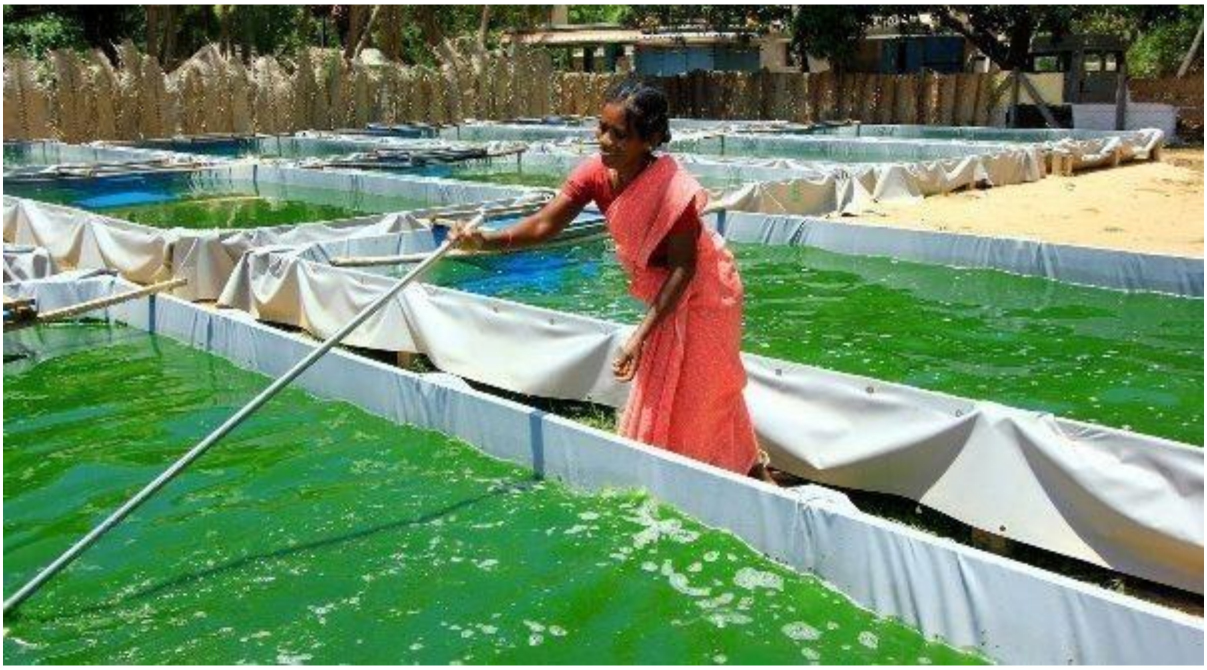
Model Bankable Project on Spirulina Cultivation



NABARD

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1. Introduction

Spirulina, a filamentous blue-green alga, finds worldwide use as a protein supplement in diets of malnourished children and as a medicine in therapeutic preparations. Spirulina production can be undertaken on a small scale at village level and may well contribute in solving the local nutritional requirement in rural areas. It is known to be an age old health food and it has been a part of the diets of ancient Mexicans and Africans. It can grow rapidly, reaching high filament densities in warm, shallow brackish lakes. It is one of the most common and abundant algae in many alkaline saline lakes in Africa and America. it also found in Sambhar Salt Lake of Rajasthan, India.

2. Morphological features

Spirulina is a multicellular, autotrophic, blue-green filament of 1 to 12 µm diameter cylindrical cells in unbranched, helicoidal trichomes. The filaments are motile, gliding along their axis and have no heterocysts. Bai and Seshadri (1986) recognized three distinct morphological variants of Spirulina fusiformis from Madurai (T.N.): (i) an S-type variant with trichomes having more or less regular and distant coils, (ii) a C-type variant with trichomes having a distinct spindle shape with close coils; and (iii) an H type variant with trichomes forming a dumb-bell shape with very close to tight coils. Under high light intensity and nutrient concentration, these distinct types readily transformed from one type to another. There are three predominant species in India namely *Spirulina platensis, Spirulina fusiformis* and *Spirulina maxima*. These belongs to the family Spirulinaceae.

3. Ecology

Spirulina is a ubiquitous organism and can be found in widely differing environments such as soils, marshes, fresh, brackish and sea waters and thermal springs. Typical examples are *S. platcnsis* and *S. maxima*, which grow profusely in certain alkaline lakes in central America and Africa. The example of ideal growth and ecology of Spirulina is found in Lake Chad of Africa. Here it may become the dominant species and it has been used as food since time immemorial. The Lake

Chad is shallow with an average depth of about 3.5 m and the lake area is about 20,000 sq.km. The climate is subdesertic, with a long dry season alternating with a rainy season of about four months. The average yearly water temperature is 27^{o}C with two maxima in June and September. The water pH rages from 7.2 to 9.0 and the water chemistry is dominated by HCO_3, with SO_4^{--} and CI^- occurring only in small quantities. It is known that the higher the salt content and pH of water, the predominance of Spirulina.

4. Nutritional Aspects of Spirulina

Algal proteins are poorly utilized when intact cells are fed to monogastric animals or humans due to their digestibility. Blue-green algae in general, and Spirulina in particular, are unique in that they are highly digestible, and thus, do not require special processing. Spirulina is very suitable as a dietary supplement in dairy and poultry feeds. It has been demonstrated to be a satisfactory source of protein for many animals like cow, buffalo, goat and pig. Spirulina increases the protein content in the milk of cow, buffalo and eggs of hen. It has also a cholesterol-lowering effect.

The nutritive value of Spirulina is amplified in that it is extremely high in vitamin B_{12} and its lipids are made up of unsaturated fatty acids that do not form cholesterol. Spirulina is easily digestible mucoprotein due to the absence of cell wall. These make Spirulina a potential food item for persons suffering from coronary illness and obesity.

In addition to being exceptionally high in protein (60-70% of its dry weight), 8% lipids and 16% carbohydrates and rich quantities of pigments, vitamins and minerals. Spirulina appears to have the highest vitamin B_{12} content of any unprocessed plant or animal food, representing a boon to vegetarian. Two heaped tablespoons of Spirulina (20g), provide all the daily body requirements of vitamin B_{12}, as well as significant quantities of other B-complex vitamins, including 70% of the recommended daily allowance (RDA) for vitamin B (thiamine), 50% for B_2 (riboflavin) and 12% for B_3 (niacin).

Other nutritional attributes of Spirulina include vitamin A and unsaturated fatty acids. Extraction methods could provide high protein power of decoloured Spirulina suitable for widespread uses. The blue water soluble pigment, phycocyanin, may stimulate the immune system, providing protection from a variety of diseases. Epidemiological studies also suggested that high dietary pro-vitamin A (B- carotene) intake decreases cancer risks.

Linolenic acid (an essential amino acid) stimulate prostaglandin synthesis. Clinical studies demonstrate that dietary linolenic acid can help arthritis, heart disease and obesity. Spirulina extracts restored a significant amount of the cholinesterase activity in human erythrocytes (RBC). The consumers of Spirulina have reported several consistent effects. These include the ability to postpone or skip a meal with quantities as little as three. This simple cyno-bacterium has been promoted as a health & slimming food the United Nations' World Food Conference declared Spirulina as the best food for tomorrow as 1 kg. of spirulina consists as much nutrition as of 1000 kg of vegetables.

5. Uses

Spirulina increases lactation in nursing mothers. Existing natural medicinal formulations get a boost with spirulina. Ayurvedic lehias, arishtas and churanas contains spirulina. It is having no side effects and non-habit forming characteristics is sure to find it a place in modern medicines too. This lowers blood sugar levels, cures pancreatitis, hepatitis cirhosis, glaucoma, cataracts, gastric ulcers, night blindness, liver disorders, anemia, etc. Most of all, it is general health medicine. Cosmetics also use spirulina. In view of its rich composition, Spirulina has varied application in medicine as curative and therapeutic agent, in animal, poultry and prawn feed and in cosmetic industries for skin care creams and lotions. It is fed to silkworms to increase silk yield. Fish fed with spirulina put-up weight. Ornamental fishes get bright colouration. It is a soil conditioner too. In view of its varied applications especially in medicine, there is good demand for the product especially from pharmaceutical industry.

6. Market Potential

The multifaceted usage areas enlisted above are more than any attempt to predict the vast potential of marketing this wonder alga processes.

7. Mass cultivation of Spirulina

Mass production of Spirulina requires inexpensive yet reliable enclosures for growing the cultures. In practice, the design of these enclosures represents a compromise between the cost of the investment in relation to the expected returns and the desire to establish conditions for the highest possible output rate.

The basic design presently employed for mass cultivation of Spirulina consists of an oblong shallow raceway stirred with paddles and lined with some plastic sheeting which is low cost but not long last. Whereas concrete ponds are very expensive due to initial investment costs but long lasting. 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 are ideal pond conditions. Based on the land availability, the pond length can be modified. In order to increase the temperature, decrease the water evaporation and also reducing the contamination each ponds can be covered with transparent polythene cover. Areas of the Commercial pond range between 500 and 5000 m^2. These ponds may be open and exposed to the atmosphere or covered with a transparent material. Another form of closed reactor consists of transparent polyethylene tubes. The tubes are placed on the ground and arranged in the form of raceway, the algal-laden medium being circulated by a pump.

The high evaporation increases the costs of water and pumping, but more importantly, it increases the salinity of the medium. The advantage of closed system is a reduction in the amount of dirt and insects contaminating the algal product. The disadvantage of closed system is that light penetration is reduced because most of the commercially available materials used for tubing or for covering are not completely transparent; in addition, dust also accumulates on the outer surface of the covers. The main environmental factors governing the production of Spirulina biomass are nutrients, temperature and light.

7.1 Factors governing the production of Spirulina

7.1.1 Nutrition: High alkalinity is mandatory for the growth of Spirulina, as reflected in the pH optimum for its growth, which ranges from 7.2 to 9.0 Spirulina can tolerate progressive changes in pH; however, the culture may rapidly deteriorate when pH is changed abruptly, as it may happen in a growth medium that is not well buffered. Good buffering capacity for the growth medium is provided by 0.2M $NaHCO_3$. Nitrates are the main nitrogen source assimilated by Spirulina, but ammonium salts may be used as long as the NH^+_4 concentration is less than 100 mg. per litre. Urea can be used with no ill effect at pH 8.4 as long as its concentration is below 1.5 per litre. The addition of 0.1 % (w/v) glucose to the growth medium enhances the growth rate and cell yield. Both Na^+ and K^+ are indispensable in the Spirulina growth medium. Inhibition of growth may occur when the ratio K^+: Na^+ iss>5. Growth is uninhibited even at very high concentration of Na^+ (18g per litre).

7.1.2 Temperature: Tropical and sub-tropical regions are well-suited for Spirulina cultivation. It requires sunshine throughout the year. The growth rate and production depends on various climatic factors such as wind, rain and temperature. The ideal temperature for growth is in between 30° to 35°C. Spirulina can survive in temperatures between 22° to 38° C, however, protein content and colour will be affected. Bleaching of cultures takes place when temperatures are above 35° C and it cannot survive in temperatures less than 20° C.

7.1.3 Light: The intensity of light plays an important role in the growth of Spirulina. Light has a direct effect on protein content, growth rate and pigment synthesis of Spirulina. The light intensity between 20 to 30 K lux is found to be ideal for Spirulina farming. The availability of light to each cell in the cultures is a function of the intensity and duration of light irradiance as well as the population density that affect the extent of mutual shading. The latter is due to the absorbance of the incident light by the algal cells closed to the illuminated surface, thereby decreasing the amount of light available to the cells below. Population density has been found to be a major factor in the production of Spirulina. The higher the density, the lower the potential photosynthetic rate. In ponds, solar irradiation is almost completely absorbed in the upper 4 to 5 cm of the cultures, leaving some 60% of the cells in the pond in complete darkness. In dense mass cultures, the cells are exposed to intermittent radiation, which imposes a light-dark cycle to which the average Spirulina filament is continuously exposed. The relative effect of decreasing the population density, and thus of increasing the rate of light utilization per cell, is most pronounced in summer.

An important point to bear in mind is that, under artificial pond conditions, growth limitation by either temperature or light alone takes place only at its extremes. In practice, the growth rate of microalgae is governed by both temperature and light, and may also be influenced by nutritional factors. It is also reported that the effects of light and temperature on algal growth rates are interrelated.

7.1.4. Construction of Raceways /Ponds: Commercial cultivation is usually carried out in shallow artificial ponds/raceways equipped with mechanical paddle wheels for stirring the culture. Ponds can be of any size and shape depending on the physical land dimensions. Construction of single or multiple ponds can be done. Length of the pond will vary depending on the land availability. Covering of each pond with transparent polythene covers will help increase the temperature, decrease water evaporation, and helps reduce chances of contamination.

7.1.5. Water Quality: The ideal water quality should be maintained throughout the micro-algae mass production by providing a controlled salt solution in the water. The pH value should be maintained between 7 to 9. The water level is important for the photosynthesis process to take place. The deeper the water level, sunlight penetration will be reduced, which will affect algae growth. A minimum shallow level of 20 cm is ideal for production and a composition of Sodium Hydrogen Carbonate (8.0 g/lr), Sodium Chloride (1.0 g/lr), Potassium Nitrate (2.0 g/lr), Hydrous Magnesium Sulphate (0.16 g/lr), Ammonium Phosphate (0.2 g/lr), Urea (0.015 g/lr), Sulphate Hepta hydrate (0.005 g/lr), Iron Potassium Sulphate (1.0 g/lr), Calcium Chloride Dihydrate (0.1 g/lr) and Ammonium Cyanate (0.009 g/lr).

7.1.6. Stirring: Spirulina needs exposure to light and carbon dioxide, as it a photosynthesizing organism. Light is maximum on the top surface, Spirulina that is on top of the culture will thrive well while the ones below have a slow growth rate and the Spirulina that remains at the bottom may die. For maximum production and proper growth rate culture has to be stirred constantly. This helps all organisms reach the top of the culture and photosynthesis takes place uniformly. Stirring can be done manually as well as mechanically. Manual stirring is done with the help of hand tools, such as long sticks or broomsticks or any other convenient device. Stirring should be done in slow circular motions in one direction, once in every two to three hours in daytime. Pump and paddle wheels can be installed for mechanical stirring and can be powered by solar.

7.1.7. Contamination: Contamination of culture medium will have a direct effect on the production of Spirulina. The contamination can happen either by insect breeding, weed/toxic algae or through chemical contaminants. This will lead to a complete loss in the production of Spirulina. Larva of mosquitoes and other insects will feed on algae leading to about an overall 10% decrease in production. At the time of harvesting, the existence of insect's larva or pupae will contaminate the Spirulina quality and yield. All extraneous materials can be removed from the culture medium by using a fine wire mesh frame.

7.2 Cultivation of spirulina mass cultures

The ponds need to be filled with water at a required height. The water has to have the right pH value and alkaline, contain required micronutrients. Spirulina seeding is done once the water has reached a standard micronutrient composition. 30 grams of dry Spirulina can be added for every 10 liters of water for the uniform growth and production. A concentrated live Spirulina culture can also be used as seeding material. In commercial farms, one pond is exclusively kept for rearing Spirulina as seed. The algae start to double in biomass within three to five days. Adequate care has to be taken to maintain the nutrient content, pH value as well as water level. The water level in the pond should be maintained at 20 to 30 cm (25 cm is ideal water level height). As most of the ponds are open the evaporation of water will affect the cultivation. Especially during summer, on an average thrice in a month, fresh water is released into the ponds to maintain consistent (25 cm) water level height throughout the cultivation.

The production process involves culture of the algae in alkaline water medium in ponds. The critical factors affecting production are light, temperature and nutrient supplements. The production flow comprises of the following steps.

Culture Multiplication in Ponds

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Commercial production in ponds (race way design)

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Harvesting of the slurry

↓

Washing to bring down the PH to neutral

↓

Spray drying / Solar drying

↓

Dry powder

7.3 Harvesting of Spirulina

The concentration and colour of the algae are the deciding factor for harvesting. The matured Spirulina changes from light to dark green in colour. Otherwise Secchi desk can be used to measure around 0.5 grams per liter of culture medium. The pond will be ready for harvest after five days of seeding. Culture is collected in a container and poured onto a cloth for filtering. The culture medium flows back into the pond, leaving Spirulina on the cloth. The excess or the culture medium residues that still remain can be drained by applying pressure or squeezing. In some production plants today, a vibrating screen is used for harvesting Spirulina biomass. This machine, however, causes some cell damage due to bruising of the delicate cells. Micro straining is another method that may be used for harvesting Spirulina from pond. After spirulina filtered from culture, distilled water used for washing in order to remove any traces of salts, contaminants, or culture medium residue. A pond of 10’ x 5’x 1.5’ size will produce around 2 kg of wet culture. 1 kg wet culture will give 100g of dry powder.

7.4 Drying of Spirulina

In commercial Spirulina production, drying constitute about 20% of the production cost. The various systems for drying differ both in the extent of capital investment and in energy requirements, and a marked effect on the food value and the taste of the products. Experience with Spirulina production is that the harvested slurry should be well rinsed in distilled, to remove the adsorbed carbonates or any traces of salts, contaminants or culture medium. Once the cleaning is done, the water content is further removed by squeezing or pressing and is ready for drying. Fresh Spirulina cannot last more than 2 days, hence it needs to be dried to preserve its nutritional values and to last for a longer duration. It can be stored at 2°C for several days. The usual method for drying of Spirulina is spray-drying, which yields a very good product for further value addition into pills/ capsule forms. For quick drying, the

Spirulina mass is squeezed into thin strands through machines and are laid in the open sun to dry. Hot air ovens can also be used for drying. Drum-drying also yields a useful product, in the form of flakes of special flavor. Direct drying of the Spirulina slurry in the sun is also feasible Sun-drying is not recommended for preparing an algal product for human consumption, for two reasons

(i) A rather unpleasant odour is associated with sun-drying, due to the slowness of the dehydration process, which enables degradative processes to set in before drying is complete.

(ii) Sun-drying does not include exposure to high heat (upto 120°C for a few seconds as in drum-drying) and may thus exhibit a higher bacterial count. In India, scientists of institutes like National Botanical Research Institute (NBRI), Lucknow and Central Food Technology Research Institute (CFTRI), Mysore are engaged in the mass cultivation of Spirulina.

7.5. Bureau of Indian Standards: For human consumptive use, BIS has prescribed spirulina food grade specification under IS 12895: 1990.

7.6. Grinding and Storage: The well-dried strands of Spirulina are ground into fine powder and packed in airtight containers. This will preserve the nutritional qualities up to two to three years.

8. Indicative Cost of Production and Economics of Spirulina

Total cost of the model bankable project has been arrived at Rs. 1287500/- for covering 20 ponds (each pond size 20ft x 10 ft x 1.5 ft) for spirulina production. The model bankable project includes recurring cost (Chemical inputs and labour cost) of Rs. 20,000/- per month which has been capitalized. For the remaining eight months in a year, details has been included cash flow. Further regarding mother culture, capital cost has been considered only once over the project period of six years. The details of investment cost, financial analysis and repayment schedule is given in the Annexure.

Annexure

Indicative Cost of Production and Economics of Spirulina

Farming Assumptions

Number of Ponds	20
Size of Pond	20ft x 10 ft x 1.5 ft
Yield per pond per month (@200g of dry powder per day per pond)	6 Kg
First year production period (in months)	7
Subsequent years production period (in months)	9
Average sale price per kg (Rs)	550

Cost of Investment

S.NO.	Item of Investment	Cost (Rs)
1.	Pond Construction @ Rs 50,000/ pond	1000000
2.	Water Treatment Plant	150000
3.	Plumbing Works	25000
4.	Electrical Works	15000
5.	Plant & Machinery	15000
6.	Tools & Equipments	5000
7.	Harvesting Screens	5000
8.	Drying Screens	10000
9.	Miscellaneous	2500
10.	Mother Culture@ 4 kg per pond @Rs 500 per kg*	40000
11.	Chemical Inputs per month*	2000
12.	Labor Cost per month*	18000
Total Investment Cost*		**1287500**

* Recurring cost for one month capitalized

Total Financial Outlay 1287500

Margin (10%)	128750
Bank Loan	1158750
R.O.I	12%

Financial Analysis

Amt. Rs.

Particulars	Yr I	Yr II	Yr III	Yr IV	Yr V	Yr VI
Investment Cost	1287500					
Recurring cost	160000	180000	189000	198450	208373	218791
Total Cost	1447500	180000	189000	198450	208373	218791
Returns	462000	594000	594000	594000	594000	594000
Net Profit	-985500	414000	405000	395550	385627	375209
NPV @15%	Rs 3,02,476.20					
IRR	29%					

Repayment Schedule

Amt. Rs.

Year	**Loan outstanding at the**		**Repayment**				**Surplus after debt servicing**
	Beginning of the year	**End of the year**	**Net Income**	**Principal**	**Interest on term loan**	**Total outgo**	
1	1158750	1158750	302000	0	139050	139050	162950
2	1158750	927000	414000	231750	139050	370800	43200
3	927000	695250	405000	231750	111240	342990	62010
4	695250	463500	395550	231750	83430	315180	80370
5	463500	231750	385628	231750	55620	287370	98258
6	231750	0	375209	231750	27810	259560	115649

Repayment Period - 6 years including 1-year grace period

DISCLAIMER

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