International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 8 Issue 5, Sep-Oct 2024 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Spirulina: Key of Health

Prof. Deepti N Chaudhari[1], Prajakta J Kokate[2], Adinath P Kakade[3], Supriya K Jadhav[4]

[1]Guide, [2,3,4]Student,
[1,2,3,4]Matoshri College of Pharmacy, Eklahare, Nashik, Maharashtra, India

ABSTRACT

Spirulina is valuable for human and animal nutrition, as well as for environmental protection through wastewater recycling and energy conservation. The review focuses on the characteristics of Spirulina platensis. It is rich in proteins (60-70%), vitamins, and minerals, making it a valuable protein supplement for undernourished children in developing countries one kilogram of assorted vegetables is equal to one gram of spirulina protein. The amino acid composition of Spirulina protein is among the best in the plant world, surpassing that of soybeans. Spirulina can be mass-cultivated in both fresh water and wastewater. When grown in clean waters under controlled conditions, it can be used for human nutrition. When grown in wastewater, it is used as animal feed and provides a source of fine chemicals and fuels. The wastewater system is highly applicable in densely populated countries like India, where large quantities of waste are generated, posing environmental problems.

KEYWORDS: *Spirulina, proteins, cyanobacterium, Phycocyanin, Chromoprotein*

How to cite this paper: Prof. Deepti N Chaudhari | Prajakta J Kokate | Adinath P Kakade | Supriya K Jadhav "Spirulina: Key of Health" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-8 | Issue-5, October 2024, pp.1127-1133, URL: www.ijtsrd.com/papers/ijtsrd70516.pdf

IJTSRD70516

1. INTRODUCTION

Blue-green algae, also known as cyanobacteria, are some of the most primitive life forms on Earth. They have a simple prokaryotic cellular structure and are able of photosynthesis, similar to plants. Unlike plants, they lack a cell wall and share characteristics with primitive bacteria. Interestingly, they also contain complex sugars on their cellular membrane, similar to animal glycogen. Blue-green algae have adapted to survive in extreme habitats, and there are both edible and toxic species. Edible cyanobacteria such as Nostoc, Spirulina, and Aphanizomenon have been used as food for thousands of years.[1]

The deterioration of current environmental conditions, increased mental and physical stress, and changes in diet have become serious risk factors for humans, leading to a higher death rate and an increase in civilization-related diseases. These are clear reasons why new progressive trends are being extensively developed in modern medicine, pharmacology, and biotechnology to seek more effective and harmless medications for treating and preventing various diseases. One of the trends in biotechnology is associated with blue-green microalgae Spirulina platensis, which have been widely used as food and feed additives in agriculture, the food industry, pharmaceuticals, perfume making, medicine, and science.[1]

Fig No: 1

1.1. Spirulina platensis:

Spirulina sp. has been used as food for centuries by different populations and has only been rediscovered recently. Once classified as 'blue-green algae,' it does

not strictly belong to the algae category, though it is still often referred to as such for convenience. It naturally grows in warm regions in the alkaline waters of lakes. Measuring approximately 0.1 mm in width, it typically takes the form of tiny green filaments coiled into spirals of varying tightness and number, depending on the strain. Its impressive protein content and rapid growth in purely mineral environments have attracted the interest of both researchers and industrialists.

Spirulina is a single-celled, filamentous cyanobacterium that is widely popular in the health food industry and is increasingly used as a protein and vitamin supplement in aquaculture diets. It has long been utilized as a dietary supplement by people living close to the alkaline lakes where it is naturally found. Spirulina has also been used as a complementary dietary ingredient in the feed for fish, shrimp, and poultry. Among the various species of Spirulina, the blue-green alga Spirulina platensis has drawn more attention due to its high nutritional content, characterized by a 70% protein content.[2]

Fig No: 02

PJ Turpin isolated Spirulina from fresh water samples in 1827. Due to their morphological appearance, members of both genera were named Spirulina, regardless of septa and focus only on stylistic similarities. In 1989, these microbes were divided into two genera, Spirulina and Arthrospira, which is the currently accepted classification. According to the classification of Berger's Handbook of Bacteriology, Spirulina belongs to the photosynthetic bacteria, which includes the phyla Cyanobacteria and Prochlorophyta, which is related to the sequence of rRNA (ribonucleic ribonucleic acid) subunit 16 by phylogeny. Based on the sequence data of this subunit and the 5s rRNA subunit, this prokaryote is classified as eubacteria. Dried cells of microorganisms such as bacteria, fungi, yeasts, and algae are grown in large-scale culture systems because proteins for human or animal consumption are known. the self-proteins (SCPs). SCP is characterized by rapid growth, high protein content (43-85%) compared to field crops, low water and soil requirements, climate independence, rely on wastewater for growth, and the ability of genetic modification to obtain desired characteristics such as acidity. and temperature tolerance. Among the microorganisms used as sources of SCP, the blue-green algae Spirulina is considered the best source. Its biological structure, including high protein, low nucleic acid, high concentration of vitamins and other plant substances, and the presence of cell walls that make it easier to digest than other microorganisms, showing that Spirulina is a good biological resource.[3] Feed source. Spirulina platensis is naturally found in tropical regions inhabiting alkaline lakes with a pH of 11 and high concentrations of NaCl and bicarbonates. These limiting conditions for other microorganisms allow the cultivation of microalgae in open reactors. Cyanobacterial light-harvesting pigments include chlorophyll a, carotenoids, and phycobiliproteins, the latter of which are proteins with linear tetrapyrrole prosthetic groups and are called phycocyanins, phycoerythrins, or allophycocyanins, depending on their structure [4].

2. Isolation and Production of Spirulina platensis:

Spirulina platensis only grows in tropical areas, living in alkaline lakes with a pH of 11 and high sodium and bicarbonate levels. Due to the binding of other microorganisms it is possible to cultivate microorganisms in open reactors.[5] In cyanobacteria, chlorophyll-a, carotenoids, and phycobiliproteins are light-harvesting pigments. The latter are proteins with a linear tetrapyrrole prosthetic group and are called phycocyanin, phycoerythrin and allophycocyanin depending on their structure. Spirulina is often found in aquatic ecosystems such as lakes, ponds and tanks. It is one of the first photosynthetic organisms in nature that can directly convert light into complex metabolic processes [6]. Spirulina has been used as food by people living in Lake Chad in Africa since ancient times. The main type of phytoplankton is Spirulina platensis. Spirulina is also consumed in Mexico under the name "Tecuitlatl"[7]. Spirulina grows best in a pH range of 9-11, with little risk of contamination by other microorganisms. Orio Ciferri [8] discovered Spirulina as a ubiquitous organism. Turpin was first isolated in 1827 from soil, sand, marsh, salt water, sea water and fresh water. It seems that these organisms can adapt to different habitats and inhabit certain environments where other microbes would have difficulty surviving. Common examples are the alkaliphilic spirulina population in some alkaline lakes in Africa and the giant spirulina in Lake Texcoco, Mexico, where spirulina is grown in monoculture. Susan Spiller et al[9]. The fine structure of cyanobacteria, especially Spirulina platensis and

Spirulina hypophysalis, was observed using an XM-1 X-ray microscope, beamline 6.1.2. These high-resolution images allow for close comparisons between the morphological features of prokaryotic and eukaryotic photoecosystems. The bright blue-green cylindrical filaments of Spirulina platensis have a slow spiral rotation, the diameter of the filament is 5-6 µm, and the cell walls are clearly visible, passing through the filament in places of 2-3 µm.

Harriet Folkman et al. [10] cultivated Spirulina platensis under controlled laboratory conditions (30 °C, 12 hours light/dark photo The lamp has a light intensity of 140 mol photon.m-2.s-1 and constant blowing gas) in three different modes Middle: (1) Middle Paoletti (official), (2) Paoletti Add to 1 g L-1 NaCl (saline) and (3) Paoletti is made from wastewater. Here This treatment affects growth, protein content and Measure the amino acid profile. largest cell The animations were found in Paoletti's voice, Paoletti Add salt or vinegar The wastewater concentrations were 2,587, 3,545 and 4,954 g L-1. Biomass in medium 3 shows high protein content (56.17%), while biology in language 2 is 48.59% protein. All amino acids except lysine and Tryptophan concentration is higher FAO Regulations. Bohra [11] studied the plant model of Spirulina Platypus in standard and modified packs Seawater chemicals and seawater fertilizers. period Method, cell concentration analysis at 540nm and protein and chlorophyll estimates. happen Monitoring patterns across species and strains 25 days with specific growth rate, daily dividend rate and calculate the doubling time. Spirulina platensis It can be found with different growth conditions different Media under environmental parameters (Temperature, pH and light intensity). Although, Spirulina platensis grows well on standard media Sample, biomass, protein content and chlorophyll content Compared to other seawater platforms, this test speaks for itself Effectiveness of seawater media. Ushalani et al. [12] Collect a water sample For the isolation of Spirulina strains from algae There are three different locations and strains of Spirulina platensis the strain was isolated and named ANS-1.

Fig No: 03

2.1. Phycocyanin:

Phycocyanin is a blue water-soluble, Spirulina is blue. found in blue-green algae Like spirulina. Phycocyanin is a powerful water-soluble medicine Antioxidants, according to Spanish scientists, are extracts Spirulina contains phycocyanin which is a powerful free radical scavenge and inhibit microsomal lipid peroxidation [13]. The Phycocyanin in Spirulina helps protect It fights kidney disease with certain medicines. Phycocyanin shows promise for cancer treatment animals and stimulate the immune system [14]. a person Clinical studies show that Spirulina hot water extract Rich in phycocyanin, it increases the production of interferon and NK Cytotoxicity.

2.1.1. Physical and chemical properties of phycocyanin

Phycobiliproteins are a very small group it doesn't exist Chromoprotein That's it is Here Phycobilisomes, macromolecular protein complexes His main job is to collect light Here The photosynthetic machinery of cyanobacteria and Eukaryotic groups. The most common parts Phycobiliprotein is different from phycocyanin, phycocyanin and Phycoerythrin is made entirely of protein a and b subunits and transport different linear tetrapyrrole imamers The prosthetic group (chromophore bilin) differs in the formation of a double bond. Phycocyanin has two types a and b The protein subunits are 17,000 and 19,500 Da, respectively. The bilin chromophore is attached to the subunit (a 84), and Two are associated with sub-section b (b 84, b 155). The PC is becoming a complex Interactive mixture of trimer, hexamer, and decamer compilation When Level 2, Level 3, Level 4 The protein structure that has undergone denaturation is visible Intake and flu groups are reduced strength Chemical structure of the bilin chromophore PC is very similar to bilirubin, which degrades heme product. Bilirubin is considered a physiological substance Antioxidants are important for active substances [15].

2.1.2. Phycocyanin Biochemistry:

It contains phycocyanin and bile proteins The harvesting reaction is simple and complete in a gel Electrophoresis of Spirulina platensis and Spirulina maxima separated from the first. c-Phycocyanin and Allophycocyanin appears to be an oligomeric complex It can be divided into two subcategories It is analyzed by electrophoresis under reducing conditions. The α and β components of c-phycocyanin show mobility Similar to atomic weights of 20,500 and 23,500, each small product The molecular weight is about 44,000. Allophycocyanin was detected. It contains small particles with a

molecular weight of ca. 18,000 and 20,000 obtained the lowest oligomer values. The molecular weight is about 38,000. swallow and The fluorescence spectrum is similar to that reported for c Phycocyanin and allophycocyanin are isolated from other substances Cyanobacteria. Research on reduction and regeneration The content of c-phycocyanin shows more These bile proteins contain chromophores [16].

2.1.3. Extraction And Purification Of Phycocyanin:

Spirulina platensis Phycocyanin is a blue water-soluble, Spirulina is blue. found in blue-green algae Like spirulina. Phycocyanin is a powerful water-soluble medicine Antioxidants, according to Spanish scientists, are extracts Spirulina contains phycocyanin which is a powerful free radical scavengers and inhibits microsomal lipid peroxidation [17].The Phycocyanin in Spirulina helps protect It fights kidney disease with certain medicines. Phycocyanin shows promise for cancer treatment animals and stimulate the immune system [18]. Phycocyanin, as mentioned above, is the blue pigment used when working with cyanobacteria. a great contribution 20% of the protein in cyanobacteria is attached to it the description membrane. C-Phycocyanin Yes Influenza, very high and strong absorption Quantum energy, long-range transfer and excitation and Emission bands at visible wavelengths. It is a stable protein Antibodies can be linked to other proteins in the following way Traditional protein-transfer methods do not require this change its visual properties. In Japan, Phycocyanin from spirulina is used as a natural blue pigment for coloring foods. Plus, you're still in debt Because of its antioxidant properties, pure phycocyanin is used as immunoassay, microscope, and cytometry. Moreover, this has been proven Spirulina is a therapeutic agent for hyperlipidemia. Therefore, it may be possible to use the medicine in the future Spirulina has many health-related benefits. Maybe It is possible to increase the production of some products Compounds like beta-carotene in spirulina are inherited from the genes project A clinical study in humans showed that burning Spirulina Water Extract is high in Phycocyanin Interferon production and Nk cytotoxicity (cancer cells) when taken orally [19].

Lorenz [20] reported that spirulina contain active c-phycocyanin Other pigments capture light energy Switch to chlorophyll a. This is spectrophotometry A good technique for taking and measuring c Phycocyanin composition of Pacific Spirulina. Sierra Romy and Ricardo Gonzalez[21] Phycocyanin was tested for its antioxidant properties. They used human red blood cells to investigate Antioxidant properties of phycocyanin. The products they deliver Effect of phycocyanin on hemolysis Peroxyl radicals in human erythrocytes, it seems This is due to the elimination of free radicals liquid phase. It inhibits lipid peroxidation, similar to Vitamin E and ascorbic acid. Noam Adil et al. [22] studied crystal formation The light-harvesting phycobiliprotein, c-phycocyanin From the thermophilic cyanobacterium Synechococcus vulcanus identified by molecular replacement as Estimate 2.5 A°. This glass belongs to the space group R32 Battery parameters a = b = 188.43 A°, c =61.28 A°, α= b =90°, γ=120°, one monomer (ab) in a symmetrical structure. units. The structure has been processed for R crystallography factor 20.2% (24.4% without R factor), total data 2.5 A°. Crystals grown from phycocyanin (αβ)3 (αβ)6 hexamer trimers are formed in crystals Similar to other phycocyanins. Minkova et al. [23] Purified C-Phycocyanin Treatment of Spirulina (Arthrospira) fusisormis by multi-step treatment Mix the crude extract with Rivanol in a certain ratio (v/v) and 40% saturated ammonium sulfate. After the cancellation Rivonal gel filtered with Sephadex G-25 (pigment) Dilute the solution with 70% ammonium sulfate. After the final purification step, C-phycocyanin is obtained. Emission and absorption maxima at 620 and 650 nm are 4.3, respectively, with an absorption ratio A620/A280, which corresponds to a pure protein. Homogeneity is Tried with sodium lauryl sulfate-polyacrylamide Gel electrophoresis produces two molecular weight bands 19 500 and 21 500 kDa, corresponding to subunits a and b A pig. C-phycocyanin production Content in crude extract: 46%. Jose et al. [24] Astaxanthin extract and Mass extraction of phycocyanin from microalgae And use oxygen. Microalgae samples It was hit with a cutter and ground using the dry method Ice (solid carbon dioxide). Haematococcus extract An analysis was conducted by liquid chromatography using astaxanthin (purity98%) as standard. Phycocyanin is not very soluble Carbon dioxide is released indirectly. Therefore, it is fat soluble The substances in spirulina are extracted and analyzed by the following method Liquid chromatography. Maximum overall recovery rate Astaxanthin, calculated based on primary and residual content Algae (0.0147 and 0.0004) is more than 97%, for Extraction of phycocyanin, and addition of co-solvent (10 mass % ethanol) has a significant effect on the extraction rate Lipid substances. The total number of withdrawals is about 3 Many%. Noam Adil et al. Crystal structure [25] New forms of C-phycocyanin, perhaps The association between the nucleus and the stem of phycobilisome A New c-phycocyanin compounds from thermophilic plants Cyanobacteria

Thermosynechcoccus vulcanus, and The wavelength is blue-shifted to 612 nm (PC612), and allophycocyanin is purified and crystallized. Here The crystal belongs to the P63 space group and has a unit cell size with a single monomer in the symmetry unit, results At a metal content of 65%, it varies by 2.7A°. Here The crystal structure of PC612 has been determined molecularly It is replaced and refined into a crystalline R factor 20.9% (no R - 27.8%). Zhang et al. [26] C-phycocyanin and Isolation and purification of Allophycocyanin from Spirulina Extraction of Bacillus platensis using ammonium sulfate and ion precipitation exchange chromatography Now rail analysis Chromatography. Pure C-phycocyanin and allophycocyanin The final value of A260/A280 is 5.06, A655/A280 scores are 5.34. Zhang Ying et al. [27] studied the spectrum Characterization of glutaraldehyde-treated phycobilisomes The results showed that glutaraldehyde was effective prevent phycobilisome due to dilution Separation and retention of energy in phycobili exchange. Badrish et al. [28] reported that phycocyanin is The main phycobiliprotein is produced by cyanobacteria, however There are only a few strains that can be played well the report said. Through the extraction of phycocyanin Freeze and pure cycle in a three-step process: Ammonium sulfate fraction, Sephadex G-150 preparation DEAE Cellulose Ion and Exclusion Chromatography Transfer chromatography. Silver et al. [29] c-Phycocyanin test It is extracted from the blue algae Spirulina Optimization using factorial design and response plots technology. Effect of temperature and biological solvent The ratio of phycocyanin concentration to pure extract is Conduct assessments to determine optimal conditions Phycocyanin extract. Best practices Phycocyanin extraction from Spirulina platensis High bio to solvent ratio, 0.08g/mL/1, 250°C. Under these conditions, the phycocyanin concentration was 3.68 mg.ml/l and the purity ratio (A615, A280) was 0.46.The experiments of Narayan and Raghavarao [30]. Direct-phase water extraction Bottom Spirulina cell homogenate C-phycocyanin processing. This can be included Process for extraction, extraction and concentration Single unit operation for two-phase water extraction. Effect of different parameters like molecular weight Bond line length, volume ratio and neutral salt (NaCl) Study Using the PEG 4000/Potassium Phosphate System Choose the best between the PEG 4000/sodium sulfate systemsystem between two. Zhu et al. [31] performed the extraction c By spreading phycocyanin on fresh spirulina Non-pathogenic nitrogen-fixing bacteria, viz. Klebsiella pneumoniae. The moss has not been cleaned Also do not centrifuge; pour the bacterial culture into it slurry, container lid, and crude C-PC extract About 24 hours. Simple and effective download, The purity and concentration of C-PC were shown to be correct quality.

Asha Palmer et al. [32] Extraction, purification and Determination of C-phycocyanin using a new method One-step analysis and chromatography. protein It is extracted from freeze-thaw cycles, the crude product The extract was filtered and concentrated into a stirred ultraconcentrate UFC Fight Night. Due to the UFC concentration only one ion exchange chromatography step is required. One The first value reaches a pure ratio of 4.15 1.05. Recovery rate of C-phycocyanin in oil.

The withdrawal rate is 63.50%. Cleanliness is checked by Electrophoresis and UV spectroscopy. Zhang et al. [33] Get C-phycocyanin Control measures for C-phycocyanin are high Use flow techniques for recovery and cleaning. crude oil Utilization of C-phycocyanin from Spirulina platensis. very good The purification method is ammonium sulfate fractionation The amount is 0-20%/20-50% compared to others. below Under these conditions, there is only one step of purification, namely purification 70% increase on original download It is 83.8%.

REFERENCES:

[1] Vonshak A. Spirulina platensis (Arthrospira) Physiology, Cell-biology and Biotechnology. Taylor & Francis, London, 1997.

[2] Campanella L, G Crescentini and P Avino. Chemical composition and nutritional evaluation of some natural and commercial food products based on Spirulina Analysis, 27, 1999, 533-540

[3] Harriet Volkmann, Ulisses Imianovsky, Jorge LB. Oliveira and Ernani S. Santanna. Cultivation of Arthrospira (Spirulina) platensis in desalinator wastewater and salinated synthetic medium, protein content and amino-acid profile. Brazilian Journal of Microbiology, 39, 2008, 98-101.

[4] Silveira ST, JFM Burkert, JAV Costa, CAV Burkert, SJ Kalil. Optimization of phycocyanin extraction from Spirulina platensis using factorial design. Bioresource Technology, 98, 2007, 1629-1634.

[5] Harriet, Volkmann, Ulisses Imianovsky, Jorge LB Oliveira and Ernani S Santanna. Cultivation of Arthrospira (Spirulina) platensis in desalinator wastewater and salinated synthetic medium, protein content and amino-acid

profile. Brazilian Journal of Microbiology, 39, 2008, 98-101.

[6] Silveira ST, JFM Burkert, JAV Costa, CAV Burkert, SJ Kalil. Optimization of phycocyanin extraction from Spirulina platensis using factorial design. Bioresource Technology, 98, 2007, 1629-1634.

[7] Farrar WV. Algae for Food. Nature, 211, 1996, 341-342.

[8] Orio Cifferi. Spirulina, the Edible Microorganism. Microbiological Reviews, 47, 1983, 551-578.

[9] Susan Spiller, Greg Denbeaux, Gideon Jones and Angelic Lucero Pearson. Fine structure of Cyanobacteria, Spirulina platensis and Spirulina subsalsa, as viewed by X-ray microscope, XM-1, beamline 6.1.2. Susan Coates Spiller, Department of Biology, Mills College, 1999.

[10] Harriet, Volkmann, Ulisses Imianovsky, Jorge L.B. Oliveira and Ernani S. Santanna. Cultivation of Arthrospira (Spirulina) platensis in desalinator wastewater and salinated synthetic medium, protein content and amino-acid profile. Brazilian Journal of Microbiology, 39, 2008, 98-101.

[11] Bohra, F. Role of light and photosynthesis on the acclimation process of the cyanobacterium Spirulina platensis to salinity stress, 1996.

[12] Usharani GP, Saranraj and D Kanchana. In vitro cultivation of Spirulina platensis using Rice mill effluent. International Journal of Pharmaceutical and Biological Archives, 3(6), 2012, 1518 – 1523.

[13] Pinero, M., K.H. Baasch and P.Pohl. Biomass production total protein, chlorophyll, lipids and fatty acids of freshwater green and blue–green algae under different nitrogen regimes. Phytochemistry, 23, 2001, 207–216.

[14] Iijima N, S Jensen and G Knutsen. Influence of light and temperature on photoinibition of photosynthesis in Spirulina platensis. Journal of Applied Phycology, 5, 1982, 495–504.

[15] Roamy G. The mass culture of spirulina platensis (nordstedt) geiteler in kitchen wastewater and fermented solution of oil extracted soybean. 31st Congress on Science and Technology of Thailand at Suranaree University of Technology, 2003, 18 20.

[16] Cifferi O. Spirulina. The edible microorganism. Microbial. Revs, 47(4), 1983, 551-578.

[17] Pinero M, KH Baasch and P Pohl. Biomass production total protein, chlorophyll, lipids and fatty acids of freshwater green and blue–green algae under different nitrogen regimes. Phytochemistry, 23, 2001, 207–216.

[18] Iijima N, S Jensen and G Knutsen. Influence of light and temperature on photoinibition of photosynthesis in Spirulina platensis. Journal of Applied Phycology, 5, 1982, 495–504.

[19] Hirahashi BL, S Sato and E Aguarone. Influence of the nutritional sources on the growth rate of cyanobacteria. Arquivos-de Biologia-Technologia, 34, 2002, 13–30.

[20] Lorenz SJ. Principles of Microbe and Cell Cultivation. Blackwell Scientific Publications, Oxford, London, 1998.

[21] Cheyla Romay, Nuris Ledon and Ricardo Gonzalez. Effects of Phycocyanin Extract on Prostglandin E2 Levels in Mouse Ear Inflammation Test. Arzeim.Forsch./Drug Res, 50, 2000, 1106-1109.

[22] Noam Adir, Yelena Dobrovetsky and Natalia Lerner. Structure of c-phycocyanin from the thermophilic cyanobacterium synechococcus vulcanus at 2.5 aê, structural implications for thermal stability in phycobilisome assembly. Journal of Molecular Biology, 313, 2001, 71-81.

[23] Minkov B, BD Kaushika and R Prasanna. Formulation of a low-cost medium for mass production of Spirulina. Division of Microbiology, Indian Agricultural Research Institute, New Delhi 110 012, India and the Centre for Conservation and Utilization of Blue–Green Algae, Indian Agricultural Research Institute, New Delhi, 110 012, India, 2003.

[24] Jose O. Valderrama, Michel Perrut. Extraction of astaxanthine and phycocyanin from microalgae with supercritical carbon dioxide. Journal of Chemical Engineering Data, 48, 2003, 827-830.

[25] Noam Adir, Yelena Dobrovetsky and Natalia Lerner. Structure of c-phycocyanin from the thermophilic cyanobacterium synechococcus vulcanus at 2.5 aê, structural implications for thermal stability in phycobilisome assembly. Journal of Molecular Biology, 313, 2003, 71-81.

[26] Zhang, Xiu Lan Chen, Wei Liu, Yu Zhong Zhang and Bai Cheng Zhou. The stabilization effect of glutaraldehyde on the Spirulina platensis. phycobilisomes, 5, 2004, 1083-1086.

[27] Ying Zhang, Si-Yuan Guo, Lin Li. Study on the process, thermodynamical isotherm and mechanism of Cr(III) uptake by Spirulina platensis. Journal of Food Engineering, 75, 2004, 129 –136

[28] Badrish, Beena Kalavadia, Ujjval Trivedi and Datta Madamwar. Extraction, purification and characterization of phycocyanin from Oscillatoria quadripunctulata—Isolated from the rocky shores of Bet-Dwarka, Gujarat, India. Process Biochemistry, 41, 2005, 2017-2023.

[29] Silveira ST, JFM Burkert, JAV Costa, CAV Burkert, SJ Kalil. Optimization of phycocyanin extraction from Spirulina platensis using factorial design. Bioresource Technology, 98, 2006, 1629-1634.

[30] Narayan, A.V and Raghavarao. Extraction and Purification of C-Phycocyanin from Spirulina Platensis Employing Aqueous Two Phase Systems. International Journal of Food Engineering, 3(4), 2007, 16.

[31] Zhu XB. Chen KB Wang, YX Li, KZ Bai, TY Kuang and HB Ji. A simple method for extracting C-phycocyanin from Spirulina platensis using Klebsiella pneumonia. Applied Microbiology and Biotechnology, 74, 2007, 244–248.

[32] Asha Parmer N, P Noor, MAA Jahan and MM Hossain. Spirulina culture in Bangladesh. V. Comparison of rice husk ash and sodium bicarbonate as source of carbon feed back in Spirulina culture. Bangladesh. Journal of Science and Research, 31, 2008, 137–146.

[33] Henrikson SJ. Principles of Microbe and Cell Cultivation. Blackwell Scientific Publications, Oxford, London, 1994.

[34] Shklar and Schwartz. Semicontinuous cultivation of the cyanobacterium Spirulina platensis in a closed photobioreactor. Brazilian Journal of Chemical Engineering, 23(1), 1988, 23-28.