CHAPTER V
CONCLUSIONS

5.1 Conclusions

The purposes of this designed and constructed photo-bioreactor were to cultivate *Spirulina spp.* by using local fertilizer as a food source and testing the suitability of this photo-bioreactor. This study uses semi-continuous culture. The results were compared with normal *Spirulina spp.* cultivation in 10 liter glass jar which was batch culture. The results can be summarized as follows.

5.1.1 Effect of low cost media on growth of *Spirulina spp.* in outdoor culture

Substrate component was the main factor for *Spirulina spp.* cultivation because it affects the growth rate. As a result, there were many attempts to make low cost substrate for *Spirulina spp.*, such as using wastewater, manure, leftover food or reduce some component. This cause cultivated *Spirulina spp.* had not high nutrition as standard media and can only be used for pasture purpose. The main purpose of this research was to find the substrate formula that can be easily found in local area, low cost, and practical. The result was satisfactory because after some period of cultivation the chemical component in satisfactory, such as the amount of chlorophyll a was nearly close to standard media.

Urea and potassium nitrate were selected to be nitrogen source because of low cost than other nitrogen source, such as ammonia nitrate, sodium nitrate and ammonia chloride. From this study, when compared these two nitrogen sources at different concentration on the *Spirulina spp.* growth rate, it was found that *Spirulina spp.* growth in urea as nitrogen source had statistically reduce in amount of biomass ($p<0.05$) when compare with *Spirulina spp.* growth in potassium nitrate as nitrogen source. This occurred when urea had high concentration of urea. The best result for urea growth was in the Treatment 3 that contains with lowest urea concentration. This

result was corresponded with the Richmond's experiment in 1990. On the other hand, potassium nitrate as nitrogen source, *Spirulina spp.* growth had high biomass and can achieve the best result at 20% nitrogen concentration (Treatment 8) which will gradually reduce when increasing nitrogen concentration. Nitrogen concentration should not be higher than 2mM because it was toxic to cell (Filali et al., 1997). This experiment shows that modified substrate formula was not only the alternative for *Spirulina spp.* cultivation that reduces cost, the algae also had essential nutrient for human health as well.

5.1.2 Design a tubular photo-bioreactor for the community level

Bioreactor was consists of clear plastic tank and clear tube with transparent 85% and diameter 0.013 meters. This tube was placed circle around the bioreactor and connected together with bending plastic (PVC). As a result, this tank was looked like a loop with total length 15 meter and total volume 7 liter. It had gas inlet and outlet. The cultivation for this study was semi-continuous. Every 24 hour, substrates which contains with sodium bicarbonate were feed into the reactor with velocity 0.0404 liter per hour. The mixing system to mix food and microorganism was worked with flow rate 2.5 liter per minute. Sodium bicarbonate that feed into the system was a carbon source. It was essential for growth and it also help to control pH within the range of 9-10. This cultivation uses only light source from the sun. The temperature was varied on seasonal and time in each day.

By constructing photo-bioreactor with high tolerance material, it will help this cultivation to be successful throughout the year and season factor was not become a major influence, especially in Thailand. Thailand climate was suitable for *Spirulina spp.* growth due to the average temperature. Photo-bioreactor was acted as a receiver of sunlight. Photo-bioreactor that uses thin surface or small diameter tube can increase concentration of cell in algae cultivation. It also helps cultivation process more easy. However, as photo-bioreactor was a light receiver it may cause the temperature too high in some season, especially summer. Therefore, it was crucial to avoid putting photo-bioreactor on the open field and only leave in the area to receive enough sunlight and prevent too high temperature in the system.

Using thin bioreactor or small diameter tube was not only way to produce high amount of algae from cultivation. Controlling the suitable system environment, such as control steady pH also increase cell production. From the experiment, it was found that *Spirulina spp.* in this bioreactor had higher growth rate than normal cultivation. This was caused by the full turbulent flow that provide completely mixing between substrates and algae and also increase light exposure. The biomass production was 0.563 gram per liter and chlorophyll A concentration was 21.05×10^{-3} milligram per milliliter. This result was higher than open pond cultivation statistically. These results were corresponded with study from Travieso (2001). It was found that algal cultures which grown photoautotrophycally outdoors were very dilute, and for maximal productivity the concentration of biomass was usually kept in the range 0.5–0.7 grams per liter.

5.2 Recommendations

Constructed photo-bioreactor had good performance even many environment factor did not be controlled. Therefore, to enhance the performance of this photo-bioreactor for algae cultivation may be done as follows;

- Study algae cultivation in multi-stage photo- bioreactor to enhance the consumption of substrate by using recycled substrate that already been filtered from cell.
- Study long term *Spirulina spp.* cultivation to find the growth pattern and other essential substrate from carbon source, such as nitrogen, phosphorus and potassium.