International Journal of Life Science and Agriculture Research

ISSN (Print): 2833-2091, ISSN (Online): 2833-2105

Volume 03 Issue 06 June 2024

DOI: https://doi.org/10.55677/ijlsar/V03I6Y2024-10

Impact Factor: 6.774 , Page No : 503-506

Protein from Plants and Algae: Potential Trends of Replacing Animal Protein for Public Health

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ABSTRACT: Meat is considered as a significant source of high-quality protein along with other nutritional benefits and sensory properties. However, meat production and consumption is associated with human health concerns, including increased risk of zoonotic diseases, chronic diseases, and air pollution-related health problems. In recent years, there has been a notable increase in the market value of alternative proteins. There is a shift in dietary preferences fromomnivorousto vegetarian or flexitarian diets, and eventuallyto plant-based and algae-based diets. Innovative technologies have been used to produce new products aimed at replacingmeat proteins. These include plant-based options such as tofu, tempeh, seitan, textured soy protein; and alternatives derived from algae such as raw ground pork meat, reduced nitrite turkey meat sausages, and pork meat batter formulations.

Published Online: June 21, 2024

KEYWORDS: animal protein, protein from algae, protein from plants, public health

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1. INTRODUCTION

Historically, animal sources have long served as the primaryprotein provider inhuman diets. Across different regions, the animals used for food encompass a wide array, includingedible insects, amphibians and/or aquatic animals andvertebrates. The choice of animal meat is based on religious beliefs, meat safety and quality, and consumer preferences [1].

Today, consumers increasingly prefer to purchase plant-based products because of the effectiveness and environmental friendliness of plant-based proteins - these are the most important reasons driving the global demand for plant-based proteins. Plant-based proteins are already consumed by vegetarians, although allergies such as lactose intolerance limit protein consumption. Plant-based proteins are becoming popular as milk protein substitutes due to their uniqueness and high nutritional value. Most of the products currently on the market as alternative proteins include single-cell proteins such as algae, yeast; plant-based proteins from vegetables, lentils, and seeds; lab-grown meat; mycoproteins, an analogue of proteins such as meat, eggs, milk, milk, and fish; beverages from plants and insects [2]. Various technologies have been used to produce fibrous products from alternative protein sources to simulate texture; molecular strategy to create a meat-like flavor and use natural colors to give a meat-like appearance. In addition, modern technologies are also used to mimic the mouth feel, taste and function of milk, dairy, and eggs.

The global plant-based protein market is expected to grow at a CAGR of 7.5% from 2019 to 2028. It is expected to reach over USD 18.7 billion in 2028. Demand for plant-based protein supplements for sports nutrition is expected to increase due to increased health disorders due to busy schedules and the nature of work, as well as growing consumer awareness of the link between healthy diet and exercise. The United States will be the largest market in North America. Domestic market expansion is driven by a strong presence of significant plant-based protein supplement manufacturers, increased concerns about weight management, and an increasing focus on on weight maintenance. Maintain a balanced, vegan and nutritious diet. Several types of plant-based proteins include isolate, concentrate, and structure. Plants are used to make plant-based proteins, including soybean, Wheat, green bean…Some products from the plants include food, meat, poultry, seafood, bakery products, Meat alternative, milk and milk substitutes, cereals and snacks, drinks…[3].

With the rise of plant-based meat alternatives, the demand for sustainable and nutritious protein sources is increasing. Algae is a rich source of protein, and early studies suggest it could be a good ingredient in the development of protein meat substitutes [4].

The paper explores current information related to “Protein from plants and algae: Potential trends of replacing animal protein for public health”.

2. CHARACTERISTICS OF ALTERNATIVE PROTEINS

Food production is one of the major concerns worldwide because the demand for food in the following decades. In this regard, animal and vegetable protein sources must be suitable with consumer requirements. Protein from animals, milk, and meat, has been most consumed protein source. However, they are facing some related questions sustainability issues as well as negative impacts on human health. Plant-based proteins are available attract the attention of a segment of the population interested in low-fat and vegan diets, with heightened interest in sustainable and renewable alternatives to animal-based proteins. In this sense, this growing demand requires more than just consideration of sustainable production protein production process without compromising nutritional and safety factors. Soybean, legumes, and oilseeds are the primary targets in the search for plant protein sources. However, new sources such as algal protein, a non-animal protein have been considered as sources relevant replacement. Algae have high growth rates, high photosynthetic efficiency and consume water and they do not need soil to grow [4].

Most alternative proteins are typically designed to mimic the desired physicochemical, functional, nutritional, and sensory properties of foods of animal origin. To evaluate the quality of these products, nutritional, quality, stability and sensory properties are considered. Plant-based alternative, often lack key nutrients such as vitamin B_{12}, vitamin D, iron, calcium, long chain ω-3 fatty acids [5]. Lower protein content, higher carbohydrate and sugar intake, and inadequate saturated fat content can contribute to dietary imbalance, potentially leading to chronic diseases. The challenge of nutrient bioavailability in plant-based alternatives highlights the need for specific nutritional guidance during production [6]. Soybeans are complete protein; however, it poses challenges due to concerns about processing, allergenic effects, and the presence of isoflavones, a type of plant estrogen (phytoestrogen) that exerts weaker estrogenic or antiestrogenic activity [7]. Hemp seeds have emerged as an alternative to high-quality proteins, including those containing sulfur (methionine and cysteine) with benefits such as antioxidant, iron-chelating, blood-lowering properties [8].

Alternative algae, including seaweed and microalgae, are rich in essential amino acids, proteins, vitamins, minerals, fiber and bioactive compounds. Although they show higher protein yield per unit than land plants, their limited digestibility due to polysaccharides or tannin derivatives poses many challenges. Combining algae with other plant-based alternatives has the potential to enhance protein quality, providing a vegan option for consumers who reject insect alternatives [4].

3. PLANTS AND ALGAE AS AN INGREDIENT IN PROTEIN MEAT ALTERNATIVES

Meat is considered a significant source of high-quality protein along with other nutritional benefits and sensory properties. However, meat production and consumption are associated with human health problems such as increased risk of zoonotic diseases, chronic diseases, and air pollution-related health problems. Plant protein can replace meat to create carbon-efficient meat analogues products with nutritional value and texture comparable to meat. Food scientists are currently researching alternative plant protein ingredients including beans for meat analogues processing because of their high nutritional content, including essential amino acids, vitamins, minerals, fiber as well as calories short. Meat analogues varieties such as emulsified sausages, burgers, patties, and steak-like meats, prepared using extrusion technology, cell cutting, and frozen structures are available on the market. However, scientists are still studying the bioavailability and consumer acceptance of MA despite being high in fiber and low in cholesterol [9].

Many plant-based meat substitutes are available on the market. Tofu, tempeh, seitan, and textured soy protein are the most popular plant-based meats available on the market. Meat consumers from Western countries are more likely to switch to similar plant-based meats when the products resemble meat in terms of texture and organoleptic qualities such as appearance, color, aroma, and tenderness succulent and can therefore be incorporated into foods that meet consumer expectations. Targeting this market segment, a growing number of food industries have introduced plant-based meat analogues that simulate meat. The focus is on chopped products, including patties and burgers, muscle-based products such as chicken and steak, and emulsified products such as sausages. Currently in Thailand, many plant-based meat substitutes are also available as plant-based ground beef, choplets, vegetable skallops, linkets, ground veggie meatless mix, vegetarian sausage, shrimp balls, jumbo balls, fish balls, crab balls, mushroom stuffed vegetable balls, black pepper balls, rugby ball with seaweed, shittake dumpling balls, seaweed balls, meat balls, fried pork balls, fish slices, plant-based crab meat rolls and plant-based original style fried chicken [10].

Algae are a source of technical and bioactive compounds including hydrocolloids, pigments, vitamins, minerals, fatty acids, antioxidants, proteins, and bioactive peptides, among others. In the protein conversion process from animal protein to plant protein, both microalgae and macroalgae are widely recognized as nutritious and sustainable options due to their high protein content (over 50% dry weight) and nutritional value. However, to introduce proteins into food systems, they need to have complete technical functional properties. Notably, the emulsifying ability and stability of proteins extracted from *Chlorella vulgaris* were comparable to those of commercial emulsifiers. However, using algal protein to produce meat analogues using only this protein as a raw material represents a significant challenge for the food industry. In fact, the common approach is to use protein from algae, or whole algae, as an ingredient substitute in meat substitutes by replacing soy protein. The main difficulty for producing meat substitutes based on microalgae lies in the initial stages of research and development of successful techniques for

creating algal biomass structures, the need to remove undesirable odors and colors often caused by algae and lack of improvement in farming processes. to perform efficient scaling [4].

Table 1. The applications of whole seaweed/microalgae and extracts in meat products

Seaweed or microalgae	Meat product	Application	Usage level
Himanthalia elongata, Undaria pinnatifida, and *Porphyra umbilicalis*	Gel-emulsion systems	Salt reduction	2.5% and 5%
Himanthalia elongata	Pork meat batter formulations	Structuring agent	3.4%
Himanthalia elongata, Undaria pinnatifida, and *Porphyra umbilicalis*	Meat emulsion formulations	Antioxidant activity	5.6%
Fucoxanthin purified from *Cystoseira barbata*	Reduced nitrite turkey meat sausages	Antioxidant activity	0.01%, 0.02% and 0.04%
Haematoccocus pluvalis extract rich in astaxanthin	Raw ground pork meat	Antioxidant activity	0.30 or 0.45 g/kg
Spirulina and *Chlorella* proteins	Replacement of soy proteins	Turkey breast formulation	1%
Fucus, Cystoseira, and *Laminaria*	Cutlets, meatballs, quenelles, and griddle sausages	Source of nutrients	2%

Algae as a sustainable and promising protein source for the development of meat substitutes. In algae, the perfect combination provides high protein content, low growth requirements, high photosynthetic efficiency and meets the need for sustainability with a low carbon footprint. However, protein extraction, purification and concentration remain upcoming challenges to produce a consistent, standard product, safe and bioavailable protein composition, especially in the context of multiple environmental and species factors influencing protein content and the presence of toxic or allergenic compounds. Algae protein can be used to develop meat analogues using high humidity extrusion as a texturing technology, especially as a partial replacement of soy protein. Antioxidant activity and bioactive peptides of algae have been incorporated into meat substitute formulations. Although research into the use of algae to develop new meat substitutes is at an early stage, promising results can be expected soon due to the diverse composition of active molecules biological and technological functions [4].

4. POTENTIAL TRENDS OF REPLACING ANIMAL PROTEIN BY PROTEINS FROM PLANTS AND ALGAE FOR PUBLIC HEALTH

Europe and the United States stand as the leading consumers of animal meat, notwithstanding their advocacy for ‘net zero’ strategies aimed at mitigatinggreenhouse gas emissions [11]. Despite such initiatives, global meat production continues to increase due to population growth, sociocultural traditions, and rising incomes. In recent years, plant-based alternative proteins have generated $1.4 billion in sales worldwide. The global market is expected to grow at a compound annual growth rate (CAGR) of 12.4% from 2022, reaching a value ofUSD 36.61 billion by 2029 [12] and surging290 billion USD by 2035 [13]. This surge shows that the market value of alternative proteins is on the rise. There is a notable shift fromomnivorous diets to vegetarian or flexitarian diets, with a gradual movetowards plant-based proteins, while the presence of other alternative proteins may take longer to become widespread. This shift is due to fewer trade barriers, regulatory permissions, and increasing consumer familiarity and understanding ofplant- and algae-based proteins. While plant-based diets are not new, there has been a significant shiftfrom animal proteins towards alternative options, thanks toinnovative technologies enabling production ofnew products such as soy milk, tofu, and noodles base [14].

Furthermore, several factors such as human health benefits, environmental impact and animal welfare are considered drivers of the acceptance and development of plant-based protein alternatives, while the price, sensory properties (texture and taste), nutritional content and availability can still create barriers [15] [16]. The use and application of certain technologies (high pressure processing, homogenization, fermentation) and texturing techniques (extrusion, shearing, spinning and others) has accelerated the integration and accept these products. Then, to enhance the flavor and texture, several new ingredients were combined with the most common ingredients being peas, oats, and green beans.

5. SUMMARY

The market value of alternative proteins is growing, marking a notabletrend towardsshifting from omnivorous diets to vegetarian or flexitarian diets, with a subsequent move towardsplant-based and algae-based diets. The emergence of other alternative proteins may take time because of reducedtrade barriers, regulatory requirements, consumer awareness, and understanding of plant- and algae-based proteins. In addition, several factors includinghuman health benefits, environmental impact, and animal welfare are considered drivers forthe acceptance and development of plant-based protein alternatives. However, challenges related to organoleptic properties (texture and taste), nutritional content and availability may still hinder widespread adoption.

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