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Seaweed as a functional ingredient and emulsifier in dairy processing

Mohamed Rifky[1,*], *Dildora* Abdusalomova[2], *Kasun* Dissanayake[3], *Kurbonalijon* Zokirov[4], *Jalaldeen Mohamed* Harris[1], *Mohamed* Jesfar[5], *Faxriyor* Esonboyev[2], and *Murodjon* Samadiy[3]

[1]Eastern University, Sri Lanka, 30350, Chenkalady, Sri Lanka
[2]Tashkent Chemical Technological Institute, 100000, Tashkent, Uzbekistan
[3]Karshi Engineering-Economics Institute, 180100, Qarshi, Uzbekistan
[4]Tashkent State Agrarian University, 100140, Tashkent, Uzbekistan
[5]Sri Lanka Institute of Advanced Technological Education, 32000, Ampara, Sri Lanka

Abstract. In response to customer demand for a balanced and healthful diet, there is a growing trend in manufacturing innovative dairy products enhanced with plant ingredients with particular pharmacological qualities. Yoghurt is a dairy product that is becoming increasingly popular among consumers since it is a great way to absorb functional food elements like probiotics, prebiotics, and antioxidants. It's critical to increase public awareness of the health hazards associated with yoghurt use in addition to adding affordable, nutrient-dense functional additives to Yoghurt. Due to their high nutritional content and potential health benefits, algae have long been utilized as a food source. However, rising interest is in using them as enrichment components in manufacturing new foods. Consequently, this paper draws attention to the potential of Seaweed in manufacturing yoghurt, as shown in current scientific literature. However, more research needs to be done on adding seaweed components to Yoghurt, which is considered safe for human ingestion and has undergone clinical testing. We hope this study will raise awareness about the need for more research to address the growing demand for Yoghurt.

1 Introduction

Because of their health advantages, functional foods have emerged among the most critical sectors of the modern food industry [1]. Functional foods are essential, naturally occurring, processed foods that satisfy the body's nutritional requirements. They can improve the host's health by reducing disease and enhancing the immune system's ability to fight infections from pathogens and diseases that alter the host's functioning [2].

The food industry and the general public have embraced Yoghurt and other fermented dairy products as superior vehicles for food's functional components, including probiotics, prebiotics, and antioxidants such as polyphenols and carotenoids [3-6].

* Corresponding author: rifkyalm@esn.ac.lk

Yoghurt has been regularly altered with functional additives to meet market demands and customer expectations while producing improved nutritional benefits, shelf life, and acceptability [7]. More than 3000 types of functional Yoghurt are available in industrialized nations, and their sales volume was found to be second to the sales volume of fresh milk [8]. Yoghurt consumption is mainly recognized for its many health advantages, including its ability to enhance digestion, prevent digestive issues, increase immunity, increase lactose tolerance in individuals who are lactose intolerant, and provide a satiating diet that is beneficial for managing weight [9,10].

Uncontrolled cell migration and proliferation are the primary causes of the terrible illness of cancer, which affects people all over the world. Of all the human cancers kinds, colorectal and lung cancer are more prevalent in men, while breast, cervical, and lung cancer are more common in women. Even though radiation and chemotherapy are used to treat cancer, these therapies have a high risk of adverse effects and a low rate. As a result of the ongoing failure of current cancer therapies to provide effective chemo-preventive drugs, experiments are being conducted in biological resources, such as plants and animals, to control this malignant illness [11].

Seaweeds are marine macroalgae that fall into three different groups based on their colour and chemical composition: Chlorophyta (green algae), Phaeophyta (brown algae), and Rhodophyta (red algae). Seaweeds inhabit subtidal and intertidal zones. Due to their abundance of bioactive compounds, which include proteins, lipids, polysaccharides, minerals, and specific vitamins, seaweeds, such as *Fucus sp., Ascophyllum sp., Ulva sp., Laminaria sp., Porphyra sp., Sargassum sp.,* and *Gracilaria sp.* are regarded as biological resources with a high level of potential as a functional ingredient in the food processing worldwide and used for a variety of value-added food products [12]. Furthermore, some chemicals and pharmaceuticals are extracted from seaweeds and incorporated into products because of the availability of these bioactive compounds and their capacity to generate secondary metabolites that exhibit potential antimicrobial, antiviral, anti-inflammatory, anti-ulcer, and anticancer properties [13].

2 Methods

The composition, nutritional structure, functional properties, and bioactivities of Seaweed and its derivatives were studied using recently published articles and books. The study provides a broad idea about the products and their bioactivities that induced food processors to incorporate them into food products. Figure 1 shows the Seaweed and the products obtained as functional ingredients.

Fig. 1. Seaweed and the Yoghurt produced from Seaweed

3 Results and Discussion

3.1 Chemical composition of the Seaweed

Seaweeds, or macroscopic alga, are nutrient-dense marine organisms [14]. Based on the colour pigments used for photosynthesis, seaweeds are classified as green (Chlorophyta), brown (Phaeophyta), red (Rodophyta), and blue-green algae [15,16]. Underutilized, reasonably priced, and sustainable Seaweed is a rich source of prebiotics such as polysaccharides and polyphenols [17]. The polyphenolic content in red and green seaweeds varies from 1–5%, whereas in brown seaweeds, it may reach up to 20% [18-20].

Polysaccharides are found in seaweeds, 20%–76% (dry weight) as structural and storing components. Seaweeds mostly include polysaccharides called cellulose, starch, hemicellulose, fucoidan, alginic acids, sulfated fucans, alginate, and laminarin, which provide cell wall strength and flexibility. Red seaweeds have the most significant protein content among the three varieties of seaweeds; they make up 30%–40% of their dry weight, compared to 15% for brown seaweeds and 30% for green seaweeds [21]. Seaweeds include a variety of critical amino acids, including glutamic acid, arginine, glycine, and alanine. However, seaweeds have a relatively modest lipid content (1-5% of the dry weight), with essential and unsaturated fatty acids like ω-3 and ω-6 [22].

Various proteins, lipids, carbs, minerals, vitamins, and bioactive substances may be found in *nature in Fucus vesiculosus* and *Ascophyllum nodosum* brown seaweeds [23]. Chlorogenic acid, Caffeic acid, catechins and coumaric acid are among the polyphenolic chemicals previously measured in brown Seaweed [24]. Ulva lactuca is a green seaweed that is very nutritious and is eaten in significant quantities by both people and animals, and it's a water-soluble polysaccharide [25]. Its disaccharide content [26] and essential monomer sugars (uronic acid, xylose, and rhamnose) make up a dry matter percentage of 38 to 54% of the highly charged variety of sulfated polyelectrolytes.

Caulerpa racemosa, or green Seaweed, contains polysaccharides that have the catalytic activity for enzymes such as phospholipase and may be used to develop nutritious diets [27]. The polysaccharide percentage of the brown algal species in the previously published data set was 37.5% for *L. japonica,* 65.7% for *F. vesiculosus,* 69.6% for *A. nodosum,* 57.8% for *Saccharina long cruise,* 35.2% for *U. pinnatifida, and* 67.8% for *Sargassum vulgare* in a dry matter basis [28-31]. Fucoidans and laminarins are the most notable of these, along with alginates, which are the salts derivative of alginic acid [32].

Fucose is included in fucoidan, a sulphated polysaccharide primarily available in the cell matrix of several kinds of brown seaweed varieties. Numerous medicinal benefits have been demonstrated, including anticoagulant, anticancer, antithrombosis, antioxidant, and immune-modulating qualities. As a result, it has been proposed as a possible functional component for creating innovative food items [33]. Moreover, seaweeds are a rich source of compounds that may enhance bacterial diversity and abundance and benefit the health of mammalian stomachs by functioning as prebiotics [34, 35]. When compared to terrestrial plants, seaweeds have a higher percentage of critical fatty acids, such as docosahexaenoic (DHA) and eicosapentaenoic (EPA) [36].

Edible seaweed supplementation is a viable approach to creating Yoghurt that is higher in nutrients and physiologically and nutritionally advantageous components for customers, which will help the dairy sector as a whole [37]. As a result, this study aims to compile information about Seaweed's potential for yoghurt manufacturing from current scientific publications. By creating a new platform for seaweed-based Yoghurt, this collection will aid the growth and development of the dairy business in future, meeting customer demand for unique foods and satiating their desire for a balanced diet.

3.2 Functional Properties of Seaweed

Some research examined seaweed extracts' potential as functional antioxidant components in milk [6]. By measuring the antioxidant ability of the seaweed extracts in milk using 2,2-diphenyl-1-picrylhydrazyl(DPPH), they found that it stayed consistent throughout time. Furthermore, the study carried and demonstrated that the inclusion of seaweed extracts in Yoghurt did not hurt parameters like pH, microbiology, and whey separation, indicating that Yoghurt may have seaweed extracts added to it without negatively impacting its shelf-life [38]. Furthermore, they demonstrated that yoghurts produced with extracts (0.25% and 0.5% (w/w) from *Ascophyllum nodosum* among sensory panellists [38].

Moreover, among the five distinct commercial species of dehydrated edible seaweeds *P. umbilicalis* (nori, laver), *H. elongate* (sea spaghetti), *S. latissima* (sugar kelp), *U. pinnatifida* (wakame) and *U. lactuca* (sea lettuce), Yoghurt incorporated with *S. latissimi* showed the highest odour and flavour quality scores during the test done by the researchers. This indicates that *S. latissimi* is the most suitable seaweed species for supplementing dairy products from a sensory perspective [37]. It's also notable that fucoidan, a substance produced from brown Seaweed, enhanced the nutritional value of the Yoghurt without detracting from its organoleptic properties. Seaweed-enriched Yoghurt was shown to have a 15-day shelf life at 5°C [15].

Additionally, milk supplemented with omega-3 fatty acids is an excellent way to increase the PUFA's bioavailability and absorption [39]. Unsaturated fatty acids are so prone to rancidity and oxidative degradation that enriching meals with ρ-3 PUFA is more complicated. The challenge was overcome in the experiment by adding algae oil emulsion, which the panellists rated as sensory acceptable ('moderate like'), and to optimize consumer lipid nutrition, strawberry yoghurt with 400 mg of ω-3 PUFA or 500 mg ω-3 PUFA per 272 g of Yoghurt were also developed by the researchers [39, 40].

The ω-3 PUFA emulsion somewhat oxidized the yoghurt samples but only slightly impacted sensory evaluations. This shows that milk proteins, particularly casein, have substantial anti-oxidative capabilities, which are likely responsible for the comparatively slow rate of oxidation [41].

3.3 Application of Seaweed in the dairy industry

Furthermore, in an experiment to create a gelatin-free set yoghurt meant for the vegetarian and Muslim communities worried about halal certification, As a textural stabilizer, 81 per cent (w/w) of dietary fibre was obtained from easily accessible local Gracilaria verrucosa red seaweed, which is used to make food-grade seaweed agar. According to the findings, Yoghurt that had been mixed with agar (0.25%) had sensory qualities that were comparable to Yoghurt that included gelatin (0.61%), indicating that G. verrucosa may be a good supply of agar for the regional food sector [42]. Furthermore, Yoghurt prepared using maize as the raw material had the highest total lactic acid bacteria (11.02 log CFU/ml) compared to Yoghurt made from pineapple, pumpkin, banana, or sweet potato.

Fig. 2 Seaweed powder and sample preparations for dairy processing

Yoghurt contains many total lactic acid bacteria because *Eucheuma spinosum* seaweed is a natural stabilizer. Studies have indicated that the amount of total lactic acid bacteria in yoghurt increases with the proportion of *E. spinosum* seaweed added [42]. Furthermore, when 1-2% ulvan type polysaccharide derived from *Ulva lactuca* was added as a prebiotic during the symbiotic type of yoghurt production process, it increased probiotic bacterial growth, activity and the rheological properties improvement of the Yoghurt by increasing its viscosity and firmness and decreasing its syneresis rate [43].

However, a recent study found that the primary advantages of eating food based on The main drawbacks of Seaweed were its taste (89.1%), nutritional content (49.1%), and health benefits (44.6%). Still, its low accessibility (59.5%), high cost (46.5%), and ugly packaging (19.0%) were its main drawbacks. Furthermore, they mentioned that even with ecologically friendly packaging and sourcing, customers wanted further advertising to increase their understanding of Seaweed [44].

3.4 Anticancer activity of Seaweed

The primary cause of cancer genesis is unchecked cell growth and proliferation. Consequently, because seaweeds contain various bioactive chemicals, their anticancer potential against human malignancies has been evaluated to regulate unrestricted cell development and proliferation. Numerous extracts, comprising water and various organic solvents, together with the chemicals extracted from seaweeds such as fucoidans and sulphated polysaccharides, are employed in this context to examine the anticancer properties of seaweeds both in vivo and in vitro. The primary mechanism of anticancer is apoptosis. Apoptosis is a process that takes place in cells, particularly in the nucleus. This is intrinsic (via the mitochondrial route) and extrinsic (through other pathways) genetically determined programmed cell death. Cells experience many changes during the early stages of apoptosis, such as cell shrinkage, chromatin condensation, and plasma membrane [45-47].

3.5 Colloidal functions of Seaweed

There are no studies that discuss how different environmental factors affect the stability of seaweed polysaccharides in emulsion. A recent study [48] addressed only the effects of long-term storage on Seaweed's DSA-modified starch in O/W emulsion. In this work, scientists looked at the stability of an O/W emulsion with a 1% (w/w) emulsifier to assess the commercial application of modified seaweed polysaccharides. Numerous environmental factors, such as ionic strength, pH, extended storage and temperature changes, were all

applied to the emulsion. These results indicate potential commercial applications for modified seaweed polysaccharides [49, 50].

3.6 Recommendations for future research

The following ideas help future studies handle the growing demand for yoghurt consumption. Although consumers are aware of the need to eat a healthy diet, more marketing is required to inform them of the nutritional content and medicinal advantages of seaweeds as well as the impact of including seaweed-based edible items in their regular diet [51]. More scientific data about using seaweeds to enhance dairy products, particularly Yoghurt, must be collected. Consequently, based on current findings, more research in this area will be a prudent course of action to satisfy customer expectations shortly. Repeated large-scale clinical experimental trials are also needed to validate any f in-vitro effects of ingesting innovative seaweed-based yoghurt products, share the results, and apply them in the dairy industry to meet the current trend of novel food production.

4 Conclusion

In conclusion, our unconventionally prepared seaweed powder can be used to produce dairy products because the colloidal behaviours of seaweed solution are directly relevant to the gelatine and carrageenan-like emulsifiers. It can be used to prepare dairy products, showing emulsion ability and bioactivities such as antioxidant, antibacterial activity and anticancer activities. Green algae and Red algae, or rhodophyta, are grouped as phaeophyta. Seaweeds live in the intertidal and subtidal zones. Seaweeds like *Laminaria sp., Fucus sp., Ascophyllum sp., Porphyra sp., Gracilaria sp., Ulva sp., and Sargassum sp*. are considered biological resources with a high level of potential as functional ingredients in food processing worldwide because of their abundance of bioactive compounds, which include proteins, lipids, polysaccharides, minerals, and specific vitamins.

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