

Potential Production of Polyunsaturated Fatty Acids from Microalgae

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Abstract

Currently, public awareness of healthcare importance increase. Polyunsaturated fatty acid is an essential nutrition for us, such arachidonic acid, docosahexaenoic acid and eicosapentaenoic acid. The need of polyunsaturated fatty acid generally derived from fish oil, but fish oil has a high risk chemical contamination. Microalgae are single cell microorganism, one of *Phaeodactylum tricornutum* which have relatively high content of eicosapentaenoic acid (29,8%). Biotechnology market of Polyunsaturated fatty acid is very promising for both foods and feeds, because the availability of abundant raw materials and suitable to develop in the tropics. This literature review discusses about the content of Polyunsaturated fatty acid in microalgae, omega-3, omega-6, Polyunsaturated fatty acid production processes, and applications in public health.

Keywords: Poly-unsaturated fatty acid; PUFA; Microalgae; Health

Introduction

Polyunsaturated fatty acid (PUFA) is an essential component which cannot be synthesized by human. Therefore, PUFA must be provided through the diet [1]. Omega-3 (PUFA n-3) and omega-6 (PUFA n-6) are well known derivative products of PUFA.

PUFAs are found in animals, plants, fungi, and microalgae. Nowadays, food habits in society are characterized by a high consumption of fast food which contain low portion of PUFAs. Some authors have compared the composition of fast food with Japanese food [2,3] and Mediterranean food [2,4] that mostly source in fish. These authors concluded that then-6:n-3 ratio in blood, in people who consume Japanese and Mediterranean food, is close to 2:1; while people who consume fast food, it can reach up to 25:1, so far than desired. For these reason, nutritionists educate the need to consume fish and green vegetables to reduce the risk of heart diseases [2]. In contrast, the availability of fish is highly dependent on season may hamper the continuity of food [5] thus encouraging the discovery of alternative sources of PUFA. Basically, fish do not produce PUFA; they will get it by eating microalgae. This realization has turned microalgae into one of the most important producers of PUFA [67,8,5,1].

Exploration of microalgae is not used as food diversification effort only, but also intended to empower agricultural land which is not feasible. As a tropical country, Indonesia has suitable temperature and contains high level of salt so it is feasible for the growth of microalgae [6]. This literature review discusses about the content of PUFA in microalgae, PUFA production processes, and applications in public health.

Polyunsaturated fatty acid (PUFA)

Microalgae are autotrophic organisms which grow rapidly through photosynthesis like land based plants. Their unicellular structure allows them to convert solar energy into chemical energy easily [9]. Microalgae can grow to high densities population by using only light, carbon dioxide, water, and other inorganic compounds [10].

Microalgae have a composition of carbohydrate, protein, and fats are widely used to meet food needs and public's health. Nutritional supplement products from microalgae can be found in form of powders, tablets, capsules, and concentrates (Table 1). The average composition of proteins, fats, and carbohydrates in microalgae are 12-35%; 7,2-23%; 4,6-23% (%dry weight) [11]. Different nutrition, environment, and

growth phases can influence the nutritional composition in microalgae, including fatty acid composition [12,11].

Fatty acids are organic compounds formed by long chain hydrocarbon and carboxylic group [1]. Based on their nature hydrocarbon chain, fatty acids can be classified into saturated and unsaturated. Polyunsaturated Fatty Acids (PUFA) are a long chain of unsaturated fatty acid. PUFA composition in the Cod liver oil and some microalgae are shown in (Table 2).

Omega-3 fatty acids (PUFA n-3) are unsaturated 74 fatty acids and contained in food as α -linolenic acid (ALA, C18:3, n-3) [13,5]. ALA is the shortest chain of n-3 and mainly found in vegetables oil and nuts [13,5]. Eicosapentaenoic acid (EPA, C20:5, n-3) and docosahexaenoic acid (DHA, C22:6, n-3) are derivatives product from n-3 found in fish and many other microorganisms, such as microalgae and bacteria [8,5,1]. ALA can be converted into EPA and DHA in the body, but

Microalgae	Producer	Product	Production (ton/year)
<i>Spirulina</i>	Hainan Simai Pharmacy Co. (China) Eartrise Nutritionals (USA) Cynotech Corp. (USA) Myanmar Spirulina Facto	Powders, tablets, dan extract Tablets, powders, drinks Extract Tablets, chip, liquor, liquid extract	3000
<i>Chlorella</i>	Taiwan Chorella Manufacturinh Co. (Taiwan) Klotze (Jerman)	Tablets, powders, nectar, mie Powders	2000
<i>Dunaliella salina</i>	Cognis Nutrition and health (Australia)	Powders of β -caroten	1200
<i>Aphanizoanon flos-aquae</i>	Blue Green Foods (USA) Vision (USA)	Capsules, crystal Powders, capsules	500

Table 1: Commercial food products from microalgae (Gouveia, L., et al., 2008)

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the conversion is very limited and inefficient [5], therefore -3 must be provided in the form of dietary supplement.

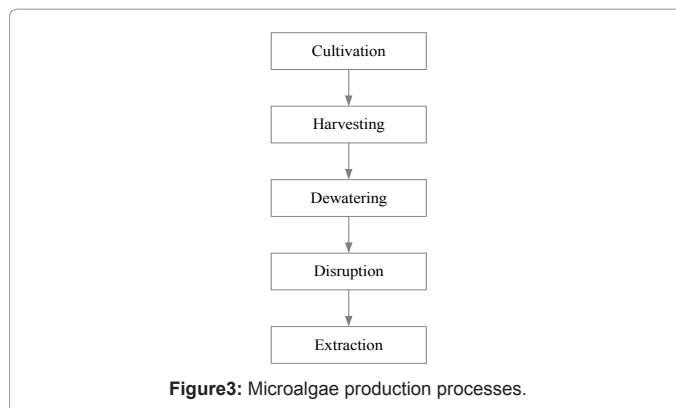
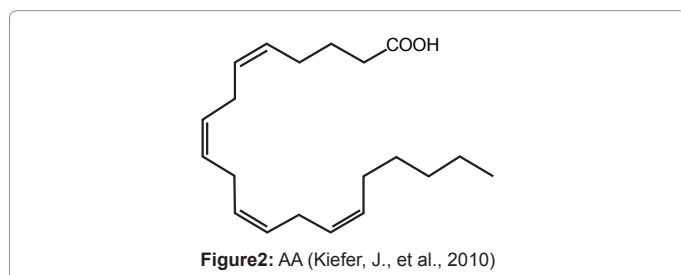
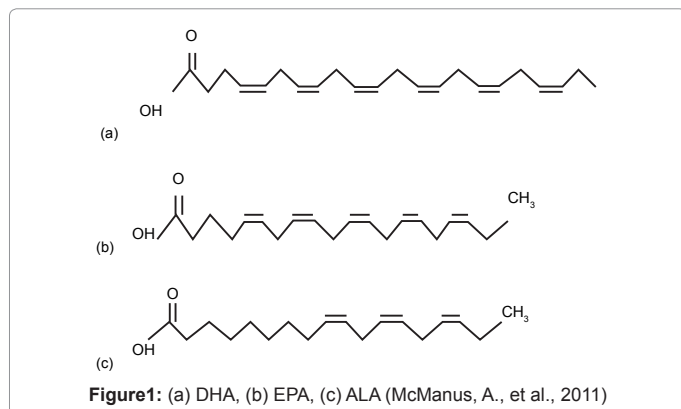
EPA and DHA have positive effects on health. Recently, EPA proven to prevent coronary heart disease, and lowers blood cholesterol [14]. DHA also has an important role in the development of central nervous system of infants [14]. EPA is widely found in *Porphyridium cruentum*, and *Monodus subterraneus* [1], while the best source of DHA derived from microalgae with *Schyzochytrium* genus [1]. Currently, some government agencies and nutritional organizations recommended daily intake level of DHA and EPA ranging from 0,2-0,3 g/day for the general population [5,15] up to 1,0-4,0 g/day for patient with coronary heart disease [5]. Chemical structure of ALA, EPA, and DHA are shown in (Figure 1).

Omega-6 fatty acid (PUFA n-6) are polyunsaturated fatty 96 acid contained in food as linoleic acid (LA, C18:2, n-6) [5,16]. LA is the shortest chain from n-6 and arachidonic acid (AA, C20:4, n-6) is one of derivatives product from n-6. AA is almost excluded from the water alga and most marine species. The only microalgae which produce AA in significant quantitative is the unicellular rhodophyte: *P. cruentum* [7]. Other Rhodophytes such as *Gracilaria* sp has a composition of AA upto 60% of total fatty acids, but the dry weight content doesn't exceed 0,2% [7]. AA is a biogenetic precursor of the biologically active prostaglandin and leucotrienes with important role in circulatory and central nervous systems [14]. AA is necessary for visual acuity, and it is valuable as an ingredient in formulations of artificial baby food [14]. Chemical structure of AA is shown in (Figure 2).

Production of PUFA

Microalgae production consists of five important stages as shown in (Figure 3).

Cultivation condition of microalgae: Most microalgae use light and carbon dioxide (CO₂) as an energy and carbon sources (photoautotrophic organism) [17,18]. Temperature must remain



Organism	PUFA (% w of total fatty acid)				
	LA	AA	ALA	EPA	DHA
<i>Isochrysis galbana</i>	0,9	0,7	1,2	22,6	8,4
<i>Phaeodactylum tricornutum</i>	2,2	3,4	0,6	29,8	0,8
<i>Porphyridium cruentum</i>	6,2	23	1	23,9	0,2
<i>Cod liver oil</i>	1,5	2,7	0,8	12,5	9,9

Table 2: PUFA composition in 320 the Cod liver oil and some microalgae [21]

generally 15-30°C for optimum growth. Growth medium must provide inorgan 118 ic elements that function in cell formation, such as nitrogen, phosphor,and iron [5,17].

Cultivation technique of microalgae: Nowadays, there are two most commonly used techniques to cultivate microalgae. These are open race way ponds and photobioreactors [9]. Open ponds are the oldest and simplest systems for cultivation [17]. Enclosed photobioreactors have been used to overcome the contamination and evaporation problems encountered in open ponds [18]. These systems are made of transparent materials and commonly placed outdoors for illumination by natural lights [9]. Photobioreactors have a large surface area to volume ratio [17,18]. Microalgae productivity of photobioreactors can reach 13 times more than open ponds [17,18]. Figure 4 shows the open raceway ponds and photobioreactors systems.

Dewatering of microalgae: Flocculation, centrifugation, and filtration are commonly techniques for dewatering microalgae [6,19,9]. Flocculation can be used as initial step that will enhance the ease of next processing. Microalgae have a negative charge, thus they need cationic chemical flocculants for coagulating biomass, such as Al₂(SO₄)₃, FeCl₃, dan Fe₂(SO₄)₃ [19,9]. Filtration has proved to be the most competitive technique [9]. The types of filtration that can be used are dead end filtration, microfiltration, ultrafiltration, pressure filtration, and tangential flow filtration [9].

Disruption: Is the separation process of lipids and other non lipids chain [20]. This process is necessary before extraction stage. Disruption agents must not degrade the lipids [14]. There are five methods of disruption that can be used, (i) autoclave (125°C, 1,5 MPa), (ii) bead-beater (bead diameter 0,1 mm, speed 2800 rpm), (iii) microwave (100°142 C, 2450 MHz), (iv) sonication using sonicator (resonance 10 KHz for 5min), and (v) osmotic shock processes [21].

Extraction of microalgae: Can be classified into two methods, (1) mechanical methods (Expression/Expeller press and Ultrasonic-assisted extraction) and chemical methods (Hexane Solvent Method, Soxhlet extraction, and Supercritical fluid Extraction) [12,11]. Each of these methods has drawbacks: (a) the mechanical methods requires

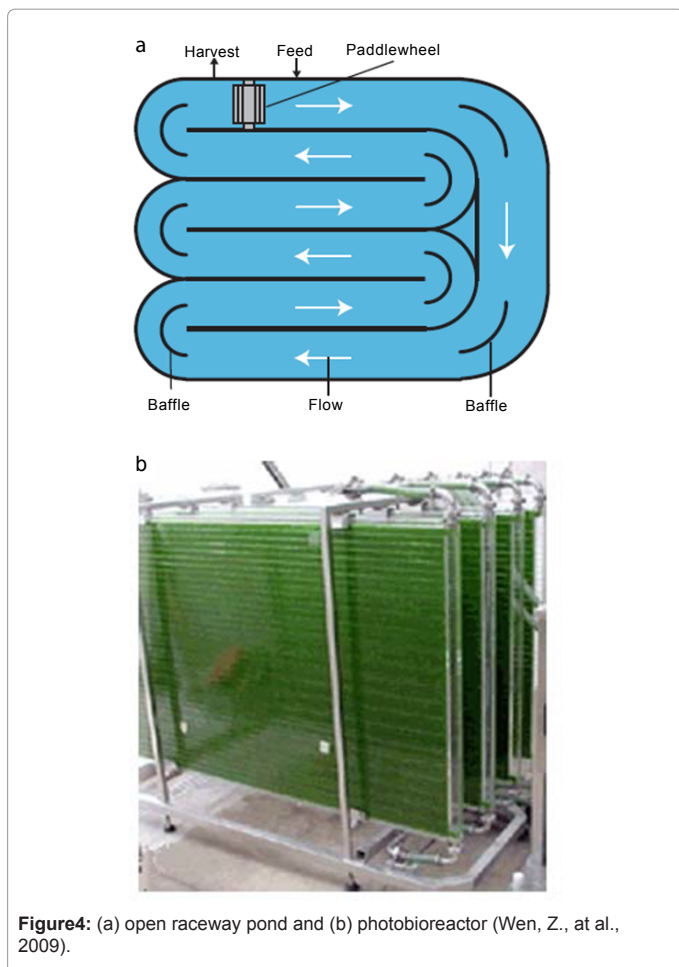


Figure4: (a) open raceway pond and (b) photobioreactor (Wen, Z., et al., 2009).

drying process which is energy intensive, (b) the use of chemical solvent should be considered to the level of safety and health, (c) supercritical extraction requires a high pressure equipment that is expensive and energy intensive [22].

Supercritical Fluid Extraction (SFE): (Figure 5) shows pressure-temperature phase diagram for carbon dioxide. In this diagram, the vapor-liquid equilibrium curve starts at the triple point (TP), where both of three phases, solid, liquid, and vapor are in equilibrium. This curve ends at the critical point (CP), where the meniscus separating vapor and liquid phases disappears and only a single phase formed. Carbon dioxide (CO₂) is in the supercritical state if its temperature and pressure higher than its critical temperature (304,1K) and pressure (7,38MPa). In its critical region, CO₂ is sensitive with very small changes in temperature and pressure [23]. Supercritical CO₂ has been the most used supercritical fluid, because non-flammable, non toxic, inexpensive, and relatively inert [23]. On the other hand, the adding of entrainer, a substance which has a volatility intermediate between the compound to be extracted and the supercritical fluid, can increase the solvent power of CO₂ [23]. Due to its non polar behavior, CO₂ cannot be used to extract the polar compound. However, the addition of polar entrainer such as water, ethanol, and methanol, thus polar compound extraction can be done [23].

Conclusions

PUFA are polyunsaturated fatty acid that has positive effects on

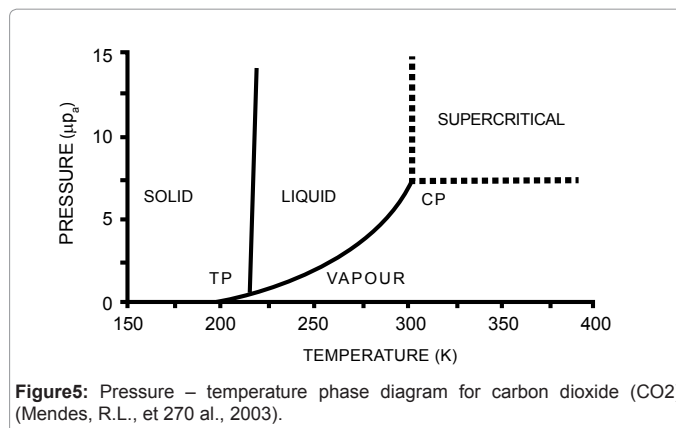


Figure5: Pressure – temperature phase diagram for carbon dioxide (CO₂) (Mendes, R.L., et 270 al., 2003).

health such as lowering cholesterol level and the risk of heart disease. Due to their continuity of their raw materials, easily developed in the tropics, and not susceptible to chemical contamination, microalgae are an alternative source of PUFA which is potential to be developed in Indonesia. PUFA extraction from microalgae can be done by several methods, mechanical and chemical methods. The potency of microalgae as feedstock PUFA is very large, it is necessary to study deeper about the extraction and purification of PUFA which is more economic with good quality and quantity.

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