



High contents of eicosapentaenoic acid and docosahexaenoic acid in the mixotrophic dinoflagellate *Paragymnodinium shiwhaense* and identification of putative omega-3 biosynthetic genes



Se Hyeon Jang^a, Hae Jin Jeong^{a,b,*}, Ji Eun Kwon^a

^a School of Earth and Environmental Sciences, College of Natural Sciences, Seoul National University, Seoul 08826, Republic of Korea

^b Advanced Institutes of Convergence Technology, Suwon, Gyeonggi-do 16229, Republic of Korea

ARTICLE INFO

Keywords:

Fatty acid
Gas chromatography
Lipid
Microalgae
Mixotrophy

ABSTRACT

Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are critical components and beneficial to human health. Some marine protists are known to have high contents of these omega-3 fatty acids, and thus the contents of newly described protists should be explored for their potential utility. The newly described dinoflagellate *Paragymnodinium shiwhaense* is known to grow mixotrophically, but not autotrophically. To examine the fatty acids of *P. shiwhaense*, the composition of the fatty acids and contents of EPA and DHA of *P. shiwhaense* fed on each of three optimal prey species, the dinoflagellate *Amphidinium carterae*, the raphidophyte *Heterosigma akashiwo*, and the cryptophyte *Teleaulax* sp., were investigated. Furthermore, the genes involved in EPA and DHA biosynthetic pathways in *P. shiwhaense* were identified by analyzing the whole transcriptomic sequencing data of this species. *P. shiwhaense* had high contents of EPA (19% of total fatty acids) and DHA (36%) when fed on *A. carterae*. However, the contents of EPA in *P. shiwhaense* fed on *H. akashiwo*, and *Teleaulax* sp. were only 7% and 3%, respectively. In contrast, the contents of DHA in *P. shiwhaense* fed on *H. akashiwo*, and *Teleaulax* sp. were 43% and 31%, respectively. Thus, the DHA contents of *P. shiwhaense* may not be largely affected by prey species, but that the EPA contents are affected. The EPA produced by *P. shiwhaense* may be converted to DHA using $\Delta 4$ -desaturase and $\Delta 5$ -fatty acyl elongase genes, which were identified in this study. Furthermore, $\Delta 5$ and $\Delta 6$ -desaturase and $\Delta 6$ -fatty acyl elongase genes were also identified. To the best of our knowledge, this is the first time that these genes have been reported in this taxonomic group of dinoflagellates.

1. Introduction

Polyunsaturated fatty acids (PUFAs) are essential components of eukaryotes [1]. In particular, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are known as omega-3 fatty acids, are beneficial to human health. These two fatty acids are known to be useful for proper fetal development [2,3]. Furthermore, they may affect diverse cardiovascular functions, weight, and cognitive function related to mild Alzheimer's disease [4,5,6]. However, it is necessary for humans to obtain adequate amounts of some omega-3 fatty acids from certain omega-3-rich sources because these omega-3 fatty acids are not efficiently produced by human bodies [7]. Thus, global consumption of the omega-3 fatty acids obtained from omega-3 rich sources is increasing [7].

Fish oils are rich sources of EPA and DHA, and a limited number of

plant oilseeds are good sources of other PUFAs [8]. Although fish oils are currently known to be the main dietary source of EPA and DHA, alternative sources of omega-3 fatty acids are required due to marine pollution and depletion of wild fish stocks [9]. Some marine protists are known to have high contents of EPA and/or DHA [10,11]. The eustigmatophytes *Nannochloropsis* spp. and the diatoms *Phaeodactylum* spp. and *Thalassiosira* spp. have been revealed to be rich sources of EPA, whereas the thraustochytrids *Thraustochytrium* spp. and *Schizochytrium* spp. and the dinoflagellates *Cryptecodinium* spp. are rich sources of DHA [10–13]. Furthermore, some dinoflagellate species are known to contain significant amounts of DHA [14–16]. In particular, *Cryptecodinium cohnii* is cultivated on a large scale for commercial production of DHA [17,18]. Accordingly, the contents of EPA and DHA in diverse dinoflagellate species, particularly newly described species, should be examined in order to discover dinoflagellates that have high contents of

Abbreviations: ALA, alpha-linolenic acid (C18:3 n-3); DHA, docosahexaenoic acid (C22:6 n-3); EPA, eicosapentaenoic acid (C20:5 n-3); FAME, fatty acid methyl esters; PUFA, polyunsaturated fatty acid; TFA, total fatty acids

* Corresponding author at: School of Earth and Environmental Sciences, College of Natural Sciences, Seoul National University, Seoul 08826, Republic of Korea.

E-mail address: hjeong@snu.ac.kr (H.J. Jeong).

<http://dx.doi.org/10.1016/j.algal.2017.06.020>

Received 22 December 2016; Received in revised form 26 May 2017; Accepted 25 June 2017

2211-9264/ © 2017 Elsevier B.V. All rights reserved.

Table 1

Information on the culture conditions for the algal prey species *Amphidinium carterae* (Ac), *Heterosigma akashiwo* (Ha), and *Teleaulax* sp. (Tel) and the predator *Paragymnodinium shiwhaense* fed on each of these prey species.

Species	TAXA	Strain	Collection	Cultivation	Growth rate (h^{-1})	Ingestion rate ($\text{pg C predator}^{-1} \text{h}^{-1}$)
<i>Amphidinium carterae</i>	Dinoflagellate	ACUSA	USA	f/2 medium		
<i>Heterosigma akashiwo</i>	Raphidophyte	HAKS9905	Kunsan, Korea	f/2 medium		
<i>Teleaulax</i> sp.	Cryptophyte	TSGS0202	Gomso, Korea	f/2 medium		
<i>Paragymnodinium shiwhaense</i>	Dinoflagellate	PSSW0605	Shiwha, Korea	Prey as Ac [34]	0.04	13.75
				Prey as Ha [34]	0.03	15.83
				Prey as Tel [34]	0.03	7.50

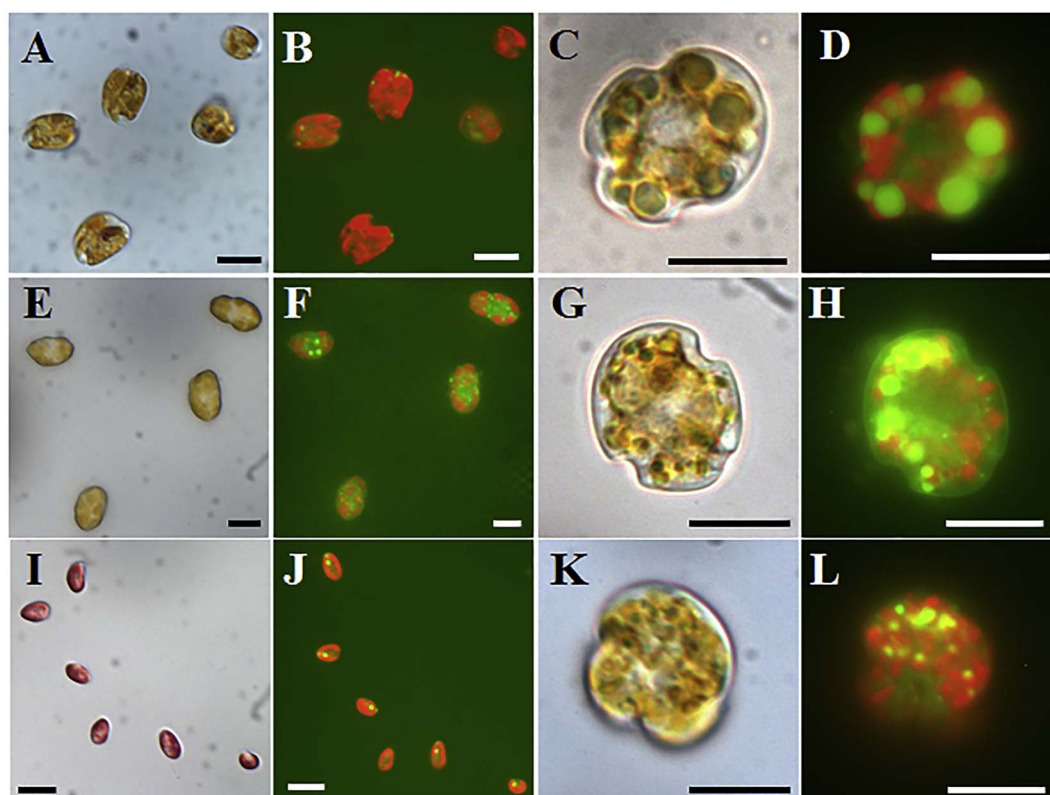


Fig. 1. Microscopic images of cells of *P. shiwhaense* and its optimal prey species containing lipid droplets (yellowish particles). (A and B) *A. carterae* prey. (C and D) *P. shiwhaense* fed on *A. carterae*. (E and F) *H. akashiwo* prey. (G and H) *P. shiwhaense* fed on *H. akashiwo*. (I and J) *Teleaulax* sp. prey. (K and L) *P. shiwhaense* fed on *Teleaulax* sp. (A, C, E, G, I, and K) are phase photomicrographs and (B, D, F, H, J, and L) are photomicrographs taken using epifluorescence. Scale bars = 10 μm . (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

EPA and/or DHA.

Due to their commercial utility, studies on the biosynthetic pathways of the omega-3 fatty acids are increasing [19,20]. Production of PUFAs, including DHA and EPA, involves consecutive serial desaturations and elongations of the fatty acyl chain [21]. EPA (C20:5 n-3) is commonly obtained from alpha-linolenic acid (ALA; C18:3 n-3) via stearidonic acid (SDA; C18:4 n-3) and eicosatetraenoic acid (ETA; C20:4 n-6) with $\Delta 5$ -desaturase, $\Delta 6$ -desaturase, and $\Delta 6$ -elongase, or from linoleic acid (LA; C18:2 n-6) via gamma-linolenic acid (GLA; C18:3 n-6), dihomo-gamma-linolenic acid (DGLA; C20:3 n-6), and arachidonic acid (ARA; C20:4 n-6) with desaturases. Furthermore, EPA can be obtained from ALA via eicosatrienoic acid (ETra; C20:3 n-3) with $\Delta 9$ -elongase and $\Delta 8$ -desaturase in some organisms, such as the euglenophyte *Euglena gracilis*; the haptophytes *Isochrysis galbana* and *Emiliania huxleyi*; and the perkinsea *Perkinsus marinus* [22–25]. In mammals, DHA is generally synthesized from tetracosapentaenoic acid (TPA; C24:5 n-3) via tetracosahexaenoic acid (THA; C24:6 n-3) with $\Delta 6$ -desaturase and β -oxidation [26]. However, in microalgae, DHA is synthesized directly from EPA via docosapentaenoic acid (DPA; C22:5 n-3) with $\Delta 5$ -elongase and $\Delta 4$ -desaturase, [27]. To test whether DHA is

synthesized from EPA in an organism, the presence of $\Delta 5$ -elongase and $\Delta 4$ -desaturase genes should be confirmed. The presence of $\Delta 5$ -elongase and $\Delta 4$ -desaturase genes have been confirmed in several marine microalgae such as *Euglena gracilis*, *Emiliania huxleyi*, the diatom *Thalassiosira pseudonana*, the chlorophyte *Pyramimonas cordata*, and *Thraustochytrium* sp. [25,27–30]. There have been many expectations regarding the genetic characterization and engineering of dinoflagellates for higher production of DHA [16,31]. However, to our knowledge, the presence of related genes has yet to be confirmed in any dinoflagellate. This is possibly because a genome-based approach in dinoflagellates is almost impossible due to their remarkably large genome sizes (1–245 Gb) [32]. Furthermore, to use the genes involved in the elongation and desaturation pathways of PUFAs in metabolic engineering, the presence and characterization of these genes in dinoflagellates should be explored.

The phototrophic dinoflagellate *Paragymnodinium shiwhaense* was established as a new species in a new genus in 2010 [33]. Although this dinoflagellate can grow by feeding on prey (i.e., mixotrophic growth), it is unable to grow exclusively via photosynthesis [34]. The maximum specific growth rate (i.e., mixotrophic growth) of *P. shiwhaense* on *A.*

Download English Version:

<https://daneshyari.com/en/article/5478405>

Download Persian Version:

<https://daneshyari.com/article/5478405>

[Daneshyari.com](https://daneshyari.com)