Literature review: potential and opportunities for the development of seaweed agro-industry

W Sudarwati1,2, H Hardjomidjojo1, Machfud1 and D Setyaningsih1

1 Agro-industrial Engineering Department, Faculty of Agricultural Technology, IPB University, Indonesia
2 Industrial Engineering Department, Faculty of Engineering, Universitas Muhammadiyah Jakarta, Indonesia
e-mail: sari_rce@yahoo.com

Abstract. Seaweed is a valuable agricultural commodity found in coastal and marine areas. The practice of seaweed cultivation is the livelihood of the coastal community. Today, seaweed is still traded in the form of raw materials, so the value is low. This article aims to provide an overview of the potential and future opportunities for seaweed agroindustry development. This study is qualitative research. The data collected is secondary data, obtained from a variety of literature related to the potential and development of seaweed. This review used a 5-step approach in analyzing articles namely 1) Database selection, 2) Keyword selection, 3) Article collection, 4) Inclusion/Exclusion criteria, and 5) Reviewing selected articles sea based on the highest value-added. Agroindustry that have the opportunity to develop is processed food. Processed foods have high value-added with low technology levels. Processed food can be produced by cultivating farmers to increase income. The results of this study can be used as information and reference for further research.

1. Introduction

Seaweed is one of the leading commodities from the marine and fisheries sector which has a variety of benefits for human life. Every year there is an increase in world demand by 5-10% [1]. These needs have met by several seaweed producing countries, one of which is Indonesia. Indonesia is the second-largest seaweed producer in the world after China, with aggregate production of the two countries of more than 23 million tons in 2014 [2]. The most widely produced and exported seaweed is Eucheuma cottonii. The export volume of Indonesia’s dried seaweed can meet 58% of the world's needs with an average increase in export volume of 11.7% per year [3]. So that Indonesia is known as one of the largest exporters of seaweed, but only in terms of volume, not export value. Indonesian seaweed market value is currently lower than other countries, even with countries with smaller seaweed production. Indonesia ranks 4th after China, Korea, and Chile. These three countries are the largest carrageenan producer in the world, where their raw material originated from Indonesia. This fact is detrimental to Indonesia because it still relies on the export of seaweed commodities in the form of raw materials, namely dried seaweed only.

The problem of low value-added will not occur if the Indonesian seaweed processing industry can absorb all seaweed production. Although the number of domestic seaweed processing industries is 34, spread in several major cities in Indonesia, it has not been able to absorb the entire seaweed

1 Corresponding author’s email: sari_rce@yahoo.com
production. Most seaweed processing industries in the country are still limited to the base product level and have not yet developed the level of end product or product formulation. Seaweed that cannot be absorbed by the domestic industry is then exported to various countries in the form of raw material. About 80% of Indonesia's seaweed has exported in raw materials, and 20% in the form of processed seaweed products (agar, carrageenan, and alginate) [1]. It shows that the use of Indonesian seaweed has not been optimal until now.

The government, with its various policies set out in [5], has tried to overcome these problems with a downstream program or industrialization of seaweed by increasing the added value of seaweed export products. Beside of that, the national seaweed revitalization program and the application of seaweed standardization are carried out. However, until now, there has not been a significant increase in value. The development program implemented by the government has not shown optimal results [6], as well as the utilization of the seaweed [4]. Until now, seaweed is still a valuable resource [7] due to the increase in value-added and can be used to increase farmers' income.

This paper aims to provide an overview of the potential of Indonesian seaweed which covers the area of cultivation, potential volume of seaweed production, utilization, and the global demand. The description of this potential can be used as information to find out opportunities for seaweed development in Indonesia.

2. Methods

Literature Review is one of the processes in research. In this process, various articles are reviewed and analyzed to find a novelty. The method used is to follow the process of adopting the literature review, as shown in Figure 1. The study material in the literature review obtained from available databases that exist in various journals, proceedings, and books.

![Figure 1. Methodology of literature tracking process.](image)

2.1 Data base selection

This literature review begun by searching for data sources that are relevant to this study. The relevant data source started from tracking the database from international journal sites which can be accessed online. The selection of the database for this site has based on the field of science from electronic journals. Databases in the fields of science relevant to this research were agriculture, development studies, strategic, engineering, and technology. The selection and search results obtained that the database used was ScienceDirect, Taylor and Francis, ResearchGate, Google Scholar, Emerald Insight, and Repository.

2.2 Keyword selection

At this stage, the determination of keywords was then used to search literature. The keywords were chosen based on the theme to be studied, namely the potential and opportunities for seaweed agroindustry development. Based on these themes, the keywords chosen include 1) Seaweed, as a raw material for various downstream products including pharmaceuticals, industries, and food; 2) Seaweed potential, which covers the area of cultivation, the amount of production, content and utilization of seaweed, demand for seaweed commodities, and others; 3) Value-added of processed seaweed products, added value of seaweed products due to processing; 4) Selection, determination of methods for selecting superior products that have the potential to be developed based on product value-added; 5) Opportunities for agroindustry development, showing opportunities for future agroindustry
development.

2.3 Collection article
An initial literature search was performed on all databases of the selected websites using all predetermined keywords. The search results obtained 80 literature relevant to the research theme. The literature was obtained from ScienceDirect, Taylor and Francis, ResearchGate, Google Scholar, Emerald Insight, Springer and others were 14, 8, 19, 23, 4, 7 and 5 articles, respectively. All articles were published in journal, proceeding, books and others about 57, 8, 14, and 1, respectively, period 2000 until 2019.

2.4 Inclusion criteria for article
The literature that has been obtained then grouped and distributed throughout the outline of the paper. This grouping based on introduction, methods, the potential of Indonesian seaweed, value-added, selection, and opportunities for agroindustry development. The grouping results were obtained 4 journals and 3 books in the introduction, 21 journals, 7 books, 5 proceedings and 1 other into the potential of Indonesian seaweed, 10 journals, 3 books, 1 proceedings into added value, 16 journals into elections, 6 journals, 1 book and 2 proceedings into opportunities for seaweed agro-industry development.

2.5 Reviewing
The reviewing process started from reading the selected journals and then criticizing by describing the results of the discussion, weaknesses, and strengths of the journal. This critical review has outlined in this results and discussion section.

3. Result and discussion
The problem of low seaweed export value is still a challenge that must be overcome until now. This increase in value must have an impact on aquaculture farmers as the main actors, given that most of the Indonesia population lives on the coast with their main source of livelihood as fishermen and aquaculture farmers. It is necessary to know the current of Indonesian seaweed, especially the potential use of seaweed, to increase the value of it so that it can be a product that has added value as well as the opportunity of its agroindustry development. The development of agroindustry is expected to have an impact on the farmers’ welfare.

3.1 Potential of seaweed
Seaweed is a marine plant that classified as a multicellular alga (Thallophyta) division, a plant that has a skeletal structure consisting of a stem/thallus and has no leaves and roots. Indonesia has various types of seaweed, and there are 555 types. There are four main groups of marine macroalgae, they are a) Red algae or Rhodophyta, b) Brown algae or Phaeophyta, c) Green algae or Chlorophyta, and d) Bluegreen Algae or Cyanophyta. Seaweed from the red algae class (Rhodophyceae) are the most cultivated species in Indonesian sea waters, which is about 452 species, after that green algae (Chlorophyceae) around 196 species, and brown algae (Phaeophyceae) around 134. Of the various types of seaweed that are widely cultivated and widely traded in Indonesia are red algae (Rhodophyta) and brown algae (Phaeophyta) [8].

Based on its colloidal content, red and brown algae seaweed is divided into 3 types namely caragenophyte, agarophyte, and alginate. Types of seaweed that contain caragenophytes include Eucheuma cottonii, Eucheuma spinosum, and hypnea; seaweed containing agarophytes is gracilaria and gelidium; whereas alginate-containing seaweed is sargassum and turbinaria.

Seaweed lives in marine waters associated with the existence of coral reef ecosystems with appropriate flow criteria for seaweed cultivation, ranging from 0.2 to 0.4 m/s [9]. The stronger the sea wave, the faster the growth of the seaweed due to the higher diffusion of nutrients into the plant cells, so the metabolism is accelerated [10]. With these criteria, not all coastal areas suitable for seaweed cultivation. Seaweed species that have the potential to be developed are Eucheuma cottonii, Eucheuma
spimosum and Gracilaria sp [11].

The total area of seaweed cultivation has currently recorded at 1,510,223 Ha of 12,123,383 Ha the total area of potential marine aquaculture (Indonesian Government Regulation No. 33 of 2019. The level of utilization of the cultivation area is estimated only around 271,336 ha or only reached 17.97% until 2016. The potential area of cultivation spread throughout Indonesia can be seen in Figure 1. The limited utilization of the potential for marine culture is due to the unavailability of a legal rule in the form of regulations that oversee the spatial management/utilization of sea space for various purposes, so there is no overlap in its use [12].

![Figure 1. Potential area of cultivation spread throughout Indonesia](image)

The total area of seaweed cultivation has currently recorded at 1,510,223 Ha of 12,123,383 Ha the total area of potential marine aquaculture (Indonesian Government Regulation No. 33 of 2019. The level of utilization of the cultivation area is estimated only around 271,336 ha or only reached 17.97% until 2016. The potential area of cultivation spread throughout Indonesia can be seen in Figure 1. The limited utilization of the potential for marine culture is due to the unavailability of a legal rule in the form of regulations that oversee the spatial management/utilization of sea space for various purposes, so there is no overlap in its use [12].

![Figure 2. The potential area of cultivation spread throughout Indonesia](image)

The volume of Indonesian seaweed production from 2013 to 2016 increased by an average of 7.92%, while from 2016 to 2017 it decreased by 7% (Ministry of Industry 2019). This is influenced by the decline in the price of seaweed at the level of farmers so that farmers contribute to their production. Data on the development of Indonesian seaweed production from 2013 to 2017 can be seen in table 1.

| Total Wet Tons (thousand tons) | 2013  | 2014  | 2015  | 2016  | 2017  |
|-------------------------------|------|------|------|------|------|
| Source: [13].                 |      |      |      |      |      |

This increase in production volume will continue up to 16 tons/ha if the cultivated land is used optimally. Therefore, the Ministry of Maritime Affairs and Fisheries Republic of Indonesia set a production target of 16.17 million tons in 2018. Indonesian seaweed production is dominated by Eucheuma cottonii seaweed at 90% of the total seaweed production, while Glacilaria sp at 8%, the rest is other seaweed. The export volume of Indonesia's dried seaweed can meet 58% of the world's consumption, with an average growth rate of 11.7% per year [3]. The high contribution of Indonesia's seaweed exports makes Indonesia the world's largest producer of Eucheuma cottonii and Glacilaria seaweed.

Seaweed has a complete nutritional content. According to [14], nutrition derived from the sea concentrated in seaweed up to 440,000 times. Chemically, seaweed consists of water (27.8%), protein (5.4%), carbohydrate (33.3%), fat (8.6%) crude fiber (3%), and ash (22.25%). In addition to carbohydrates, proteins, lipids, and fiber, seaweed also contains enzymes, nucleic acids, amino acids, vitamins (A, B, C, D, E and K), and macro minerals such as nitrogen, oxygen, calcium, and selenium as well as micro minerals such as iron, magnesium, and sodium. Amino acid, vitamin, and mineral content of seaweed reach 10-20 times compared to land plants. With the nutritional composition as mentioned above, seaweed can be processed and utilized in various fields including food and...
beverages, pharmaceuticals, agriculture, and industry [15], which is estimated to play an important role in creating value [16].

In the industrial sector, seaweed is used in the agar carrageenan, and alginate industry. The three industries produce raw materials that are useful for downstream industries, including the pharmaceutical industry and the food industry. In the field of pharmacy, nutrients contained in seaweed include polysaccharides, fiber, minerals, proteins, lipids, fatty acids, vitamins, and polyphenols [17]. All of these nutrients are beneficial for health, including strengthening the immune system, antioxidants, etc. Seaweed contains high levels of antioxidants, carotenoids, and phenols, including the anti-cancer fucoxanthin compound which can be used as a supplementary drug [18], for health maintenance, to treat chronic NCDs like cancer [19], cardiovascular disease and diabetes mellitus [20]. Seaweed has potential as a cosmetic ingredient including as a sunscreen cream [21], and as a raw material for lip balms [22]. Seaweed has seen as a potential source of bioactive compounds for pharmaceutical, biomedical, and nutraceutical [23]. In Agriculture, seaweed has many bioactive compounds that are beneficial for plant development, fertilizer, and have a positive effect on seed germination, and animal feed production [24]. Also, four red seaweed, namely Gracilaria corticata, G. edulis, Hypnea musciformis and Spyridia hypnoides were found as suitable sources for nanopaste and formulations [25]. In the food sector, seaweed has been used as fast food by coastal residents. Seaweed can also be processed by various food industries as a resource for food production, food additives, and nutritional supplements [26]. Seaweed has been shown to function to improve health, shelf life, and overall food quality through the addition of either seaweed or seaweed extracts [27]. This potential provides opportunities for the development of seaweed-based functional food products [28]. Optimizing seaweed processing as a functional food product is an alternative utilization of the potential of Indonesian seaweed. It can increase the economic value and more importantly can provide access to healthy food for the wider community which is of potential interest as an ingredient in the development of new food products.

In addition to these 4 fields, seaweed also has an ecological/environmental function. It can absorb nutrients, as carbon sinks (carbon dioxide absorption and decomposition), and as a substitute for the role of the wheel [29]. Seaweed also has potential as a raw material in the production of bioethanol and biogas [30]. Seaweed has been considered a promising alternative source of biofuel due to higher growth rates, greater production yields, and higher levels of carbon dioxide fixation than land plants [31]. With varying potentials [32], seaweed has a value of up to US$ 7 billion (FAO 2010, 2011) with an estimated production of 130 million tons. The market share for human consumption is the dominant one, valued at US$ 6 billion or around 81% of the global market share in 2016. This value will continue to increase along with population growth, increased income, and awareness of healthy eating habits. The remaining, more than one billion dollars, is for the production of value-added products such as hydrocolloids, bioactive, animal feed, and fertilizers.

The current condition of Indonesian seaweed utilization is limited to utilization in industry, food, and for export. Seaweed processing industry in Indonesia, in general, is divided into two, agar and carrageenan. Agar industry absorbs seaweed by 18%, carrageenan industry absorb seaweed by 17%, and others 1%. Production data of processed seaweed products (carrageenan and agar) can be found in the table.

| Types of processed seaweed products | 2013 | 2013 | 2014 | 2015 | 2016 | Growth (%) |
|------------------------------------|------|------|------|------|------|------------|
| Carrageenan                        | 12500| 13125| 13640| 12858| 13116| 1.71       |
| Agar                               | 3690 | 3873 | 4100 | 4056 | 4140 | 3.41       |

Table 2. Developments in the production of processed seaweed products.

The processed food industry is still undeveloped, even though the demand for bioactive materials in the form of functional foods and preventive or protective foods is increasing in the global market [33]. As for the development of the seaweed processing industry market seen in Figure 3.
The data above explains that the utilization of carrageenan more than 80% is used by (i) processed meat; (ii) milk and (iii) desserts and jellies (Fig.3). Carrageenan demand for these three markets grew by 1.5 - 3% per year for the past 10 years, from 2006-2015. This reflects the global trend of increasing demand for processed food and in response to population growth and changes in the regional economy [34].

Now, Indonesia's main challenge is the decline of cultivated seaweed species, lack of innovation, low development of new products, hence more products have a lower value compared to processed seaweed products [35]. Problems in the low value-added of seaweed need to be overcome by developing agroindustry as an effort to increase the value-added of agricultural product [36].

3.2 Value-added of seaweed

Seaweed is a sea product that can be processed into a variety of high-value products including food, cosmetics, medical applications, pharmaceuticals, and industry which plays an important role in creating value. Value-added is an increase in the value of a commodity due to the addition of inputs or further processing in the production, thereby increasing value or price [37]. The creation of value-added is not only seen based on the number of stages of the process, the number of additional inputs, and the technology used, but also on the market, that is, how much the final consumer wants to pay [38]. It is evidenced by consumer spending on processed products that are six times higher than fresh products [39].

The amount of value-added can be seen based on the industrial tree (Fig. 4). In the seaweed industrial tree, the seaweed processing industry is divided into three groups, namely: (1) Upstream industry, processing seaweed into ATC chips, paper, and food/beverage; (2) Downstream industry, processing seaweed into SRC, RC, agar and alginate; (3) Derived industry, raw material for hydrocolloid derivative products, energy, and nutrition [40].

The value-added for all seaweed derivative products is not yet fully known. The value-added for semi-refined carrageenan (SRC) is Rp13,979/kg, meaning that one kilogram of seaweed will produce a profit of Rp13,979.16, while the value-added ratio is 44.48%. The amount of value-added is the result of calculations using the Hayami method [41]. The value-added of this study differ from the study by [42] which produces value-added of 274%, researcher [43] by 285%, and the report of the Ministry of Industry of Republic of Indonesia [44] by 600%. As for carrageenan, research [45] explains that with the Hayami method the added value of carrageenan products is Rp 9,362.5, which means that every 1 kilogram of seaweed will produce a profit of Rp9,362.5 with an added value ratio of 48%. The value-added of this study differ from the calculation of the value-added of refined carrageenan food-grade conducted by [42] which produced an value-added of 444%, research [43] of 674%, and the report of the Ministry of Industry of Republic of Indonesia [44] of 1900%. This
difference occurs because of differences in calculation methods and prices for the raw materials.

While the value-added for seaweed derivative products consisting of pharmaceutical grade, industrial grade, and food-grade, not all have a value-added study. Based on literature studies, there is value-added for some food grade that has been developed and marketed such as jelly, jam, and ice cream [46]. Research [47] compared the value-added of several processed seaweed products with other carrageenan raw materials, namely the value-added of noodles, jelly, sweets, sticks, and crackers per kg of raw materials in a row is Rp17,419, Rp90,213, Rp52,247, Rp62,496 and Rp27,104. Researchers [48] calculated the value-added of seaweed dodol by using gross value-added analysis. The results showed that the value-added per raw material of seaweed dodol was Rp24,445/kg. This added value can give high benefits for the industry and seaweed cultivation community. Thus the seaweed dodol business is feasible to be developed [49]. Likewise, with research of [50], it produced a value-added of seaweed snack tortillas of Rp 42,742,417/kg of raw materials. Based on the analysis of the value-added mentioned before, processed seaweed foods have a higher value-added than carrageenan. High diversification of seaweed products, especially processed foods, makes various alternative products can be developed.

![Figure 4](image-url)

**Figure 4.** Industrial trees [12] processed and value-added of seaweed derivative products.

To get high added value, there is a need for appropriate processing and technology. The processing of processed grass food is done by means of extraction, fermentation, dozing, and other processing. The technology developed in the processing process is still simple, generally still in the home industry scale. Large scale seaweed processing companies are more interested in processing seaweed into upstream products and intermediate products [51].

### 3.3 Product selection

Diversification of processed food products made from seaweed is quite a lot, so it is necessary to choose the best product. The method that can be used for the selection is the Process Hierarchy Analysis (AHP). AHP is a measurement process through pairwise comparisons that depends on expert knowledge. According to [52], AHP is one of the most effective multi-criteria approaches in complex
decision-making environments from a cognitive point of view and has been used to select the best products in the process of technological diversification. AHP is also used in the selection of regional superior product development, where the selection is a business strategy in the regional development effort [53]. The multi-criteria selection tool used in the methodology is based on an AHP, that allows integration of various scenarios, actors, and criteria, both tangible and intangible [54]. AHP is also used to select suppliers [55]. Supplier selection is a multi-criteria issue that includes quantitative and qualitative criteria. AHP provides a framework for making effective decisions in complex decision-making situations (e.g. vendor selection), helping to simplify and speed up the decision-making naturally [56].

Along with the development of knowledge in new complex decision making, it is necessary to improve the AHP method by combining with other multi-criteria decision-making methods. Researchers [57] proposed the AHP method with the Fuzzy approach to choose among energy alternatives. Researchers [58] used Fuzzy AHP to select critical locations for pipeline security in the offshore process. Related to seaweed commodities, Fuzzy AHP is used to formulate strategies for developing carrageenan agroindustry competitiveness [59]. Research [58] used FAHP as a centralized approach to select the location of critical pipelines for inspection and repair, but the results found that the triangle distribution in the analysis might not represent expert opinions about the technical condition of the system accurately. Because it was centered on the value of capital at a lower cost, it was recommended to use a stochastic-based FAHP approach. Research [60] conducted AHP integration with Goal Programming (GP) to combine conflicting criteria in selecting the best suppliers and allocating the optimal number of orders that resulted in cost savings. Meanwhile, to deal with uncertainties that exist in real-world situations, fuzzy mathematical programming can be used [61]. Uncertainty in these resources is an obstacle that can be overcome by the fuzzy optimization model [62].

TOPSIS is a multi-criteria decision-making technique that tries to determine the best alternative based on the concept of a compromise solution. The integration between fuzzy, AHP, and TOPSIS allows decision-makers to combine several criteria in the process of evaluating and selecting the types of products used by logistics service providers [63]. Fuzzy AHP method is used to determine the criteria weights. Simulation models are applied to determine the value of quantitative criteria. Finally, the technique for order preference by similarity to ideal solution (TOPSIS) is used to rank alternative product types used. The fuzzy TOPSIS approach was used in research [64] to find the main or most ideal alternative of a Gayo coffee agroindustry development system.

The expansion of the AHP (Saaty 1996) is known as the Analytic Network Process (ANP), which is one of the most promising tools for capturing the interdependence and interconnection that is characteristic of the community's knowledge and holistic vision. ANP is used for product selection [65]. In research [66], the ANP method was used to choose the best alternative concepts to achieve product sustainability by exploring the interdependence relationships between criteria and attributes that formulate a triple-bottom-line of sustainability.

3.4 Development opportunities of seaweed agroindustry

*Eucheuma cottonii* and *Eucheuma spinosum* seaweed have been proven to have economic value and the opportunity to be developed [67]. The development of seaweed agroindustry aims to meet the increasing global consumption. The increasing trend of global seaweed consumption is around 11% per year. Global seaweed consumption is higher for direct consumption (40%) as fresh food/salad and indirect consumption through processed food (by 40%), compared to industrial applications (hydrocolloids) by 20%. In general, there are trends in all sectors of marine resources towards value-added. As long as there is a market demand for higher-value products that can provide food security, the development will pursue this high-value market. There is a very recent change in the research focus, apart from commodity production techniques (e.g. carrageenan), namely the focus towards functional products with a higher value [68].

Now, seaweed for functional food is a trend all over the world. This trend is developing because of
higher consumer knowledge so that awareness of fresh and healthy food is higher [69]. This development was marked by an increase in world seaweed consumption which reached 5-10% per year [70]. According to [71], seaweed that functions as a functional food, source of pigments, and natural antioxidants are G. salicornia, T. decurens, and H. macroloba. These three types of seaweed are not dominantly cultivated in Indonesia. So, the development opportunity must begin from cultivation.

Opportunities for the development of processed seaweed agroindustry are still wide open. Trends in demand for processed seaweed foods are also increasing. In Europe, food and beverage enthusiasts with seaweed flavor increased to 147% during 2011 and 2015, with 37% is snacks (Mintel 2016) [72]. The market for these snacks is young people under 35, have a steady income, and are highly educated [73]. In its development, seaweed is also made into cookies products with 20% seaweed content that is suitable and liked by children [74]. Based on the research of Bosch et al. 2015, consumption of seaweed as processed food is associated with a tendency to snack. This is an opportunity for the seaweed industry to develop seaweed snacks that are healthy, delicious, convenience, and attractive to consumers, replacing the option/perception that snacks are "unhealthy" [73]. Strategies that can be carried out for the development of processed seaweed food agroindustry include the development of business scales from micro-scale to industrial scale. The development of the business scale is carried out to increase business independence through business development including the development of new products [75]. This paper is limited to the number of journal provider data bases taken.

This paper uses 6 journal database providers, namely emerald insight, google scholar, research gate, science direct, springerlink and taylor and francis. So there is a possibility that there are articles or journals related to this material, the results of which are not used as material information in this paper. Based on the results of searches of various literature that has been done, it was found that seaweed is a sea product that has the potential to be developed into various derivative products that have high added value. So that future research that will be carried out is the development of value-added processed food agroindustry

4. Conclusion
Seaweed is a potential commodity to be developed. Abundant production is a source of income for coastal communities. Seaweed is a food source that rich in fiber and can be utilized as a raw material in the food, pharmaceutical, and other industries. Increased population and public awareness of healthy food make the consumption of seaweed to increase. This increase in consumption is an opportunity for the development of processed seaweed food agroindustry. The development of processed seaweed food agroindustry is carried out on a home industry scale because it applies simple technology and can be done by farmer groups. The development of processed seaweed food agroindustry can increase the value-added of seaweed and increase the income of farmers and the community.

5. References
[1] Khaldun R I 2017 *J. Sospol.* 3 99–125
[2] Buschmann A H, Carolina C, Infante J, Neori A, Israel A, Hernández-González M C, Pereda S V, Gomez- Pinchetti J L, Golberg A, Tadmor-Shalev N and Critchle A T 2017 *Eur. J. Phycol.* 52 391–406
[3] Zamroni S and Ernawati 2015 *Info Komoditi Rumput Laut* (Jakarta: Badan Pengkajian dan Pengembangan Kebijakan Perdagangan)
[4] Erniati, Zakaria F R, Prangdimurti E and Adawiyah D R 2018 *Acta Aquatica* 3 12–17
[5] Kementrian Perindustrian 2015 *Rencana Induk Pembangunan Industri Nasional 2015 – 2035* (Jakarta: Pusat Komunikasi Publik Kementrian Perindustrian)
[6] Hidayat A and Safitri P 2019 *J. Kebijak. Sosek. Kp.* 62 45–56
[7] Delaney A, Frangoudes K and Li S A 2016 *Seaweed in Health and Disease Prevention*, ed Fleurence J and Levine I (Massachusetts: Academic Press) chapter 2 pp 7-40
[8] Suparmi and Sahri A 2009 *Majalah Ilmiah Sultan Agung* 44 95–116
[9] Rohman A, Wisnu R and Rejeki S 2018 *J. Sains Akuakultur Trop*. 2 73–82
[10] Darmawati, Niartiningssih A, Syamsuddin R and Jompa J 2016 *Pros. Sem. Nas. Hasil Penelitian dan Pengabdian Masyarakat* 11 196–201
[11] Yusuf S, Arsyad M and Nuddin A 2018 *IOP Conf. Ser. Earth Environ. Sci.* 157 012041
[12] Kementrian Kelautan Dan Perikanan 2015 *Peraturan Menteri Kelautan dan Perikanan Nomor 45/Permen-Kp/2015* (Jakarta: KemenKumHam)
[13] Kementrian Perindustrian 2019 *Peraturan Presiden No 33 Tahun 2019 Tentang Road Map Pengembangan Industri Rumput Laut Nasional 2018 – 2021* (Jakarta: MenKumHam)
[14] Verkleij F N 1992 *Biol. Agric. Hortic.: An Int. J. for Sust. Produc. Sys.* 8 309–324
[15] Wijesinghe W A J P and Jeon Y 2012 *Int. J. of Food Sciences and Nutrition* 63 225–235
[16] Stévant P, Rebours C and Chapman A 2017 *Aquac. Int.* 25 1373–1390
[17] Nedumaran T and Arulbalachandran D 2016 *Environmental Sustainability* (India: Springer)
[18] Khalid S, Abbas M, Saeed F, Bader-Ul-Ain H and Suleria H A R 2018 *Therapeutic Potential of Seaweed Bioactive Compounds* (London: Intechopen)
[19] Murphy C, Hotchkiss S, Worthington J and Mckeown S R 2016 *J. Appl. Phycol.* 26 2211–2264
[20] Collins K G, Fitzgerald G F, Stanton C and Ross R P 2016 *Mar. Drugs* 14 1–31
[21] Nurjanah, Luthfiyana N, Hidayat T, Nurilmala M and Anwar E 2019 *IOP Conf. Ser. Earth Environ. Sci.* 278 012055
[22] Nurjanah, Abdullah A, Fachrozan R and Hidayat T 2018 *IOP Conf. Ser. Earth Environ. Sci.* 196 012018
[23] Yi-Yi, Lim, Wei-Kang, Lee, Thean-Chor A, Leow, Parameswari, Namastivayam, Janna-Ong, Abdullah and Chai-Ling 2018 *Pertanika J. of Scholarly Research Reviews* 4 1–17
[24] Daniel S L, Kiril B and Leonel P 2019 *J. Oceanol. Limnol.* 37 918–927
[25] Roseline T A, Murugan M, Sudhakar M P and Arunkumar K 2019 *Environ. Technol. Innov.* 13 82–93
[26] Fleurence J 2016 *Seaweed in Health and Disease Prevention*, ed Fleurence J and Levine I (Massachusetts: Academic Press) chapter 5 pp 149–167
[27] Roohinejad S, Koubaa M, Barba F J, Saljoughian S, Amid M and Greiner R 2017 *Food Res. Int.* 1066–1083
[28] Mendis E and Kim S 2011 *Advances in Food and Nutrition Research* vol 64, (Elsevier Inc.) chapter 1 pp 1-15
[29] Kurnia H, Rifadi R R, Agustono, Amin M N G, Sudjarwo S A and Alamsjah M A 2019 *IOP Conf. Ser. Earth Environ. Sci.* 236 012110
[30] Bolong N, Asri H A, Ismail N M, and Saad I 2018 *Green Energy and Technology* (Singapore: Springer)
[31] Tabassum M R, Xia A and Murphy J D 2017 *Renew. Sustain. Energy Rev.* 68 136–146
[32] Nayar S and Bott K 2014 *World Aquac.* 45 32–37
[33] Kılınç B, Cirik S, Turan G, Tekogul H and Koru E 2013 *Food Industry* (INTECH) chapter 31 pp 735-748
[34] Campbell R and Hotchkiss S 2017 *Tropical Seaweed Farming Trends, Problems and Opportunities, Developments in Applied Phycology* 9 (Ireland: Springer)
[35] Porse H and Rudolph B 2017 *J. Appl. Phycol.* 29 2187–2200
[36] Machfoedz M M 2015 *Ital. Oral Surg.* 3 20–25
[37] Yao Z, Leung S C H and Lai K K 2008 *Eur. J. Oper. Res.* 186 637–651
[38] Trierekens J H 2011 *Int. Food Agribus. Manag. Rev.* 14 51–82
[39] Hendrawati T Y 2016 *Pengolahan Rumput Laut dan Kelayakan Industrianya* (Jakarta: UMJ Press)
[40] Qalsum U, Adhi A K and Fariyanti A 2018 *J. Ilm. Manaj.* 8 541–561
[41] Irianto H E and Soesilo I 2007 *Seminar Nasional Hari Pangan Sedunia* (Bogor) 67 pp 4–21
[42] Hikmah 2015 *J. Kebijakan Sosok. Kp.* 5 27–36
[43] Rachbini D J et al. 2012 *Outlook Industri 2012: Strategi Percepatan dan Perluasan...*
Agroindustri (Jakarta: Kementrian Perindustrian Republik Indonesia).

[44] Ngamel A K 2012 *J. Sains Terap*. 2 68-83
[45] Alonso A D 2011 *Br. Food J.* **113** 187-204
[46] Dentalia Y 2014 *Analisis Nilai Tambah Agroindustri Berbahan Karaginan di Kota Mataram (Studi Kasus UD. Harkat Makmur)* (Mataram: Repository Universitas Mataram)
[47] Subhan H A 2014 *E-J. Agrotekbis* 2 495-499
[48] Nurviana B E, Anwar and Maryati S 2016 *Analisis Pendapatan dan Kelayakan Agroindustri Dodol Rumput Laut di Kota Mataram* (Mataram: Repository Universitas Mataram)
[49] Baksh R, Hadayani and Tang Y H A 2015 *E-J. Agrotekbis* **3** 547–554
[50] Hasibuan S 2015 *Jurnal OE* 7 64–81
[51] Muezza V, Arcochab D d, Larrodéa E and Moreno-Jiménez J M 2014 *Prod. Plan. Control Manag. Oper.* **25** 715–728
[52] Keprate A and Ratnayake R M C 2016 *Int. J. Public Procure.* 16 83–117
[53] Mahmoudkelaye S, Azari K T and Pourvaziri M 2018 *Case Stud. Constr. Mater* **9** E0020
[54] Jayakrishna K, Vimal K E K and Sekar Vinodh 2015 *J. Model. Manag.* **10** 118–136
[55] Wijayanto E, Kurniani and Silitonga L M 2017 *Pros. Sentrinov. (Sem. Nasional Terapan Riset Inovatif)* 3 EB261–EB272