CHAPTER 7

PARTIAL BUDGET ANAYSIS OF BIODIESEL PRODUDTION

7.1 Introduction

Cost assessment is important to be considered in commercial up scaling. The success at the smaller scale lead to algal growth systems to be scale up for commercial applications. Various factors are investigated for optimal operation. The final step is to evaluate the economic feasibility of microalgal bio-oil production by the capital estimation of some fixed cost parameters. Each process has different factors that should be investigated including, nutrient sources, light source, water and energy input. Moreover, labor cost in the cultivation and harvest process are also evaluated including chemicals and energy consumption in lipid extraction and transesterification.

This partial budget analysis is based on the open system cultivation with CMU03 medium without temperature control under natural sunlight. All the budget were estimated based on the lipid productivity obtained from conventional extraction method, compared with UASE method.

7.2 Partial budget analysis

The final production cost of lipids and fuels is calculated using some fixed cost parameters. The cost of structure construction for cultivation is not included in this analysis.

7.2.1 Cultivation cost

7.2.1.1 Medium

Nutrients are essential factor for algal growth. CMU03 medium is the promising medium for this study because it is cheap. It consistes of necessary nutrients, such as urea as N source, triple super phosphate (TSP) as P source and Premix as the trace elements. This analysis is based on using the medium formulations in Table 20 that show the prices of each chemical which can be used for estimation of the cost of biomass and total lipid in Table 21.

Table 20 Amount of nutrient components in CMU03 medium for *Carteria* sp. AARL G045 cultivation

Nutrients	**Amount (g.L^{-1})**	**Prices per unit (฿.g^{-1})**
Nitrogen source	0.0248	0.0150
Phosphorus source	0.03104	0.0198
Trace element	104	0.0146

Table 21 Cost of biomass and total lipid base on medium price

Lipid extraction method	**Biomass (g.L^{-1})**	**Total lipid (g.L^{-1})**	**Biomass cost (฿.g^{-1})**	**Total lipid cost (฿.g^{-1})**
Conventional extraction method	0.23	0.0514	0.0046	0.0201
UASE method	0.23	0.1070	0.0046	0.0097

7.2.1.2 Energy input for aeration

The estimation of required energy was calculated from energy input for aeration by air pump (LP100). The pump with 100 watt of input power was applied in microalgal cultivation for 24 hr. The culture reached the stationary phase on Day 14. The electrical energy value was calculated by the following equation:

$$\text{Electrical energy (E)} = P \times t /1000$$

Where E is electrical energy (units), P is electric power (Kw) and t is the time (hr) used in the cultivation.

Each unit of electrical energy was calculated following the cost of electrical power provided by the Provincial Electricity Authority (PEA) in Table 22.

Table 22 Cost of electrical power provided by PEA

Electrical energy used (units)	**Electricity costs (Baht)**
1 – 15	1.8632
16 – 25	2.5026
26 – 35	2.7549

7.2.1.3 Water

Water source is filtered tap water. It was not assessed in this study since *Carteria* sp. AARL G045 can autoflocculated hence water can be reused in the next cultivation for 3-5 times.

7.2.2 Harvest cost

Since the cell size of *Carteria* sp. AARL G045 is large (7-15µm), it is capable to autoflocculate in a short time. Then the medium is removed for cell concentration by filtration. The labor is quite important in this process. Thus, the cost of harvest depends on the wage of employment. The labor wage in this experiment was the minimum wage of 30 baht per hour. Working volume of 190,000 L requires two workers to filter wet cells (based on the data from Boonsom *Spirulina* farm, Chiang Mai, Thailand). One person works for 3 hours on harvesting process, hence, the labor cost is 90 bath per one person.

However, the biodiesel yield was different due to extraction techniques. The percentage of lipid as 22.7% and 47.43% were derived from the conversional extraction and UASE methods, respectively. This means that 1 kg lipid can be produced from the biomass productivities of 4.4 kg by the conventional method and from 2.1 kg of biomass by UASE method. Thus, for 190,000 L of cultivation the algal biomass and gave about 9.5 L of biodiesel from traditional extraction and 21L from UASE method.

The compensation for labor was calculated according to the lipid recovery method (Table 23).

Table 23 Harvesting cost calculated on the labor cost

Extraction method	Biodiesel (L) (190,000 L of medium)	Labor cost (Baht)	Harvest cost (Baht per 1 L of biodiesel)
Conventional extraction	9.5	180	18.95
UASE	21	180	8.57

7.2.3 Capital cost of extraction process

7.2.3.1 Chemicals

Different extraction methods were used in this study. Chemicals are the main factor in lipid extraction method. These chemicals were based on the industrial grade. The price of chemicals were estimated for 1 kg of lipid (Table 24).

Table 24 Price of chemicals estimated for 1 kg of lipid

Extraction method	Chemicals	Volume using (L per 1 L of biodiesel)	Amount (kg)	Prices per unit ($Baht.Kg^{-1}$)	Total (Baht)
Conventional extraction	$CHCl_3$	73.14	109.56	12.4	1,358.54
	Methanol	36.57	28.93	21	607.53
UASE	$CHCl_3$	35.14	52.64	12.4	652.74
	Methanol	17.57	13.90	21	291.9

However, these chemicals can be reused (non fixed cost factor) thus their prices are not included in this cost evaluation.

7.2.3.2 Energy input for ultrasonic device

UASE technique requires energy to drive the sonochemical reaction. Ultrasound with 6.96 Kw was applied to extract 1 kg of lipid for 30 min. The electrical energy value was calculated by the equation mentioned in the cultivation step.

7.3 Biodiesel production

In this study, the biodiesel production process was through transesterification. Alcohol:oil at ratio of 6:1 is generally used to complete the reaction. Acidic or basic catalysts were used to catalyze and enhance the transesterification reaction rate, but commonly, in the industrial processes, homogeneous alkali catalysts (e.g. NaOH or KOH) in batch reactor with stirrer were used (Sivasamy *et al.*, 2009). The amount of chemicals used and the prices are shown in Table 25.

Table 25 Amount of chemicals used and their prices for industrial grade

Chemical	**Amount (kg)**	**Prices per unit (Baht.Kg^{-1})**	**Total (Baht)**
NaOH	0.01	0.21	0.0021
Methanol	0.22	21	4.62

The overall cost of biodiesel from *Carteria* sp. AARL G045 biomass under UASE method is 21.46 bath.L^{-1} which is less than the traditional extraction method about two times due to the more lipid recovery (Table 26). However, this cost estimation was calculated exclusively on some fixed factors but other doubtful parameters were not considered. These uncertain factors such as water and chemicals for lipid extraction can be reused. From capital analysis, it implied that the microalgal cultivation in the open system could reduce some expenses for example, electrical cost from fluorescent lamp. Moreover, *Carteria* sp. AARL G045 auto-flocculated in a short time which is most useful for harvesting. It does not also require chemical or other process such as ultrasound to promote flocculation.

Table 26 Summary of estimated cost from biodiesel production

Process		**Conversional method (฿.L^{-1} of biodiesel)**	**UASE (฿.L^{-1} of biodiesel)**
Cultivation	Medium	18.07	8.69
	Electrical cost (Pump)	0.093	0.045
Harvest	Labor	18.95	8.57
Extraction	Chemical	1,966.07**	944.64**
	Electrical cost (Ultrasound)	-	0.0065
Biodiesel	Chemical	4.15	4.15
	Total	**41.26**	**21.46**

** The chemical costs in extraction process are not included with overall costs since they can be recycled.