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A review: The potential of microalgae as a marine food alternative in Banyuasin Estuary, South Sumatra, Indonesia

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ABSTRACT

Microalgae are organisms that contain excellent nutrients as a food source. It can be used directly like supplements, medicinals, biofuels, and others. In addition, microalgae are considered a food source for fish in cultivation. This review is to describe the direct and indirect benefits of microalgae as an alternative source of seafood in Banyuasin Estuary, South Sumatra. The data used are secondary data including microalgae biodiversity and biochemical content, as well as analysis of potential fishing zones on chlorophyll-*a* content and sea surface temperature using Aqua MODIS L-3 imagery in the same season and in different periods August 2013 and 2017. Bacillariophyceae showed the highest abundance with the Chaetoceros genus dominated of the whole observation area, where it was shown from the chlorophyll-a concentration and average sea surface temperature were optimum and stable conditions for fish growth. The Chaetoceros has great potential for development in food, medical, and bioenergy because it is high in protein, lipid, and carbohydrate content. Besides that, it can also be used as a source of food in aquaculture activities of that location.

INTRODUCTION

Microalgae, in particular those inhabiting the marine waters in Indonesia are considered as a natural resource as food supplements. Microalgae were introduced as a food source several years ago. However, the community response to this resource seems less enthusiastic due to limited information on microalgae benefits, whereas microalgae have better nutritional content than other foods in general, which should be known by the public **(Novianti, 2019).**

Microalgae have direct benefits for food availability because they contain fat, protein, pigments, and vitamins. The biochemical content of microalgae is a source of energy produced from the photosynthesis process **(Prince and Kheshgi, 2005).** These biochemical contents can be developed as pharmaceutical ingredients, cosmetics, antioxidants, and supplements **(Spolaore, 2006; Tang *et al.,* 2020).** Besides, it has indirect benefits in the waters. Microalgae act as primary aquatic producers and become a food source for fish in the waters.

According to FAO (Food and Agriculture Organization) data in 2016, the level of fish consumption per capita in the last six years (2011-2016) has increased by 6.8%. Based on 2018 KKP data, the fisheries sector contributes 50% of the total national food sources **(Santoso, 2016).** Banyuasin Regency, South Sumatra in 2011-2014 experienced an increase in production by 2.5%, in 2011 amounting to 38,196.25 tons and in 2014 amounting to 41,149.32 tons **(Banyuasin Regency Fishery, 2016).** This reflects that fisheries are an important sector for national food sources. In this regard, this potential can be further enhanced with information on the potential fishing zone so that production activities are higher and more efficient. These efforts can assist fishers in fishing independently and increase fishing production **(Li *et al.,* 2021).**

Therefore, this article examines the direct and indirect benefits of microalgae in their role as an alternative marine food source in Banyuasin Estuary, South Sumatra. Satellite image analysis in SST and *Chlorophyll-a* data can find potential fishing zones as indirect benefits and biochemical microalgae analysis as direct benefits.

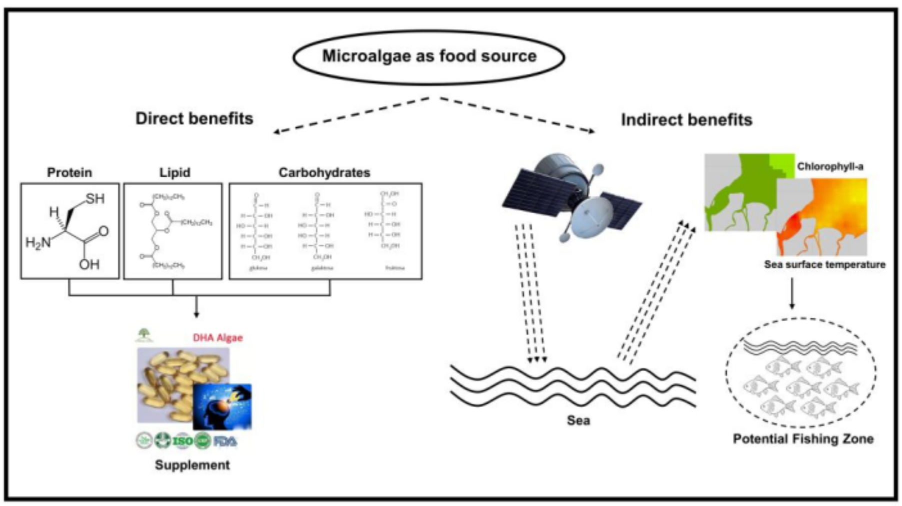

Fig. 1. Review Illustration

2 Abundance of Phytoplankton

There were three classes of phytoplankton dominating in Banyuasin Estuary and Musi Estuary. They were Bacillariophyceae, Cyanophyceae, Dinophyceae. Phytoplankton abundance data in Banyuasin Estuary Waters in August 2013 had a higher abundance than in Musi Estuary in August 2017 (Tabel 1).

The abundance of phytoplankton in Banyuasin Estuary in 2013 comprised Bacillariophyceae class of 26,742,859 cell.m^{-3}, Cyanophyceae 74,310 cell.m^{-3}, Dinophyceae 21,585 cell.m^{-3}, while the abundance of phytoplankton in Musi Estuary in

2017 includes Bacillariophyceae class of 1,600,000 cell.m^{-3}, Cyanophyceae 309,000 cell.m^{-3}, Dinophyceae 112,000 cell.m^{-3}. The abundance of phytoplankton showed Bacillariophyceae class, which had the highest abundance, followed by Cyanophyceae class, and the lowest abundance of Dinophyceae class.

Table 1. Abundance of phytoplankton in Banyuasin Estuary 2013 and Musi Estuary 2017

No	Class	2013 (cell.m^{-3})	2017 (cell.m^{-3})	References
1	Bacillariophyceae	26,742,859	1,600,000	(Aryawati et al., 2017;
2	Dinophyceae	21,585	112,000	Ridho, Patriono and
3	Cyanophyceae	74,310	309,000	Mulyani, 2020)

The Bacillariophyceae class was the class that had the highest abundance compared to other classes. Bacillariophyceae class was the most common class found in waters (**Nurhatika *et al.,* 2018; Rozirwan *et al*., 2019**). Bacillariophyceae class could adapt to water conditions (**Huliselan *et al.,* 2017; Pratama *et al*., 2019**). Generally, the Bacillariophyceae class could respond to changing water conditions (**Parakkasi *et al.,* 2020**). Bacillariophyceae class had high tolerance and adapted to environmental conditions (**Aryawati *et al*., 2017**), it was cosmopolitan. Bacillariophyceae class was more supportive of surviving longer than other classes (**Armbrust, 2009**). The diversity of phytoplankton species found in Banyuasin Estuary and Musi Estuary was presented in Fig. (2).

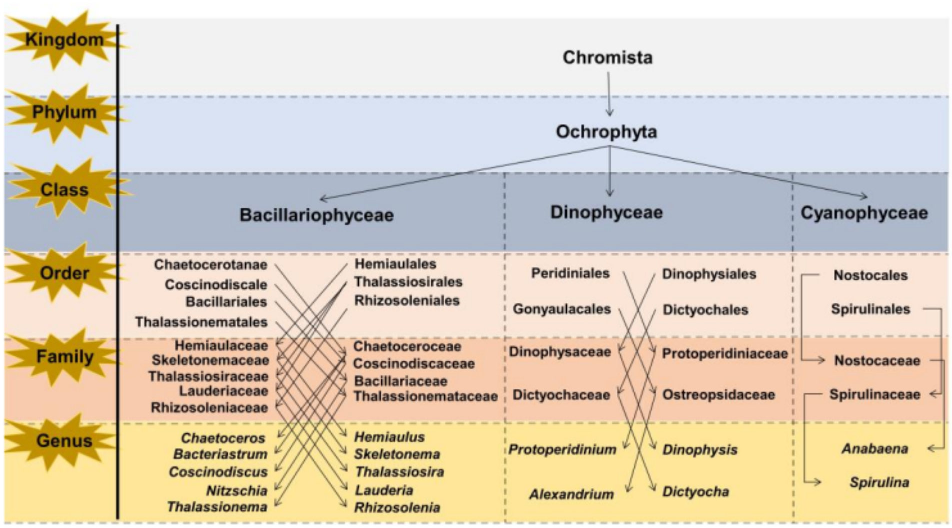

Fig. 2. Phytoplankton taxonomy in Banyuasin Estuary and Musi Estuary

Based on phytoplankton abundance data obtained in Banyuasin Estuary and Musi Estuary indicated that these waters were classified as eutrophic. Eutrophic was a water condition indicated by the high abundance of phytoplankton in water **(Taipale *et al.*, 2019)**. According to **Zhang and Wang (2020)**, eutrophic was a water condition with a high density of phytoplankton. Eutrophic conditions were caused by a higher concentration of nutrients in the water **(Novais *et al.*, 2018)**. The abundance of phytoplankton was affected by nutrients as its food source **(Rozirwan *et al.*, 2019)**.

Eutrophication was caused by an increase in the concentration of nutrients, such as nitrogen and phosphorus in water **(Aryawati *et al.*, 2017).** Nutrients came from different sources including agriculture, stormwater, wastewater, fossil fuel combustion and anthropogenic activity **(Taipale *et al.*, 2019).** Eutrophication occured during spring and summer season, low flow water, high water residence times, sufficient light levels and high water temperature would promote rapid alga growth **(Sharabian *et al.*, 2018).**

3 *Chlorophyll-a* and Sea Surface Temperature

The spatial distribution of *Chlorophyll-a* and Sea Surface Temperature in Banyuasin Estuary in August 2013 and 2017 was presented in Fig. (3). The spatial distribution of *Chlorophyll-a* concentrations in Banyuasin Estuary in August 2013 was lower than in August 2017. The range of *Chlorophyll-a* concentration in August 2013 was 2.8 to 9.9 mg.m^{-3} (Fig. 3.A) whereas in August 2017 was 2.0 to 13.2 mg.m^{-3} (Fig. 3.B). The average *Chlorophyll-a* concentration fluctuation in 2013 was 5.77 mg.m^{-3}, whereas in 2017 was 5.64 mg.m^{-3}.

The *Chlorophyll-a* concentrations in Banyuasin Estuary were classified into mesotrophic and eutrophic categories. Mesotrophic was a water condition with moderate fertility, whereas eutrophic had a high fertility rate **(Dornhofer *et al.*, 2018)**. According to **Suhadha and Asriningrum (2020)**, mesotrophic was a water condition with a *Chlorophyll-a* concentration ranged 2.0 to 5.0 mg.m^{-3}, while eutrophic was 5.0 to 15 mg.m^{-3}. The value of *Chlorophyll-a* concentration > 1 mg.m^{-3} were classified as high concentration **(Wicaksono *et al.*, 2019)**.

Based on the explanation above, these waters were perfect for fish survival because *Chlorophyll-a* concentration was getting higher. *Chlorophyll-a* was an essential parameter in the food chain system in waters. Therefore, *Chlorophyll-a* affected phytoplankton as a primary producer in waters **(Purwanto *et al.*, 2020)**.

According to **Chen *et al.* (2017)**, *Chlorophyll-a* was a vital component used as the leading indicator to estimate primary water productivity. As a primary producer, these organisms converted inorganic materials into organic materials through the photosynthesis process. Therefore, chlorophyll content in water used as a fixed stock of phytoplankton indicated primary water productivity **(Ridho *et al.*, 2020)**.

Chlorophyll-a was an organic product of phytoplankton that had a proportional relationship with fish abundance. Water fertility could be seen from *Chlorophyll-a* concentration in water, which was also one of the parameters predicting the potential fishing zone with 80% success **(Suhadha and Asriningrum, 2020)**. The fish distribution could be predicted from *Chlorophyll-a* concentration in water, and it was often used to determine potential fishing zones (**Nurdin *et al.*, 2017**). According to **Syah *et al.* (2020)**, *Chlorophyll-a* was a factor that can provide a direct indication of the fish presence and fish migration pathways. There was a relationship between catching and *Chlorophyll-a* concentration. Getting higher *Chlorophyll-a* concentration was followed by getting higher fish catching (**Purwanto *et al.*, 2020**).

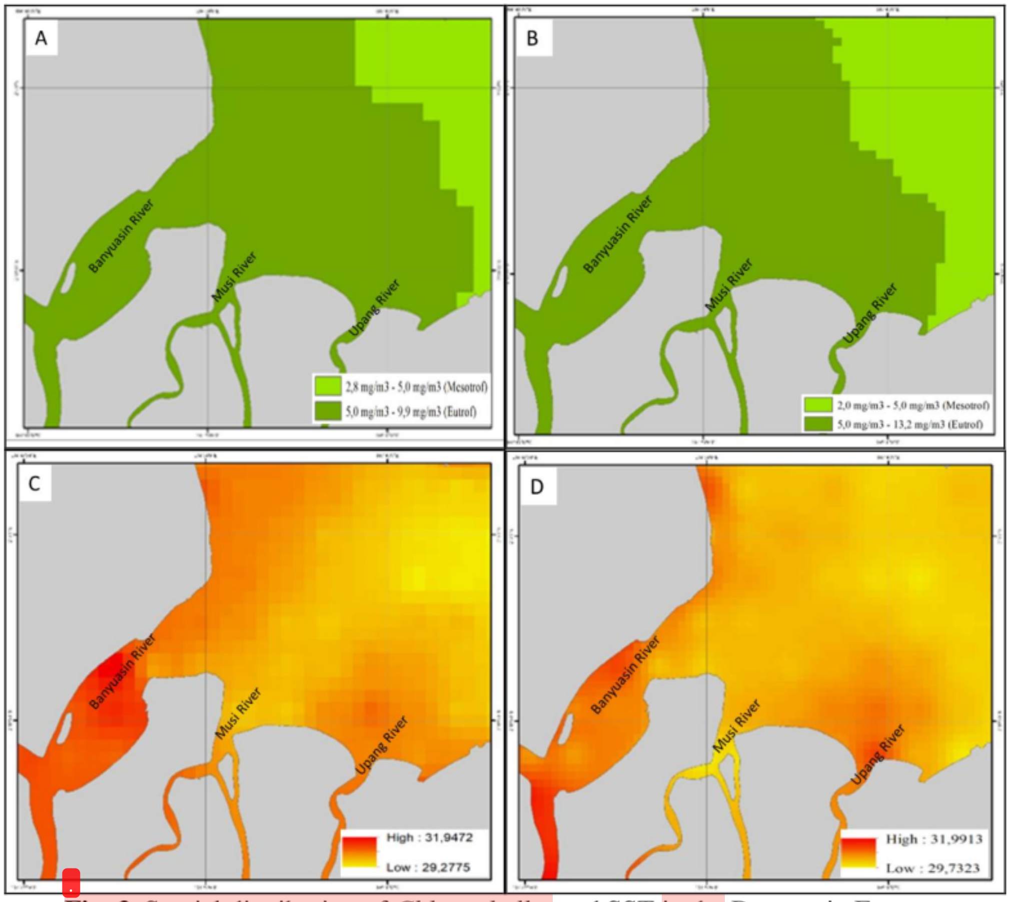

Fig. 3. Spatial distribution of *Chlorophyll-a* and SST in the Banyuasin Estuary, A) *Chlorophyll-a* August 2013; B) *Chlorophyll-a* August 2017; C) SST August 2013; and D) SST August 2017.
Source: **oceancolor.gsfc.nasa.gov**

The distribution of Sea Surface Temperature in Banyuasin Estuary Waters in two periods was relatively the same. The spatial distribution of Sea Surface Temperature in August 2013 ranged from 29.2 to 31.9˚C (Fig. 3.C), and in August 2017 of 29.7 to 31.9˚C (Fig. 3.D). The fluctuation in the average Sea Surface Temperature in Banyuasin Estuary in 2013 was 30.2˚C, and in 2017 was 30.6˚C.

The value of Sea Surface Temperature in this water was included in optimum conditions for biota survival. Based on the Environment Ministry's water quality standards, the temperature value in the optimum category for biota growth ranged from 28 to 32˚C. According to **Ridho *et al.* (2020)** optimum temperature range for plankton growth was between 20 to 30˚C. Sea Surface Temperature could be used as an indicator and significantly affects fish presence **(Dutta *et al*., 2016)**.

Sea Surface Temperature was an important variable in controlling fish populations in water **(Solanki *et al.,* 2010)**. According to **Wicaksono *et al.* (2019)**, temperature parameter was used as an indicator in determining the presence of fish. Sea Surface Temperature could affect upwelling, which carries nutrients from bottom to surface that can be a feeding ground for fish. Sea Surface Temperature could also be used in determining the thermal front area that was defined as an encounter of warm and cold water masses. The front formed was a trap of nutrients to become a feeding ground for fish **(Wijesekera *et al.,* 2016)**.

4 Potential Fishing Zones

The distribution of fishing potential zone points in the Banyuasin Estuary was presented in Fig. (4). Determination of potential fishing ground based on the distribution of *Chlorophyll-a* and Sea Surface Temperature in Banyuasin waters. The distribution of fishing potential zone points in two periods was higher in a direction outside Banyuasin and Musi Estuary.

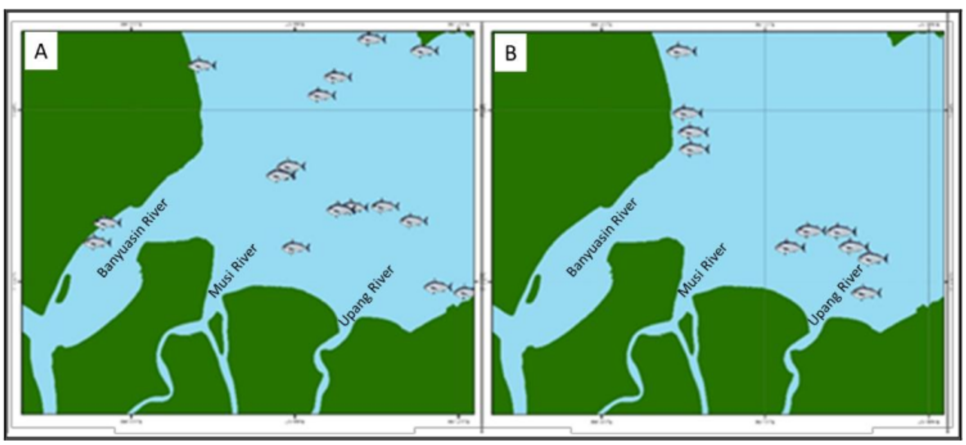

Fig. 4. Distribution of potential fishing zones in the Banyuasin Estuary, A) August 2013; B) August 2017. Source: **oceancolor.gsfc.nasa.gov**

The fishing potential zone on August 2013 were more than August 2017 (Fig. 4). In August 2013, there were 16 potential fishing zone points, while in August 2017, there were 11 potential fishing zone points. The difference of potential fishing zones points in two years was caused by the variability of supporting parameters for fish presence, such as *Chlorophyll-a* and Sea Surface Temperature. The value of *Chlorophyll-a* in Banyuasin Estuary had a relatively high value of > 2.0 mg.m^{-3} in 2013 and 2017. Sea Surface Temperature was ranged between 29 to 31.9°C in 2013 and 2017. This condition showed support for fish survival.

The distribution and abundance of biological resources were inseparable conditions and variations of *Chlorophyll-a* and Sea Surface Temperature parameters. These parameters had a strong correlation with the aquatic environment (**Roy *et al.,* 2018; Lestari *et al*., 2021; Rozirwan *et al*., 2021**). Fishing ground for fish was not permanent, but it always changed based on water conditions **(Selao *et al.,* 2019)**. *Chlorophyll-a* and Sea Surface Temperature parameters were fish migration factors. *Chlorophyll-a* acted as a food source, and Sea Surface Temperature affected marine organisms metabolism and reproduction that could determine feeding ground for fish **(Rozirwan *et al*., 2020; Saragih *et al.,* 2020**).

5 Microalgae Biochemical Content

Based on **Aryawati *et al.* (2017)**, the genus *Chaetoceros* was the dominant taxon, whereas *Skeletonema* and *Thalassiothrix* were the dominant genera in the second and third order. Bacillariophyceae class had a high tolerance level to aquatic environmental parameters. The genus *Chaetoceros*, which was dominated in Banyuasin Estuary, could be cultivated by an open pond or closed pond cultivation. The growth patterns of *Chaetoceros* at several water volume conditions were presented in Fig. (5).

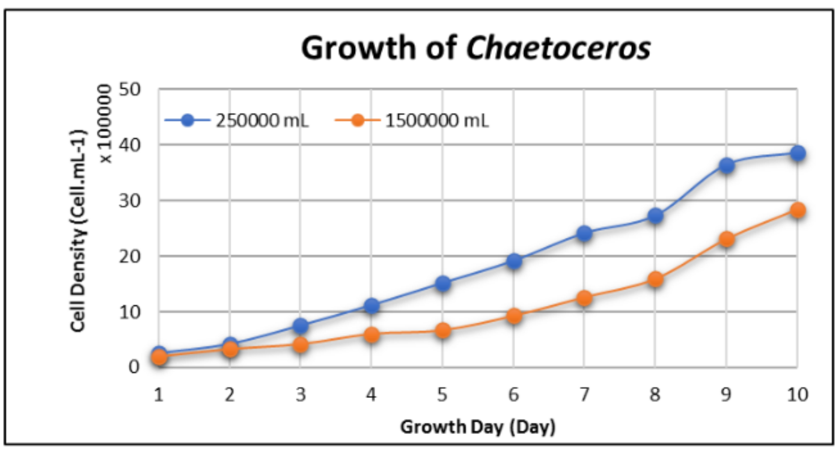

Fig. 5. *Chaetoceros* Cell Growth

Source: **(Ortega-Salas and Reyes-Bustamante, 2014)**

The cell density data presented in Fig. (5) showed that *Chaetoceros* cell growth was speedy. The average cell density in culture media 250,000 mL was more than of media volume 1,500,000 mL, this finding was due to the difference in the density of the cultured cells on the first day. According to (**Koyande *et al.*, 2019**), the biochemical composition of *Chaetoceros* was presented in Table 2.

Table 2. Biochemical composition of *Chaetoceros*

Microalgae	Composition (% dry Biomass)			
Genus	Protein	Lipids	Carbohydrate	References
Chaetoceros	36	15	27	**(Koyande *et al.*, 2019)**
Chaetoceros (L)	34.99	19.28	10.78	**(Rodriguez-Nunez and**
Chaetoceros (S)	27.84	23.78	17.19	**Toledo-Aguero, 2017)**

L: *Logarithmic phase*, S: *Stationary phase*

Based on Table 2, various biochemical data in protein, lipids, and carbohydrates of the *Chaetoceros*. There was a biochemical content of *Chaetoceros* in the logarithmic phase and the stationary phase. Microalgae growth phase conditions could affect the value of its biochemical content. So, harvesting techniques with specific objectives were needed when harvesting the cultivated microalgae.

5.1 Protein

Proteins were known as building blocks for the human body and were essential macronutrients responsible for the individual's overall growth (**Koyande *et al.*, 2019**). Alternative protein sources and better production methods were needed to meet consumer demand and meet global protein needs expected to increase.

The microalgae group was considered a viable source of protein. Microalgae for protein production had several advantages over traditional high protein crops in terms of productivity and nutritional value. Microalgae had a higher protein yield per unit area (4–15 tonnes/ha/year) (**Bleakley and Hayes, 2017**).

Table 3. Comparison of microalgae protein content and other types of food

Food types	Protein content (% Dry Biomass)
Meat	17.4
Fish	19.2 to 20.6
Chicken	19 to 24
Peanut	26
Cheese	36
Milk powder	36
Chaetoceros	27.84 to 36

Source : (**Koyande *et al.*, 2019**)

The microalgae *Chaetoceros* which was dominant in the Banyuasin Estuary Waters had a high potential protein content of around 27 to 36%. The protein content of the *Chaetoceros* was more excellent than several main types of human food such as meat, fish, chicken, and nuts (Table 3).

5.2 Lipid

Many species of microalgae experienced changes in lipid levels according to their growth phase. As shown in Table 2, the lipid levels during the logarithmic phase were 19.28%, and the stationary phase increased to 23.78%. The lipid content of microalgae ranged from 20 to 50% of the dry biomass **(Sun *et al.,* 2018)**.

Lipid was a substance needed by microalgae as food reserves. Therefore, many processes to obtain these lipids were harvested at a time of nutrient deficiency, and the most appropriate stage was at the fixed period. Apart from harvest, microalgae lipid content could be increased by making environmental conditions different from their natural habitats, such as nutrient restrictions and other external factors, including temperature, salinity, photoperiod, and light intensity **(Aziz *et al.,* 2020)**.

Lipids of microalgae were classified into two groups according to their carbon number. Fatty acids, which had 14 to 20 carbons, were used for biodiesel production. Polyunsaturated fatty acids (PUFAs) with more than 20 carbon atoms were used as health food supplements, especially docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) **(Sun *et al.,* 2018)**. The further processing of microalgae lipids could produce vegetable oil to manufacture food and health products **(Visca *et al.,* 2017)**.

5.3 Carbohydrates

Carbohydrates of microalgae acted as structural components of cell walls, as storage components and energy providers needed for metabolic processes. Based on Table 2, It was known that the carbohydrate content of the *Chaetoceros* microalgae was 10.78 to 27%. To carbohydrate production increased, so needed some control over-cultivation or environmental conditions such as nutrient deficiencies, salinity levels, light intensity, and many more **(Markou *et al.,* 2012)**.

Carbohydrates were composed of carbon compound components. Microalgae had a large carbon source for biofuels, health supplements, pharmaceutical products, and cosmetics. Microalgae produced several types of sugars such as glucose, fructose, maltose, and rhamnose used by microorganisms in the fermentation process and converted into bioethanol. These were excellent ingredient for produced bioethanol. Some microalgae species were most likely to produced bioethanol because of their higher sugar content. However, carbohydrates in the microalgae biomass were mostly in polymers and needed to be converted into monomer units for easy fermentation by microorganisms to produce bioethanol **(Khan *et al*., 2018)**.

CONCLUSION

The distribution of potential fish zones in the Banyuasin Estuary from the two periods was different due to changes in water quality that directly impacted aquatic life. The chlorophyll-a concentration and sea surface temperature are classified as optimal and stable for fish growth. The microalgae of *Chaetoceros* genus are shown the highest abundance of observed area, which is high protein, lipid and carbohydrate content. Further studies will be able to develop the microalgae products of the food, health, pharmaceutical and bioenergy sectors.

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