

## CARRAGEENAN RAW MATERIAL SUPPLY PROJECTION IN THE SEAWEED PRODUCTION CENTER AREA IN TAKALAR REGENCY, SOUTH SULAWESI PROVINCE

Leffy Hermalena<sup>\*)1</sup>, Melinda Noer<sup>\*\*</sup>), Novizar Nazir<sup>\*\*\*</sup>), Rika Ampuh Hadiguna<sup>\*\*\*\*</sup>)

<sup>\*)</sup>Doctoral Program in Agricultural Sciences, Universitas Andalas

Jl. Kampus M. Hatta Unand Limau Manis Padang, Univesita Andalas, Padang 25166, West Sumatra, Indonesia

<sup>\*\*</sup>Faculty of Agriculture, Andalas University, Padang

Jl. Kampus M. Hatta Unand Limau Manis Padang, Univesita Andalas, Padang 25166, West Sumatra, Indonesia

<sup>\*\*\*</sup>Faculty of Agricultural Technology, Andalas University, Padang

Jl. Kampus M. Hatta Unand Limau Manis Padang, Univesita Andalas, Padang 25166, West Sumatra, Indonesia

<sup>\*\*\*\*</sup>Faculty of Industrial Engineering, Andalas University, Padang

Jl. Kampus M. Hatta Unand Limau Manis Padang, Univesita Andalas, Padang 25166, West Sumatra, Indonesia

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### ABSTRACT

**Background:** The seaweed industry has experienced rapid growth, especially in the production of food, feed, biofuels, and biochemicals. Indonesia has become the largest exporter of fresh, frozen, and dried seaweed; However, carrageenan derivative products are still limited. The demand for seaweed continues to increase, but the supply of seaweed raw materials for carrageenan-derived products has not met international standards, so it has failed to meet the demand in full. Seaweed production is exported as raw materials, and its added value has not been enjoyed by farmers, producers, local governments, and other stakeholders. The demand for carrageenan, especially as a raw material for the food industry, is increasing, which emphasizes the importance of seaweed supply.

**Purpose:** This research aims to manage the supply of seaweed as raw material for carrageenan derivative products in the seaweed production center area in Laikang Village, Takalar Regency.

**Design/methodology/approach:** This study uses qualitative analysis of interactive models Miles, Huberman, and Saldana. Techniques used include semi-structured interviews, where the implementation is more flexible to identify problems openly. Respondents were asked to provide more detailed information and ideas, which were then observed

**Findings/Results:** The results of the study show that the management of seaweed supply in Laikang Village is sufficient in terms of quantity but still lacks in terms of quality according to the demand of the agroindustry.

**Conclusion:** In order to improve seaweed quality through more inexpensive seeds, improved distribution, and eco-friendly practice training, government help is essential. Strategic planning in market research and supply management is emphasized in this study, which projects the seaweed supply for carrageenan derivatives in Laikang. While downstream processing regulations can optimize economic potential by minimizing the export of raw materials, effective supply

**Originality/value (State of the art):** This study makes an original contribution by investigating a problem that is not clearly defined, poorly understood, or under-investigated (exploratory), thereby gaining a better understanding of the problems that exist in the supply of carrageenan raw materials in Laikang village., so that can provide an objective picture of the real conditions of the subjects being studied.

Keywords: carrageenan, control, supply chain, production, quality of seaweed

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<sup>1</sup> Corresponding author:  
Email: [vicoremapii@gmail.com](mailto:vicoremapii@gmail.com)

## INTRODUCTION

The seaweed industry is seaweed farming that is experiencing rapid growth in several countries (Leffy et al. 2023). Seaweed is currently generally produced on a large scale for food, feed, biofuel, and biochemicals. Seaweed farming provides a variety of ecosystem services, which are ecologically and economically valuable (Neori et al. 2007; Forster & Radulovich, 2015). The food industry is becoming a market leader for high-value seaweed products, especially those containing carrageenan (Cyber Colloids Ltd, 2012). Seaweed is a marine resource rich in nutrients of polyunsaturated fatty acids, polysaccharides, vitamins, proteins (essential amino acids), and minerals (MacArtain et al. 2007; Misurcova, 2011). The content of organic materials, namely minerals and vitamins, is used in the food sector, for example, agar-agar products, seaweed salad, carrageenan, and alginate.

Seaweed in Indonesia has been used as a commercial food source, for example, seaweed noodles (Keyimu, 2013; Atiqoh et al. 2021) seaweed salt (2019; 2020; Manteu et al. 2021; Nurjanah et al. 2021a) cakes, puddings, and food additives, candy, milk, bread, jelly, and jam (Mamat et al. 2014; Ministry of Industry, 2015) and raw materials for the food industry, ice cream crystallization inhibitors, flavor enhancers, as well as thickeners and stabilizers for salad dressings, sauces, yogurt, and mayonnaise (Salim & Ernawati, 2015). Seaweed also functions as an antioxidant in making body scrub cream (Nurjanah et al. 2021b). According to Subaryati et al. (2013) Seaweed plays a role in fulfilling food needs and industrial development, and is a marine biological resource that has an ecological role and economic value (Satheesh and Wesley, 2012; Chaves et al. 2013).

Based on global seaweed demand trend data (average 2015-2019), Indonesia is the largest exporter of fresh/chilled/frozen/dried seaweed at 53.35%, but only 4.49% for carrageenan derivative products. Indonesia's seaweed exports are still dominated by products in the form of dried seaweed (suitable for human consumption), followed by non-consumption products, carrageenan, and agar-agar. The demand for seaweed continues to increase with a growth of 10.4% per year, with demand growth between 11.2% to 16.2% in 2020 to 2022, reaching USD 7.71 billion (Directorate General of PDSPKP, 2021; Directorate General of

PDSPKP, 2023). However, the supply of seaweed raw materials for carrageenan derivative products still does not meet international standards so that the demand for these raw materials has not been optimally met. (Astruli, 2020).

South Sulawesi Province is the largest seaweed producer in Indonesia. The Ministry of Maritime Affairs and Fisheries (2023) noted that South Sulawesi Province produced 3,976,882 tons of seaweed in 2022 with the dominant types being *Kappaphycus varezii* which is often referred to as *Eucheuma cottonii*, *Eucheuma spinosum*, and *Gracilaria* spp. Takalar Regency is one of the regencies that contributes to producing seaweed, namely 374,888.6 tons. Seaweed production in South Sulawesi Province is a source of livelihood for more than 35,000 households (BPS, 2020).

South Sulawesi Province is the largest producer of *Eucheuma cottoni* in the world, with Takalar Regency contributing 32 percent of its production. Global demand continues to increase, but *Eucheuma cottoni* production is constrained by various challenges, such as low-quality seed stocks, declining water quality, seasonal changes, and pest and disease attacks. These constraints hamper the achievement of Indonesia's seaweed production target, which the government has set to increase from 9.78 million tons in 2019 to 12.3 million tons in 2024. Seaweed production in 2017 was only 10.81 million tons, lower than 2016 of 11.05 million tons. Conditions continued to decline from the third quarter of the 2020 period of 7.78 million tons to 7.14 million tons. The figure achieved in 2021 also explained that there was no achievement of the target as set by the KKP in the 3rd quarter of 8.45 million tons (KKP, 2023). Takalar Regency with an area of 240.88 km with a coastline of 74 kilometers, consists of nine sub-districts including Mangarabombang District, Mappakasunggu District, Sanrobone District, South Galesong District, Galesong District, North Galesong District located on the coast is the center of seaweed cultivation. This research focuses on Laikang Village, Mangarabombang District, Takalar Regency, one of the areas producing superior seaweed for carrageenan raw materials. The novelty of this research is to enrich the concept of agro-industrial estate development by using supply chain management through the management of raw material availability and the involvement of various parties.

How to Approach Problem solving from this study involves a strategic approach to overcome the main challenges faced in the supply chain, production, and marketing, including:

1. The quality of seaweed is still not up to consumer demand standards, which is caused by farmers' knowledge related to cultivation and post-harvest techniques that are still simple (traditional), as well as contamination from microplastics and dirt. This can be overcome by providing intensive training to farmers on modern cultivation techniques and post-harvest handling, encouraging the use of environmentally friendly technologies (such as HDPE buoys) to reduce the risk of microplastic contamination, and distributing superior seeds from the government or research institutions to increase crop yields.
2. Price instability and dependence on intermediaries, farmers rely heavily on intermediaries which causes price fluctuations and the lack of direct access of farmers to markets or processing industries. This can be addressed by establishing direct partnerships between farmers and the processing industry, increasing price transparency by providing market information to farmers, and providing incentives to farmers to improve supply and price stability.
3. The supply chain has not been integrated, this is due to the lack of coordination between farmers, collectors, and industry, and the absence of effective inventory management to ensure supply according to industry needs. This problem can be overcome by adopting integrated supply chain management involving all stakeholders, establishing an inventory system to control inventory so that the supply of raw materials is available in sufficient quantities and in accordance with industry needs, and forming cooperatives or farmer associations to improve information, coordination in production and distribution.
4. Marketing for derivative products is still not optimal in the global market. The need to conduct market research to identify consumer needs and preferences in various international markets and product promotion through domestic and international exhibitions, cooperation with distributors, and branding of Indonesian seaweed derivative products.

With the above problem solving, all aspects of the seaweed supply chain from upstream to downstream will be optimal, so that it can increase the competitiveness,

added value, and sustainability of the seaweed industry at the research site

The procurement of raw materials to be used as carrageenan derivative products often faces obstacles that cause a lack of raw material supply so that the production process of the processing industry cannot run smoothly. These constraints affect the ability to meet the increasing demand. Inventory control is needed so that there is no shortage of raw materials, so that each company can maintain a sufficient supply of raw materials to ensure that production activities run smoothly. The purpose of this research is to analyze the management of seaweed stocks as a raw material for carrageenan and the hypothesis proposed is that integrated supply chain management through collaboration between farmers, suppliers and industry affects the availability of carrageenan raw materials in the seaweed production center area of Takalar district, South Sulawesi.

## METHODS

The results of the study are presented to provide an objective picture of the real conditions of the subjects studied. This study was conducted to investigate problems that have not been clearly defined, poorly understood, or poorly investigated (exploratory), to gain a better understanding of the problems that exist in the supply of carrageenan raw materials in Laikang village.

The types of data in this study are primary and secondary data. Primary data were obtained from seaweed farmers, collectors, wholesalers, and seaweed agroindustry players. Primary data collection techniques are carried out by means of interviews, questionnaire distribution, and direct observation. Secondary data was obtained from data from related agencies or agencies, namely the West Sumatra Provincial Plantation Office, the West Sumatra Provincial Department of Industry, Trade and Cooperatives, the Central Statistics Agency and also through literature studies.

The required data sources can be obtained from various sources relevant to this study, namely: 1) data informants are obtained by conducting direct interviews with sources on the research object. Key informants in this study include; the government, universities, associations, related stakeholders, traders, farmers, and

industry. 2) direct observation of activities related to research problems, so that researchers can cross-check verbal information provided by the subjects studied. 3) documents in the form of written archives that have relevance to the focus of the research. This document is related to the focus of the research such as production data, Presidential Regulations, Regional Regulations, and others.

This study has supply chain actors in the seaweed agroindustry consisting of seaweed farmers as the main respondents, seaweed traders, and seaweed agroindustry as supporting respondents. The respondents came from one village that is the largest producer of seaweed in South Sulawesi Province, namely Laikang Village, Mangarabombang District, Takalar Regency. The respondents in the study consisted of seaweed farmers totaling 352 respondents from Laikang Hamlet as many as 83 people, Boddia Hamlet as many as 74 people, Puntondo Hamlet as many as 63 people, Ongkoa Hamlet 49 people, Pandala Hamlet 43 people and Puntondo Hamlet as many as 40 people Then, dry seaweed collector traders with the number of respondents in this study amounting to 30 small collector traders and 7 respondents large collector traders and 1 unit of seaweed industry. Research activities were carried out in December 2023.

Data collection techniques in research are needed to obtain results as expected in completing this research. The techniques used include interviews, especially semi-structured interviews, where the implementation is more flexible to openly identify problems. Respondents were asked to provide more detailed information and

ideas, which were then observed. Then a research questionnaire was also distributed to respondents (seaweed farmers, collectors, agroindustry).

The data analysis technique uses qualitative data analysis “Miles and Huberman, Saldana”, which states that activities in qualitative data analysis are carried out interactively and continuously until complete so that the data is saturated. Activities in analysis consist of collecting data (data collection) in the initial stage of the researcher collecting data through various techniques such as interviews, observations, or documentation, to obtain data relevant to the focus of the research. This stage is not only the process of collecting information, but also an effort to understand the context and meaning behind the data obtained, data condensation to obtain written data in the field, which later the interview transcripts obtained are sorted to get the research focus needed, data presentation (data display) is an organization, unification, and information that is concluded. The presentation of data helps in understanding the context of the research because it conducts a more in-depth analysis, as well as conclusion drawing and verification are carried out from the beginning of collecting data such as looking for understanding that does not have a pattern, recording the regularity of explanations, and the flow of cause and effect, which is the final stage of concluding the entire data obtained. (Figure 1). The purpose of this qualitative descriptive research is to provide a systematic, factual, and accurate description of a particular fact. The fact in question is about the projection of carrageenan raw material supplies in Laikang Village, Takalar Regency, South Sulawesi Province.

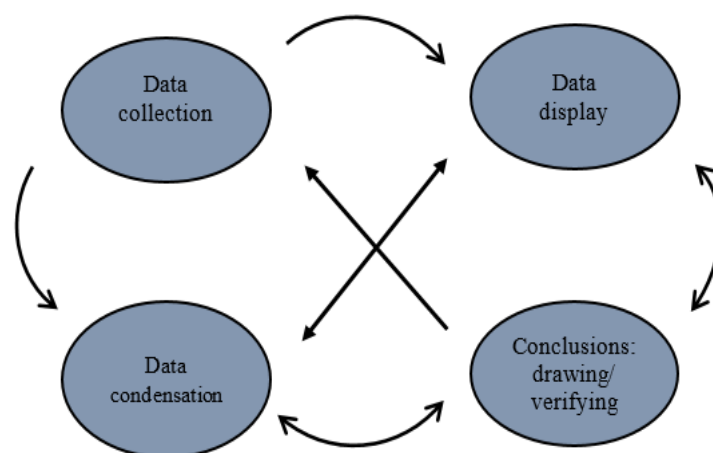


Figure 1. Components in data analysis using the Miles and Huberman, Saddana Model (2014)

The hypothesis in this study is that integrated supply chain management through collaboration between farmers, suppliers, and industry affects the availability of carrageenan raw materials in the seaweed production center in Takalar Regency, South Sulawesi, based on relevant conditions where the problem of carrageenan raw materials is the main challenge in the seaweed production center. Dependence on farmers as a provider of raw materials has resulted in various obstacles. Although Indonesia has the potential to produce high-quality seaweed seeds, various efforts must be increased in order to increase the volume of seeds and the efficiency of their distribution. Support from government agencies at the provincial or district level, such as the Ministry of Maritime Affairs and Fisheries plays an important role in providing affordable and appropriate access to seeds to farmers.

The minimal supply of raw materials can cause the production process to be hampered and cause operational congestion. Likewise, if the inventory is too excessive, the problem that arises is the accumulation of raw materials in the warehouse which causes storage and increases the cost of storage. Therefore, it is very necessary to have a method that is able to control the supply of raw materials to facilitate the continuous production process and can minimize the total cost of raw material inventory

The development of seaweed agroindustry in derivative products in the form of carrageenan begins with a deep understanding of the problems that are being faced by actors, namely: farmers, suppliers, processors, marketing and collecting information on opportunities and advantages of seaweed raw materials as derivative products. The management of seaweed supply chain management is still limited, especially for the supply of raw materials. The framework of thought is shown in Figure 2.

## RESULTS

Takalar Regency has 4,340.2 hectares of marine cultivation area and around 3,046.7 hectares or 70 percent of it is used for planting seaweed.(Fatony et al. 2023). The potential for growth of the seaweed industry in this region is still very large, even at the district level there are significant growth opportunities. Seaweed production in Takalar Regency can be optimized from upstream to downstream in the supply chain by increasing production and diversifying seaweed cultivation to expand product variations upstream. Diversification efforts are carried out through demonstration plots or small-scale cultivation for species such as Sargassum, Caulerpa, Halymenia, Porphyra, and Asparagopsis. Seaweed production in Takalar Regency can be seen in Figure 3.

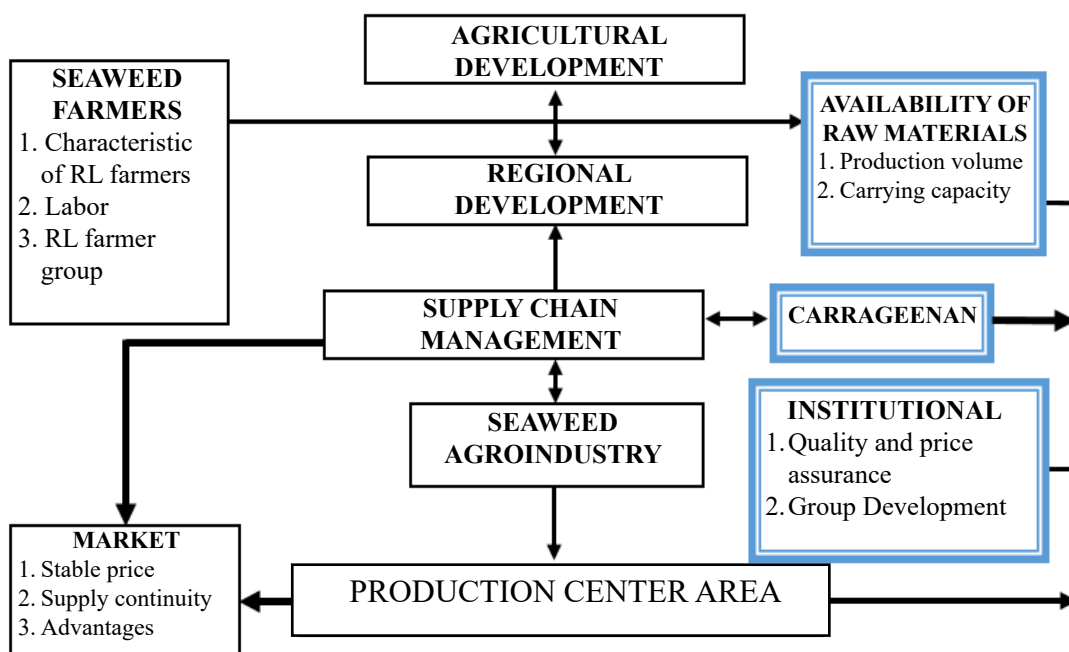


Figure 2. Framework

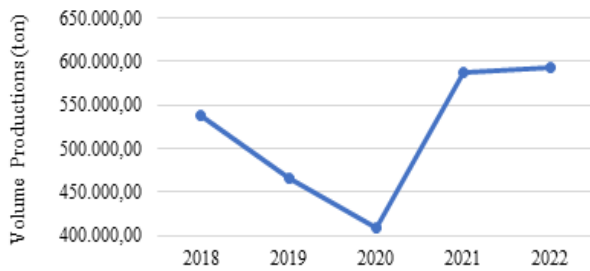


Figure 3. Seaweed Production in Takalar Regency (2018-2022)

Figure 3 shows that seaweed production in Takalar Regency has fluctuated. Production increased in 2018, decreased in 2019 and 2020, then increased again in 2021 and 2022. This variation is caused by natural factors, the availability of quality seeds in the area, and the instability of commodity prices that follow international market price trends.

Laikang Village is a village producing seaweed located on the South coast of Mangarabombang District, Takalar Regency, South Sulawesi Province. The main livelihood of the Laikang village community is that of seaweed farmers, farmers, and fishermen. Seaweed cultivation in addition to increasing community income can improve the sustainability of the surrounding waters. The most commonly cultivated type of seaweed is *Eucheuma cottoni*. Seaweed cultivation technology still uses simple and traditional technology (Darmawan, 2022). So far, seeds have been obtained by setting aside part of the harvest or collecting them from nature. Mangarabombang District, especially in Laikang Village, is considered a suitable location because it is protected from the effects of wind and large waves, has good current movement, suitable water temperature, clean and pollution-free water, the bottom of the waters is sand mixed with coral fragments, sufficient labor and close to the marketing area of the results.

### Projection of Seaweed Stock in Laikang Village, Mangarabombang District, Takalar Regency

Seaweed produced by farmers in Laikang Village, Mangarabombang District, Takalar Regency, South Sulawesi Province is generally of good quality. Some farmers have understood cultivation and post-harvest techniques according to market needs. Before cultivation, selection of quality seeds is carried out to increase yields. Usually, farmers use seeds from the previous harvest if the cultivation cycle is successful

and disease-free. However, if the quality of the previous harvest is low, farmers will buy seeds from other areas in Takalar Regency or other regency such as Jeneponto Regency.

Seaweed cultivation generally uses the long line method with nylon rope and plastic bottles because it is efficient and low cost. However, this material can cause microplastic contamination, and broken plastic bottles often become waste after 2-3 uses, piling up along the coast of the cultivation area. This problem creates environmental and food security challenges, so it is necessary to adopt environmentally friendly technologies, such as high-density polyethylene (HDPE) buoys that are more resistant to microplastic degradation. However, the use of these buoys requires high costs, capital support, and education for farmers about environmentally friendly equipment (Prajogo et al. 2023).

During the seaweed cultivation process, farmers will periodically check the growth to produce quality products. Cleaning is done if there are other organisms attached to the seaweed. If “moss” is found, farmers will sink the seaweed using weights to remove them, then lift the weights after the pests have decreased so that the seaweed returns to the surface. Farmers conduct regular monitoring to check the growth of the seaweed. If the weight of the seaweed increases in 3 to 4 weeks, farmers add buoys so that the rows of seaweed remain on the surface and receive sunlight for photosynthesis. Seaweed is ready to be harvested in 40 to 45 days (especially *Eucheuma cottonii*). Trimming and full harvesting are two methods of seaweed harvesting used by farmers. Trimming is done at the farm site (at sea) by cutting the harvested part from the parent, while full harvesting involves taking all the seaweed in the farm area by pulling a rope containing the harvest; while sorting the seeds for the next planting season.

In both harvesting methods, farmers rinse the seaweed with seawater to remove dirt that sticks to it, then dry it until it reaches a water content of 16 percent. The three drying methods used by farmers in Laikang village are drying on the ground, drying on a rack, and drying by hanging. In the first method, farmers spread plastic tarpaulin on the ground and dry the harvest on it, although this method is susceptible to contamination from soil, sand, and other dirt. The second method uses a rack, which is a bamboo rack with a 2 cm polyethylene plastic net base. The rack is placed on the beach because

the air circulation and heat are good, shortening the drying process. The third method, drying by hanging, is rarely used because hanging ropes are also needed for the next harvest and planting season (Prajogo et al. 2023).

Optimal drying usually takes 2 to 3 days in the sun until the water content reaches 35 to 38 percent. To meet market standards, the desired dried seaweed has a moisture content of 18 to 20 percent and an impurity level below 3 percent. Laikang village seaweed is considered to meet national and international quality standards and can compete with products from other regions in Indonesia.

Carrageenan-producing seaweeds include *Eucheuma cottonii* producing kappa-carrageenan and *Eucheuma denticulatum* producing iota-carrageenan. Carrageenan is a hydrophilic colloid from certain red seaweeds, containing sulfate-rich hydrocolloids that function similarly to cellulose in land plants (Fathmawati et al. 2014). The sulfate esters in carrageenan make it a stronger anionic polymer than agar and alginate, making it widely used as a gelling agent, thickener, and emulsifier, especially in the dairy industry (Guiseley et al. 1980). In the dairy industry, carrageenan helps control melting, stabilizes emulsions, and reduces syneresis in products such as pasteurized milk and ice cream. Carrageenan is also used in the manufacture of low-calorie jellies, fish gels, and desserts, and plays an important role in fat stabilization and thickening in the canned food industry. In cosmetics, carrageenan functions as a binder in toothpaste, a thickener in shampoo, and an emollient and moisturizer in lotions (Prajogo et al. 2023).

Carrageenan-based products can be processed into finished or semi-finished products, such as alkali-treated Cottonii (ATC), Semi-Refined Carrageenan (SRC), or Refined Carrageenan (RC). To produce quality products, farmers can use seaweed seeds from tissue culture managed by the Ministry of Marine Affairs and Fisheries (KKP) in various regions, including South Sulawesi. In South Sulawesi, this program is run by the Takalar Brackish Water Aquaculture Center (BPBAP) and the Maros Brackish Water Aquaculture Research and Fisheries Extension Center (BRPBAP3). Since 2016, seeds have been used by farmers in Takalar and its surroundings, although the scale is still small because the seed production capacity is still limited in the research center laboratory.

Seaweed cultivation in *Eucheuma cottonii* in Laikang Village has a very big prospect because of its high economic value. Increasing the use of grass extract in various industries will increase the demand for seaweed. Seaweed cultivation that is attempted must have a good production system and produce quality products. Seaweed development has a strategic value from upstream to downstream. Grass production in Laikang Village can be seen in Figure 4.

Figure 4 shows the fluctuating production of *Eucheuma cottonii* in six hamlets in Laikang Village from 2018 to 2022. Laikang Hamlet has the highest production volume each year compared to other hamlets. Seaweed production in Laikang Hamlet decreased in 2019 and 2020 but increased in 2021 and 2022. Overall, each hamlet showed a trend of increasing production in 2021 and 2022, due to improvements in cultivation techniques, and environmental conditions that support seaweed growth.

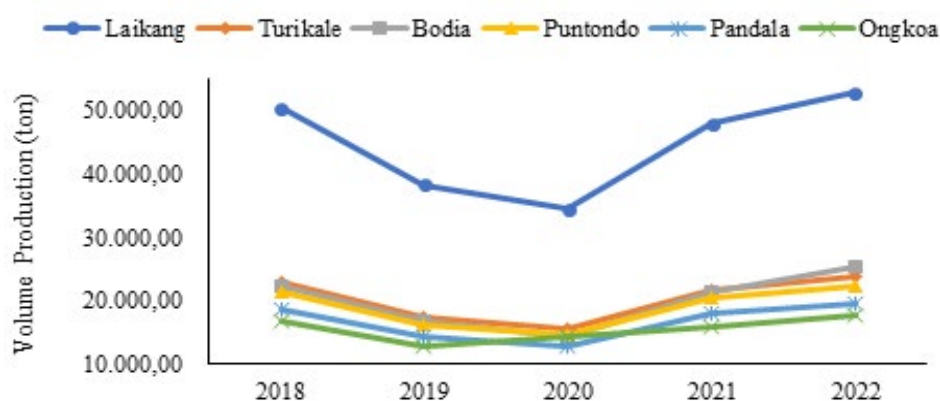


Figure 4. *Eucheuma cottonii* seaweed production volume in Laikang Village

The government recognizes the importance of the seaweed derivative product processing industry and prioritizes increasing production through skills and knowledge training programs for farmers in South Sulawesi. Technical support is provided through farmer communities to encourage intensive learning. The government highlights the development of seaweed derivative products as a regional advantage to meet growing international demand. Government policies are needed to improve the knowledge and skills of farmers in managing seaweed cultivation and processing it into value-added derivative products, so that they are able to improve quality and be able to compete in the international market, strengthening the economy through local economic development by utilizing the potential of seaweed as a regional leading commodity. As one of the largest seaweed producers in the world, Indonesia has the potential to become a leader in the seaweed derivative product industry.

#### **Marketing of Seaweed in Laikang Village, Mangarabombang District, Takalar Regency**

Marketing of dried seaweed harvest in Laikang village is done individually, depending on intermediaries or collectors who act as a link between farmers, producers, and exporters. However, this role often causes price instability, forcing farmers to sell seaweed at low prices. The increase in seaweed production in Takalar Regency should be supported by an efficient marketing system so that it is hoped that the seaweed marketing performance can provide opportunities for fishermen to increase their income. An efficient marketing system can be seen from the price level and price stability (Nurmalina et al. 2013; Dilana. 2013). The price of seaweed in Takalar Regency, which tends to fluctuate, is suspected to be related to marketing institutions, marketing chains, and communication gaps between producers and users. Fishermen have not received enough information about seaweed-related market information. Such conditions, according to (Achmad, 2012) where market information at the level of exporters and importers that are not clearly known can cause rapid changes in seaweed prices and tend to fluctuate. Limited distribution alternatives make farmers dependent on collectors, who generally make greater profits. The limited knowledge of farmers in developing businesses and creating quality derivative products according to agro-industry demand requires support from the Regional Government and Central Government to improve the knowledge of farmers, encourage quality production, and add added value to

export products such as carrageenan. Carrageenan is a derivative product of the seaweed type that is most widely used in food applications and is abundant in abundance (Nafiah and Suyatso, 2012).

Infrastructure support also plays an important role for South Sulawesi Province to manage direct exports. The seaweed distribution chain relies on local collectors to collect dried products from farmers, then taken to storage warehouses in Makassar City including to agro-industries located in the Makassar Industrial Area, before being processed in the processing industry and exported, mainly to China.

The seaweed value chain includes pre-production, production, distribution, processing, and marketing stages. The pre-production stage involves nurseries and suppliers of fisheries production facilities, which provide seeds and essential facilities such as mines, ropes, and buoys. At the distribution stage, small collectors, large collectors, brokers, and large export companies play a role in collecting and distributing seaweed. Marketing efficiency drives increased production and quality of seaweed, which is important for increasing farmers' incomes in South Sulawesi Province. Laikang Village has great potential for the development of the seaweed processing industry, as indicated by adequate land and seaweed production volume and productivity. Thus, the growth of the seaweed industry goes hand in hand with the development of the processing industry that produces added value for the sustainability of the seaweed agro-industry. In addition, to increase added value, it can be verified through the processing of different types of seaweed (*Eucheuma cottonii*) from other seaweed processing into food products with high nutritional value so that it can be used as an alternative to attractive, healthy and economical products (Badarudin, 2016; Hendrawati, 2016).

The seaweed marketing process shows that each marketing and distribution entity increases added value. Improvements from the cultivation stage to post-harvest allow for increased quality and production results. Incentives for farmers and collectors can help stabilize prices, reduce marketing margin costs and increase the economic value of seaweed commodities, making them the main export pillar of South Sulawesi Province. Marketers (downstream sector) tend to be selfish and exploitative. Fisheries networks are only tied and coordinated by market mechanisms. There are three main problems on the fisheries market side, namely (1)



low commodity diversification, both raw and processed materials; (2) low control of the market caused by lack of intelligence, strategy and market promotion; (3) market distortions that cause the market mechanism to not run and boost production costs. Market distortions also result in commodity prices below the price they should be (under value), production margins are much smaller than market margins so that there is a tendency for people to only try in the trade sector (Yulisti et al. 2017) The development of small industries for processing derivative products such as carrageenan can have a positive impact on all entities in the seaweed marketing chain.

### Problems and Strategies

The problem with Indonesian seaweed is the low perception of product quality, especially related to maintaining purity from contaminants such as dirt, microplastics, and other chemicals. This low quality is caused by limited cultivation, harvesting, and drying technology. Therefore, improvements in the upstream supply chain are very important because they directly affect the quality of the seaweed produced. Seaweed production is exported in the form of raw materials whose added value has not been enjoyed by cultivators, producers, local governments and other stakeholders. The development of seaweed agroindustry has strategic value from upstream to downstream. The demand for carrageenan as a raw material, especially for the food industry, is increasing so that this demand further emphasizes the importance of seaweed supply (Aramyan et al. 2007; Aramyan et al. 2006).

Indonesian seaweed exports generally have low added value, while the international market demands high-quality products according to International Standards. Most of the seaweed exported only goes through a drying process and requires further processing before it is ready to become a final product. The Indonesian Seaweed Industry Association (ASTRULI) stated that Indonesian exporters have a stronger business network with the Chinese market compared to Australia. The closeness to Chinese partners is driven by efforts by Chinese importers and producers to secure raw material supplies through foreign direct investment, business alliances and supply chain integration. As a result, Indonesian producers tend to prefer the Chinese market. To reduce this dependency, Indonesian producers can improve the quality and marketing of products such as carrageenan.

Some of the problems of the seaweed agroindustry are related to: (1) the quality of seaweed produced by cultivators is generally still low, has not produced semi-finished products (carrageenan) in accordance with international quality standards (Elizabeth, 2019; Victoria et al. 2010; Rebours et al. 2014; Dentalia, 2014; Nuryadi et al. 2017; Hidayat and Purnami, 2019; Mirera et al. 2020); (2) The specific characteristics of agri-food products contribute to supply chain risks (Wibowo, 2007; Wibowo, 2011; Mulyati, 2015); (3) the instability of seaweed availability causes it to be unmet to meet customer needs (Wibowo, 2009; Hasibuan, 2015; Hikmah, 2015; Khaldun, 2017); The volatility of seaweed prices also greatly affects the profitability of price changes that are difficult to transfer to customers, resulting in lost profits. The processing industry does not get a guarantee of the supply of raw materials in the right quantity, quality, time and price (Yulisti et al. 2012; Yulisti et al. 2017; Balina et al. 2017; Stévant et al. 2017); (5) There is no strategy to improve the quality of seaweed as a raw material for derivative products in the form of carrageenan (Wibowo, 2011; Anwar, 2013; Farida et al. 2014; Santoso et al. 2015; Fajariyah and Eko, 2015).

The South Sulawesi Provincial Government sees great opportunities and is actively fostering new exporters in the seaweed sector. Currently, the South Sulawesi Provincial Government is seeking funding to develop a value-added seaweed processing industry. This effort is coordinated by the Ministry of Investment/ Investment Coordinating Board and the South Sulawesi Provincial Government, especially through the One-Stop Integrated Investment Service Office (DPMPTSP). The Indonesian government will make efforts to increase seaweed competitiveness as a step to increase profits in the global seaweed trade and the welfare of coastal communities. These efforts are carried out by the Government of Indonesia through improving the upstream (cultivation) of seaweed in improving the yield and quality of seaweed production, the downstream (industrial) sector by industrializing seaweed to increase the competitiveness of seaweed based on upgrading by providing added value to Indonesian seaweed export products, and the application of standardization as the main reference in maintaining the quality of seaweed products (Khaldun, 2017; Rompas, 2018).

Although seaweed production in this area is abundant, there is still a lack of foreign investment in the value-added product processing industry. The development of seaweed cultivation and processing requires support in the form of research activities and human resource development, technology, strengthening networks, social communities of cultivators and economic and marketing actors is very important. Increasing the quantity of processed seaweed exports in the form of carrageenan by promoting domestic investment to build the seaweed processing industry sector and the development of seaweed utilization in the carrageenan industry sector is expected to be a locomotive in creating job opportunities, community welfare, and a driver of economic growth (Adiguna et al. 2022). Cooperation between academics, government, business sectors, and NGOs will also have a positive impact on expanding the development of the seaweed industry in this area. The managerial implications include improving seaweed quality through farmer training, strengthening local supply chains, government policy support in the form of subsidies or credits, product promotion in international markets, and educating farmers about environmentally friendly cultivation in accordance with market standards.

### Managerial Implication

Managerial implications show the importance of a holistic strategy in managing the seaweed supply chain and supporting the carrageenan industry as a derivative product:

- 1) Product Quality Improvement, improving the quality of seaweed is a key step to meet international market standards. Through farmer training and the application of environmentally friendly technology, seaweed production can become more competitive. For example, reducing microplastic contamination not only protects the environment, but also increases the marketability of products in the global market.
- 2) Strengthening the Supply Chain, the sustainability of the local supply chain is essential to maintain the stability of industrial raw materials. Stronger collaboration between farmers, collectors, and the processing industry has an impact on ensuring the availability of raw materials in adequate quantities and quality, thereby minimizing dependence on other regions.
- 3) Government Support, government support such as subsidies, credits, and distribution of superior seeds helps create an ecosystem that is conducive

to smallholders. This provides opportunities for technology investment, which can increase efficiency and productivity. This policy strengthens the upstream sector and supports the industrialization of seaweed derivative products.

- 4) Market Diversification, promotion of products to international markets and diversification of export destinations, such as studying new markets outside China, thereby increasing sales volume and revenue, reducing risks arising from fluctuations in demand, competition, or changes in economic conditions.
- 5) Collaboration involves various parties such as the government, academics, and the private sector in the development of the carrageenan industry so that it can accelerate innovation and solve problems on the quality of raw materials.

This approach emphasizes the transformation from raw material-based seaweed production to value-added products such as carrageenan. If done well, this strategy can increase farmers' incomes, support local industrialization, reduce negative environmental impacts, and create a stronger and more sustainable economic ecosystem. And this approach requires synergy between the government, academia, the private sector, and the community to create a significant impact on Indonesia's seaweed industry.

## CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

Support from government agencies such as the Ministry of Marine Affairs and Fisheries is important in providing affordable and suitable seeds for farmers so that the quality of seaweed products throughout the production chain increases. To increase the volume of seed production and distribution efficiency, optimal efforts are needed. In providing the necessary equipment and training for farmers to implement environmentally friendly agricultural practices are very necessary. Efforts to increase utilization by farmers will speed up the drying process, producing cleaner and higher-quality seaweed. Other aspects that need to be improved include product purity and the reduction of microplastics and chemical contaminants during the processing process. The transition to commercialization and industrialization must be carried out through collaboration with investors and government agencies to improve product development.

This research is the result of projecting the supply of seaweed raw materials for carrageenan derivative products in Laikang village, the need for encouraging wider industrialization of seaweed products requires strategic planning that focuses on two main aspects, namely in-depth market research and effective supply management. In-depth market research plays a role in matching product specifications with market needs and ensuring product value meets quality standards. On the other hand, effective supply control is essential to balance export needs with domestic processing needs. Currently, the majority of seaweed is exported in raw form, so the economic potential of this sector is not yet optimal. Government policy support is crucial to encourage downstream processing, including regulations that govern the flow and distribution of harvested seaweed so that supply is adequate for domestic and international processing industries.

### Recommandations

As the world's leading seaweed producer, Indonesia is uniquely positioned to capitalize on the many opportunities in the global market. Its contribution to Indonesia's national Gross Domestic Product (GDP) also shows a significant increase. This research study explores the potential expansion of the seaweed industry in terms of production output, product diversification, and potential partnerships with Australia. Australia has emerged as an attractive potential partner for Indonesia to drive the growth of the seaweed industry. Despite its relatively small population, Australia offers significant purchasing power as well as advanced research and technology capabilities. Its geographical proximity to Indonesia also provides strategic advantages. Given our key findings, we propose the following recommendations: 1) Quality improvement in industry practices, 2) Product matching and speeding.

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