Arthrospira as a potential raw material for functional food development in Indonesia

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Abstract. Modern people's awareness of health affects the shifting patterns of food needs. Currently, food is not just necessary to meet the body's nutritional needs, but brings health and fitness benefits. One type of food that can meet these needs is known as functional food. *Arthrospira* is a microorganism that has successfully attracted attention because of its high nutritional value, complex chemical composition, and safety for human consumption, making it one of the raw materials for functional foods. Apart from being rich in nutrients, *Arthrospira* also contains anti-viral, antioxidant, and antibacterial properties. *Arthrospira* is a genus of microalgae that lives in both fresh and marine waters, sometimes erroneously considered as *Spirulina*. *Arthrospira* and *Spirulina* are two different genera. In Indonesia, the bio-chemical study of *Arthrospira* is a research topic that has been widely carried out in the last 10 years. This paper aims to compare the potential of *Arthrospira* in Indonesia with other countries as a raw material for functional foods.
Key Words: food raw materials, highly nutritional, microalgae.

Introduction. Modern people's awareness of health affects shifting patterns of food needs. Currently, food does not just meet the body's nutritional needs, but brings health and fitness benefits (Suter 2013). One type of food that can meet these needs is the functional food. Functional food is food that can be consumed every day, derived from natural ingredients that are high in nutrients and have the benefit of maintaining endurance and preventing diseases (Goldberg 1994). Health Canada defines functional foods as "products that resemble traditional foods but have physiological benefits'' (Shahidi 2009).

With the increase in people's desire to live healthily and fit through dietary regulation, the demand for functional food is increasing (Suter 2013). The potential for increasing market demand for functional foods provides a large space for exploration and development of alternative functional food ingredients based on local raw materials in Indonesia. According to Subroto (2008), based on the source, functional food is classified into vegetable functional food and animal functional food. Vegetable functional foodstuffs that are currently widely developed and circulating in the community are dominated by terrestrial plants. Meanwhile, marine plants use is limited. Thus, the exploration and development of vegetable functional foods from the sea is an interesting topic to study.

Arthrospira is a microorganism that has successfully attracted attention because of its high nutritional value, complex chemical composition and safety for consumption, making it one of the microalgae cultivated on an industrial scale (Whitton 2012). Therefore, *Arthrospira* is one of the potential functional food raw materials, widely mistakenly known as *Spirulina*. This often leads to a misnomer in the naming of these microorganisms. *Arthrospira maxima* and *Arthrospira fusiformis* are usually reported as *Spirulina maxima* and *Spirulina platensis*, respectively (Whitton 2012). To distinguish *Spirulina and Arthrospira*, in the Bergey's Manual of Systematic Bacteriology, Castenholz & Waterbury (1989) suggested the use of three features of the helical circular trichomes, namely: (1)

the degree of tilt of the trichome's helical pitch (from the transverse axis); (2) the visibility aspect of the cross walls between cells in filaments; (3) the distribution of junctional pores in the cell wall. Another difference lies in the size of the trichome helix diameter, being 6-12 mm in *Arthrospira* and 2-4 mm in *Spirulina* (Castenholz 2001).

Species of the genus *Arthrospira* have been isolated from alkaline brackish and saline waters in tropical and subtropical regions (Belay 2008). *Arthrospira* is a blue-green alga (cyanobacterium) in the form of multicellular helicoidal (spiral) filaments with a length of 200 to 300 μm and a width of 5 to 10 μm (Benelhadj et al 2016). *Arthrospira* is an organic food ingredient that contains a high protein content, with a balanced amino acid composition, rich in carbohydrates, minerals, vitamins and fats (Belay 2008). *Arthrospira* protein content reaches 65% (Henrikson 1989), carbohydrates 15-25%, essential fatty acids 18%, and *Arthrospira* also contains vitamins, minerals and pigments such as chlorophyll and phycocyanin (Sanchez et al 2003). Apart from being rich in nutrients, *Arthrospira* also contains anti-virus (Basha et al 2009), antioxidant (Guan et al 2009), and antibacterial compounds (Richmond 2004).

The bio-chemical study of *Arthrospira* is a research topic that has been widely carried out in the last 10 years in Indonesia. Several research results in Indonesia show that *Arthrospira* (or *Spirulina fusiformis*) from freshwater contains 17 amino acids, 9 of which are essential amino acids (Setyaningsih et al 2011). Commercial *Arthrospira* powder contains non-polar pigments, consisting of chlorophyll a and carotenoids (Pangabean 1998). Polar pigments, consisting of phycocyanin, allophycocyanin, and fikoeritin with the highest percentage of phycocyanin content, have the potential to be developed as an additive for natural blue dye (Sedjati et al 2012). These results are reinforced by other research, which state that *Arthrospira* has a high phycocyanin content and has great potential to be developed as a natural anti-oxidant (Ridlo et al 2015). The results of Notonegoro et al (2018) showed that *Arthrospira* from brackish water has a total protein and nitrogen content of 44.3 and 7.09%, respectively and contained flavonoids, steroids, phenols, and saponins, with a concentration of phycocyanin of 1.32 mg mL^{-1} and total flavonoids of 16.56%. The results of these studies indicate that *Arthrospira* in Indonesia has a very good profile for human health, having a high potential to be developed into raw materials for medicine, cosmetics, and functional foods. However, the origin of *Arthrospira* isolates, the location of harvest and the continuity and availability of the biomass, and the exact species are often not mentioned. This will become an obstacle in the development of large-scale *Arthrospira* products.

In the last five years, the microalgae industry in Indonesia has started to grow. There are two companies that produce microalgae products established in Indonesia. Some flagship products are *Arthrospira* powder, natural food coloring and food supplement products. With the development of this business, there are challenges for researchers and academics to explore *Arthrospira* from various regions in Indonesia and develop superior strains. This paper aims to review the research on *Arthrospira* that has been carried out and its development in Indonesia.

History of Genus *Arthrospira*. The classification of this genus of spiral microorganisms has undergone several changes over a long period. *Spirullina* is a name that is more popular in the community than *Arthrospira*. This often causes mistakes in the naming of these microorganisms. Therefore, the taxonomic history needs to be explained as an introduction in order to understand and differentiate the two genera. The history of naming the genus *Arthrospira* was first reported by Stizenberger in 1852, having been previously classified into one genus, *Spirullina*, by Turpin 1829. Subsequent studies conducted by Geitler (1925) revised the *Arthrospira* genus and included all orders of Oscillatoriales, which were regularly circular (or as a spiral), into the genus *Spirullina*. With the development of research carried out in the following period, these microorganisms were finally classified into two genera, namely *Spirullina* and *Arthrospira.* Research that reveals morphological differences and classifies them into two different genera was carried out by Castenholz & Waterbury (1989), and the classification has remained valid (Vonshak & Tomaselli 2000).

Morphology and taxonomy. The main morphological feature of *Arthrospira* is the typical arrangement of multicellular cylindrical trichomes in an open helix, which usually has a relatively larger diameter than *Spirullina* and has a distinct transverse wall (Figure 1). *Arthrospira* is a blue-green alga (Cyanobacteria) in the form of multicellular helicoidal (spiral) filaments, 200 to 300 μm in length and 5 to 10 μm in width (Benelhadj et al 2016). The classification of *Arthrospira* according to Komarek & Lund (1990) is as follows: empire Prokariota, Eubacteria kingdom, Neginacteria subkingdom, Cyanobacteria phylum, Cyanophyceae class, Oscillatoriophycidae subclass, Oscillatoriales order, Microcoleaceae family, *Arthrospira* genus.

Arthrospira maxima and *Arthrospira platensis* are filamentous cyanobacteria recognized by the main morphological features of the genus, having an arrangement of multicellular cylindrical trichomes and an open left helix (Koru 2012). Under a light microscope, the filaments are blue-green in color, composed of vegetative cells that undergo binary fission in a single plane, showing easily visible cross-walls. A solitary, free-floating filament displaying motility trichoma, covered by a thin sheath, shows a slight narrowing in the cross wall and has a slight apex (Koru 2012).

The apical cells may be rounded or widely pointed and may take the form of capitals and caliprates. Trichomes are composed of short and wide cylindrical cells, measuring about 6 to 12 μm in various shapes (Tomaselli 1997). *Arthrospira* is autotrophic and performs photosynthesis to produce its food. *Arthrospira* reproduces by binary fission. The capsules have a fiber structure and cover each filament that protects them. The presence of an irregular capsule around the filament in *S. platensis* is a different morphological characteristic compares with *S. maxima* (Tomaselli 1997). The differences between *Arthrospira* and *Spirulina* genera are presented in Table 1.

Table 1

The main separating features of the genus *Arthrospira* Stizenberger 1852 and *Spirulina* Turpin 1829 (Vonshak & Tomaselli 2000)

Criteria	*Arthrospira*	*Spirulina*
Trichome diameter	2.5-16 μm	0.5-5 μm
Helicity type (circular)	loosely looped	tight circle
Transverse walls	visible under a light microscope	not visible under a light microscope
Cell wall pore pattern	one line around the trichome	several rows on the concave side of the coil
Trichome fragmentation method	intracellular (necridium)	between cells
Cylinder body	present	absent
Anoxygenic photosynthesis	absent	present in several strains
C-phycoerythrin	absent	present in several strains
Γ-linolenic acid	present	absent

Physical and chemical conditions can affect helix geometry (Bai 1985). Environmental factors greatly influence the morphology, especially temperature (Van Eykelenburg 1979). This drastic change in geometry is the reversible transition from a helix to a spiral, first observed by Van Eykelenburg & Fuchs (1980) after transferring filaments from a liquid to a solid medium. Although the helical form of trichomes is considered a stable and constant property that is maintained in culture, there may be considerable variation in the degree of helicity between different strains of the same species and within the same strain. In general, the cultivation parameters affect the metabolism and morphology of algal cells, in the case of *Arthrospira* sp. helical orientation changes or even trichome alignment being observed (Vonshak & Tomaselli 2000; Mühling et al 2003). However, this phenomenon occurs both in nature and in cultivation. It has not been explained in detail, neither from a taxonomic point of view, nor from a biochemical point of view. For a longer period it was believed that the alignment was irreversible (Tomaselli 1997), but Wang & Zhao (2005) proved that the straight trichomes of *A. platensis* could restore their morphology to a regular helical (spiral) structure.

Even in naturally occurring monospecific populations, variations in the geometry of trichomes can be observed (Tomaselli 1997). A similar opinion states that the species of *Arthrospira* show great plasticity in morphology. It is caused by environmental factors such as temperature and other physical and chemical factors and may also be due to genetic changes. Transmission Electron Microscopy observations show the prokaryotic organization of *Spirulina*, capsule, pluristrative cell wall, photosynthetic or thylakoid lamellae system, ribosomes and fibrils of DNA regions and many inclusions (Koru 2012).

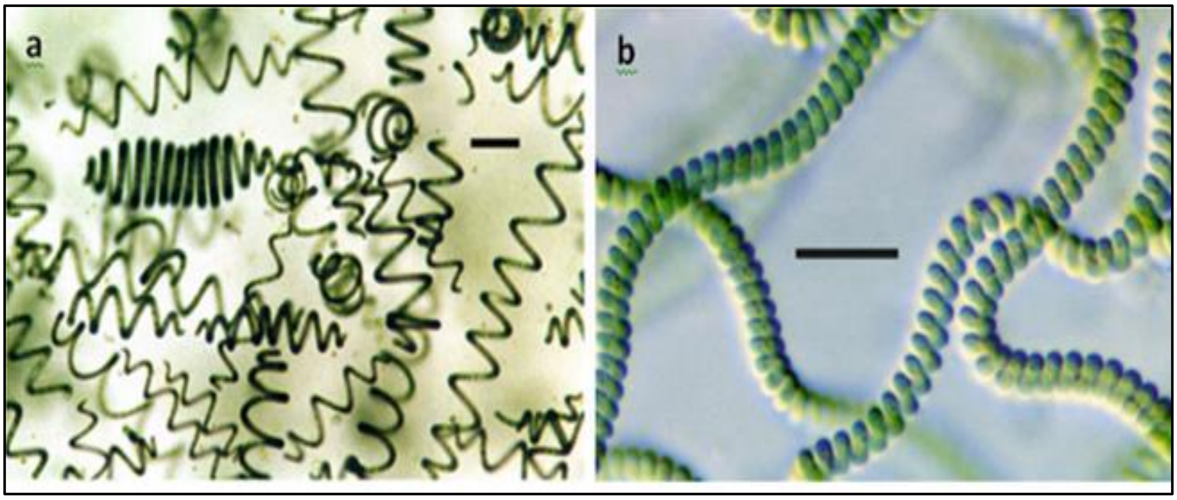

Figure 1. Morphological aspects of (a) *Arthrospira fusiformis*, bar marker = 40 μm; (b) *Spirulina subsalsa,* bar marker = 10 μm (source: Whitton 2012).

Cultivation of *Arthrospira*. In the mass culture of microalgae, nutrition is one of the key factors that control growth and productivity (Faintuch et al 1991). *Arthrospira* growth and the composition of the resulting biomass are influenced by many factors, especially the availability of nutrients, temperature, and light (Cornet et al 1992). In addition, *Arthrospira* requires a relatively high pH value between 9.5 and 9.8 (Belkin & Boussiba 1991). The growth of phytoplankton depends not only on the availability of essential macronutrients (nitrogen, carbon, phosphorus, silicon) and major ions (Na+, 7 K^+, Mg2+, Ca^{2+}, Cl-, and SO_4^{2-}), but also on a number of metal micronutrients (Fe, Mn, Zn, Co, Cu, and Mo) as well as selenium. The main macronutrients and ions are soluble and non-toxic (except ammonium) and, if available in large quantities such as HCO_3- , Na^+ , Mg^{2+}, Ca^{2+}, K^+ , Cl^-, and SO_4^{2-} in seawater and fresh water (or can be added in large quantities, eg. phosphate, nitrate and silica) can support rapid algae growth. On the other hand, many elements such as Cu, Zn, and Co and Fe in the form of ferric oxide are toxic at high concentrations (Andersen & Kawachi 2005).

Nutritional costs of the growth media are considered the second major factor affecting the cost of producing *Arthrospira* biomass after labor (Vonshak 1997). Lower cost *Arthrospira* production is required when considering large-scale cultivation for industrial use. This encourages development research and media modification to obtain media formulas at lower costs. Zarrouk media has become the standard medium for the cultivation of *Arthrospira* for many years (Zarrouk 1966). Research and media development has been carried out using seawater (Faucher et al 1979), industrial waste (Tanticharoen et al 1993), the use of fertilizers and local commercial materials (Madkour et al 2012). However, in general, the composition of Zarrouk media is still used as a basis for comparison. A comparison of Zarrouk's media composition with other media is presented in Table 2.

Apart from nutrition, cultivation methods are a factor that influences productivity and production costs. In general, the methods commonly used in *Arthrospira* cultivation are the circulation pool method and photobioreactor. Circulation ponds are generally applied to areas that receive adequate light intensity and sunlight frequency, so that production costs and investment are more efficient. The maximum specific growth rates of *Arthrospira* from the available literature using several modified media with the circulation pool method are presented in Table 2. Some of the nutritional compositions of *Arthrospira* growth media commonly used are presented in Tables 3 and 4.

Table 2

Maximum specific growth rate of *Arthrospira platensis* from the available literature

Maximum growth rate (μ_{max})	*Culture*	*Temperature (^0C)*	*Medium*	*Reference*
1.80	Batch	35	Zarrouk's	Ogawa & Teruyi (1970)
1.68	Continuous	35	Zarrouk's	Aiba & Ogawa (1977)
0.69	Batch	25	50% Zarrouk's	Tedesco & Duerr (1989)
1.39	Batch	33	50% Zarrouk's	Tedesco & Duerr (1989)
1.53	Batch	37	50% Zarrouk's	Tedesco & Duerr (1989)
1.87	Batch	35	50% Zarrouk's	Olaizola & Duerr (1990)
1.78	Continuous	30	Zarrouk's	Kebede & Ahlgren (1996)
0.77	Batch	30	Schlösser (1982)	Rodrigues et al (2011)
0.242	Batch	30	Zarrouk without $NaHCO_3$	Da Rosa et al (2015)

Table 3

Composition of Zarruk's media

No	*Ingredients*	*Amount (g L^{-1})*
1	$NaHCO_3$	16.8
2	$NaNO_3$	2.5
3	NaCl	1.0
4	K_2SO_4	1.0
5	K_2HPO_4	0.5
6	$MgSO_4.7H_2O$	0.2
7	$FeSO_4.7H_2O$	0.01
8	$CaCL_2.2H_2O$	0.04
9	EDTA	0.08
10	Distilled water	1000 mL

Table 4

Composition of Walne medium

No	*Ingredients*	*Amount (g L^{-1})*
1	NH_4NO_3	100
2	NaH_2PO_4	20
3	H_3BO_3	33.6
4	$MnCl_2$	0.36
5	$FeCl_3$	1.3
6	EDTA	45
7	Trace elements	1 mL for 1 L
8	Vitamin B12	1 µL
	Trace element composition	
1	$ZnCl_2$	2.1
2	$CoCl_2$	2
3	$(NH_4)6Mo_7O_{24}$	6
4	$CuSO_4$	0.9
5	NH_4	2

Environmental criteria for *Arthrospira* sp. Laboratory experiments under autotrophic conditions showed that light saturation in *A. platensis* at 150–200 μmol photons m^{-2} s^{-1} from Zarrouk's medium with both original and modified compositions was widely used for its culture (Belay 1997). Optimal growth temperatures are in the range of 35-38°C, with a minimum temperature of 15°C in the strain reported by Belay (1997). *Arthrospira* sp. is considered an alkalophilic organism, with the optimum pH between 9.5-12 (Hu 2004).

The results of laboratory culture observations conducted by Vonshak & Richmond (1988) showed that the optimum temperature for the growth of *Arthrospira* sp. (*Spirulina*) is in the range of 35-37^{o}C and will be dangerous if it reaches 40^{o}C. The culture outside laboratory, the temperature rise to 39^{o}C for several hours does not cause harmful effects. The minimum temperature that can be tolerated is around 20-18^{o}C. Furthermore, *Arthrospira* sp. (*Spirulina*) can tolerate low night temperatures up to 12^{o}C (Vonshak & Richmond 1988). The results of other studies showed that the optimum temperature for the growth of cyanobacteria is in the range of 15-25^{o}C (Diao 1996) and for nitrogenase activity the temperature should be 21-28^{o}C (Zhong et al 1992). Heat tolerance is limited in dry conditions (Danxiang et al 2004). Among the many protective mechanisms involved in drying tolerance are the presence of high molecular weight extracellular polysaccharides that prevent membrane fusion of phosphytidyl choline, as well as the presence of water stress proteins (Hill et al 1997). Lighting is an important factor in the culture of cyanobacteria *Arthrospira* sp. (*Spirulina*), because it is a photosynthetic organism. Algae growth will be disrupted if light is too intense or too low. Lighting can be done continuously or follow a cycle of light and dark (Andersen & Kawachi 2005).

High alkalinity is decisive in the growth of *Arthrospira* sp. This is indicated by the optimum growth pH, which is between 8.3 to 11 (Vonshak & Richmond 1988). Nitrates are the main nitrogen source of *Arthrospira*, but ammonium salts can be used as long as the NH_4+ concentration is less than 100 mg L^{-1}. Urea can be used without any effect at pH 8.4 as long as the concentration is less than 1.5 g L^{-1}. Nitrogen is a basic element needed in the formation of peptides, proteins, enzymes, chlorophyll, energy transfer (ATP and ADP), genetic material (RNA and DNA), and constituents of other basic elements. Nitrogen has many chemical forms, both organic and inorganic, in the atmosphere, biosphere, hydrosphere, and lithosphere and can be found in gaseous, liquid and solid phases. Nitrogen can be combined with carbon (organic type) and elements other than carbon (inorganic) (Barsanti & Gualteri 2005). Frequent comparisons in phytoplankton growth media are 106C:16N:1P or 6.7C:1N. When the pH of the culture increases to 9 or more, it can indicate that carbon is limiting growth. These species can use bicarbonate to grow, while some other species are more dependent on CO_2 in decreasing growth rates (Andersen & Kawachi 2005). Ethylenediaminetetraacetic acid (EDTA) functions as a metal chelator/buffer (micronutrient element), widely used in freshwater and marine algae culture. The use of EDTA serves to support the growth of algae. In fresh water media, EDTA buffer is more effective because of the lower calcium content, so that the competition between calcium and other metals is lower (Andersen & Kawachi 2005).

Bio-Chemical Content of *Arthrospira*. *Arthrospira* is an organic food ingredient that contains a high protein content, fatty acids and antioxidants. The biochemical composition of *Arthrospira* has been analyzed since 1970, showing a high protein concentration, 60-70% of its dry weight, whose nutritional value is related to amino acid quality. *Arthrospira* contains essential amino acids, including leucine, isoleucine and valine. It also contains relatively high levels of provitamin A, vitamin B12 and β-carotene (Koru 2012). A comparison of the protein content of *Arthrospira* and other foods is presented in Table 5.

Belay (1997) further stated that *Arthrospira* has a high protein content, with a balanced amino acid composition, rich in carbohydrates, minerals, vitamins and fats. It has linolenic and γ-linolenic acids, and ω-3 and ω-6 polyunsaturated fatty acids (Koru 2012). The complete content of *Arthrospira* nutritional compounds from commercial *Spirulina* powder is presented in Table 6.

Table 5

Protein content of *Arthrospira* and other foods (Henrikson 1989)

Food	*Protein content (%)*
Spirulina (*Arthrospira*) powder	65
Chicken eggs	47
Brewer's yeast	45
Chicken	24
Skim powder milk	37
Cheese	36
Beef	22
Fish	22

Table 6

Commercial *Arthrospira* (*Spirulina*) powder content (Koru et al 2008)

Composition	*Quantity (per 100 g dry weight)*
General composition	
Moisture	3.5 g
Protein	63.5 g
Fat	9.5 g
Fiber	3.00 g
Ash content	6.7 g
Free Nitrogen Extract	15
Pigments	
Phycocyanin	15.6 g
Carotenoids	456.00 mg
Chlorophyll-a	1.3 g
Vitamins	
Provitamin A	213.00 mg
Thiamine (Vit B2)	1.92 mg
Riboflavin	3.44 mg
Vitamin B6	0.49 mg
Vitamin B12	0.12 mg
Vitamin E	10.40 mg
Niacin	11.30 mg
Folic acid	40 μg
Pantothenic acid	0.94 mg
Inositol	76.00 mg
Minerals	
Phosphorus	916.00 mg
Iron	53.60 mg
Calcium	168 mg
Potassium	1.83 9
Sodium	1.09 g
Magnesium	250 mg

Phycobiliprotein Content and Extraction of *Arthrospira* sp. The content of phycobiliprotein contained in *Arthrospira* is one of the supporting factors in its use as a functional food ingredient. In addition to being useful as an antioxidant, phycobiliproteins can also be used as natural food colorants. Therefore, the phycobiliprotein content and its extraction method are important factors in the process of utilizing *Arthrospira* sp. as a functional food. Phycobiliprotein is a protein-pigment complex contained in cyanobacteria, rhodophyta, cryptomonads and cyanella (Aftari et al 2015). *Arthrospira* sp. (*Spirulina*) is a cyanobacteria containing phycobiliprotein compounds consisting of phycocyanins, allo-phycocyanins, and phycoerythrins (Saleh et al 2011). Phycocyanin is the main phycobiliprotein (Pleonsil & Suwanwong 2013) contained in *Arthrospira* (*Spirulina*). This component is located on the outer surface of the thylakoid membrane with a content that can reach 40-60% of the total dissolved protein in the cell (Bogorad 1975). Other information mentions that 100 g of *Arthrospira* (*Spirulina*) sp. powder have 15.6% phycocyanin (Koru et al 2008). Brilliant blue phycocyanin has fluorescence properties and is a water-soluble protein component (Eriksen 2008), while allophycocyanin is bluish green and phycoerythin is dark red (Sekar & Chandramohan 2008).

According to Harborne (1986), extraction is the process of withdrawing a component of the active substance from the sample using a certain solvent. The nature of the components to be extracted affects the extraction method. Phycobiliproteins can be extracted by different procedures that combine cell wall breakdown and solvent type (Eriksen 2008). A combination of physical and chemical methods is generally developed for cell damage (Kuddus et al 2015). Homogenization and sonication are physical methods that help break down cell walls to release phycobiliproteins (Pan-utai & Iamtham 2019). Homogenization is an efficient method to damage cell walls and release intracellular proteins in aqueous solution, while sonication is a physical extraction method providing more energy to the solution in order to increase cell damage (Viskari & Colyer 2003). Factors that affect the extraction of C-phycocyanin (C-PC) are cellular interferences, solvent type, biomass concentration and extraction time (Abalde et al 1998).

Various methods for C-PC extraction are based on chemical or physical disruption of cells (Aftari et al 2015). Previous reports have shown that the extraction of C-PC from fresh microalgae is generally carried out by freezing and thawing (Da Costa Ores et al 2016). The ultrasonication technique can assist the extraction of phycobiliproteins. The combination of ultrasonication with freezing and thawing resulted in the highest extraction efficiency of allophycocyanin (A-PC) and C-PC from dry *A. platensis* biomass (Tavanandi et al 2018). The purity index is defined as the ratio of the active substance to the total amount of the substance (Moraes & Kalil 2009). Cisneros & Rito-Palomares (2004) stated that there are 2 types of phycocyanin based on purity concentration (PC), namely food grade phycocyanin (PC>0.4 mg mL^{-1}) and analytical phycocyanin (PC>4).

Developments, potentials and challenges of research on *Arthrospira* in Indonesia. The summary of the biochemical research results of *Arthrospira* is presented in Table 7. Table 7 shows that *Arthrospira* isolates used for various studies in Indonesia are limited and the research topics carried out are generally related to bio-chemical content. Other studies in the form of exploration of superior isolates and strains from various regions in Indonesia have not been carried out. Therefore, the exploration of *Arthrospira* isolates and strains is a challenge for the development of the *Arthrospira* products industry in Indonesia.

The coastline and regional resources owned by Indonesia are a great potential for the development of *Arthrospira* products (Nur 2014). This is because the natural resources owned by industrial-scale microalgae production can be realized with lower investment costs when compared to other countries that have limited resources. In addition, the tropical climate supports the *Arthrospira* industry, free of charge. Extensive water resources also become a supporting factor. According to Khotimah (2018), the potential of the microalgae in Indonesia includes an area of 27700 ha and a potential production of 462400 tons per year.

Currently, research on *Arthtrospira* is limited to a laboratory scale. The use of indigenous Indonesian strains for industrial scale has not been carried out to date. The biodiversity of aquatic microorganisms in Indonesia is very rich. This could be an advantage, to obtain *Arthrospira* strains with superior growth and biochemical content. Therefore, the isolation of new *Arthrospira* strains is an interesting topic to study to support the realization of the functional food industry and other food products from *Arthrospira*. In addition, *Arthrospira* cultivation from native Indonesian strains needs special attention in order to reduce production costs and increase productivity.

Table 7

Arthrospira biochemical research development in Indonesia

No	*Reference*	*Types of microalgae and origin of isolates*	*Research focus*
1	Ridlo et al (2015)	*Arthrospira* (*Spirulina* sp) - the origin of isolate unknown	Antioxidants and phycocyanins
2	Rahmawati et al (2017)	*Arthrospira* (*Spirulina plantesis*)- the origin of the isolate is unknown	Pigments and phycocyanin content
3	Notonegoro et al (2018)	*Arthrospira* (*Spirulina plantesis*) - BBPBAP Jepara (Salin)	Total protein
4	Purnamayati et al (2016)	*Arthrospira* (*Spirulina*) - the origin of the isolate is unknown	Phycocyanin
5	Setyaningsih et al (2011)	*Arthrospira* (*Spirulina fusiformis*) - LIPI isolate (fresh water)	Protein, phycocyanin, and chlorophyll
6	Astuti et al (2019)	*Arthrospira* (*Spirulina plantesis*) - BBPBAP Jepara (Salin)	Optimization of phycocyanin extraction
7	Sedjati et al (2012)	*Arthrospira* (*Spirulina* sp). - the origin of the isolates is unknown	Biochemical profile (chlorophyll a carotenoid, phycocyanin, and allophycocyanin

Conclusions. The biochemical composition of *Arthrospira* from Indonesia can make it a promising functional food raw material. The development of research that has been carried out still needs to be improved with various other topics that can support the development of the Arthrospira industry today and in the future. Therefore, the use of Arthrospira as a functional food in Indonesia has the potential to develop on a larger scale. The biggest challenge faced is how to develop Arthrospira isolates and strains and utilize them efficiently with appropriate technology.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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