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Aquaculture of Seaweeds

A Multipurpose Resource

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Abstract— Weed is a wild plant growing in cultivated field and is generally useless, troublesome and injurious to the cultivated plant. Hence weeds have been neglected for determining their beneficial uses. Seaweed is a sustainable natural resource with potential that has not been fully utilised. Although seaweeds have been traditionally used as food in the eastern countries, research is needed on expanding the potential of multiple products for their wide range of uses. Commercial harvesting of seaweeds occurs in about 35 countries, in waters ranging from cold, through temperate, to tropical. Seaweeds can now be used as multipurpose resources. This paper describes beneficial uses of seaweeds and their aquacultural farming.

The following Seaweeds used as human food are given as illustrations: **(1)**. Nori or purple laver is among the most nutritious seaweeds **(2)**. Aonori or green laver: Monostroma and Enteromorpha are the two green seaweeds generally cultivated in Japan. **(3)**. Kombu or Haidai: Laminaria species contain about 10 percent protein, 2 percent fat and useful amounts of minerals and vitamins. **(4)**. Wakame, quandai-cai (Undaria pinnatifida): Wakame has high total dietary fibre content and the fat content is quite low. **(5)** Hiziki (Hizikia fusiforme): Contains protein, fat, carbohydrate and vitamins. The iron, copper and manganese contents are relatively high and fat content is low. **(6)**. Dulse (Palmaria palmata): Dulse contains minerals, iron and all the trace elements needed for human nutrition. Its vitamin content is also much higher than spinach. Nutritional details of all these six seaweeds are given in the paper.

Other illustrative uses of Seaweeds include the following: **(1)** Fertilizers and soil conditioners in farming **(2)**. Animal Feed. **(3)**. Biomass for fuel.(**4)**. Cosmetics.**(5)** Waste water treatment. **(6)**. Removal of toxic metals from industrial wastewater. Seaweeds are also used as biological indicators of heavy metal pollution. This paper is a brief literature review of multiple uses of different types of Seaweeds. It gives details of Aquaculture Technology used for cultivating them. Several topics on which additional research is needed are given in the paper. It is concluded that the seaweeds form one of the vital components of almost all ecosystems. Several important uses of seaweeds along with their names are listed in the paper.

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I. INTRODUCTION

According to Oxford Dictionary, "weed" is a wild plant growing in cultivated field and is generally useless, troublesome and injurious to the cultivated plant. Hence weed is removed from the group. Because of such background, many weeds have been neglected for determining their special properties and beneficial uses. Seaweed is a sustainable natural resource with industrial potential that has not yet been fully utilised. Although seaweeds have been traditionally used as food in the eastern countries, such as in China, Korea and Japan, for the past many centuries, research has started only recently on expanding the potential variety of products for their wide range of uses. With the rapidly growing population all over the world, and inadequate supplies of essential commodities, alternatives such as multi-purpose seaweeds appear very promising. According to one estimate, the Irish seaweed production and processing sector will be worth €30 million per year by 2020. The world Seaweed Industry is estimated to be worth US$ 5.5 – 6 billion annually, with US$ 5 billion being generated from products destined for human consumption. There is a growing interest in France, USA, Canada and Ireland in the commercial use of seaweeds.

Seaweeds are harvested either from wild habitats or from cultivated crops. The farming of seaweed has expanded rapidly as demand has outstripped the supply available from natural resources. Commercial harvesting occurs in about 35 countries, in waters ranging from cold, through temperate, to tropical. The global seaweed industry uses 8 million tonnes of wet weed annually. Over 90% of the seaweed used is cultivated. Seaweeds can now be used as multipurpose resources such as Human food, Fertilizers and soil conditioners, Animal feed, Biomass for fuel, Cosmetics, Waste water treatment, Integrated aquaculture, and Medicine

Seaweeds can be classified into three broad groups based on pigmentation, namely a) Brown seaweeds, b) Red seaweeds, and c) Green seaweeds. Botanists refer to these broad groups as Phaeophyceae, Rhodophyceae and Chlorophyceae, respectively. The more useful brown seaweeds grow in cold waters in both the Northern and Southern Hemispheres. They thrive best in waters up to about 20°C. Useful red seaweeds are found in cold waters such as Nova Scotia (Canada) and southern Chile; in more temperate waters, such as the coasts of Morocco and Portugal; and in tropical waters, such as Indonesia and the Philippines. Green Seaweeds are very common where the salinities vary a lot.

(Bays, Estuaries, Tide Pools). There are about 7,000 species of green algae, out of which about 700 are marine.

II. SEAWEEDS AS HUMAN FOOD

While several varieties of seaweeds are consumed as human food, the following are given as illustrations.

1) Nori or purple laver is among the most nutritious seaweeds, with a protein content of 30-50 percent, and about 75 percent of that is digestible. Sugars are low (0.1 percent), the vitamin content very high, with significant amounts of Vitamins A, C, niacin and folic acid,

2) Aonori or green laver: Monostroma and Enteromorpha are the two green seaweeds generally cultivated in Japan. Enteromorpha cultivation has also been attempted in Korea. It is cultivated in shallow, calm waters, found in bays and estuaries. It averages 20 percent protein, and has useful vitamin and mineral content. Enteromorpha prolifera and Enteromorpha intestinalis are both cultivated. Both species thrive in salt and brackish waters. They contain about 20 percent protein, little fat, low sodium and high iron and calcium. Its vitamin B-group content is generally higher than most vegetables, and its vitamin A content is also high,

3) Kombu or Haidai: Laminaria species contain about 10 percent protein, 2 percent fat and useful amounts of minerals and vitamins.

4) Wakame,quandai-cai (Undaria pinnatifida): Wakame has high total dietary fibre content and the fat content is quite low. It is relatively rich in the vitamin B especially niacin. Raw wakame contains appreciable amounts of essential trace elements such as manganese, copper, cobalt, iron, nickel and zinc.

5) Hiziki (Hizikia fusiforme): Contains protein, fat, carbohydrate and vitamins. The iron, copper and manganese contents are relatively high and fat content is low.

6) Dulse (palmaria palmate): Dulse contains minerals,iron and all the trace elements needed for human nutrition. Its vitamin content is aslo much higher than spinachease of use.

III. OTHER USES OF SEAWEEDS

While there are multiple uses of seaweeds, the following are given as illustrations.

1) Fertilizers and soil conditioners in farming: In all cases, the addition of the compost increases water holding capacity and plant growth. Composting simultaneously solves environmental pollution problems and produces a useful organic fertilizer. Species of *Ascophyllum*, *Ecklonia* and *Fucus* are the common ones. They are sold as soil additives and function as both fertilizer and soil conditioner. They have a suitable content of nitrogen and potassium. The large amounts of insoluble carbohydrates in brown seaweeds act as soil conditioners (improve aeration and soil structure, especially in clay soils) and have good moisture retention properties. *Ascophyllum* is used as a soil conditioner in controlling losses of top soil. Maerl is a fertilizer derived from red seaweeds that grow with a crust of calcium carbonate on the outside, the calcareous red algae, *Phymatolithon calcareum* and *Lithothamnion corallioides*. They are harvested by dredging and are used to neutralize acid soils, as a substitute for agricultural lime. Seaweed extracts are now widely accepted in the horticultural industry. When applied to fruit, vegetable and flower crops, improvements have included higher yields, increased uptake of soil nutrients, increased resistance to some pests such as red spider mite and aphids, improved seed germination, and more resistance to frost. There have been many controlled studies to show the value of using seaweed extracts. For example, they may improve the yield of one cultivar of potato but not another grown under the same conditions. No one is really sure about why they are effective, despite many studies that have been conducted. The trace element content is insufficient to account for the improved yields, etc. It has been shown that most of the extracts contain several types of plant growth regulators such as cytokinins, auxins and betaines, but even here there is no clear evidence that these alone are responsible for the improvements. Guiry & Blunden (1991) have summarized the situation: "There is a sufficient body of information available to show that the use of seaweed extracts is beneficial in certain cases, even though the reasons for the benefits are not fully understood".Seaweeds may not be an economically attractive alternative when used on their own, but when used with NPK fertilizers they improve the effectiveness of the fertilizers, thus reducing the quantity and cost of other fertilizers. They are also the preferred "organic" or "natural" fertilizers rather than chemicals.

2) Animal Feed: Norway was among the early producers of seaweed animal feed, using *Ascophyllum nodosum*, a seaweed that grows in the eulittoral zone so that it can be cut and collected when exposed at low tide. France has used *Laminaria digitata*, Iceland both *Ascophyllum* and *Laminaria* species, and the United Kingdom, *Ascophyllum*. Because *Ascophyllum* is so easily accessible, it is the main raw material for seaweed meal and most experimental work to measure the effectiveness of seaweed meal has been done on this seaweed. The seaweed used for meal must be freshly cut, as drift seaweed is low in minerals and usually becomes infected with mould. The wet seaweed is passed through hammer mills with progressively smaller screens to reduce it to fine particles. These are passed through a drum dryer starting at 700-800°C and exiting at no more than 70°C. It should have a moisture level of about 15 percent. It is milled and stored in sealed bags because it picks up moisture if exposed to air. It can be stored for about a year. The immune system of some animals is boosted by feeding a particular Canadian seaweed meal.

3) Biomass for fuel: In 1974, the American Gas Association decided to look for a renewable source of methane (natural gas) and sponsored a project to cultivate seaweed on farms from the ocean, harvest it and convert it to methane by a process of anaerobic fermentation. The project was divided into two parts: one the production and harvesting of the seaweed (biomass), the other was conversion of the biomass to energy (methane that could be burned to produce energy). The seaweed chosen was the "giant kelp" that grows off the coast of California, *Macrocystis pyrifera*, because of its high growth rate and ease of harvesting by mechanical means. A test farm was built in the ocean, 8 km off the coast of southern California, and 100 kelp plants, 12-22 m long. Several storms and the resulting waves and currents caused abrasion of the kelp plants and many were lost. Further studies were made to find better ways of attaching the kelp and to make engineering improvements to the farm structure. However, it was eventually decided to move to smaller-scale, near-shore trials, but the offshore experiments did show that kelp would grow

offshore and could utilize the nutrients in deep water upwelling by either natural or artificial means.

The near-shore work concentrated on kelp yield and agronomic practices to improve growth rate and yield and avoided involvement in the engineering of offshore structures. Useful information was gathered in this work, and other types of seaweed were also investigated, such as species of *Laminaria, Gracilaria* and *Sargassum.* However, those conducting the other half of the project - biomass conversion to methane by anaerobic fermentation - found that *Sargassum* gave a poor gas yield. For *Macrocystis*, the gas yield was good and dependent on the mannitol and alginate content of the seaweed. More gas was produced if the mannitol concentration was high. For *Gracilaria*, the methane yield related closely to the carbohydrate content, and sometimes the protein content as well.

More work is necessary to find better methods for the conversion step, biomass to methane, on a large scale; although the bench-scale work already done indicated that net energy can result from bioconversion, with good yields of methane. More engineering research is needed for the design of suitable open-ocean structures that will allow the kelp to survive storms and excessive wave movements and currents. Methane from marine biomass is a long-term project and research and development have been scaled down, probably to be revived when a crisis threatens in natural gas supplies.

4) Cosmetics: Extract of seaweed is used in face, hand and body creams or lotions. Bath salts with seaweed meal are also sold. Thalassotherapy has come into fashion in recent years, especially in France. Mineral-rich seawater is used in a range of therapies, including hydrotherapy, massage and a variety of marine mud and algae treatments. It is said to be useful in various ways, including relief of rheumatic pain or the removal of cellulite.

5) Waste water treatment: The first use is the treatment of sewage and some agricultural wastes to reduce the total nitrogen- and phosphorus-containing compounds before release of these treated waters into rivers or oceans. The second use is for the removal of toxic metals from industrial waste water and treatment of wastewater to reduce nitrogen- and phosphorus-containing compounds. Seaweeds can be used to reduce the nitrogen and phosphorus content of effluents from sewage treatments. Many types of seaweed have a preference to take up ammonium as the form of nitrogen for their growth and ammonium is the prevalent form of nitrogen in most domestic and agricultural wastewater. Another important feature of many types of seaweed is their ability to take up more phosphorus than they require for maximum growth.

6) Removal of toxic metals from industrial wastewater: The accumulation of heavy metals from industrial wastewater can be considerably reduced by cultivating seaweeds. Seaweeds can be used as biological indicators of heavy metal pollution, either from natural sources or from activities such as mining or disposal of industrial wastes.

7) Seaweeds have medicinal value. The single most important element provided by seaweeds, is Iodine. It is more abundant in seaweeds than any plants or animals. Selenium is present in all seaweeds in physiologically significant amounts. Selenium is required for many critical metabolic actions. Seaweds contain Algin, which has great therapeutic value as a heavy metal detoxifying agent.

IV. FARMING OF SEAWEEDS

The aquaculture of seaweeds is run predominantly as a small-scale family business by fishermen, with a production of about 1000 tons per year per family. Places that are exposed to wind driven currents are best for seaweed harvesting because here the currents bring all the nutrients for growing seaweeds. A hard bottom is chosen for farming, not a clayey bottom. Places near coral beds are avoided because the fish will graze on seaweeds. The water should be deep enough to avoid exposure of seaweeds to sun at low water stages of tides. The seaweed sticks are tied together on ropes. The lines may be 5 m long. They are hanged in the same direction as the current flows onto the farm site. The ropes are tied tightly to the posts driven in sea bed.

Wet seaweed is removed and placed on racks. This helps the seaweed to dry more quickly and prevents many impurities getting into it. In a sunny area, it will take only three days to dry. The seaweed is covered with a piece of black plastic sheet to get the best quality. A floating cage can be used for holding a lot of seaweed and protecting them from being eaten. At low tide, the family goes to the farm and takes all the seaweed ashore with the help of the harvesting bags. There it is dried and packed in bags for selling. The next crop is replanted. There is potential with some culture systems to integrate seaweed culture with other forms of aquaculture to make better use of marine resources and reduce the impacts of more intensive forms of aquaculture.

V. ENVIRONMENTAL ASPECTS

The influence of seaweed culture on benthic communities has not been well studied. Shading or smothering by large scale seaweed farming could potentially reduce benthic productivity in shallow inshore areas. Increased sedimentation of organic matter from seaweeds and associated organisms could also increase benthic production in areas with low current velocity, although there may be some community changes. The area below seaweed culture areas can be used very positively for production of other aquatic animals. For example, farms in Republic of Korea, Japan and China find that the benthic area below seaweed farms can be used for culturing of invertebrates, such as abalone or sea cucumber, thus maximising the production and profit per unit area.

The seaweeds and farm structures may also have a significant influence on coastal invertebrate and vertebrate populations. The introduction of seaweed and structures can considerably enhance the productivity of invertebrates and fish much the same way as artificial reefs, due to increased availability of shelter and food organisms. Studies in Japan have shown that *Laminaria japonica* farms act as shelters for commercially important fish fry and workers in China have shown increased numbers of fish, sea urchins, sea cucumbers and abalones in giant kelp culture areas. The attractiveness of seaweed farms can also cause problems for seaweed farmers, by attracting invertebrates and finfish which may predate on the seaweed.

The culture of seaweed is also significantly influenced by environmental factors. Turbidity, nutrient levels, phytoplankton blooms, temperature, pollution by heavy metals and organic pollutants, salinity fluctuations are all significant factors in the successful development of culture areas. The deteriorating water quality in some coastal locations is also a threat to present and future seaweed culture.

VI. CONCLUSION

This paper is a brief literature review of multiple uses of different types of Seaweeds. It also gives details of Aquaculture Technology used for cultivating them. Several topics on which additional research is needed are given in the paper. It is concluded that the seaweeds form one of the vital components of almost all ecosystems. Hence the studies based on them have become the most important aspect because seaweeds are highly productive and play a vital role as nursery grounds for many commercially important species. Several important uses of seaweeds along with their names are listed in the paper.

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