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Research Article

The Use of Microalgae-Based Functional Foods in Family Medicine

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Abstract – Microalgae, including genera such as *Spirulina* sp., *Chlorella* sp., and *Haematococcus* sp., are gaining prominence as sources of functional food ingredients due to their rich profiles of bioactive compounds. This paper systematically analyses microalgae-based functional foods' nutritional and therapeutic potential and evaluates their relevance in preventive and integrative family medicine. Through a structured literature review using PRISMA guidelines, 67 peer-reviewed articles were analyzed to assess clinical efficacy, safety, regulatory frameworks, and applicability in primary care. The evidence suggests that microalgae supplementation can enhance metabolic health, modulate immune function, and reduce oxidative stress. Despite regulatory advancements, challenges persist regarding dosage standardization and clinical integration. The study concludes that microalgae hold substantial promise as dietary adjuncts in family medicine, warranting further clinical validation.

Keywords – Microalgae, Functional Foods, Family Medicine, Preventive Care, Spirulina, Chlorella, Nutraceuticals.

I. INTRODUCTION

Algae play a critical role in addressing environmental challenges and achieving sustainable development goals. Their potential for atmospheric generation has been highlighted in Mars terraforming studies, while plasma-enhanced microalgal cultivation presents a sustainable method for biofuel and biomass production. Furthermore, algae demonstrate efficiency in removing hazardous dyes from wastewater and offer innovative, eco-friendly solutions in green building technologies. Collectively, these applications underline algae's biotechnological promise, especially when evaluating the environmental impacts of functional foods, emphasizing their significance for a sustainable future [1-6]. Chronic non-communicable diseases (NCDs), including cardiovascular disorders, type 2 diabetes mellitus, obesity, and certain cancers, remain among the leading causes of morbidity and mortality worldwide [7]. These conditions impose a substantial economic burden on healthcare systems and significantly diminish quality of life and life expectancy [8]. Within the framework of family medicine—an essential discipline that emphasizes holistic, continuous, and preventive care—the need for practical, sustainable strategies to mitigate the long-term impact of NCDs is becoming increasingly urgent [9]. One promising avenue in this regard is functional foods, which offer health benefits beyond their essential nutritional value, mainly by reducing disease risk or enhancing physiological functions [10]. Among the vast array of functional food candidates, microalgae-based products have garnered growing scientific and clinical interest due to their rich profile of bioactive compounds [11]. These unicellular photosynthetic organisms are a natural source of high-quality proteins, essential amino acids, omega-3 and omega-6 polyunsaturated fatty acids

(PUFAs), vitamins (especially B12 and E), minerals, polysaccharides, pigments (such as phycocyanin, astaxanthin, and chlorophyll), and potent antioxidants [12]. Species such as *Spirulina platensis*, *Chlorella vulgaris*, *Haematococcus pluvialis*, and *Dunaliella salina* (Fig.1) have already been incorporated into nutraceuticals, fortified food products, and dietary supplements, owing to their demonstrated health-promoting properties [13]. Given the increasing integration of lifestyle medicine into primary care settings, microalgae-derived functional foods present a compelling adjunct to conventional nutritional interventions [14]. These compounds have shown promising effects in modulating immune responses, improving lipid profiles, reducing systemic inflammation, and regulating glycemic control—outcomes directly relevant to preventing and managing NCDs [15]. This study seeks to synthesize the current state of scientific evidence regarding the nutritional and therapeutic potential of microalgae-based functional foods, focusing on their applicability in preventive, integrative, and patient-centered models of family medicine. Furthermore, it explores the clinical relevance, regulatory frameworks, and future research needs to facilitate their broader implementation in primary healthcare systems.

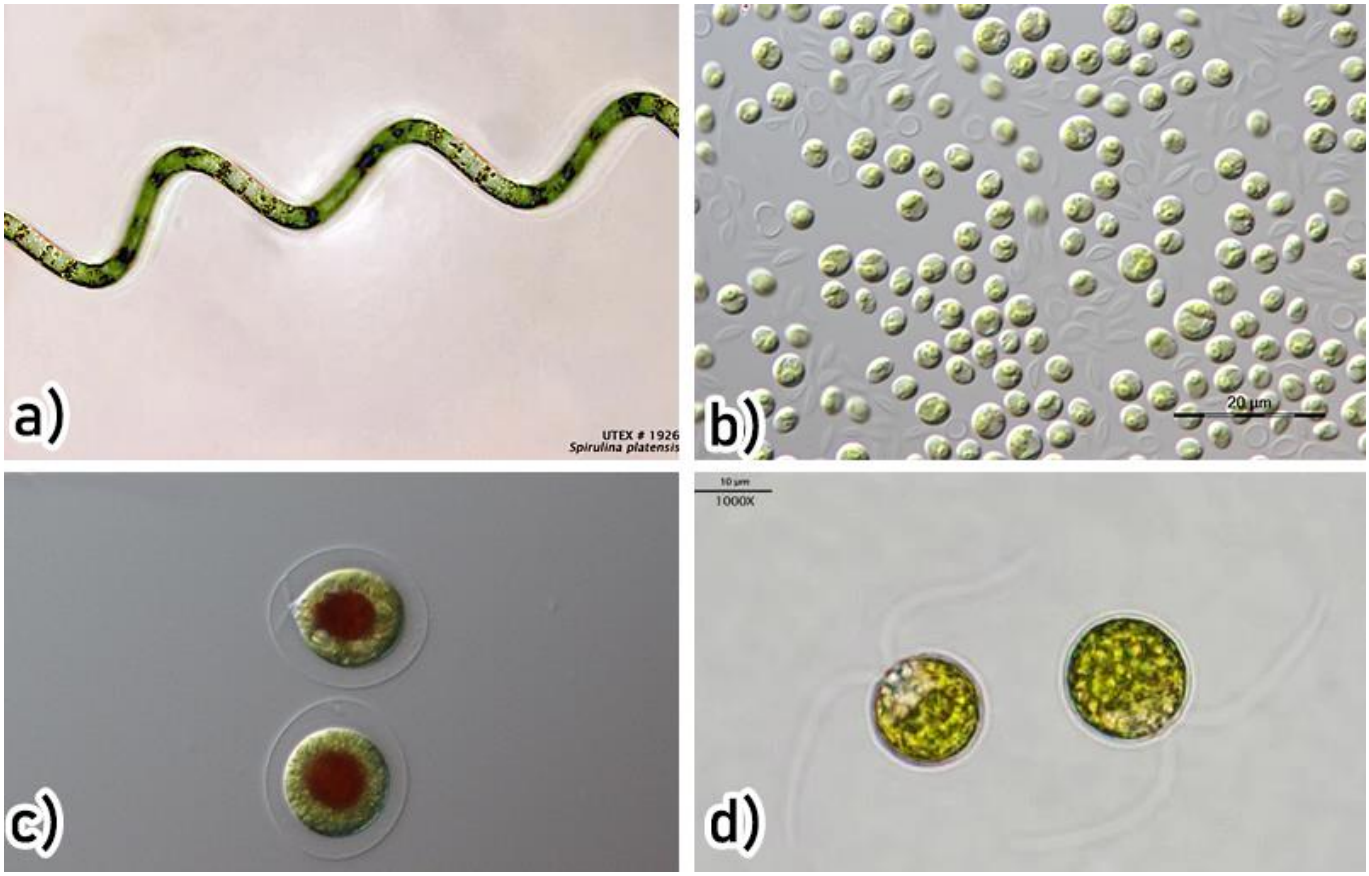

Fig. 1. a) *Spirulina platensis*, b) *Chlorella vulgaris*, c) *Haematococcus pluvialis*, and d) *Dunaliella salina* [10,11]

II. MATERIALS AND METHOD

This study employed a systematic literature analysis conducted by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological transparency and rigor [18]. The literature search was performed using three major scientific databases: PubMed, Scopus, and ScienceDirect, covering January 2014 to December 2024. The search strategy was designed to capture a broad scope of relevant studies using combinations of keywords such as “microalgae AND functional foods,” “*Spirulina* AND health benefits,” “*Chlorella* AND clinical trial,” “microalgae AND family medicine,” and “algal nutraceuticals.” Articles were included if peer-reviewed, published in English, and focused on clinical trials, systematic reviews, or meta-analyses involving human subjects.

Studies must be relevant to public health, preventive medicine, or primary care applications. Exclusion criteria included non-English publications, research conducted solely on animal models or in vitro systems without human data, and non-peer-reviewed works such as editorials, commentaries, or conference abstracts. Following duplicate removal, titles and abstracts were screened, and eligible articles underwent full-text review. Data extraction focused on microalgae species studied, type and dosage of intervention, characteristics of the study population, measured health outcomes, and the relevance of findings to family medicine. Due to the heterogeneity of study designs and outcome variables, a narrative synthesis approach was applied to organize and interpret the data thematically across nutritional, therapeutic, and clinical dimensions.

III. RESULTS AND DISCUSSION

Microalgae contain a wide array of bioactive components, including essential amino acids, omega-3 fatty acids (EPA and DHA), minerals (iron, calcium, magnesium), vitamins (especially B12 and E), and pigments like phycocyanin and astaxanthin (Table 1) [19]. These nutrients support cardiovascular health, immune modulation, anti-inflammatory effects, and metabolic regulation[20].

Table 1. Nutritional Composition of Selected Microalgae Species

Species	Protein (%)	Lipids (%)	Notable Compounds	References
Spirulina platensis	60–70	6–8	Phycocyanin, GLA	[21]
Chlorella vulgaris	50–60	10–20	Lutein, Chlorophyll	[22]
Haematococcus pluvialis	20–25	20–25	Astaxanthin	[23]
Nannochloropsis oculata	30–35	30–40	EPA, Zeaxanthin	[24]

Family medicine emphasizes early intervention, lifestyle modification, and nutritional therapy. Microalgae-based foods can support these pillars by enhancing nutritional status and mitigating risk factors for chronic illness [25]. Their antioxidant and anti-inflammatory properties are ideal for preventive interventions in at-risk populations.

Numerous clinical trials support the efficacy of microalgae in managing metabolic and inflammatory conditions. Studies demonstrated reductions in LDL cholesterol and systolic blood pressure after 12 weeks of *Spirulina* intake [26]. Reported significant improvements in insulin sensitivity and glycemic control in patients with type 2 diabetes following *Chlorella* supplementation [27]. Astaxanthin from *Haematococcus* showed potent antioxidant activity and skin health benefits [28]. These findings illustrate that microalgae-derived compounds are bioavailable and clinically relevant for common health issues addressed in family medicine.

In the United States, the Food and Drug Administration (FDA) has designated *Spirulina* and *Chlorella* as generally recognized *as safe (GRAS*) [29]. The European Food Safety Authority (EFSA) has similarly authorized their use as food supplements [30]. However, practical implementation in clinical settings remains limited due to variability in product quality, lack of standardized dosing, and insufficient clinician training. Collaborative efforts are needed to establish clinical guidelines and integrate microalgae-based nutrition into routine primary care.

IV. CONCLUSION

Microalgae-based functional foods represent a highly promising and environmentally sustainable avenue for enhancing preventive and integrative healthcare strategies within family medicine. Their vibrant nutritional profiles—comprising high-quality proteins, essential amino acids, omega-3 and omega-6 polyunsaturated fatty acids, vitamins, minerals, and potent antioxidants—equip them with the capacity to address a broad spectrum of chronic non-communicable diseases, including metabolic syndrome, cardiovascular disorders, type 2 diabetes, and inflammatory conditions. In this context, microalgae can serve as nutritional supplements and therapeutic adjuncts in patient-centered care models that prioritize disease prevention, lifestyle modification, and long-term wellness. The growing body of preclinical and clinical evidence underscores the immunomodulatory, lipid-lowering, antihypertensive, antioxidant, and anti-inflammatory effects of microalgae-derived compounds, particularly those found in species such as *Spirulina platensis*, *Chlorella vulgaris*, and *Haematococcus pluvialis*. These effects align closely with the preventive focus of family medicine, which emphasizes reducing the burden of chronic disease through holistic and cost-effective interventions. Additionally, the sustainable cultivation of microalgae, requiring minimal land, freshwater, and chemical inputs, further enhances their suitability as future-proof nutritional solutions in global healthcare systems increasingly concerned with environmental impact and food security. Although regulatory agencies such as the U.S. Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA) have approved for several microalgae species for human consumption, their integration into mainstream clinical practice remains limited. Barriers include a lack of standardized dosing guidelines, insufficient clinician awareness, product quality and formulation variability, and a shortage of robust, large-scale clinical trials assessing long-term safety and efficacy. To bridge this gap, future research should prioritize multicenter, randomized controlled trials to determine optimal dosages, evaluate therapeutic outcomes across diverse patient populations, and assess potential interactions with conventional medications. Additionally, health economic evaluations are needed to ascertain the cost-effectiveness of microalgae-based interventions compared to standard care. Equally important is developing comprehensive clinical guidelines and continuing medical education programs to equip primary care providers with the knowledge to safely and effectively recommend these functional foods. With a multidisciplinary, evidence-driven approach, microalgae hold considerable potential to become a cornerstone in the evolution of integrative and preventive family medicine.

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