CHAPTER 3

A Popular Dietary Supplement: Chlorella

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INTRODUCTION

What is a dietary supplement?

The definition of food supplement was first mentioned in the Dietary Supplement Health and Education Act (DSHEA) in 1994. According to the FDA (Food & Drug Administration), food supplements are used for products that are recommended to be taken with nutrition, which is beneficial for the body but not in the definition of medicine, which can be in pills, tablets, capsules, powder, gel or liquid form. Generally, food supplements come in the form of vitamins, minerals, amino acids, or plant extracts. However, in some cases, for example, herbal teas and protein bars, these products are also labeled as food supplements and offered for sale because they are not provided as a meal or as a single member of the diet.

It has been reported in various studies that the use of supplements is higher in people with higher education levels and older people (Chen et al., 2011; Doğan et al., 2020; Çağındı et al., 2022). Reasons for this include suffering from various diseases or using drugs that reduce food absorption in people who cannot eat healthily enough or eat primarily fast food due to intense work tempo. Even if a balanced and high-quality diet is consumed, the absorption of vitamins, minerals, etc., in foods decreases with advancing

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age. As this increases the supply in the market, new products are added to the products marketed as food supplements every day. Although microalgae such as *Chlorella* have been used for years in the Far East for nutrition, drug production, etc., the spread of this microalgae as a food supplement to the world corresponds to recent years.

What is *Chlorella*?

Although algae are similar to plants in their ability to perform photosynthesis, they differ from plants in that they store photosynthesis products differently as starch, contain chlorophyll c and other pigments that are not found in plants, and are unable to form embryos. Algae are taxonomically divided into microalgae and macroalgae. Microalgae is a term used for algae smaller than 2 micrometers in diameter. A single-celled green freshwater algae *Chlorella* that originates in Korea, Taiwan, and Japan has rich in protein, dietary fiber, lipid-soluble vitamins, choline, and essential minerals. *Chlorella* mainly contains approximately 60% protein, and the amino acid quantity is regarded as the perfect protein except for methionine and tyrosine (Lee et al., 2008).

The genus *Chlorella* was discovered in 1890 by Beijerinck, and C. vulgaris is the type species of the genus. The culture of *Chlorella*, one of the green algae, was first made by Otto Warburg in 1919. This single-celled organism was tried to be grown under laboratory conditions, and in 1931, this study brought the German biochemist a Nobel Prize in medicine and physiology. Chlorella's popularity increased after it was heard that it was used on space stations and was known as "space algae" among the people. It is used to produce oxygen and biofuel required for astronauts in spacecraft. *Chlorella* vulgaris-assisted trials continue in hybrid life support unit tests at the International Space Station (Detrell, 2021).

Chlorella is known as a "superfood" because of its impressive nutrient profile. According to the study by Lee et al., 100 g of C. vulgaris powder contains 60.6 g of protein, 13 g of dietary fiber, 12.8 g of fat, 3.7 g of carbohydrates, 2400 mg of chlorophyll, 106 mg of carotene, 22.8 mg of vitamin E, 0.74 mg of vitamin c. and 100g is only 372kcal (Lee et al., 2008). It has a valuable biomass containing amino acids and bioactive peptides, mono and polyunsaturated fatty acids, chlorophyll, xanthophyll and beta carotene, beta1,3 glucan, and exopolysaccharides causes them to be used for various purposes (Figure 1-2). *Chlorella* is a good source of iron. It meets between 6-40% of your daily need. It is also an excellent source of vitamin C—this aids in the absorption of iron. *Chlorella* contains small amounts of magnesium, zinc, copper, potassium, calcium, folic acid, and other B

vitamins. These small green cells provide a rich content of antioxidants. Like other seaweeds, *Chlorella* has a high omega-3 content. Just 3 grams of *Chlorella* provides 100 mg of omega-3s.

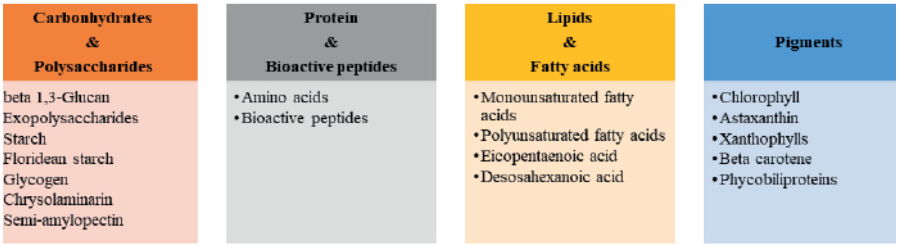

Figure 1. Chlorella Biomass Content

Figure 2. Chlorella application fields

Studies on the biological activity of *Chlorella* are generally related to *C. vulgaris, C. zofingiensis, C. sorokiniana, C. pyrenoidosa* species. There are studies about strengthening the immune system by *Chlorella* (An et al., 2008; Kang et al., 2013). *C. pyrenoidosa*, a single-celled microalga that grows in freshwater, is widely used in Japan and is consumed as a food supplement known to have beneficial effects on immune function. *Chlorella* is rich in antioxidants (Hernayanti & Simanjuntak, 2019; Yu et al., 2019; Wan et al., 2021). It was reported that *Chlorella* extract has an anticancer effect on hepatocellular cancer cell line (HepG2) and Ehrlich ascites carcinoma cell (Adzahar et al., 2021). It has been reported by Zhang et al. that *Chlorella* has an antitumoral effect on human colon cancer cells. In the same articles,

it has been reported that the exopolysaccharides of *Chlorella* have this effect (Zhang et al., 2019a; Zhang et al., 2019b).

Chlorella intake was adequate for blood glucose regulation in rats fed a high-fat diet. *Chlorella* intake may prevent insulin resistance in Wistar rats fed a high-fat diet. Lee & Kim, in their article published in 2009, reported that 10% *Chlorella* intake was effective in blood sugar regulation in Wistar rats fed a high-fat diet. This study has a promising result in preventing insulin resistance (Lee& Kim, 2009).

Chlorella helps regulate total cholesterol and LDL_C levels in Wistar rats and human adults (Lee et al., 2008; Sherafati et al., 2022). It has been reported that *C. vulgaris* decreases total lipid in the liver and serum and increases the amount of lipid excreted in feces in Wistar rats. Therefore, the consumption of *Chlorella* is promising in preventing dyslipidemia (Lee et al., 2008). Sherefati et al., In a systematic review study published in 2022, reported that *C. vulgaris* dietary supplements had beneficial effects on total cholesterol and LDL-C levels. They stated that the most effective dosage should be lower than 1500 mg per day (Sherefati et al., 2022).

Lower the risk of anemia in pregnant women: In the article Nakano et al. in 2010, they gave 6 grams of *Chlorella* dietary supplement to 32 pregnant women from the 12th week to the 18th week. In the control group trial conducted on 70 pregnant women, the anemia rate of pregnant women in the experimental group was found to be significantly lower than those in the control group (Nakano et al., 2010).

C. vulgaris has the potential to be an alternative antidepressant (Soetantyo & Sarto 2019; Dome et al 2019). Dietary supplements can be used to support drug therapy in standard antidepressant treatment. There are limited experimental studies in which Chlorella dietary supplement is used in addition to drug therapy in the antidepressant treatment, and positive results are obtained (Panahi et al., 2015).

Chlorella contains lutein and zeaxanthin, two carotenoids that protect the eye and reduce the risk of cataracts and macular degeneration. It has been mentioned in various studies that *Chlorella* primarily supports the nervous system with its high content of carotenoids and antioxidants. They also have potent anti-inflammatory effects. Due to these properties, it has been reported that it has a protective effect, especially in tissues exposed to intense oxygen and, therefore, oxidative stress. We can add hepatoprotective to this protective effect (Hernayanti & Simanjuntak, 2019; Zafar et al., 2021; Zhang et al., 2019c; Capek et al., 2020).

Antimicrobial effect of *Chlorella*: The first antibacterial studies on *Chlorella* were made in 1944 by Pratt et al. in his work. They reported that *Chlorella* has an antibacterial content, which they call Chlorellin. Najdenski et al. In the antimicrobial activity study, they applied to some microalgae they selected in 2013, reported that the water extract of *Chlorella* sp. was effective only against *Stahylococcus aureus* and *S. pyogenes*, but not on *Pseudomonas aeroginosa* and *Candida albicans*. Mashhadinejad et al., in their study published in 2017, affect the effects of *C. vulgaris* microalgae growing conditions and extraction solvent on antimicrobial activity on *S. aureus, B. subtilis, E. coli, P. aeroginosa*, and *C. albicans* agar well diffusion and minimum inhibitory concentration. Research method. Among the acetone, chloroform, and ethyl acetate solvents, the most effective solvent was chloroform, and the least effective was acetone. Velichkova et al. (2018) investigated the antimicrobial activity of ethanolic extracts of *Spirulina* sp., *Chlorella* vulgaris, and *Lemna minuta* by agar well diffusion method. *S. aureus* ATCC 25923, *E. coli* ATCC 25922, *P. aeruginosa* ATCC 27853), *Bacillus cereus*, *Salmonella typhimurium*, *C. albicans*, Malassezia pachydermatis were used as a pathogen. they were reported to be effective. In the study conducted by Dineshkumar et al. in 2017, *K. pneumoniae*, *P. mirabilis*, *V. cholerae*, *S. typhi, E. coli, S. aureus, B. subtilis, Enterococcus* sp., *Clostridium botulini*, *Nocardia* sp. They tried the antimicrobial effect of ethanolic, methanolic chloroform, and diethylether *Chlorella* extracts on ethanolic extracts by disc diffusion method and found low antimicrobial activity (Syed et al., 2015; Pradhan et al., 2021).

In which forms is Chlorella used as a dietary supplement?

Chlorella has supplements in liquid, tablet, and powder form. Its nutritional value can be increased when the powder form is added to salads, cheese, sauces, smoothies or other beverages.

Diprat et al., in their study in 2020, *C. sorokiniana* was used to make gluten-free-beta carotene-rich bread. Bread with 2.5% microalgae had an acceptance rate of over 70% (Diprat et al., 2020). *Chlorella* has also been used by adding organic energy bars, noodles, and yogurt (Raja et al. 2018). *Chlorella* is also used in the famous Japanese wasabi.

Points to consider about *Chlorella*

It is vital to consult a physician, pharmacist, or other healthcare professional before starting to use a food supplement. A product that is "natural" may also not be "safe." Because an allergic situation may develop against the nutritional supplement that is planned to be taken, or it may interact with the drug or other food supplements being used. For this reason, it is an

essential point at which age, condition, etc., to use the food supplement. It should not be ignored that vitamin and mineral supplements are made into packaged products today. When nutritional supplements, multivitamins, and a diet rich in vitamins and minerals come together, the intake of a mineral such as iron may exceed the recommended dose.

Like plants, the chemical composition of algae is affected by the habitat in which it grows. In recent years it has been reported that *C. vulgaris* can absorb heavy metals, and it has been widely used in wastewater treatment and advanced biological treatment systems (Manzoor et al., 2019; Blosi et al., 2022). In this context, if *Chlorella* is to be used as a food or nutritional supplement, it is very important to provide a product with clean ingredients.

Another point to be considered is to control the purity, quality, and potency of the nutritional supplement. The FDA in the United States and the Ministry of Agriculture and Forestry in the Republic of Turkey are responsible for the implementation of laws and regulations governing dietary supplements. The current list of approved supplements or restricted substances in Turkey can be accessed from the food safety information system on the official website of the Ministry of Agriculture and Forestry (https://ggbs.tarim.gov.tr/).

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