Development of Value Added Products From Spirulina Platensis Microalgae

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Abstract- *Spirulina platensis being a functional food has numerous nutritional and therapeutic benefits due to it richness in protein along with other essential fatty acids, vitamins, minerals and pigments of great biological importance. Hence, this algae addition in different product formulations can be successfully applied to overcome the deficiency of some trace elements to increase its nutritional and biological value. Therefore, it has been considered as a 'Super food'. Spirulina fortification also increases the protein content, levels of vitamins and essential amino acids in the products. Spirulina has the potential to Spirulina has the potential to be a major food source in the future*

Keywords- Spirulina platensis, Fortification, superfood, fortification, Biological importance

I. INTRODUCTION

Spirulina platensis is a multicellular and filamentous planktonic cyanobacterium (length: 50–500 m, width: 3–4m) and it is found mostly in tropical and subtropical water bodies with high levels of carbonate and bicarbonate having pH values of upto 11 (Tomaselli, 1997). Spirulina draws its name from the Latin word "helix" or "spiral," which refers to an organism's physical structure when it spins minuscule strands. Spirulina is a blue-green microalgae that contains symbiotic bacteria that fix nitrogen from the atmosphere. As seen in Fig. 1, Spirulina can be rod- or disk-shaped. Spirulina is autotrophic because it is photosynthetic and reproduced by binary fission.

Spirulina platensis dried biomass normally comprises 3 to 7% moisture, 55 to 60%

protein, 6 to 8% lipids, 12 to 20% carbohydrate, 7 to 10% ash, 8 to 10% fibre, 1 to 1.5 percent chlorophyll a, and a variety of vitamins. The biliproteins (e.g., c-phycocyanin and allophycocyanin), which are water soluble blue pigments, are abundant in Spirulina platensis and have the largest commercial potential. Cyanobacteria have the ability to produce a large number of commercially valuable compounds, such as phycocyanin. Spirulina platensis contains 45–50% saturated fatty acids and 50–55% unsaturated fatty acids. Gamma-linolenic acid, a rare polyunsaturated fatty acid with therapeutic potential, makes upto 30% of fatty acids. The general composition of Spirulina platensis varies by location and type of production, it approximately contains 55-70% proteins,15-25% carbohydrates,6-8% lipids,7-13% minerals,3-7% humidity (dried algae) and 8-10% dietary fibres (Jung et al., 2019).

PHYSICO-CHEMICAL PROPERTIES OF *SPIRULINA PLANTENSIS*

The principal photosynthetic pigment present in Spirulina platensis is blue colored phycocyanin. These bacteria also contain chlorophyll (a dark green pigment) and carotenoids. Phycoythrin, a pigment found in some bacteria, which gives a red or pink colour (Iijima et al., 1982). Spirulina has been considered as the only fruit, vegetable, or meat that provides all of the essential nutrients for human health. Spirulina has a greater protein concentration than spinach, ranging from 65 to 71%. The fatty acids contain omega 6 (gamma linolenic, essential linolenic and dihomogamma linolenic) and omega 3 (alpha linolenic, decosahexaenoic, palmitoleic, oleic and euric) oils. Spirulina contains more vitamins than liver, carrots, spinach, and many other plants. Due to its high concentration of key bioactive molecules, Spirulina has been utilised to stimulate the immune system by increasing the manufacturing of antibodies and cytokines, and therefore improving human resistance to infections. Spirulina platensis has a unique combination of antioxidant and anti-inflammatory minerals, spirulina provides a variety of health benefits, including cardiovascular support and prevention of cardiovascular disease, arthritis, obesity, colon, oesophagus, breast malignancies, and blood sugar levels. (Khan, 2005).
The protein content in spirulina (65%) is much higher than that in milk (4.3%), eggs (13.3%), pulses (24%) and soybean (43.2%). The beta carotene in spirulina (1900 µg/g) is much higher than that in carrots (18.9 µg/g), spinach (55.8 µg/g) and mango (27.4 µg/g). The iron content in spirulina (0.522 mg/g) is also higher than spinach (0.109 mg/g) and soy bean (0.115 mg/g). (Ghaly et. al, 2015).

Spirulina (Arthrospira) is a common bacterium. Since Turpin's discovery in 1827 from a freshwater stream, Spirulina species have been discovered in a variety of environments, including dirt, sand, marshes, brackish water, ocean, and freshwater. (Koru, 2009). As a result, the organism appears to be capable of adapting to a wide range of habitats and colonizing situations that are challenging for other bacteria. (Ciferri, 1983 and Tomaselli, 2003).

Food, dietary supplement, and feed supplement species include Arthrospira platensis and Arthrospira maxima. In the late 1970s and early 1980s, when Spirulina was reintroduced as a human health food, it was accompanied by a plethora of claims that Spirulina is a “magic agent” capable of practically everything, from treating certain tumours to serving as an antibiotic. (Wikfors and Ohno, 2001).

Table 1: Quantity of Spirulina proteins with other foods (Henrikson, 1989)

Food Type	CrudeProtein(%)
Spirulina powder	65
Chicken Egg	47
Beer Yeast	45
Chicken meat	24
Skimmed Powdered milk	37
Cheese	36
Beef meat	22
Fish	22

Table 2: Taxonomy of Spirulina platensis

CLASS	MYXOPHYCEAE
ORDER	HORMOGONALES
FAMILY	OSCILLATORIACEAE
GENUS	*Spirulina platensis*

UTILIZATION OF SPIRULINA PLANTENSIS INTO VALUE ADDED PRODUCTS

Spirulina platensis is a cyanobacterium that has been widely utilised in many countries and is GRAS (generally regarded as safe) with no toxicological effects, and has been licenced by the FDA (United States) and ANVISA (BRASIL, 1998). (Navacchi et. al, 2012). The United Nations World Food Conference of 1974 declared Spirulina platensis to be the best food for the future, and the World Health Organization (WHO) stated that Spirulina platensis is an interesting food for a variety of reasons, including its high iron and protein content and ability to be given to children without risk (Geneva, Switzerland June 8th 1993). IIMSAM (International institution for the use of microalgae Spirulina against malnutrition) initiated a revised draught resolution on the "Use of Spirulina to Combat Hunger and Malnutrition and Help Achieve Sustainable Development" during the United Nations General Assembly's sixty-fifth session (Second Committee, Agenda item 52). Microalgae can thus be used as an alternative to produce high- quality food with a low environmental impact because they can be grown on non-cultivable terrain. Spirulina is a source of several nutrients, including minerals, and it can be used in recipes. (Belay 2002).

Spirulina is a taxonomic term that refers to two Cyanobacteria species: Arthrospira platensis and Arthrospira maxima. Both have been employed in the food, dietary supplement, and feed supplement industries. Spirulina was previously a single genus that included this and other Arthrospira species that create helical trichomes. Prior to this, the two genera were classified independently based on the presence of septa: The Spirulina species do not have septa, while the Arthrospira species have (Jung et. al., 2019).

Belay et al. (1997) found that the dried biomass of Spirulina platensis typically contains 3 to 7% moisture, 55 to 60% protein, 6 to 8% lipids, 12 to 20% carbohydrate, 7 to 10% ash, 8 to 10% fiber, 1 to 1.5% chlorophyll and a wide range of vitamins. Cohen et al., (1997) searched that Spirulina platensis is especially rich in proteins. The proteins with the highest economic potential are the biliproteins (e.g., c-phycocyanin and allophycocyanin), which are water-soluble blue pigments. The protein fraction may have a phycocyanin content of up to 20%. Fatty acid composition is largely influenced by environmental conditions. Spirulina platensis can be characterized by about 45 to 50% saturated and 50 to 55% unsaturated fatty acids. Up to 30% of fatty acids is gamma-linolenic acid, a rare polyunsaturated fatty acid claimed to have medicinal properties. Beneficial Spirulina strains and an efficient processing procedure should yield biomass with at least 1% gamma- linolenic acid.

Saharan and Jood (2017) evaluated the physico-chemical properties of Spirulina platensis powder and its incorporation at different levels i.e. 2, 4, 6 and 8% in wheat flour for development of biscuits, buns, noodles and macaroni and evaluated for their consumer acceptability in wheat flour for development of value added products and their consumer acceptability. Spirulina was found to be very rich source of protein i.e. 71.90% with high in vitro digestibility (92.59%) and containing all essential amino acids specially total lysine (5.72 g/16gN) as this amino acid is lacking in wheat flour. It also contained good amount of crude fibre (9.70%), ash (3.50%) and total dietary fibre (14.98%), whereas, carbohydrate (13.63%) and fat (1.27%) were found to be in very low amount which contributed low energy (353.55 Kcal/100g) content. Various products like biscuits, buns, noodles and macaroni were developed using standard recipes by incorporation of Spirulina platensis powder at 2, 4, 6 and 8 % levels in wheat flour along with their respective control products. Acceptance on hedonic scale was observed and up to 6% levels were also found at par with their respective control and acceptable by majority of respondents.

Microalgae are increasingly being included into food formulations, resulting in a large increase in the number of food products containing microalgae that have been introduced to the market, however most of these use microalgae as a coloring ingredient or a marketing technique. The majority of Spirulina biomass generated now is used as a dietary supplement, dried powder, flakes, or capsules.

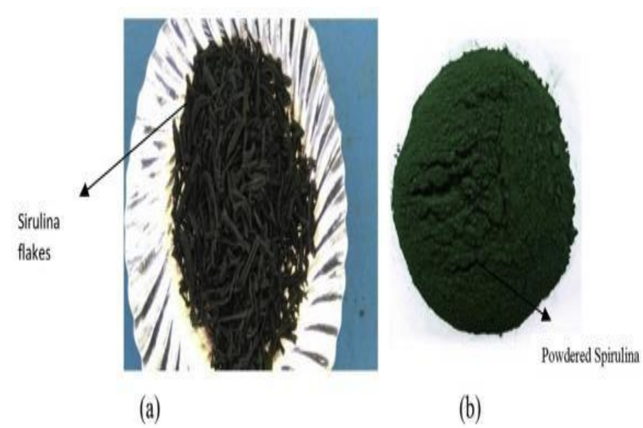

Fig.1: Dried Spirulina a) Spirulina Flakes b) Powdered form of Spirulina (Soni et al., 2017)

Varga et al., (2002) studied how the microbiota of a probiotic fermented dairy product was altered by cyanobacterial (Spirulina platensis) biomass during storage at two different temperatures. Spirulina enriched and control (plain) fermented acidophilus bifidus- thermophilus (ABT) milks were made using a fast fermentation starter culture (ABT-4) as the source of Lactobacillus acidophilus (A), bifidobacteria (B), and Streptococcus thermophilus (ST). The incubation time and temperature was 6 hours/40°C. The Spirulina platensis biomass was introduced to the processed milk during stirring at pH 4.5 to 4.6 for the cyanobacteria product. Thereafter, the ABT type fermented milks were cooled to 25°C in ice water, filled into sterile, tightly capped centrifuge tubes, further cooled at 4°C for 24 h, and then stored either at 15°C for 18 days or at 4°C for 42 days. Microbiological analysis and acidity measurements were performed at regular intervals. Results showed that the counts of the starter organisms were satisfactory throughout whole storage period. The Spirulina platensis biomass showed positive result on the survival of ABT starter microorganism despite the storage temperature. Post acidification was observed at 15°C, whereas pH remained stable during refrigerated storage at 4°C. The abundance of bioactive substances in S. platens is of great importance from a nutritional point of view because the cyanobacterial biomass provides a new opportunity for the manufacturing of functional dairy foods.

Silva et al., (2019) studied different encapsulating methods for incorporating Spray- dried Spirulina platensis as an effective ingredient in yogurt formulations. Foods that have been functionalized with spirulina may have beneficial health effects. Spirulina-based food products, on the other hand, are sometimes associated with a disagreeable flavour and odour, as well as a non-homogeneous look, which reduces customer acceptance. Furthermore, it is critical to ensure that bioactivity is maintained. To develop a novel food ingredient, spirulina was chemically characterized, and spray-dried using two encapsulating materials: i) maltodextrin and ii) maltodextrin crosslinked with citric acid. Thereafter, free and encapsulated spirulina were evaluated for their bioactive properties. In terms of thermal stability and anti-inflammatory effectiveness, microencapsulated spirulina surpassed the base materials without causing cytotoxicity. Spirulina was also added to yoghurt, both free and encapsulated, to see if it might be used as a functionalizing agent. Yogurts added with encapsulated spirulina presented a more homogeneous appearance, and the best solution was spirulina encapsulated in maltodextrin crosslinked with citric acid, considering the nutritional profile, attractive color, and improved antioxidant activity throughout storage time.

Danesi et al., (2010) worked on the applications of Spirulina platensis in Protein Enrichment of Manioc Based Bakery Products. As the world's population grows and forecasts of insufficient protein supplementation more likely, researchers are looking for alternate protein and cyanobacteria sources that can help. When compared to other agricultural products, the use of Spirulina spp. as a protein supplement in populations with food shortages is deemed practical because it offers various advantages.

Navacchi et al. (2012) studied the cassava cake generated by supplementing it with Spirulina platensis biomass and a form of bran made from the cassava's own starch. Apart from being high in protein, this biomass also contains vitamins, vital fatty acids, and minerals. The goal of this work was to propose that cassava cake be enriched with fibres from its own starchy bran and biomass from Spirulina platensis. Food based on cassava lacks in protein. Therefore it is justified to study sources of enrichment such as the biomass of Spirulina platensis. The product thus developed can be an interesting alternative to availability of nutritional low cost functional food.

Zlateva et al. (2019) carried this study to evaluate the effect of 2 and 4% Spirulina powder supplement on the iron and zinc content of bread made from wheat flour. The addition of Spirulina platensis algae to wheat bread increases its biological value and helps to achieve iron and zinc content amounts close to the recommended daily intake levels. When enriched with 2% Spirulina platensis, the amount of iron in the bread is almost doubled, and the addition of 4% results in an increase in the amount by 3.4 times compared to control sample. Men are scheduled to have a daily intake of 11 mg and for women 8 mg zinc. It is clear that bread with 4% Spirulina platensis provides over 15% of the recommended daily intake for men and over 21% for women, whereas in the control sample these values are lower (13.61 - 18.75%). Hence, this algae addition in the bread formulation can be successfully applied to overcome the deficiency of some trace elements, respectively to increase its nutritional and biological value.

Fradique et al. (2010) found that the addition of microalgae leads to increase the quality parameters. After cooking, the color of microalgae pastas remained quite constant. When compared to the control sample, the addition of microalgae increased the raw pasta stiffness. Of all the microalgae studied, an increase in the biomass concentration (0.5– 2.0%) resulted in a general tendency of an increase in the pasta firmness. Sensory analysis revealed that microalgae pastas had higher acceptance scores by the panelists than the control pasta. Microalgae pastas had very appealing colors, such as orange and green, similar to vegetables-based pastas, as well as nutritional benefits, with energy levels comparable to conventional pastas. The addition of microalgae biomass to pasta can improve its nutritional and sensory qualities while maintaining its cooking and textural aspects.

According to Shklar and Schwartz, (1988) Spirulina ingestion for four weeks lowers serum cholesterol levels in humans by 4.5 percent and dramatically reduces body weight. In macrophages, spirulina extract increases tumour necrosis factor, suggesting a putative tumor-killing mechanism. An extract of sulfated polysaccharides, called Calcium-Spirulina (Ca-SP), made up of rhamnose, ribose, mannose, fructose, galactose, xylose, glucose, glucuronic acid, galacturonic acid, and calcium sulfate, obtained from Spirulina, showed activity against HIV, Herpes Simplex Virus, Human Cytomegalovirus, Influenza A Virus, Mumps Virus and Measles Virus. Cell extract of Spirulina maxima has shown antimicrobial activity against Bacillus subtilis, Streptococcus aureus, Saccharomyces cerevisiae, and Candida albicans. Spirulina reduces: hepatic damage due to drug abuse and heavy metal exposure, inflammatory response, cells degeneration, anaphylactic reaction. Spirulina contains vitamin A, important in preventing eye diseases; iron and vitamin B12, useful in treating hypoferric anemia and pernicious anemia, respectively; γ-linolenic acid, appropriate in treatment of atopic child eczema therapy; to alleviate premenstrual syndrome, and in immune system stimulation. Spirulina has been studied as an animal cell-growth stimulant and in the treatment of residual waters using alginate.

Scientists at Harvard Medical School in Boston discovered that a water extract of spirulina prevents HIV-1 viral replication in human T-cell lines (production was reduced by approximately 50 percent). They determined that the antiretroviral action of spirulina water extracts is attributable to the presence of reducing chemicals (polyphenols, bioflavonoids, phycocyanide, and chlorophyll pigments) (Ayehunie et al., 1998). It's a food that helps to control blood sugar, blood pressure, and cholesterol levels while also giving antioxidant protection against life-threatening diseases including cancer, Alzheimer's disease, and stroke. Zeaxanthin and phycocyanin pigments are found in spirulina. Some observational studies have also suggested that xanthophylls may lessen the risk of certain malignancies, such as breast and lung cancers. Lutein and zeaxanthin may help prevent heart disease and stroke, according to new studies. Phycocyanin, a fantastic new water soluble pigment found only in blue green algae like spirulina, is found only in blue green algae like spirulina (bluish colour). According to Spanish researchers, a phycocyanin-rich spirulina extract has been proven to inhibit microsomal lipid peroxidation and act as a free radical scavenger. (Iijima et al., 1982)Its protein-dense whey water contains anti-oxidant qualities and helps to boost immune function. When it comes to using Spirulina as a human food source, the presence of linoleic and y-linolenic acid in quantities more than 20% is critical. These two acids, when combined, provide a significant amount of necessary fatty acids for supplementation

Finally, non-heme iron is found only in plant foods, which is more susceptible to absorption inhibitors (i.e., phytates). Spirulina may be able to help with both of these issues: a) It has a high iron content: cereals, which are commonly thought to be good sources of iron, contain 150-250 mg/kg; blue-green algae has 580-1800 mg/kg; b) Because algae does not have a pericardium (as cereals do), it does not contain phytates/ oxalates, which could chelate iron and reduce its absorption (this is what happens, for example, with spinach). Spirulina's important components have a high bioavailability, which means they may be absorbed optimally and without much loss (digestibility of 86 percent) and do not require chemical or physical processing to become dilute. Spirulina was discovered to be a very rich source of protein, with a protein content of 71.90 percent, high in vitro digestibility (92.59 percent), and all essential amino acids, including total lysine (5.72 g/16gN), which is missing in wheat (Saharan and Jood, 2017)

Spirulina has a one-of-a-kind ability to detoxify (neutralise) or chelate toxic minerals that no other microalgae has demonstrated. Spirulina can help you detox from arsenic in water and diet. It could also be used to chelate or detoxify heavy metals (minerals) harmful effects in water, food, and the environment.

Bhat & Madyastha et al., (2000) reported that Spirulina also includes a wide range of natural mixed carotene and xanthophyll phytopigments, which, along with phycocyanin, appear to be linked to its antioxidant properties. Phycocyanin appeared to have an anti- inflammatory impact via inhibiting the synthesis of leukotriene B4, an inflammatory metabolite of arachidonic acid. C-phycocyanin is an antioxidant and a free radical scavenger. Antioxidant properties Spirulina has been shown to have strong anti-oxidant effects in vitro and in vivo in several investigations. The water extract of Spirulina is also shown to have more anti-oxidant effect (76%) than gallic acid (54%) and chlorogenic acid (56%). Phycocyanin also inhibited liver microsomal lipid peroxidation.

Kanojia, et al., (2019) studied that beta carotene present in it, can defeat eye issue or eye sicknesses brought about by inadequacy of nutrient in kids. It is the main nourishment source fusing huge measures of fundamental amino acids, gamma-linoleic-corrosive (GLA) and basic unsaturated fats, which helps to decide the whole hormonal framework. Spirulina platensis assumes an incredible job in treating individuals who are experienced kwashiorkor.

II. CONCLUSION

Spirulina has been used in the formulation of several food products, and the number of new foods introduced to the market each year that incorporate this precious resource is growing. Spirulina is not only a marketing strategy, but it's also packed with nutrients like proteins, PUFAs, and biological pigments like chlorophyll. When compared to synthetic alternatives, one of the key advantages of Spirulina -derived pigments is that they have various health-promoting effects when consumed and could be exploited as a component in the development of novel functional meals. Furthermore, Spirulina -derived proteins have been shown to be great sources of bioactive peptides that might be used in functional foods as antihypertensive, antidiabetic, antiobesity, and antioxidant components, among other favourable bioactivities.

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