SPIRULINA GROWTH OPTIMIZATION IN THE EGYPTIAN COASTAL ENVIRONMENT

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ABSTRACT

Spirulina is one of the most important species of algae due to its different benefits, Spirulina can be used as a food source for human, animals and aquaculture especially in the coastal area. Also, Spirulina can be used in many pharmaceutical products and can be used as compost for plant growth, on other hand Spirulina has a great positive impact on the surrounding environment because it consumes carbon dioxide from the air during its photosynthesis processes and produce oxygen. In this paper we established an algae unit adjacent to the aquaponic system inside Heliopolis university campus, by the help of the fresh water that resulted from the RO unit inside the aquaponic system we were able to breed the Spirulina which is a rich source of protein and can be used a source of fish food inside the aquaponics system, the suitable media and the adequate growth condition in the Egyptian environment were investigated, that were done by using three different media and for each media growth rate was observed. We found out that the most suitable medium for Spirulina growth rate in the Egyptian coastal environment was Zarrouk medium rather than the other medium. At the end of this study different charts were yielded, a group of recommendations were deduced in order to give reliable guidelines for other researchers.

Key words: Coastal zone, Spirulina, Egyptian environment, Algae growth

Spirulina Growth Optimization in the Egyptian Coastal Environment

1. INTRODUCTION

1.1. Coastal Environment

The northern coast of Egypt extends for about 1,050 km along the Mediterranean Sea from Rafah Town in the east to Salloum Town in the west as shown in figure 1[1]. The Nile delta coast is a very important sector of the Egyptian northern coast which extends for 240 km from Alexandria to Port Said and this region is of highly population almost 1600 capita per square kilometer, the northern coast include many important cities such as Alexandria, Port Saied, Marsa Matruh, Rosetta, Damietta, Arish and Rafah. This coast contributes by large section of the Egyptian economy such as tourism, fishing, commercial goods trading through ports, agriculture and industrial activity[2].

Figur 1 The Egyptian northern coast map [3].

There are five large lakes that constitute almost 25 percent of the total Mediterranean wetlands, those lakes are Manzala Lake, Maryut Lake, Bardawil Lake, Edko Lake and Borolus Lake. This Egyptian northern coastal zone has many economical activities such as industrial activity, agriculture, fisheries and tourism, the industrial activities include petroleum and chemical production. Lives Within 100 kilometers of the coast there are almost 53 % of Egypt’s population living there, on the northern coast there are many harbors such as Alexandria port, Damietta port and Port Saied port that contributes large portion of the Egyptian trading and transportation networks, the Egyptian coastal zone share 9 percent of the Middle East and North Africa economic zone[1].

The Major coastal zone management issues in Egypt are Protection against shore line erosion, Land stress, land degradation, Sea water intrusion, soil salinization, environmental pollution and Climate change effect, climate change will affect on the coastal zone by negative impacts such as sea level rise, sea water intrusion, environmental pollution, land stress, economic depression, ecosystem degradation, population displacement and the decreasing in agriculture production, the coastal zone climate is considered to be suitable for many typical Mediterranean flora and fauna on land and in marine life because it is moderately hot and humid, while the winters moderately wet and mild, the Temperatures range between a daily mean average of 9.5 °C in winter and 26.3 °C in summer as shown in figure 2, while the average relative humidity is of 66.54 % in winter and 71 % in summer as shown in figure 3, the mean daily sunshine hours is of 6.8 in winter and 12.78 in summer as shown in figure 4[4].
Figure 2 The daily mean average temperature

Figure 3 The relative humidity

Figure 4 Mean daily sunshine hours
2. THE STUDY CASE

The main idea for this project was to find the possibility of breeding spirulina in fresh water that resulted from the reverse osmosis unit inside the Heliopolis University aquaponics. Heliopolis university aquaponics system consists of two main units the greenhouse and the algae unit, the algae unit system consists of tanks, piping network, stirring devices work spaces and storage units as shown in figure 5.

![Figure 5 The Algae unit system](image)

This algae unit was added to the main aquaponics system to increase the added value of the whole system, the reason for choosing spirulina to breed it in algae unit is due to its economic benefits, this type of fresh water algae can be used as source of protein for both human and animals in coastal region that may suffer from food availability in the future under the effect of climate change scenarios.

Also the algae is a source of many pharmaceutical products and can be considered as rich source of vitamins, the algae has a positive impact on the surrounding environment because it absorbs carbon dioxide from air and produce oxygen instead of it, this will improve the air quality and will decrease greenhouse gases emissions which is responsible for climate change effect especially in the coastal zone. Through this paper we were able to adopt the spirulina algae in lab by using different medium to find out the most optimized one, according to lab experiments results that will be discussed later, after that we transferred the spirulina from the lab flasks to the algae tanks that filled with the suitable medium inside the algae unit beside the Heliopolis university aquaponics.
3. SPIRULINA
Spirulina is blue-green algae that grow in the alkaline medium and its protein is complete due to containing all essential and no essential amino acids as shown in figure 6. Spirulina is a type of blue-green algae that absorbs the sun’s rays to produce nutrients and convert carbon dioxide into oxygen. It is one of the oldest foods on our water planet, it is alkaline food that maintains the pH of the body in perfect equilibrium around 7.2 - 7.4, Its Scientific classification can be shown in table 2 [5],[6].

![Figure 6 Spirulina](image)

**Table 1** Scientific classification of Spirulina[5],[6].

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Class</th>
<th>Order:</th>
<th>Family</th>
<th>Genus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanophyta</td>
<td>Cyanophyceae</td>
<td>Oscillatoriales</td>
<td>Oscillatoriaceae</td>
<td>Spirulina platensis</td>
</tr>
</tbody>
</table>

3.1. Spirulina Benefits
1-Weight loss: Eating an aspirin tablets an hour before the meal (especially lunch and dinner) helps to saturate and reduce their food intake.
2-People with anemia: Spirulina is an ideal dietary source for those who take their first steps towards healing as they are rich in nutrients and minerals, especially iron, which increase the speed of healing.
3-Useful for the growth of infants, children and adolescents: they are very rich in vegetable protein, vitamin B complex, calcium, iron and magnesium.
4-Useful for pregnant and lactating mothers: During pregnancy, mothers need more nutrients to feed their infants and fetuses. Vitamin B, for example, is useful in folic acid in the development of the fetal brain, while calcium, iron and magnesium contribute Nutrients lost during motherhood.
5-Useful for the elderly: Spirulina is a substance rich in carotene, which is an anti-oxidant, which delays the symptoms of aging, besides it is useful in reducing the risk of osteoporosis because of the presence of calcium.
6-Anticancer: Spirulina contains many amino acids and vitamins [8].

3.2. Effects of Environmental Factors on Spirulina Strains
The effect of temperatures:[9] stated that pigment content gradually increased up to 35 °C but reduction in pigments was observed with further increase in temperature. Cultures grown at 35 °C showed the highest chlorophyll as a percentage of dry weight (1.54 %) was observed at 35 °C, while the maximum carotenoid accumulation (.27 % of dry weight) was observed as
the same temperature. On other hand minimum growth was observed at 20 °C as shown in figure 7.

The effect of light intensities: [9] stated that 2,000 lux light intensity was found optimum for pigment accumulation. Chlorophyll a was maximum (1.5 % of dry weight) at 2,000 lux light intensity as shown in figure 8. But on other hand carotenoid/chlorophyll value (0.181) was found maximum at 3,500 lux due to the effect of light irradiance level increasing.

**Figure 7** Effects of temperature on Strains [9]

**Figure 8** Effects of light intensities on Strains [9]
4. EXPERIMENTAL STEPS
The Spirulina was first adopted in distilled water media in our lab before adopting it in the algae unit water, the water media to be suitable for the chosen Algae must satisfy many different parameters as follows:

- Luminosity (photo-period 12/12, 4 luxe)
- Temperature (30 °C),
- Inoculation size,
- Stirring speed,
- Dissolved solids (10–60 g/litre),
- pH (8.5–10.5),
- The presence of micronutrient such as (C, N, P, K, S, Mg, Na, Cl, Ca and Fe, Zn, Cu, Ni, Co, Se).

In our laboratory experiments Spirulina was cultured in three different fabricated medium, three different types of strain medium were tested for their effects on the growth of Spirulina, the first type was (Zarrouk) which contains of 5 ML Algae in media of 100 ml of (Zarrouk medium)[10], the second type was (BG-11) which contains 5 ML Algae in a media consists of 100ML of (BG-11 medium)[11], the third type was (CFTRI) which contains 5 ML Algae in a media consists of 100 ML (CFTRI )[12].

![Figure 9 Spirulina cultivation in medium](image)

Media and nutrients were sterilized. All glass and plastic ware were washed with 10% HNO3 and rinsed with distilled water. The cultures were illuminated with continuous cool white fluorescent lamps (Philips 40 W) at light intensity provided with controlled temperature and light intensity as shown in figures 9.
This allowed us to adopt it in the chosen optimum medium after satisfying the desirable conditions according to the experimental results that will be discussed later. This step was followed by algae mass production in order to place it in the Algae unit basin as shown in figures 10.

It was concluded that adaptation was successful when green growth was obvious by naked eye and under the microscope as shown in figures 11.

**Figure 10** Cultivation of Spirulina  
**Figure 11** The microscopic image of Spirulina

### 4.1. The Growth Medium

The three fabricated growth medium (Zarrouk), (BG-11) and (CFTRI) for the Algae depends on different parameters such as temperature, Light, mixing, odor, oxygen, Nutrients and the Planned Cultivation structure. In our lab we formed cultivation media for the Spirulina as shown in tables (2), (3) and (4).

**Table 2** Optimized cultivation media for Spirulina cultivated in HU experiments (Zarrouk growth medium) [10]

<table>
<thead>
<tr>
<th>Item number</th>
<th>Item</th>
<th>Amount (g L(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NaHCO(_3)</td>
<td>16.8</td>
</tr>
<tr>
<td>2</td>
<td>K(_2)HPO(_4)</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>NaNO(_3)</td>
<td>2.5</td>
</tr>
<tr>
<td>4</td>
<td>K(_2)SO(_4)</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>NaCl</td>
<td>1.00</td>
</tr>
<tr>
<td>6</td>
<td>MgSO(_4), 7H(_2)O</td>
<td>0.20</td>
</tr>
<tr>
<td>7</td>
<td>CaCl(_2)</td>
<td>0.04</td>
</tr>
<tr>
<td>8</td>
<td>FeSO(_4), 7H(_2)O</td>
<td>0.01</td>
</tr>
<tr>
<td>9</td>
<td>Solution A: micronutrient (H(_3)BO(_3), MnCl(_2).4H(_2)O, ZnSO(_4).4H(_2)O, Na(_2)MoO(_4), CuSO(_4).5H(_2)O)</td>
<td>1 mL</td>
</tr>
</tbody>
</table>
Table 3 Optimized cultivation media for Spirulina cultivated in HU experiments (BG 11 growth medium) [11]

<table>
<thead>
<tr>
<th>Item number</th>
<th>Item</th>
<th>Amount / Liter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NaNO₃</td>
<td>37.5 g</td>
</tr>
<tr>
<td>2</td>
<td>K₂HPO₄</td>
<td>1.0 g</td>
</tr>
<tr>
<td>3</td>
<td>MgSO₄·7H₂O</td>
<td>1.875 g</td>
</tr>
<tr>
<td>4</td>
<td>CaCl₂·2H₂O</td>
<td>0.9 g</td>
</tr>
<tr>
<td>5</td>
<td>Citric acid</td>
<td>0.15 g</td>
</tr>
<tr>
<td>6</td>
<td>Ammonium ferric citrate green</td>
<td>0.15 g</td>
</tr>
<tr>
<td>7</td>
<td>EDTANa₂</td>
<td>0.025 g</td>
</tr>
<tr>
<td>8</td>
<td>Na₂CO₃</td>
<td>0.5 g</td>
</tr>
<tr>
<td>9</td>
<td>H₃BO₃</td>
<td>2.86 g</td>
</tr>
<tr>
<td>10</td>
<td>MnCl₂·4H₂O</td>
<td>1.81 g</td>
</tr>
<tr>
<td>11</td>
<td>ZnSO₄·7H₂O</td>
<td>0.22 g</td>
</tr>
<tr>
<td>12</td>
<td>Na₂MoO₄·2H₂O</td>
<td>0.39 g</td>
</tr>
<tr>
<td>13</td>
<td>CuSO₄·5H₂O</td>
<td>0.08 g</td>
</tr>
<tr>
<td>14</td>
<td>Co(NO₃)₂·6H₂O</td>
<td>0.05 g /</td>
</tr>
</tbody>
</table>

Table 4 Optimized cultivation media for Spirulina cultivated in HU experiments (CFTRI growth medium) [12]

<table>
<thead>
<tr>
<th>Item number</th>
<th>Item</th>
<th>Amount (g L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NaHCO₃</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
<td>K₂HPO₄</td>
<td>0.050</td>
</tr>
<tr>
<td>3</td>
<td>NaNO₃</td>
<td>1.5</td>
</tr>
<tr>
<td>4</td>
<td>K₂SO₄</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>NaCl</td>
<td>1.00</td>
</tr>
<tr>
<td>6</td>
<td>MgSO₄·7H₂O</td>
<td>0.20</td>
</tr>
<tr>
<td>7</td>
<td>CaCl₂</td>
<td>0.04</td>
</tr>
<tr>
<td>8</td>
<td>FeSO₄·7H₂O</td>
<td>0.015</td>
</tr>
</tbody>
</table>

5. RESULTS DISCUSSION

The results for temperature versus days are the same for the three groups as shown in figure 12, this is due to the fact that we exposed the flasks of the three groups to the same temperature (room temperature) at the same time all over the days, the temperature changed from 23 °C to 19.5 °C as a results of weather changes, the temperature changes were within the acceptable range that satisfy the suitable growth conditions for Spirulina, also the temperature range is similar to Egyptian northern coast temperature range.

Regarding the figure 13 that represents PH versus days for the three groups we can see that PH values for both (BG-11 and CFTRI) were almost of high values ranging from 10.6 to 10.8 beyond the acceptable range for spirulina, the situation caused the algae to be under stress during the whole growth processes, while the range for PH values for (Zarrouk vary from 9.6 to 10.4 and that made it more acceptable medium for algae growth rather than the other two groups.

Regarding the figure 14 that represents TDS versus days we can see that TDS values were constant at 15500 ppm for Zarrouk medium during the whole growth period, while it was constant for CFTRI medium at 9000 ppm, Also TDS was constant for BG-11 medium at 3500 ppm below the acceptable limits, the acceptable limits for Spirulina growth range from 10000 to 50000 ppm and that was satisfied by both Zarrouk and BG-11 medium.

Referring to figure 15 that represents chlorophyll versus days we can find that Zarrouk and CFTRI results curves almost coincides with each other, both of them reach its highest
value at the day 21 then the algae was under stress until it ended at the day 27, while CFTRI medium reach its highest chlorophyll value at the day 18 then the algae was under stress until it ended at the day 27. This results lead us to conclude that both Zarrouk and BG-11 have the larger growth period before stress stage.

The results of figure 16 that represents chlorophyll versus temperature indicted that the temperature effect has the influence on both Zarrouk and BG-11 medium, the temperature increasing increased the chlorophyll unit it reach its maximum value at 4.5 then the further temperature increasing led to the decreasing of the chlorophyll to its minimum value at 2.5, while for CFTRI medium the temperature increasing increased the chlorophyll unit it reach its maximum value at 5.5 then the further temperature increasing led to the decreasing of the chlorophyll to its minimum value at 2.5, the optimum temperature range for chlorophyll production is from 20 to 22 °c.

From figure 17 that represents chlorophyll versus PH we found out for both Zarrouk and BG-11 medium that the increasing of PH increased chlorophyll until it reach the highest value at 5.5, the continuous PH increasing led to the decreasing of chlorophyll value until it reach minimum value at 3.5, while for CFTRI medium the increasing of PH increased chlorophyll until it reach the highest value at 5.5 then continuous PH increasing led to the decreasing of chlorophyll value until it reach minimum value at 3. So the suitable range for PH values range from 9.5 to 10.25.

![Figure 12](image-url) The effect of Temperature values on Spirulina growth for different media

![Figure 13](image-url) The effect of pH values on Spirulina growth for different media
Figure 14 The effect of TDS values on Spirulina growth for different media

Figure 15 The Chlorophyll values for Spirulina for different media

Figure 16 The Chlorophyll values for Spirulina for different media VS Temperature
6. CONCLUSIONS

- Results indicated that Spirulina preferred Zarrouk medium much more than BG-11 and CFTRI mediums.
- Results indicated that the preferred temperature for spirulina growth to produce maximum chlorophyll range from 20 to 22 °c.
- Results indicated that the preferred PH values for spirulina growth to produce maximum chlorophyll range from 9.5 to 10.25.
- We concluded that the maximum biomass production with high bio pigment content (Chlorophyll) in Spirulina were observed in both Zarrouk and BG-11 because they provide the longest growth period without limited stress conditions.
- Spirulina is the most promising source of protein for both human and animals, also it can be used as fertilizers for plants.
- The climate conditions at the Egyptian northern coast is suitable for Spirulina growth.
- Spirulina could be food solution for climate change scenarios adoption methodology in any coastal zone especially in Egypt.
- The suggested system of sustainable algae system is environmental friendly.

REFERENCES

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