moisture content test, it can be seen in Table 1. In addition to the standards in Table 1, companies that generally engaged in seaweed business indicate that the ideal level of moisture content in seaweed is in the range of 30% to 40%. In the process of moisture content test, sampling was firstly conducted at PT XYZ, and then tested in the laboratory.

2. Sensory test.
   In the sensory test, there is a form sheet about seaweed specifications assessment regarding appearance and texture filled by PT XYZ employees showed in Figure 1.

3. Data Processing of Control Chart
   Statistical process control (SPC) is one of the applicable methods, a problem solving technique used to monitor, control, analyze, manage and conduct process improvement. The goal of the control process is to suppress and reduce variations during whole process, especially variations caused by specific factor (Ariani, 2004; Stevenson, 2009; Heizer & Render, 2013).
   a. Control Chart $x - r$
      Control chart average ($x$) and range ($r$) are two control charts that have mutual support in the process of decision making regarding quality of process. The average control chart ($x$) is a control chart to monitor whether the process is still in control or not. It shows the average production that meets control standard used by company. The producing process has met product specification if it is on or around center line and in control limit. But, if the data lied out of statistical control limit due to common variation (cause contained and attached to the process) then it does not need to be omitted and is considered in control limit. The data contained outside of the average control limit are called statistical control caused by particular variation.
      Range control chart ($r$) is a chart to identify the level of accuracy or precision of the process by finding out the range of samples during observation. As well as the average control chart, range control chart is

### Table 1. BSN standard for dried seaweed

| Test Parameter | Unit | Requirement |
|----------------|------|-------------|
|                |      | Carragenophyte | (Agarophyte) | (Alginothyle) |
|                |      | Eucheuma cottonii | Eucheuma spinosum | Galidium spp | Gracllaria spp | Sargasum spp |
| 1. Sensory     |      | Min. 7 (skor 1-9)* |
| 2. Moisture    | %    | Max. 30.0 | Max. 30.0 | Max. 12.0 | Max. 12.0 | Max. 15.0 |

Note * for each sensory parameter

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is also used to identify and eliminate specific causes. Data within the statistical control limits for a range is called in statistical control which have variations due to general causes. Moreover, data that is outside the control limits of statistics is called out of statistical control, which have variations due to particular reasons.

The following equation of (1) up to (4) is a measurement to determine central line of mean and range.

\[
\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{1}
\]

\[
\bar{X} = \frac{\sum_{i=1}^{n} R_i}{g} \tag{2}
\]

\[R = x_{\text{max}} - x_{\text{min}} \tag{3}\]

\[\bar{R} = \frac{\sum_{i=1}^{n} R_i}{g} \tag{4}\]

Symbol \( n \) denotes number of sample for each observation/sub group/group, \( g \) is the number of observation has been conducted, \( R_i \) is range of each sub group, \( X_i \) denotes data of sub group or sample that has been taken, and \( \bar{X} \) is the average of each observation.

Equation (5) is used to measure upper center line (UCL) and Equation (6) for measuring lower center line (LCL) on the average control chart. For the range control chart, the upper center line (UCL) can be determined using equation (7) and lower center line (LCL) using equation (8). \( A_2 \), \( D_3 \), and \( D_4 \) are constant factors of chart of quality control limit that depends on subgroup measure of each sample.

\[UCL_{\bar{X}} = \bar{X} + A_2 \times R \tag{5}\]

\[LCL_{\bar{X}} = \bar{X} - A_2 \times R \tag{6}\]

\[UCL_R = R \times D_4 \tag{7}\]

\[LCL_R = R \times D_3 \tag{8}\]

4. Measuring Process Capability (Analysis of Process Capability)

Process capability analysis is a study to estimate the capability of processes in the form of probability distributions that have form, mean and spread. The process defines
the ability of the process to meet specifications or to measure process performance. Additionally, it has purpose to predict the variability of existing processes, test theories about the causes of errors during quality improvement programs, and others. The main reason is in quantifying the ability of the process is to be able to stick to product specifications (Ariani, 2004; Heizer & Render, 2013; Stevenson, 2009). In the process in a condition of statistical control, the steps to conduct a process capability analysis described as follow:

a. Process capability ratio or Cp value

The process is within statistical control limit if the process of the statistical process control chart categorized as “normal” and the average centered on the target, then index or ratio of process capability can be measured using Equation of (9) and (10).

\[
Cp = \frac{UCL - LCL}{6\sigma} \quad (9)
\]

\[
\sigma = \frac{R}{d_2} \quad (10)
\]

Cp stands for process capability ratio. Factor of \(d_2\) is a constant factor to estimate sigma value for control limit chart depending on subgroup of each sample. UCL (Upper Control Limit) and LCL (Lower Control Limit) are established by consumer and must be fulfilled by producers, and \(\sigma\) is deviation standard of the process. According to the measurement, the standard value of \(Cp\) describe as follows:

1) If the value of \(Cp > 1\), it shows a capable process,
2) \(Cp \leq 1\) shows incapable process, and
3) \(Cp = 1\) shows appropriate process or it has met consumer specification.

If process capability index higher than the product that lied outside, the specification limit becomes lesser.

b. Process Capability Index (Cpk)

The value of process capability index is a parameter made to observe the real capability of a process. Value of \(Cpk\) is formulated using Equation (11).

\[
Cpk = \min \left( \frac{UCL - \mu}{3\sigma}, \frac{\mu - LCL}{3\sigma} \right) \quad (11)
\]

Standard value of sigma of \(Cpk\) are as follow:

1) \(Cpk < 0\), shows process average outside of specification limit, means a low accuracy.
2) \(0 < Cpk < 1.5\), shows that accuracy and precision are still low if the value of \(Cpk < 1.5\), however, if the value of \(Cp > 1.5\), then it has high precision but low accuracy.
3) \(Cpk > 1.5\), if it is followed by \(Cp > 1\), then, it is categorized as capable process with high accuracy and precision. If \(Cp < 1\), it means high accuracy and low precision.

5. Analysis of Cause and Effect using Fishbone Diagram. Kaoru Ishikawa is a figure who developed a fishbone diagram in 1943, so that it is known as the Ishikawa diagram. It is useful to provide the cause of a problem specifically for further development steps or corrective actions.

6. Arrangement of recommended seaweed quality improvement. Recommendation arrangement is according to the result of the prior analysis using fishbone diagram.

RESULTS AND DISCUSSION

Result of Seaweed Test

Moisture Test

Content of Sample water was tested in Food Chemistry Analysis Laboratory of Animal Husbandry of Hasanuddin University with the result presented in Table 2.

Sensory Test

Sensory test was performed as an additional instrument of the results of the moisture content test. Table 3 presents the results of sensory test conducted by employees of PT The XYZ.

The specifications measured are in terms of appearance and texture of the seaweed samples. A good standard value of seaweed sensory is 7. Based on the sensory test has been conducted by expert employees on seaweed field showed that the average of seaweed sample concerning its appearance lied on the established standard, several sub groups have value of 9 that means a very good result in fact. Moreover, regarding the texture, 3 subgroups that have value of 5 means not good, but it did not significantly affect the result of moisture test.

Data Processing

The research is not possible to conduct an examination of each product regarding quality of the product. Therefore, an assessment with a
Table 2. Average of seaweed moisture in each sub group

| Date of Entry | Sub Group | Supplier | Sample Water Content (%) | X̅ |
|---------------|-----------|----------|--------------------------|----|
| 21/08/2018    | 1         | Nunukan  | A: 52.85, B: 46.47, C: 45.72 | 48.35 |
| 27/08/2018    | 2         | Bulukumba| A: 32.44, B: 27.27, C: 24.09 | 27.93 |
| 28/08/2018    | 3         | Takalar  | A: 19.47, B: 44.93, C: 49.48 | 37.96 |
| 29/08/2018    | 4         | Nunukan  | A: 47.34, B: 41.38, C: 30.49 | 39.74 |
| 29/08/2018    | 5         | Bone     | A: 39.24, B: 35.96, C: 31.91 | 35.70 |
| 29/08/2018    | 6         | Nunukan  | A: 43.08, B: 42.96, C: 40.30 | 42.11 |
| 29/08/2018    | 7         | Nunukan  | A: 41.27, B: 36.40, C: 37.87 | 38.51 |
| 29/08/2018    | 8         | Nunukan  | A: 40.99, B: 44.48, C: 38.63 | 41.37 |
| 30/08/2018    | 9         | Polmas   | A: 42.15, B: 41.48, C: 39.26 | 40.96 |
| 30/08/2018    | 10        | Polmas   | A: 46.49, B: 39.36, C: 57.60 | 47.82 |
| 03/09/2018    | 11        | Nunukan  | A: 39.51, B: 38.57, C: 42.24 | 40.11 |
| 03/09/2018    | 12        | Nunukan  | A: 46.81, B: 38.50, C: 58.26 | 47.86 |
| 03/09/2018    | 13        | Nunukan  | A: 42.09, B: 41.76, C: 40.13 | 41.33 |
| 04/09/2018    | 14        | Pangkep  | A: 44.40, B: 40.89, C: 40.50 | 41.93 |
| 04/09/2018    | 15        | Pangkep  | A: 43.72, B: 43.09, C: 38.22 | 41.68 |
| 05/09/2018    | 16        | Polmas   | A: 35.84, B: 31.93, C: 50.48 | 39.42 |
| 05/09/2018    | 17        | Nunukan  | A: 52.04, B: 50.12, C: 30.02 | 44.06 |
| 06/09/2018    | 18        | Nunukan  | A: 50.59, B: 41.58, C: 48.88 | 47.02 |
| 06/09/2018    | 19        | Pangkep  | A: 38.20, B: 43.13, C: 46.21 | 42.51 |
| 07/09/2018    | 20        | Pangkep  | A: 50.21, B: 45.12, C: 41.24 | 45.52 |
| 08/09/2018    | 21        | Polmas   | A: 33.15, B: 40.90, C: 38.21 | 37.42 |
| 08/09/2018    | 22        | Morowali | A: 51.28, B: 48.11, C: 41.80 | 47.06 |
| 08/09/2018    | 23        | Pangkep  | A: 34.77, B: 35.01, C: 36.56 | 35.45 |
| 08/09/2018    | 24        | Nunukan  | A: 32.48, B: 31.36, C: 34.23 | 32.69 |
| 09/09/2018    | 25        | Nunukan  | A: 27.10, B: 37.95, C: 45.80 | 36.95 |
| 09/09/2018    | 26        | Nunukan  | A: 32.62, B: 34.20, C: 32.12 | 32.98 |
| 09/09/2018    | 27        | Nunukan  | A: 37.77, B: 41.17, C: 37.91 | 38.95 |
| 10/09/2018    | 28        | Jeneponto| A: 37.70, B: 43.46, C: 44.06 | 41.74 |
| 10/09/2018    | 29        | Wajo     | A: 34.87, B: 42.20, C: 36.23 | 37.77 |
| 10/09/2018    | 30        | Pangkep  | A: 47.24, B: 45.54, C: 43.89 | 45.56 |

The statistical method is needed so that it eases to find out the overall quality of the product by taking several samples on each truck which is conducted 30 times, on August to September 2018.

Statistical methods used to analyze data of the defect of *Eucheuma cottonii* are the average control chart (X̅) and range (R). The result of the first data processing shows that two data are outside of control limit, namely 2nd data and 3rd data called as particular cause variant. Then, data processing is repeated by using 28 data. According to the results of this revision I of data processing, there are two data which are out of control limits, namely the 22nd and 15th data. Then the data processing is repeated with a total data of 26. The results of the revision II data processing showed there is still one data that comes out of the control limit that is the 22nd data. Finally, data processing is performed again with the amount of data as much as 25. The results of data processing revision III showed all the data are in statistical control and no outlier data.

Based on the results of data processing (Figure 2), it is known that three data are outside the average control limit (X̅) and two data are outside the distance control limit (r). Therefore, variations of specific causes can be identified and a revision of the average control chart (X̅) and distance (r) needs to be performed three times. After revising, the value of the center line, upper control limit and lower control limit on the average control chart (X̅) are obtained, which are 41.71; 50.04; 33.39 sequentially. The center line (CL), upper control limit, and lower control limit on the distance control chart sequentially are (R) of 8.14; 20.95; so that all data is in statistical control and there are no outlier data.

**Analysis of Process Capability**

According to BSN, the maximum value of...
seaweed moisture is 30%. In addition, several requirements and certain specification limit must be met by the company regarding the product quality. The next phase is measuring value of $\sigma$, process capability ratio (Cp), and process capability index (Cpk). The measurement as follows:

1. **Process Capability Ratio (Cp)**

   $\sigma = \frac{R}{d_2}$  \hspace{1cm} (12)

   $Cp = \frac{UCL - LCL}{6\sigma}$  \hspace{1cm} (13)

   The measurement as follows:

   $\sigma = \frac{8.14}{1.693} = 4.80$

   $Cp = \frac{40.00 - 30.00}{6(4.80)} = 0.35$

2. **Process Capability Index (Cpk)**

   $Cpk = \left\{ \frac{UCL - \mu}{3\sigma}, \frac{\mu - LCL}{3\sigma} \right\}$  \hspace{1cm} (14)

   $\{Cpu, Cpl\}$

   Then, the measurement of the data as follow:

   $Cpu = \frac{3(4.80)}{41.71 - 30.00} = -0.12$

   $Cpl = \frac{3(4.80)}{41.71 - 30.00} = 0.81$

   $Cpk = \{Cpu, Cpl\}$

   $=-0.12$

   The result of data processing presented the value of process capability ratio (Cp) of 0.35 < 1 means it is outside of the specification. Moreover, process capability index (Cpk) value of -0.12 < 0 that showed the accuracy of process capability is relatively low. According to the value of Cp and Cpk, it can be concluded that seaweed receiving process is not capable, so that improvement action is needed to increase the process.

### Table 3. Data of seaweed sensory

| Date of Entry | Sub Group | Appearance (x̅) | Texture (x̅) |
|---------------|-----------|----------------|--------------|
| 21/08/2018    | 1         | 7              | 7            |
| 27/08/2018    | 2         | 7              | 9            |
| 28/08/2018    | 3         | 7              | 7            |
| 29/08/2018    | 4         | 7              | 9            |
| 29/08/2018    | 5         | 7              | 9            |
| 29/08/2018    | 6         | 9              | 7            |
| 29/08/2018    | 7         | 7              | 7            |
| 29/08/2018    | 8         | 7              | 7            |
| 30/08/2018    | 9         | 9              | 7            |
| 30/08/2018    | 10        | 9              | 5            |
| 03/09/2018    | 11        | 7              | 5            |
| 03/09/2018    | 12        | 7              | 7            |
| 03/09/2018    | 13        | 7              | 7            |
| 04/09/2018    | 14        | 9              | 7            |
| 04/09/2018    | 15        | 9              | 5            |
| 05/09/2018    | 16        | 7              | 7            |
| 05/09/2018    | 17        | 7              | 7            |
| 06/09/2018    | 18        | 9              | 7            |
| 06/09/2018    | 19        | 7              | 7            |
| 07/09/2018    | 20        | 7              | 7            |
| 08/09/2018    | 21        | 7              | 7            |
| 08/09/2018    | 22        | 7              | 7            |
| 08/09/2018    | 23        | 7              | 7            |
| 08/09/2018    | 24        | 7              | 7            |
| 09/09/2018    | 25        | 7              | 7            |
| 09/09/2018    | 26        | 7              | 7            |
| 09/09/2018    | 27        | 7              | 7            |
| 10/09/2018    | 28        | 7              | 7            |
| 10/09/2018    | 29        | 7              | 7            |
| 10/09/2018    | 30        | 7              | 7            |

![Figure 2. X-R Chart of Eucheuma cottonii Seaweed Revision III](image-url)
Analysis of Fishbone Diagram

Based on the analysis using average control chart ($\bar{x}$) and range (R), 3 uncontrolled data of average control chart ($\bar{x}$) and 1 data of the control chart range (R) is figured out. Particular causative factors resulted in moisture content that is outside of control limit. To find out those factors, analysis of deep interview with head of production was conducted according to fishbone diagram consisting several factors, namely human, machine, method and material. Following factors that affects moisture content of *Eucheuma cottonii*:

1. Human
   Moisture content that did not meet standard was caused by the low level of knowledge regarding seaweed, the measurement conducted using intuition without validation, and factor of employee fatigue is affecting as well.

2. Machine
   Unavailability of moisture content meter of seaweed caused manual measurement, human performs moisture measurement using his intuition and experience during seaweed handling.

3. Method
   Moisture content that is not in accordance with BSN standards is caused by the methodology used to measure moisture content. The methodology that is commonly used to measure moisture content by trial and error according to the experience of seaweed handling, seaweed storage handling, and selecting good suppliers will determine the quality of seaweed with moisture content corresponding to BSN.

4. Material Factor
   The low quality is generally caused by seaweed seeds selection without considering the quality aspects of superior seeds, cultivation place that do not meet specific requirements for seaweed, and inconsistent harvesting period. Additionally, it is also caused by the process of seaweed treatment at post-harvest period without considering the ideal time of the drying process, drying area, and drying duration.

Suggestion to the Process Quality Improvement

Based on the results of the identification and analysis of problems using fishbone diagram, several recommendations are provided for improving the process quality so that the moisture content can meet the BSN standards. The solution was developed according to the evaluation results using the fishbone diagram approach. Some considered suggestions are provided as follows:

1. Building constructive partnerships with suppliers (knowledge management and sharing) particularly respecting quality and quantity of seaweed so that it encourages to produce high quality seaweed.

2. Procurement of a reliable seaweed measurement tool so that measurements are no longer carried out directly by employees using intuition or based on their experience in handling seaweed.

3. Improving knowledge of employee, suppliers, and farmers about good handling or cultivation techniques according to the water condition. The ideal harvesting period is around 6-8 weeks, good drying process is 2-3 days by using a mat in order that seaweed is not polluted, and the need of caution for employees or farmers in handling seaweed.

CONCLUSION

Accuracy in determining the value of seaweed moisture at the phase of receiving process is a crucial factor because it will determine level of seaweed quality during its storage prior to processing phase. Moreover, it eases the cleaning process as well. According to the mapping using control chart and the result of analysis of process capability, the process was out of control limit with low level of accuracy. Those results denote the receiving process of the company is not capable, hence, it needs an improvement to increase the capability of seaweed receiving process.

The knowledge limitation of human resources on seaweed handling of material receiving process and during distribution process from the farmers, the limit of reliable measuring instruments, and the weakness of a constructive partnership between farmers, suppliers and industry are actual factors that caused incapability of the process. The suggestions for seaweed quality improvement are by conducting knowledge improvement to the employees, suppliers and farmers regarding seaweed cultivation and handling, procurement of reliable measuring instruments and developing a constructive partnership among farmers, suppliers and industry. The study is not
yet comprehensive because it only measured one of the parameters of BSN, i.e. moisture content of *Eucheuma cottonii* to find out the process capability and quality of seaweed. Consequently, to develop further research, it is suggested to consider another parameters such as sensory, *Clean Anhydrous Weed* (CAW), metal or physical contamination.

References

Anggadiredja, J. T., Zatnika, A., Purwoto, H., & Istini, S. (2006). *Rumput Laut*. Jakarta: Penebar Swadaya.

Anton. (2017). Pertumbuhan dan kandungan karaginan rumput laut (*Eucheuma*) pada spesies yang berbeda. *Jurnal Airaha*, 5(2), 102–109.

Ariani, D. W. (2008). *Manajemen Produksi dan Operasi*. Jakarta: Lembaga Penerbit Fakultas Ekonomi Universitas Indonesia.

Badan Standardisasi Nasional. SNI 2690:2015. *Rumput Laut Kering*. Indonesia.

Dahuri, R. (2011). Mengembangkan Industri Rumput Laut Secara Terpadu. *Samudra*.

Failu, I., Supriyono, E., & Suseno, S. H. (2016). Peningkatan kualitas karaginan rumput laut Kappaphycus alvarezi dengan metode budidaya keranjang jaring. *Jurnal Akuakultur Indonesia*, 15(2), 124–131. https://doi.org/10.19027/jai.15.2.124-131

Fathea, F., Wibowo, S., Santoso, J., Agusman, A., & Uju, U. (2019). Optimization of processing conditions of alkali treated cottonii (atc) from sappfree Eucheuma cottonii. *Squalen Bulletin of Marine and Fisheries Postharvest and Biotechnology*, 14(2), 65–72. https://doi.org/10.15578/squalen.v14i2.397

Heizer, J., & Render, B. (2013). *Operations Management* (11th ed.). New Jersey: Pearson Education.

Kumayanjati, B., & Dwimayasanti, R. (2018). Kualitas karaginan dari rumput laut Kappaphycus alvarezi pada lokasi berbeda di perairan Maluku Tenggara. *Jurnal Pascapanen Dan Bioteknologi Kelautan Dan Perikanan*, 13(1), 21–32. https://doi.org/10.15578/jpbkp.v13i1.490

Putri, N. P., Sanjaya, A. S., Sari, N. K., Sari, R. P., & Bindar, Y. (2018). Carrageenan extracted from Eucheuma cottonii through variant of drying time. In *MATEC Web of Conferences* (Vol. 156, p. 02014). https://doi.org/10.1051/matecconf/201815602014

Rimantho, D., Hernadi, D., Cahyadi, B., Prasetyani, R., & Kurniawan, Y. (2017). The application of six sigma in process control of raw water quality on pharmaceutical industry at Indonesia. *International Journal of Applied Engineering Research*, 12(6), 848–860.

Rimantho, D., & Mariani, D. M. (2017). Penerapan metode six sigma pada pengendalian kualitas air baku pada produksi makanan. *Jurnal Ilmiah Teknik Industri*, 16(1), 1–12. https://doi.org/10.23917/jiti.v16i1.2283

Sarira, N. H., & Pong-Masak, P. R. (2018). Seaweed selection to supply superior seeds for cultivation. *Jurnal Perikanan Universitas Gadjah Mada*, 20(2), 79–85. https://doi.org/10.22146/jfs.36109

Sedayu, B. B., Basmal, J., & Utomo, B. S. B. (2008). Optimalisasi penggunaan air pada proses pembuatan semi-refined carrageenan (src). *Jurnal Pascapanen Dan Bioteknologi Kelautan Dan Perikanan*, 3(2), 183–191. https://doi.org/10.15578/jpbkp.v3i2.23

Setyadewi, N. M., & Cakravastia, A. (2013). Pengembangan model untuk kestabilan pasokan dan harga bahan baku industri (Studi kasus: industri pengolahan rumput laut). *Majalah BIAM*, 9(1), 40–51.

Soenardjo, N. (2011). Aplikasi budidaya rumput laut *Eucheuma cottonii* (Weber van Bosse) dengan metode jaring lepas dasar (net bag) model cidaun. *Buloma (Buletin Oseanografi Marina)*, 1(1), 36–44.

Stevenson, W. J. (2009). *Operations Management* (10th ed.). New York: McGraw-Hill.

Surata, I. W., Nindhia, T. G. T., & Atmika, I. K. A. (2012). Peningkatan Mutu Rumput Laut Kering Menggunakan Pengeriting Tipe Kabinet. Denpasar.

Triajie, H. (2010). Optimasi karaginan rumput laut asal Madura melalui periode pencahayaan berbeda. *Jurnal Kelautan: Indonesian Journal of Marine Science and Technology*, 3(2), 105–111.

Valderrama, D., Cai, J., Hishamunda, N., & Ridler, N. (2013). *Social and Economic of Carrageenan Seaweed Farming*. Rome: FAO.
Yudiastuti, K., Dharma, I. G. B. S., & Puspitha, N. L. P. R. (2018). Laju pertumbuhan rumput laut Gracilaria sp melalui budidaya IMTA (integrated multi trophic aquaculture) di Pantai Geger, Nusa Dua, Kabupaten Badung, Bali. *Journal of Marine and Aquatic Sciences*, 4(2), 191–2003. https://doi.org/10.24843/jmas.2018.v4.i02.191-203