Review Article

Seaweeds as Potential Product for Pakistan's Blue Economy: A Review

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Abstract | Seaweeds across the world are a collection of intriguing and varied creatures. Seaweeds, i.e., brown (Phaeophyta), green (Chlorophyta), and red algae (Rhodophyta), are one of the natural resources that have received significant attention in terms of study for their biological properties. Marine organisms rely on Seaweeds as a crucial component of their environment and the food chain. People can use Seaweeds for many purposes, such as food, medicine, cosmetics, and industrial processes. Several types of aromatic and cosmetic Seaweeds used in the cosmetics industry may be found off the coast of Pakistan. Pakistan generated $1.94 million in 2020 as the 57th-highest exporter of Seaweeds, locust beans, and related items. Five-year projections for Pakistan (2016–2020) suggest considerable expansion, with a cumulative $8.36 million in trade volume. This review article uses a descriptive approach to understand Pakistan's potential and the state of its seaweed trade.

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Introduction

Physical and biological systems on Earth are being impacted by global warming and environmental stressors at a rate that exceeds their capacity for natural restoration (Weiskopf *et al*., 2020). Recent Nasa-led research confirms that rising emissions of greenhouse gases, including CO2, N20, CH4, CF3, and CFC, have contributed to climate change, which in turn has led to permafrost melting, acid rain, and decreased lake production (Lee and Wang, 2020). In addition to providing food for humans and essential chemical components, marine plants serve a crucial role in preserving the stability of marine ecosystems. There is much hope that microalgae and Seaweeds may help slow or even reverse climate change (Wood, 2019). When exposed to light, algae absorb carbon dioxide (CO_2), release oxygen (O_2), and make solar biofuel via a process called photosynthesis (Dobrijevic, 2022).

Seaweed, a significant marine bioresource, is now being underused. Each species is unique in terms of color, size, form, and composition, but in general, Seaweeds are divided into three categories: green, red, and brown (Kadam *et al*., 2015). Until recently, most people saw Seaweeds as nothing more than an annoyance-something that sticks to us as we swim and makes the beach smell bad when it rots in the sun.

However, as sushi restaurants proliferate throughout the world, Seaweeds are rapidly expanding their role in the average person's diet (Valeem, 2012). Even though many of us like seaweeds-based dishes like maki, miso soup, and seaweed salads, we tend to be woefully ignorant about Seaweeds' health benefits (Embling and Wilkinson, 2022). The greek word for Seaweeds are phycos, which is where the field of study known as phycology originates (Abbott and Norris, 2005). Chinese pharmacopeias and media attest to the widespread usage of Seaweeds as a treatment for a range of conditions, including goiter, tumors, fever, angioedema (chest infections), and renal problems (Choi *et al*., 2021).

Seaweeds are types of aquatic plants, critical to the health of the marine ecosystem in coastal locations (Babahan *et al*., 2019). Freshwater environments also give an optimal growth advantage to Seaweeds (Hasselstrom *et al*., 2018). These are creatures that resemble plants and stick to rocks or other types of hard surfaces in coastal areas (Zafar *et al*., 2022). There are around 9000 species of Seaweeds, which the researchers classify into one of three categories (Abbot and Norris, 2005). Three primary categories of macroalgae may be distinguished from one another by the presence of a photosynthetic pigment, a storage food product, and components of the cell wall structure.

- Brown Algae (Phaeophyta)
- Green Algae (Chlorophyta)
- Red Algae (Rhodophyta)

The greenest types of Seaweeds are higher up on the beach, where they get the most sunshine and expose to the freshest air (Butcher *et al*., 2020). The green chlorophyll in red Seaweeds hides a characteristic crimson tint along the lower shore and grows in abundance beneath the seawater. Brown Seaweeds grow in the intertidal and subtidal zones of the ocean (Abbot and Norris, 2005). As the depth of the water increases, the color of the Seaweeds' leaves becomes more pronounced (Khan *et al*., 2009). The people use approximately 145 species of Seaweeds for food, 24 as traditional remedies, and nearly 25 in agriculture, including livestock feed and manure (Zemke-white and Ohno, 1999). There are approximately 221 species of Seaweeds that industries widely use for commercial purposes globally (Hasselstrom *et al*., 2018) (Rhodophytes 125, Phaeophytes 64, and Chlorophytes 32). When referring to the several types of marine plants and algae in lakes, rivers, oceans, and other bodies of water, the phrase 'Seaweeds' refers to all (Abbot and Norris, 2005).

There is a significant increase in the quantity of Seaweeds growing on coastal beaches (Khan, 2017). Along the coast of Pakistan, there are several resources of seaweed. Along the coastline that encompasses Manora, Sandspit, Hawkes Bay, Paradise Point, Pacha, Nathiagali, and Cape Monze, one may see crystal clear water and a wide variety of marine life (Rizvi and Shameel, 2008). According to reports, the coastal regions of Pakistan are home to a staggering total of seventy different classes and twenty-seven distinct kinds of Seaweeds (Siddiqui *et al*., 2019). The Seaweeds species in these locations most often include Ulva fascia, Chondria, Sargassum spp., and Valoniopsis pachynema (Siddiqui *et al*., 2019).

Although it has a reputation for being unappealing due to its slimy texture, pungent smell, and questionable provenance, Seaweeds are really one of the oldest human sources of nutrition (O'Connor, 2017). Seaweeds and sea vegetables are at the cutting edge of sustainable cuisine since they are beneficial to humans and have the potential to greatly decrease our carbon footprint (Kreischer and Schuttelaar, 2016; Radolovich *et al*., 2015). These vegetables from the sea must find a prominent position in our kitchens (Mouristsen *et al*., 2013). If done well, it can be quite tasty. Seaweeds, a mainstay in Asian cooking for centuries, is now gaining popularity throughout the world as a "superfood" (O'Connor, 2017; Kreischer and Schuttelaar, 2016; O'Connor, 2017; Kreischer and Schuttelaar, 2016) because of its reputation as a sustainable and very nutritious natural product. There are above 10,000 types of Seaweeds (O'Connor, 2017) that thrive on our planet one of the last major renewable resources and a culinary treasure waiting to be discovered. Although many people now associate Seaweeds with the poor, several types of Seaweeds were considered royal fare in ancient times. Some Seaweeds are twice as healthy as kale and taste exactly like bacon; they are true superfoods and should be treasured as such. Seaweeds may be used to help alleviate the world's ever-increasing need for a healthy and environmentally friendly food supply (Tiwari and Troy, 2015).

Seaweeds (algae, not plants) have been used by various cultures (such as Pakistan and India) for a wide variety of reasons (Mouritsen *et al*., 2013), and their uses include food and fodder, salt production, medicine, and cosmetics, fertilizer, building materials, and a variety of industrial applications (Anil *et al*., 2017; Mouritsen *et al*., 2013). There are countless health benefits of Seaweeds, including their high content of minerals, trace elements, proteins, vitamins, dietary fiber, and valuable polyunsaturated fatty acids, and offer advice on how to use Seaweeds in cooking (Mouritsen *et al*., 2013). Seaweeds are great for combating hunger and obesity since they can be produced in the ocean in large numbers using extremely sustainable methods.

The hidden potential of Seaweeds must be explored as a sustainable food and feed for humans and animals, and the importance of seaweed farming (Tiwari and Troy, 2015). This book provides various viewpoints on the commercial use of marine and freshwater algae, both wild-harvested and produced. This account talks about the many different microalgae and macroalgae used to make food and feed. It also talks about how Seaweeds could be used as a source of energy and how seasonal and cultivar differences affect Seaweeds in commercial applications. Concerning this, Algae-based polymers are becoming popular, and they might serve as a low-cost resource for various industries. Seaweeds Polymers (also known as polysaccharides) derived from algae have come a long way in recent years, especially for use in biomedical settings, including medication, wound dressings, and tissue engineering (Anil *et al*., 2017). The antithrombotic, anti-inflammatory, anticoagulant, and antiviral effects of algal polymers in addition to their structure and chemical alteration, are phenomenal. Researchers are also looking at algae as microalgae and macroalgae. Microalgae are used to make food and feed, and macroalgae show how Seaweeds could be used as an energy source (Radulovich *et al*., 2015) while carrying commercial exploitation of wild-harvested or cultured algae and marine and freshwater Seaweeds. Ancient civilizations used Seaweeds for various purposes, including as fertilizers, food, animal feed, and source of carbohydrates like agar-agar and carrageenan (Kadam *et al*., 2015). Biofuels, including ethanol, butanol, and biogas, have been the primary focus of recent advances in seaweed biorefining (Kadam *et al*., 2015; Tiwari and Troy, 2015; Anil *et al*., 2017). Iodine, trace minerals, lipids, and vitamins from Seaweeds, are harvested easily (Kadam *et al*., 2015). Evidence of their biological activity has led to their application in a wide variety of human and animal consumables. Possible advantages include decreased risk of hyperlipidemia, thrombosis, malignancy, and obesity. While seaweed has a wide range of potential applications, its variable bioactive content presents substantial problems in product development (Kadam *et al*., 2015). These differences in bioactive chemicals might be attributable to species, harvest time, and harvest location. For instance, the number of carbohydrates in Seaweeds is said to change significantly over the year (Kadam *et al*., 2015; Tiwari and Troy, 2015; Kasanah *et al*., 2015).

Uses for various types of seaweeds

Seaweeds as an important additive in cosmetics: The Pakistani coast is home to a wide range of aromatic and cosmetic Seaweeds used in the cosmetics industry. They may support the development and manufacturing of a variety of products, including but not limited to shampoos, soaps, fragrances, dyes, lotions, and skin cleansers (Rizvi and Veelam, 2012). Compounds found in Seaweeds, such as phenolic compounds, polysaccharides, pigments, sterols, proteins, peptides, and amino acids, exhibit a wide range of bioactivity and can be used as active ingredients in cosmetic products (Jesumani *et al*., 2019). These compounds include phenolic compounds, polysaccharides, pigments, and amino acids (Gomes *et al*., 2012, 2022). These biologically active components in Seaweeds pave the way for their use in the cosmetic sector as an active ingredient. Their ability to protect the skin opens the door for this application. The use of these active compounds derived from Seaweeds is frequent in the cosmetics sector as an antioxidant, an antibacterial brightening agent, an anti-ageing agent, an anti-acne agent, and for moisturizing (Bedoux *et al*., 2014).

Antimicrobial application of seaweeds: It is crucial to investigate the therapeutic potential of Seaweeds, macroalgae, and their preparations. They do a thorough job, covering everything from the nutritional value of seaweed to its potential as a nutraceutical (Shannon and Abu-Ghannam, 2019). As a result of its rising economic worth, several million tons of seaweed are harvested each year in several nations (Farming of Seaweeds, 2015). Conveniently, Seaweeds have qualities and impacts that make it useful in the food sector, including effects on angiogenesis, cancers, diabetes and glucose regulation, oxidative stress, fungi, inflammation, the gastrointestinal tract, and the liver (Penalver *et al*., 2019). Seaweed's role in the fight against microbes is unique as it has anti-microbial characteristics (Perez *et al*., 2016). Seaweeds are also a preservative that increases the cosmetic product's shelf life by preventing the growth of microorganisms, particularly fungi, that are likely to cause the product to spoil (Jesumani *et al*., 2019). Seaweeds have overwhelming properties to kill fungi, which means it can replace synthetic preservatives (Kolanjinathan *et al*., 2014).

Seaweeds and biological processes: Most phenolic compounds have a wide range of biological activities, including anti-diabetic, anti-inflammatory, anti-microbial, antiviral, anti-allergic, anti-diabetic, antioxidant, anti-photoaging, anti-pruritic, hepatoprotective, hypotension, neuroprotective, and anticancer properties (Praparatana *et al*., 2022). Phenolic compounds are frequent in foods such as tea, coffee, cocoa, and fruits and vegetables (Giada, 2012). These diverse bioactivities make Seaweeds candidates for developing products or ingredients for industrial applications such as pharmaceuticals, cosmetics, functional foods, and even bioactive food packaging films to maintain the quality of food products (Anti-allergic Effects of Ethanol Extracts from Brown Seaweeds, 2009). Seaweeds have a wide range of bioactivities, making them a candidate for developing products or ingredients for industrial applications (Jesumani *et al*., 2019).

Seaweeds as a source of fertilizer

In agriculture, using seaweed as organic fertilizer compensates for deficiencies and shortages of plant nutrients such as nitrogen, phosphorus, and potassium, and it also has a significant amount of potential for commercialization (Vafa *et al*., 2022). The use of Seaweeds extracts has beneficial effects on plant growth and development (Ali *et al*., 2021). These extracts promote seed germination, root development, higher nutrient absorption, and excellent frost resistance in unfavorable environments (Tuan *et al*., 2019). Not only can Seaweeds promote plant development, but they also give plants resistance against the biotic and abiotic stresses that they experience (Aina *et al*., 2022). Seaweeds provide an organic alternative to fertilizer, which may help enhance agricultural productivity and fulfill the need for food worldwide (Raghunandan *et al*., 2019).

Economic seaweeds found off Pakistan coast

The phaeophyte Sargassum tentorium is said to be found all along the coast of Pakistan, making it the most common species (Shaikh and Shamee, 1995). The phaeophyte S. Swartz is a common species (Mattio *et al*., 2015). In most cases, the use of Sargassum species is frequent for algin extraction; humans also consume them (Labowska *et al*., 2019). In the kingdom of chlorophytes, species of Ulva and Enteromorpha are responsible for a significant amount of growth (Wichard et al., 2015). Consumption by humans, as well as medical applications, are both possible with these. It would indicate that Hypnea musciformis is the most prevalent species of the phylum Rhodophyta, a carrageenan source (Kasanah *et al*., 2022). The next in abundance are *H. pannosa*, *H. valentia, Scinaia hatei,* and *Saifullahii* (Rizvi and Shameel, 2008; Pharmaceutical Biology of Seaweeds from the Karachi Coast of Pakistan). All these things are present in significant quantities and strengthen the production of agar and carrageenan extraction.

Pakistan's seaweeds trade

Pakistan's abundant seaweed resources have not yet been utilized to their full potential. It would not be inaccurate to say that relevant stakeholder groups lack a comprehensive understanding of the resources, such as Seaweeds, available for exploitation, and the figures currently available are only estimates that may not be used for efficient planning regarding the administration and utilization of these resources. Several factors are preventing Pakistan from using its marine resources to their full potential. These factors might include a deficiency in protection, difficulties encountered at sea, or sea blindness (Shahzad, 2020).

However, in Pakistan, the knowledge and culture on Seaweeds production and usage is growing. As the 57th largest exporter of Seaweeds, Locust beans (and related products in this category) in 2020, Pakistan made $1.94 million in revenue from these sales. For comparison, in the same year, this group of goods ranked 344th in terms of exports from Pakistan. The top export markets for Pakistani goods are Vietnam ($813,000), Germany ($239,000), the United Arab Emirates ($150,000), the Netherlands ($141,000), and Saudi Arabia ($93,100). However, during 2019 and 2020, Vietnam ($813,000), South Korea ($684,000), and Thailand ($62,800) were Pakistan's fastest-growing export markets for Seaweeds, Locust beans (and related products in this category) for food (Figure 1). Besides, Pakistan's 5 years of data (2016-2020) shows a substantial growth indicating a total on $ 8.36 m in trade volume. Imports, on the other hand, have not crossed a $ 150 k threshold per annum (Figure 2). Pakistan bought $279k worth of Seaweeds, Locust beans (and related products in this category) for food in 2020, making it the 91st highest importer of these products worldwide. In the same year, products in this category ranked 1001st on the list of most imported goods into Pakistan (Figure 3). Pakistan's top four import markets during 2019 and 2020 were China ($130k), South Africa ($35.2k), Thailand ($11.1k), and Chinese Taipei ($6.36k).

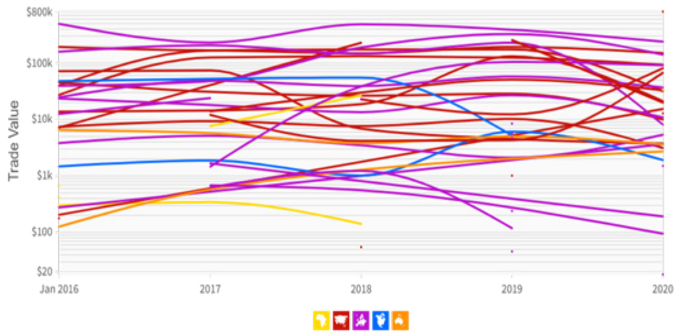

Figure 1: *Pakistan's exports of Seaweeds, Locust beans, and related products in this category (2016-2020) (OEC, 2021).*

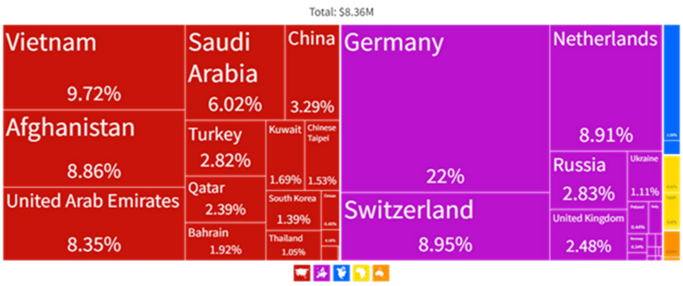

Figure 2: *Pakistan's total trade volume of Seaweeds, Locust beans, and related products in this category (2016-2020) (OEC, 2021).*

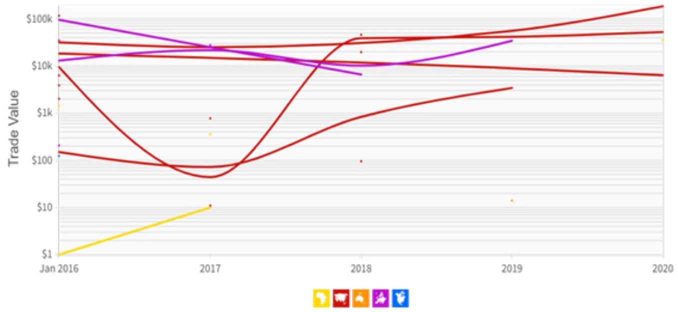

Figure 3: *Pakistan's imports of Seaweeds, Locust beans, and related products in this category (2016-2020) (OEC, 2021).*

Conclusions and Recommendations

Seaweed compounds have diverse bioactivities and can function as cosmetic catalysts. Thanks to their abundance of bioactive compounds, Seaweeds are now used in the cosmetics industry. Studying the healing properties of Seaweeds, macroalgae, and their extracts is essential. Fortunately, seaweed possesses characteristics and effects that make it valuable to the food industry. Seaweeds' importance in the Western diet is growing quickly as sushi restaurants spring up all over the globe. In addition, there is much optimism that microalgae and Seaweeds may assist in retarding or even reversing climate change. The Seaweeds resources along the coast of Pakistan provide a huge potential for economic growth. Many types of marine organisms rely on Seaweeds as a crucial component of their environment and the food chain. Once we have a better understanding of the importance of these unique coastal resources as well as their economic worth, we will be able to appreciate the need for Pakistan to preserve and commercialize its Seaweeds.

Novelty Statement

This study is novel as it investigates the current status of marine seaweeds and their relationship to Pakistan's maritime commerce.

Conflict of interest

The authors have declared no conflict of interest.

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