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Blue – Green Revolution: The Art of Spirulina Cultivation

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Spirulina, also referred to as blue-green algae, is a kind of cyanobacterium bacteria that can thrive in both fresh and saline water. It uses the process of photosynthesis to generate energy from sunlight, just like plants do. It develops and flourishes in rivers and ponds with warm, alkaline water. The scientific name for domesticated spirulina is Crocus sativus L and belongs to Iridaceae family. In human diet, one of the key elements is protein. Spirulina is among the greatest possible protein sources. Commercially, spirulina is cultivated with this protein in a large-scale culture system to use in both human and animal nutrition. Spirulina grows at an extremely rapid rate and has a protein content ranging from 40% to 80%. It can grow in tropical places with any climate and needs less land and water for growth. Wet or dry spirulina is utilized as a supplemental food element in commercial aquacultures that raise fish, prawns, and animals.

Spirulina are blue-green, unicellular filamentous algae that are coiled into spirals with a distinct amount and tightness, each measuring roughly 0.1 mm in length. It grows quickly in surroundings with enough minerals, high nutrient content, poor nucleic acid content, and high vitamin and mineral concentrations. It is utilized as a possible source of fuel, feed, and food in developing countries. It is grown on a big scale in controlled environments and clean waters for human consumption; it can also be grown in wastewater and used as animal feed.

Health Benefits of Spirulina

- Improves health of the digestive system.
- Improves muscle strength and endurance.
- Boosts brain energy as it increases Ribonucleic acid.
- Effective against anaemia.
- Anti-aging property.

- Appears to have anti-cancer properties and works well against oral cancer.
- Contains antioxidant and anti-inflammatory properties.
- It is good for the heart as it can lower LDL and triglyceride levels.
- Stops LDL cholesterol in becoming oxidized.
- Spirulina contains many nutrients in high concentrations.
- Controls inflammation in the nasal airways (allergic rhinitis symptoms).
- Useful for HIV patients as it strengthens the immune system.
- In animals, its use resulted in lowering of blood sugar levels.
- A tablespoon of spirulina contains:

1. 4 grams of protein
2. Vitamin B1 (Thiamin11 % of RDA)
3. Vitamin B2 (Riboflavin 15% of RDA)
4. Vitamin B3 (Niacin 4% of RDA)
5. Copper (21% of RDA)
6. Iron (11% of RDA)
7. Omega-6 & Omega-3 fatty acids (about 1 gram)
8. Manganese, Potassium, and Magnesium.

Growing Conditions of Spirulina

1. **Climate:** Large-scale and commercial spirulina production is best suited for tropical and subtropical climatic zones. It needs sunlight all year round. Spirulina development and production are influenced by a number of variables, including wind, rain, temperature changes, and sun exposure.
2. **Temperature:** The best temperature to have both high production and high protein content is between 30° and 35° C. Spirulina can withstand temperatures ranging from 22° to 38°C, although it will lose some of its protein content and colour. Cultures will be bleached at temperatures over 35°C as well as they cannot live at temperatures below 20°C.
3. **Light:** A significant factor in spirulina growth is light intensity. Spirulina's protein content, growth rate, along with pigment synthesis are all directly impacted by light. It has been discovered that 20 to 30 K lux of light is optimal for spirulina cultivation. The experiment was conducted over a 10-hour period at 2 K lux with varying light colours. The results showed that blue light produced the highest protein content, followed by yellow, white, red, and green light.
4. **Water Quality:** Blue-green algae develop naturally in a close culture medium, which must be replicated in commercial spirulina farming. The primary growth medium for spirulina is water. All the nutrients required for spirulina to grow healthily should be present in water. By supplying a regulated salt solution in the water, the optimal water quality should be preserved during the mass production of microalgae. It is recommended that culture media have a pH of approximately 8 to 11. Pits and tanks should have controlled water levels. All organisms rely on the water level to carry out the process of photosynthesis. Algal growth will be impacted by decreased solar penetration as water depth increases. The ideal height of water in the tanks for the good production of spirulina is 25 cm.

The chemical composition of the culture medium is as follows:

Chemical Component	Concentration (grams per liter)
Sodium Hydrogen Carbonate ($NaHCO_3$)	8.0
Sodium Chloride (NaCl)	1.0
Potassium Nitrate (KNO_3)	2.0

Hydrous Magnesium Sulphate ($MgSO_4.6H_2O$)	0.16
Ammonium Phosphate ($(NH_4)_3PO_4$)	0.2
Urea ($CO(NH_2)_2$)	0.015
Sulphate Hepta hydrate ($FeSO_4.6H_2O$)	0.005
Iron Potassium Sulphate (K_2SO_4)	1.0
Calcium Chloride Dihydrate ($CaCl_2.2H_2O$)	0.1
Ammonium Cyanate (CH_4N_2O)	0.009

Precautions to be taken while culturing the Spirulina

1. **Stirring:** Spirulina is a photosynthetic organism. Sunlight must be provided continuously for the spirulina to grow at its fastest rate. The top surface experiences the lightest during farming, while the bottom surface experiences the least. As a result of the varying light intensities in the various water layers, the spirulina on top of the culture will grow more quickly than the ones below, and the spirulina that is at the bottom may occasionally even perish. To have the best possible development rate and maximum production, the culture must be continuously shaken. This enables uniform photosynthesis and aids all organisms reach the very top of the culture. Both mechanical and manual stirring are possible. In mechanical stirring, paddle wheels and pumps on solar electricity are used. During manually stirring, the utmost caution should be exercised. A stick, broom, or any other handy object can be used. Stirring must be done in a single direction, slowly in circles. During manual stirring, only once every two to three hours stirring is done in a day. After every stirring, the instruments are carefully cleaned.
2. **Avoid contamination:** Spirulina production output will be directly impacted by contamination of the culture medium. Chemical contaminants, alien algae, or insect reproduction are the three possible sources of contamination. Chlorine, in any amount, will destroy the algae growth in the water. Mosquito and other insect larvae consume algae, which results in a 10% reduction in overall production. Spirulina production will completely cease as a result of above factors. Both the amount and quality of spirulina will be contaminated during harvesting if there are any larvae or pupae present. An exquisite wired mesh frame can be used to eliminate any unnecessary components from the culture media.

Spirulina Cultivation and Production

- **Natural Habitat:** Among the many types of algae that can be seen thriving in natural freshwaters is spirulina. Additionally, they can be found in natural environments including brackish waters with alkaline waters, soil marshes, and the ocean. They do best in extremely alkaline, intensely solar-radiated waters that are inhospitable to other microbes. Additionally, they can withstand lows of 15°C at night and 40°C for a brief period of time during the day. Their growth cycles in their native habitats are reliant on the finite amount of nutrients available. The algae develop quickly and reach their maximum density of population when fresh nutrients from rivers or pollution enter the bodies of water. The spirulina dies off when its nutrients run out, sinks to the bottom, and decomposes, releasing nutrients into the water. More nutrients entering the lake or pound start a fresh cycle of spirulina.
- **Commercial and Mass Cultivation:** In the early 1960's, Japan started large-scale culture cultivation of microalgae of chlorella followed by spirulina in the early 1970's. Today, there are more than 22 countries that cultivate spirulina commercially on a large-scale.
- **Ponds:** Commercial cultivation is usually carried out in shallow artificial ponds equipped with mechanical paddle wheels for stirring the culture. The cultivation is carried out in two ways. i.e. Concrete ponds and Pits lined with PVC or other plastic sheets. Concrete

ponds can last for very long time with mass cultivation, but it is very expensive. The cost of production in the early years will be high. Low-cost clay sealing and durable plastic sheets will not last long, but incur investment at regular periods when the materials start to wear and tear. Concrete ponds will be more cost-effective in the spirulina business over the years while low-investment structures will be more expensive in the business over the years. Ponds can be of any size and shape depending on the physical land dimensions. The ideal pond conditions for construction of single or multiple ponds can be done with each pond size of 50 m long, 2-3 m wide and with 20 to 30 cm depth. Length of the ponds can be varied depending on the availability of land. Covering of each pond with transparent polythene covers will help increase the temperature, decrease water evaporation, and also helps to reduce the chances of contamination.

- **Stirring Devices:** There are two ways of stirring the culture evenly and they are manual mixing and mixing the culture mechanically. Hand tools, such as long sticks, or broomsticks, or any convenient devices can be used for the manual mixing. Commonly used mechanical devices are paddle wheels, these are installed for stirring the culture. Stirring the culture helps all the organisms reaching to the top that they can take carbon dioxide and solar energy for photosynthesis. Paddle wheels are installed according to the size of the ponds. A large paddle wheel of diameter about two meters should rotate at a speed of 10 rpm. A small paddle wheel of diameter up to 0.7 meters can rotate at a speed of 25 rpm for proper stirring of culture.
- **Process of Cultivation:**   Cultivation can be started after water is fed into each concrete pond at a required height and only after paddle wheels are installed. The water has to have the right pH value and alkaline by adding required salts at the required rate. Once the water has a standard micronutrient composition, the pond is ready for spirulina seeding. To have uniform growth and uniform harvesting, 30 grams of dry spirulina is added for every 10 liters of water. A concentrated live spirulina culture can also be used for seeding the pond. In commercial farms, one pond is exclusively kept for rearing the seed of spirulina. This will reduce the regular purchase and the farm becomes self-sustainable and also can sell live spirulina seed to other farmers. The algae start to double in biomass within three to five days. The algae thrive growing by consuming the nutrients in the culture medium. Farmers have to continually check the nutrient content value and if required, addition of fresh water at regular periods for good production and for better yields. Farmers should also be alert to control environmental conditions as this prevents the culture medium from contamination. Cultures grow rapidly as well as perish rapidly when spirulina cultures are not properly taken care. The matured spirulina changes from light to dark green in colour. The concentration of algae and colour of the algae is the deciding factor for harvestable maturity of spirulina. The other way is by using Secchi disk (or Secchi disc) to measure and it should be around 0.5 grams per liter of culture medium. The water level in the pond should be maintained at 20 to 30 cm (ideal water level is 25 cm height). As most of them are open ponds, the evaporation of water will affect the cultivation. Especially during summer, in order to maintain consistent (25 cm) water level height in the ponds throughout the cultivation, fresh water is released into ponds on an average thrice in a month.

Harvesting of Spirulina

1. **Filtering of Culture Medium:** As stated previously, the concentration of spirulina in the pond will be the deciding factor for harvesting. In general, the pond will be ready for harvest after five days from the date of seeding. Because of the availability or limitation of various resources and finance, different farmers use different methods to harvest spirulina. The principle carried out to harvest spirulina is the filtration. In the filtration process, culture is collected in a container and poured onto the cloth. The culture medium flows back into the pond, leaving spirulina on the cloth. The excess culture medium residues that still remains can be drained by applying pressure or squeezing it. Farmers have designed various filtering process for the easy and quick process. After filtering, the collected spirulina is thoroughly washed in distilled water to remove any traces of salts, contaminants, or any residues of the cultured medium. Once the cleaning is done, the water content is further removed by squeezing or pressing and finally, it is ready for drying. Freshly harvested spirulina will be at its best in its nutritional values. Fresh spirulina cannot last more than two days, hence it needs to be dried to preserve its nutritional values and to last for a longer duration.

2. **Drying of Fresh Spirulina:** Spirulina, if dried will last for many months and the nutritional content present in it can be preserved for longer duration. For quick drying, the spirulina mass is kept inside the kitchen press grater and then pressed into thin strands on a long clean cloth under the sun. This process helps in quick drying. The kitchen press comes with various discs of different hole sizes in it. Use the disc which is comfortable and which will help in quick drying. The spirulina mass is squeezed into thin strands through machines which are used for noodles and are laid in the open sun to dry for a while. Some farmers apply the spirulina mass into a thin layer using a knife over the cloth. Some uses syringe for noodle-like strands. Whatever methods and materials used, shortening the drying period will lessen contaminators. Ovens that run electrically or solar powered can be used for speed drying. The temperature in the oven when maintained at 60° C takes about four hours while 40° C takes about 15 to 16 hours for the drying.

3. **Grinding and Storage:** The well dried strands of spirulina are now ready for grinding. Grinding machines for flour making can be used for grounding of the dried algae. Spirulina is grounded and made into soft powder dust which is then packed with different weights and sealed for marketing. Vacuum dried and airtight packing will preserve the nutritional qualities up to three to four years.

Economics of Spirulina Farming

The estimated economics is to give entrepreneurs a general overview of investment and revenues pertaining to spirulina farming. The economics mentioned below are not actuals but purely for a business understanding. Each pond constructed is of 10 x 20 feet size. For Example, 20 such ponds are used for cultivation. Each pond will generate on an average

about 2 kg wet culture per day. The farmer has to understand this equation that a one kg wet culture will give 100 grams of dry powder only. Based on this, on an average 20 tanks of spirulina farming business will generate 4 – 5 kg of dry spirulina powder on a daily basis. The production of spirulina will be around 100 to 130 kg per month. Dry spirulina powder in the market will fetch about Rs. 600/- per kg. A farmer can earn about 40,000 – 45,000 rupees per month. A farmer can reduce his fixed investment by going for earthen pits covered with durable plastic sheets which can cost him around Rs. 3 – 4.5 lakhs. A farmer can make more profits by increasing tanks made with low-cost, durable materials apart from concrete ponds by utilizing maximum space available in the land, which will reduce labour and investment with more profits.

Spirulina Quality Specifications

S. No	Particulars	Quality %
1	Moisture	3%
2	Protein	65%
3	Fat	7%
4	Crude Fiber	9%
5	Carbohydrates	16%
6	Energy (100 gms)	346 K Cal
7	Mold & Fungus	Nil
8	Coliforms, Salmonella, Streptococci bacteria and fermented odour	Nil

Tips and Challenges in Spirulina Cultivation

- Maintain uniform nutrient content in the culture medium throughout the cultivation.
- Maintain temperature of the culture medium and 20 – 25 cm level of water height.
- Thorough stirring of culture medium gently in one direction should be carried out once in three to four hours in the daytime.
- Avoid contamination of culture medium.
- Mosquito larva will destroy 10% production by feeding on it.
- The protein content of 65% will fetch market value, to achieve that standard nutrient content in the culture medium should be maintained consistently throughout the cultivation.
- Direct sunlight should be available for healthy growth.
- Freshwater is provided when the pond starts to smell ammonia.
- Thick green layer formation indicates a delay in harvesting.
- Dried spirulina powder is stored immediately in an airtight sachet.