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FEASIBILITY STUDY OF A RECIRCULATION AQUACULTURE SYSTEM

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ABSTRACT

Two types of recirculation aquaculture systems (RAS) were designed, built and evaluated in this study. Pre-operation test results indicated that both systems were capable of delivering sufficient dissolved oxygen and removing carbon dioxide to acceptable levels for fish growth. Arctic charr (*Salvelinus alpinus*) were raised to assess the technical functionality of the systems. Based on the results of the water parameter analysis, both systems were technically able to deliver optimum water quality for fish growth in the cold water environment at the facility. Commercial simulation of a scale-up system culturing seabass (*Lates calcarifer*) in Malaysia shows that it is financially feasible, but sensitive to changes in price, operation costs and production quantity. Starting an RAS farm is a challenge, where application of knowledge in aquaculture engineering, water quality management and financial prudence will have to be coordinated before profits can be realised.

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1 INTRODUCTION

1.1 Background

There is growing interest in recirculation aquaculture system (RAS) technology especially in intensive finfish culture in the world. This is due to the perceived advantages that RAS greatly reduces land and water requirements, offering a high degree of control of the culture environment that allows year round growth at optimal rates and fish biomass can be determined more accurately than in ponds (Masser *et al*. 1999, Duning *et al*. 1998). A typical RAS consists of a water supply system, mechanical and biological filtration, pumps to maintain water flows, aeration and oxygenation system and other water treatment components that deliver optimal water quality for fish growth within the system (Hutchinson *et al*. 2004).

RAS also offers other potential advantages for aquaculture including the ability to place the farm in locations where water resources are limited and near to the market to reduce product transport time and costs (Hutchinson *et al*. 2004). With more stringent water pollution control, RAS provides greater environmental sustainability than traditional aquaculture in managing waste production and also a possibility to integrate it with agricultural activities such as using water effluent for hydroponics (Summerfelt *et al*. 2004). Another key advantage is that RAS technology is species-adaptable which allows operators to switch species to follow market preference for seafood products (Timmons *et al*. 2002). “Even though RAS is capital intensive, claim of impressive yields with year-round production is attracting growing interest from prospective aquaculturist” (Losordo *et al*. 1998, p.1). This includes government policy makers in the fisheries sector and also fish farming companies in Malaysia (Mispani 2006).

Commercial RAS technology is relatively new in Malaysia. A system was introduced in Malaysia in 2000 where a local aquaculture company is dependent on a joint venture partner from Australia to operate the farm in order to achieve the production level to sustain the fish farm. The Malaysian Fisheries Development Authority, through its subsidiary, Majuikan Fish Protech had set up an RAS culturing seabass (*Lates calcarifer*) in Sepang, Selangor in 2006. The Authority is planning to set up a smaller scale RAS in other states in the country as a means of introducing the system to local Fishermen’s Associations and aquaculture farmers in the area.

1.2 Fisheries sector in Malaysia

Malaysia is located in Southeast Asia. It has a total area of 329,758 km^2 and a coastline of 4,810 km (FAO 2007). Malaysia comprises eleven states in the Malaysian Peninsula and the states of Sarawak and Sabah in Borneo Island. The Malaysian Peninsula forms the southern tip of the Asian mainland. Located along the equator, it has an equatorial climate that has uniformly warm temperature all year round averaging 30^0C.

Figure 1: Geographical location of Malaysia (Source: World Fact Book 2008)

The fisheries sector in Malaysia played an important role in supplying food and a source of income for around 90,000 fishermen and 22,000 aquaculture farmers in the year 2005. It contributed about 15% of the national food production and 1.3% of our national Gross Domestic Product (GDP) in 2005. From 2000-2005, it constantly contributed between 1.0 and 2.0% of the GDP as shown in Table 1.

Table 1: Contribution of the fisheries sector to the GDP 2000-2005

Years	2000	2001	2002	2003	2004	2005
Capture fisheries (million t)	1.29	1.23	1.27	1.29	1.33	1.43
Aquaculture (million t)	0.12	0.14	0.15	0.15	0.15	0.21
Total production (million t)	1.41	1.37	1.42	1.44	1.48	1.64
Value (RM billion)	5.37	5.45	5.41	5.31	5.50	4.3
Percentage of GDP	1.6	1.5	1.5	1.4	1.7	1.3

Source: Malaysian Fisheries Department Annual Statistics (2005) and FAO (2007)

The fisheries sector also contributed to the national export earnings, enhanced food security and self-sufficiency in fish to meet the increasing demand for fish due to the population increase and rise in consumption per capita of fish in Malaysia. Malaysian fish consumption per capita was 59 kg in 2005 (FAO 2007).

Production from marine capture fisheries in Malaysia from 2000 until 2005 had stagnated at around 1.2 to 1.4 million metric tons annually. This trend is generally similar to global fish landings. Aquaculture production had doubled in the same period. Though the sector produced around 15% of the total fish production in these years, it has been identified as having the most potential for further development. Therefore, under the Third National Agriculture Policy (NAP3) which covers the period from 1998 to 2010, the government formulated a strategy to develop aquaculture. The Ministry of Agriculture and Agro-based Industry and the relevant authorities under its jurisdiction such as Maine Fisheries Department and Malaysian Fisheries Development Authority (MFDA) were entrusted with an action plan to promote and increase aquaculture production to 600,000 metric tons by the year 2010 (Mohd. Fariduddin 2006).

1.3 Project statement

The operation of RAS which are mechanically sophisticated and biologically complex requires education, expertise and dedication (Duning *et al.* 1998). Prospective operators of RAS need to know about the required water treatment processes, the component of each process and the technology behind each component. Many commercial RAS have failed because of component failure due to poor design and inferior management (Masser *et al*. 1999). Good knowledge of the design of the system, specification of the technical components and operation of the system is therefore a prerequisite for a sustainable RAS farm.

Capital investment for the setup of an RAS is normally much higher than that of a conventional production system due to the requirement for additional equipment to treat water for reuse. The water treatment process could increase operation costs and failure of the treatment system would result in huge economics losses (Summerfelt *et al*. 2001). Therefore, the aspect of economic feasibility has to be taken into consideration before embarking on the system.

Generally, a feasibility study is conducted during the planning stage prior to obtaining approval for funds or financing of a project. The study analyzes different scenarios and assesses technical feasibility, financial feasibility and other factors that could influence the sustainability of the project. It is done to determine its potential as a viable business.

There are three possible outcomes of a feasibility study (Amanor-Boadu 2007). These possible outcomes are:

i. Feasible within the defined system and environment, i.e. the technology and water parameters of the project,
ii. Feasible with changes to certain systems or factors, and
iii. Infeasible within the defined system.

It is important to critically evaluate the outcome or conclusions of a feasibility study. A good study may uncover alternatives and save significant time and money for the stakeholder of the project.

1.4 Objectives

This project involves the setting up of two types of recirculation system at Holar College Aquaculture Facility at Saudarkrokur. There are two culture tanks for each system. The two systems are:

i. Recirculation aquaculture system with biological filter.
ii. Recirculation aquaculture system without biological filter.

The main objective is to gain knowledge on the technical design, test the performance of the two systems and study the feasibility of scaling up the systems in a different environment in Malaysia.

The specific objectives are:

i. To identify the design, layout and technical specifications of the system components that includes:
  - Water pump and pipes for delivery of fresh and oxygenated water to the culture tanks and effluent water to the filtration component.
  - Aerator to generate oxygen required for stock growth and biological filtration.
  - Shape, size and material used to build the culture tanks that enable self-cleaning of settling solids and good working environment for manual labour efficiency.

ii. To test the performance of the pump, aerator and biological filter in delivering water, addition of oxygen and removal of carbon dioxide and ammonia.

iii. To perform a financial feasibility study of the systems in a bigger set up and compare it with the literatures on the economics of RAS.

1.5 Significance of the study

The development of RAS technology in Malaysia is in accordance to the government's policy to promote a production system that utilises the latest technology in aquaculture especially the system that involves mechanical and automated operation, precision control of culture environment, production of quality and high value fish product. In RAS, fish can be stocked intensively in culture tanks because the culture environment are monitored and continuously controlled.

The government is continuously enhancing the profitability and competitiveness of the fisheries sector through agricultural education, upgrading its research and development capabilities, setting up modern physical infrastructure and other support services as the prerequisites for a modern and productive fishery sector.

1.6 Limitations and constraints

Financial models to assess profitability are based on a set of assumptions. Some of the assumptions could be close to reality and others are little more than educated guesses. It has to be recognised that the assumptions and cost estimations are bound to be inaccurate (Calberg 2007). A sensitivity analysis on the assumptions of uncertainty factors such as production quantity, production costs and selling price and their impact on the project is necessary to assess the feasibility of this project.

The scale-up system may not provide a good fit for the culture requirements or management ability specific to all situations. However, scaleable recirculation system designs could also be tailored to fit each specific application and environment by selecting and adapting technologies to fit the scale and requirements of each application (Summerfelt *et al*. 2001).

2 RECIRCULATING AQUACULTURE SYSTEMS

2.1 Development of RAS

RAS had been developed for fish culture since the 1960s. Most of the early and truly ground breaking RAS design work was developed in state fish hatcheries (Burrows and Combs 1968, Liao and Mayo 1972 and 1974, Speece 1973), which produce fish for fisheries management. Application of RAS for commercial finfish production became more widespread between 1970 and 1980 (Timmons *et al 2002*). However, during these years, many large commercial finfish producers that were using recirculation systems have also been notable in their failure (Timmons *et al 2002*.)

Research and development to improve commercial recirculation systems continued (Muir 1981 and 1982, Rosenthal and Black 1993, Summerfelt 1996, Losordo 1998a, Eikebrokk and Ulgenes 1998, Muir 1998, Blancheton 2000, Losordo *et al.* 2000, Summerfelt *et al.* 2000a, and successful commercial systems have been reported (*Timmons et al. 2002).* Research on the development of RAS for commercial scale fish production has increased dramatically in the last two decades (Masser *et al*. 1999). Research had been done on unit process development and their integration into functional water-reuse systems (Timmons *et. al 2002).* The ultimate goal of these research projects was to make finfish production more cost competitive within recirculation systems.

2.2 RAS design

RAS offers an alternative to pond culture but is more capital intensive than most other types of traditional aquaculture systems and must rely on high stocking density and productivity per unit volume of rearing space for profitability (Timmons *et al*. 2002). To achieve this, Hutchinson *et al.* (2004) said that the design of the water treatment components in the system need to accommodate the input of high amount of feed required to sustain high biomass that are required to meet the financial goal.

Hutchinson *et al.* (2004) recommended a comprehensive analysis of the water source for the RAS fish farm when designing the system. The results of the water analysis could influence the system and species suitability of the chosen water source. Even though RAS requires much less water volume and even if only 10% of the water volume is replaced daily, the selected site should be able to provide at least 20% of the system volume for daily water exchange and additional water needed for cleaning and water loss in reservoir tanks.

There is a wide range of RAS designs and many options for the water treatment component (Hutchinson *et al.* 2004). But Timmons *et al*. (2002) said that stocking density is one of the main criteria for consideration when designing an RAS because it will define the feeding rate from which the specification of technical components is determined. The volume of water flowing in and out from the tanks and concentration of oxygen required can be calculated based on the feeding rate. As such, it is possible to specify the technical performance for every component based on the level of biomass in each tank and the total projection of the fish farm.

In a flow-through system, intensive farming uses flowing water resources for transporting oxygen to the fish and to remove metabolic by-product and waste so that it does not accumulate to undesirable levels. However, such systems require a large volume of water resources.

RAS consists of an organised set of complementary processes that allow water leaving a fish culture tank to be reconditioned and then reused in the same fish culture tank or other fish culture tanks (Liao and Mayo 1972, Timmons *et al.* 2002). Dissolved oxygen supply is usually the first process applied to prepare water for further use, because dissolved oxygen is often the first water quality parameter to limit production in intensive culture systems (Colt *et al.* 1991). Even though the availability of dissolved oxygen could be increased, other fish wastes can begin to accumulate to concentrations that must be reduced to maintain a healthy fish culture environment (Colt *et al.* 1991). Hence several complementary water treatment processes are required to reduce waste accumulations to maintain a healthy fish culture environment.

Water treatment processes are used to change the physio-chemical conditions or characteristics of the water that pass through the process. Sometimes water treatment processes can change more than one characteristic of the water. For example, water flowing through a trickling biofilter can gain dissolved oxygen and nitrate, while dissolved carbon dioxide and un-ionised ammonia are removed (Wheaton *et al*. 1991, Summerfelt *et al*. 2004). The general processes and flows of water in RAS are shown in Figure 2.

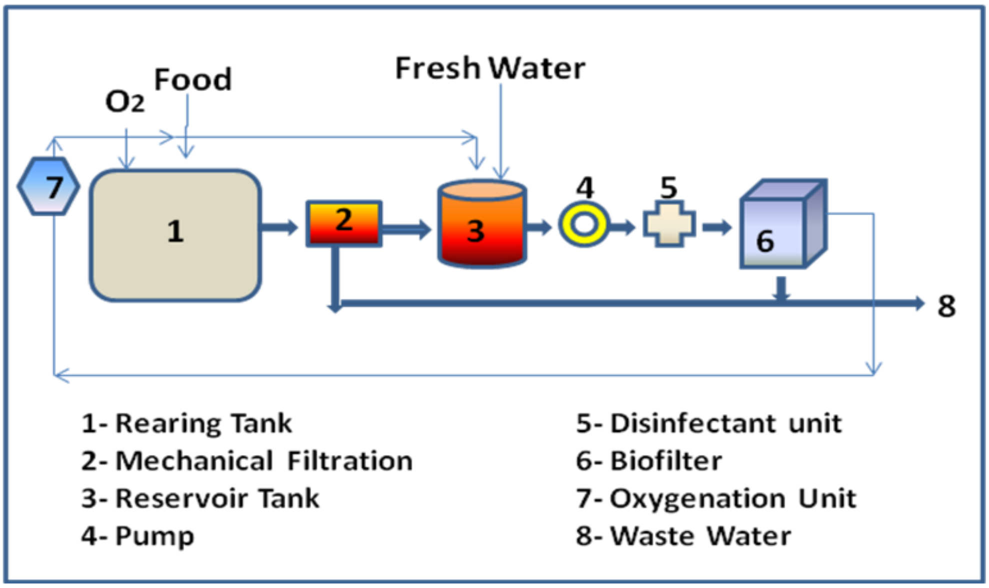

Figure 2: General processes and water flows in RAS (Blancheton 2002)

Based on Figure 2, water from the rearing tanks flows to the mechanical filtration for removal of suspended solids. From the mechanical filter, the water flows to the reservoir and the pump delivers the water to the treatment unit such as UV treatment. The water is then pumped to the biofilter for nitrification process. Nitrified water is then delivered to the aeration and oxygenation unit before returning the water to the rearing tank for reuse. Effluents exit the system either from the mechanical or biofiltration unit.

There are a variety of commercial RAS designs and technologies available and the selection of water treatment units is dependent upon the water quality required and the reliability and cost-effectiveness of the technologies. Technology selection also depends upon cost and the size of the application (Colt *et al*, 1991), because at larger scales many water treatment units are not available, cannot be fabricated, or do not function as effectively as smaller units.

Efforts have been made to develop “turn-key” recirculation systems by carefully integrating unit processes in a manner that could be easily replicated and suited to producing a certain type of fish under most conditions common to a given region. However, a number of “turn-key” systems that have been marketed have not proven successful. The reasons for the failures could be due to technology problems or inadequacies in knowledge in operating the system and many of these systems were not large enough to produce fish to support the required profit margin (Summerfelt *et al*. 2001).

2.3 Economics of RAS

An investment in a commercial RAS farm has a similar level of risk and uncertainty as other fish farm enterprises that include uncertain and risky operational characteristics, uncertain future market price and uncertain input costs (O‘Rouke, 2007). For RAS farms to be economical, they must produce a valuable fish. Currently, RAS are used to raise high value species or species that can be effectively niche marketed, such as salmon smolt, ornamental fish, fingerlings, hybrid-striped bass, sturgeon, yellow perch, eel, rainbow trout, walleye, African catfish, channel catfish, and Arctic charr. Marine RAS are being used to produce many species at both fingerling and food-size, including flounder, seabass, turbot and halibut (Summerfelt *et al*. 2001).

Financially, it is very important to have the accurate specification of all components because if the components are oversize, the system will function but not be cost effective. For undersized equipment, the system will not be able to maintain the optimal environment for fish growth, resulting in lower production and financial loss (Duning *et al*. 1998). It is very important for RAS farm operators to know the optimal environment for growth of the selected species, volume of market demand, size and shape of the fish product required by the market and other factors that might influence and affect the farm operation (Masser *et al.* 1999).

There are basically three methods used by businesses to evaluate investment opportunities. These are:

i. Break-even analysis
ii. Profitability analysis
iii. Sensitivity analysis

The break-even analysis is done to determine the required production quantity to cover production cost and requirement for profit and annuity payment. A simple break-even analysis is the first measurement that could be made by using cost estimation and assumption of revenue (Pillay and Kutty 2005). However, the break-even analysis is not a formal method for measurement of profitability.

The net present value (NPV) is a popular measurement in profitability analysis because it takes into account the time value of money and interest rates. The NPV assessment also enables comparison with alternative investments at different levels of risk (O'Rouke 2007). In profitability analysis, simulations of budgeting and assumption of revenue are used in evaluating investment opportunities and the likelihood of achieving profitability is estimated through obtaining a positive value of NPV (Curtis and Howard 1993). The internal rate of return (IRR) is also used in profitability analysis. IRR is related to the NPV method since IRR is the rate when applied to the projected future cash inflows which resulted in NPV equal to zero (NPV=0).

Sensitivity analysis is used to determine how different values of independent variables such as cost of production, price, production quantity and interest rate will affect the NPV, IRR and break-even quantity. Sensitivity analysis is used to predict the financial feasibility, if a situation turns out to be different from the assumption or estimation.

2.4 RAS and environmental issues

Aquaculture is faced with challenges created by population growth and the resulting competition for water, land, and other natural resources. In some cases, these challenges are being met by intensifying the culture operations. The tendency to intensify fish culture in RAS, like other agricultural projects, is an attempt to obtain higher yields for a given critical resource which is water (Piedrahita 2003).

Aquaculture effluents contain various constituents that could cause negative impacts when released into the environment. The constituents include dissolved or particulate organics and the impact on the environment depends on the amount, concentration and the assimilative capacity of the environment for the particular constituent.

RAS is seen as an environmentally friendly aquaculture method. This is because the RAS water treatment process is designed to minimise water requirements which leads to a small volume of effluents. The effluents are accumulated into a sedimentation basin or tank which will facilitate treatment before discharging to the environment (Piedrahita 2003).

3 MATERIALS AND METHOD

3.1 Materials

Two types of RAS were set up for this project, i.e. a system with and without a biological filter. Each system has two culture tanks and the total water volume for each tank is 750 l. Both systems were fitted with identical pipe size, pump, aerator, oxygenator, reservoir tank and sedimentation tanks of similar capacity. The setting up of the system at Holar College Aquaculture Facility in Saudarkrokur was completed on 4 January 2008. The layout of the system is shown in Figure 3.

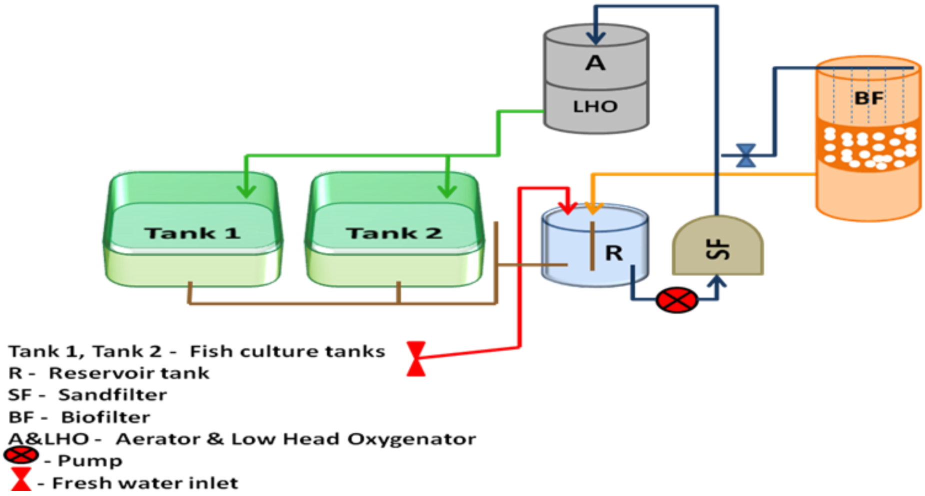

Figure 3: Layout of the RAS project at Saudarkrokur Aquaculture Facility.

Storage and fresh water enters the system at the reservoir tank. The water is then pumped to the two fish culture tanks. The water level in the culture tanks is controlled by the external stand pipe that delivers the discharge or used water to the reservoir tank. Discharge water in the reservoir tank is pump to the sandfilter for removal of suspended solids and then delivered to the aerator and oxygenator to add oxygen or remove carbon dioxide or delivered to the biofilter for the nitrification process. Treated water from the biofilter is delivered back to the reservoir for recirculation.

3.2 Component description

3.2.1 Culture tank

The tanks are made of fibreglass reinforce plastic (FRP). They are octagonal, 100 cm width x 80 cm height, operating at 750 litre capacity. Water is delivered to the tanks through four 8 mm orifice holes in the PVC pipe. The water flow rate and velocity to meet dissolved oxygen requirements and body length of fish could be adjusted by a valve. A picture of the culture tanks is shown in Appendix 1(a).

The water level in the tank is controlled or set by the difference in height between the external stand-pipe at the outlet to the reservoir tank. Water is discharged to the reservoir tank through the bottom central drainage. The water flow from the central drainage and outlet pipe could also be periodically discharged to remove settling solids in the pipe joints and surface.

3.2.2 Reservoir tank

The reservoir tank is made of high density polyethylene (HDPE). It is circular, 68 cm diameter x 64 cm height, thus having a 230 l capacity. Water is delivered to the reservoir tank through connection with the external stand-pipe that controls the water level in the culture tanks. From the reservoir tank, the water is pumped through the sandfilter unit and delivered to the aeration or biofiltration unit.

Fresh or make up water enters the system from the reservoir tank and the water that exits the reservoir through a discharge pipe, controls the water level in the reservoir tank. For the system with the biofilter, the biofilter unit returns the treated water to the reservoir tank for recirculation. The reservoir tank unit is shown in Appendix 1(b).

3.2.3 Sedimentation tank

The 15 l sedimentation tank is attached to the culture tank as shown in Appendix 2(a). It is circular with a cone shape bottom for settlement of solids such as uneaten feed and faeces. The sedimentation tank could be flushed out periodically and the excess water that flows through is delivered to the reservoir tank.

3.2.4 Pump and sandfilter

A 0.55 kWh Pinnacle 75 water pump is plumbed to the reservoir tank. The water pump works as part of the sandfilter, Triton TR-60. It delivers the water for treatment to the aerator or biofilter via the sandfilter. The pipe size for the inflows from the reservoir and outflows to the sandfilter is 40 mm. Based on the manufacturer's specification, the Triton TR-60 sandfilter has a water flow or treatment capacity of 14 m^3 per hour. The sandfilter has a 40 kg of activated carbon and 108 kg of sand substrate capacity. The layout of the pump and sandfilter is in Appendix 2(b).

3.2.5 Aerator and low head oxygenator (LHO)

The aerator and LHO is a combined unit. Its measurement is 37 cm diameter x 180 cm height. The aerator and LHO is custom made for the existing facility and is used for this project. The aerator and LHO unit is shown in Appendix 3(a). Water from the sandfilter flows through the aeration chamber filled with polypropylene bio ring, shown in Appendix 3(b) for carbon dioxide stripping. Ambient air with a content of 20% oxygen is absorbed by the aerator and flows in the opposite direction of the water dropping down the aeration chamber for infusion of oxygen and stripping of carbon dioxide. The water then flows to the LHO column where air containing 90-95% of pure oxygen generated by the oxygenator is added to the water. The SeQual Workhorse-12 Oxygen Generator at the facility could generate up to 5.5 standard l per minute of 90-95% pure oxygen (SeQual Technologies Inc. 2008).

The hydraulic loading volume of the aerator and LHO unit could be adjusted using the transparent tube that gauges the water level inside.

3.2.6 Pipes and valves

The size of all PVC pipes is 40 mm except for the discharge or drainage pipe from the culture tank to the reservoir tank and clean-out point. The size and slope of pipe were selected to transport water at a velocity sufficient to deliver oxygen, prevent sedimentation and minimise head loss. Pipe clean-out points were installed to allow flushing of solids that might deposit in the pipe surfaces.

3.2.7 Biofilter

The biofilter tank for this project is made by the staff of Holar University College. It is made of HDPE, measuring 68 cm diameter x 150 cm in height. The biofilter used was a 1 mm polystyrene microbead as substrates for colonising bacteria film to attach on. Weighing around 2 kg, the specific surface area of the substrate is estimated at 492 m^3.

Water is delivered to the biofilter through the orifice holes made in the PVC pipe. The water then drips through the orifice plates to the floating microbead. The hydraulic loading to keep the microbead afloat is controlled by the elevation of the flow of nitrified water from the biofilter to the reservoir tank. The polystyrene microbead and biofilter tank design are shown in Appendix 4(a) and (b).

The summary of size and specification of the system components is in Appendix 5.

3.3 Performance evaluation methods

3.3.1 Standard oxygen transfer test

The standard oxygen transfer test was used to test the efficiency of the aerator during pre-operation testing. The reservoir tanks were filled with deoxygenated water using nitrogen gas to lower the level of dissolved oxygen concentration at 40-55%. Gradual measurements were made at equal time intervals on the time taken to achieve 100% saturation levels of oxygen concentration and the oxygen transfer coefficient was used to estimate the standard oxygen transfer rate and standard aerator efficiency.

3.3.2 Carbon dioxide removal test

The carbon dioxide removal test is done by adding 5 ml of sulphuric acid to 230 l of water in the reservoir tank to lower the water pH. Acid addition will shift the total carbon equilibrium from bicarbonate (HCO_3) to carbonic acid (H_2CO_3) and then carbon dioxide (CO_2) at a lower pH value.

3.3.3 TAN removal test

Testing for the efficiency of the biological filter in removing total ammonia nitrogen (TAN) started after stocking of 30 kg of fish per tank. The biomass of fish is set at 40 kg per m^3 and 155 pieces of 200 g Arctic charr (*Salvelinus alpinus*) per tank. The measurements of TAN were made twice a week from 29 January until 15 February 2008.

3.3.4 Water flow rate

Testing for performance of the pump was conducted by measuring the flow rate of water per unit time. However, the flow rates could be controlled using valve and adjusted to the required level which is calculated at 18.75 l per minute based on the expected time taken by water to circulate and exit the 750 l tank in 40 minutes.

3.3.5 Comparison of performance

Data collection for comparing any difference in performance of the system in delivering oxygen and removing carbon dioxide were done after stocking of fish. Measurements of dissolved oxygen were made daily from Monday to Friday and twice a week for carbon dioxide in the two systems.

3.4 Financial feasibility

3.4.1 Assessment method

The financial feasibility of the scale-up system in Malaysia is assessed using the break-even analysis, profitability analysis and sensitivity analysis. The first two methods calculate the break-even quantity, net present value, internal rate of return and other financial indicators.

The sensitivity analysis analyses the impact of one uncertain factor change at a time, such as change in selling price or cost of production or production quantity that affect the feasibility of the project.

3.4.2 Financial requirement

The total financial requirement to start the project is Malaysian Ringgit (MR) 323,700.00 (Table 2). Thirty percent will be financed by an equity contribution from MFDA Internal Funding and 70% by bank loan.

Table 2: Financial requirement

Particulars	**Amount**
Start-up	
Investment cost	RM 263,700
Working capital	RM 60,000
Total financing required	RM 323,700
Annual operation	RM87,600
Fixed cost	RM166,500
Variable cost	RMRM 254,100 refer to costing in appendix 7 (Fixed Cost and variable cost)
Total	

Sources for estimation of the investment costs, fixed costs and variable costs are stated in Appendix 6 and 7. The amount for working capital needed is based on the cash flows in the balance sheet (Appendix 17) and the cash flows should not be negative.

3.4.3 Financial assumptions

The project assumes a constant production of 22.5 metric tons of fish from the third year based on the production capacity. The market price of seabass produced in net cage in Malaysia is MR 12.00–14.00 per kg (Mohd. Fariduddin 2006). However, this project set a selling price of RM 16,000.00 per ton based on the assumption that an RAS farm could produce better quality and more uniform sized fish, thus selling at a higher price.

To perform the simulated measurement of profitability, the financial rate and assumptions are as shown in Table 3.

Table 3: Financial rate and assumption

Particulars	Rate	Source/reference
Loan	70%	Malaysian Agriculture Bank
Equity	30%	Internal funding of MFDA
Loan interest	4%	Malaysian Agriculture Bank
Income tax	20%	Malaysian tax structure
Discounted rates	10%	Marginal attractive rate of return
Payment period	8 years	Negotiation
Dividend payment	30% of profit	Negotiation
Debtors	15 % of turnover	45 days credit
Creditors	15% of variable cost	45 days credit

The loan interest rate is 4% per annum under the Fund For Food Program (Malaysian Agriculture Bank, 2008) and the income tax rate is based on the existing Malaysian income tax structure (Malaysian Inland Revenue Board 2008). The marginal attractive rate of return is based on the best possible alternative investment in the market.

3.5 Scale-up system

3.5.1 Size and specification

The scale-up system in Malaysia has a production projection of 22,500 kg of seabass (*Lates calcarifer*) annually. Assuming an 80% survival rate, the stocking density of fish at market size is 50 kg per meter^3 of water. The size and specification of the scale-up system in Malaysia is summarised in Table 4.

Table 4: Size and specification of the main components of the scale-up system in Malaysia

Component	**Size/model**	**Capacity**	**Quantity**
Culture tanks	Circular, 3.6 mϴ x 1.5 m height Circular, 3.0 mϴ x 1.5 m height Circular, 2.2 mϴ x 1.5 m height	15,000 l 10,000 l 5,500 l	6 6 3
Reservoir tanks	Circular, 1.6 mϴ x 1.2 m height Circular, 1.4 mϴ x 1.0 m height	2,400 l 1,500 l	5 1
Sedimentation tanks	Circular, 0.3 mϴ x 0.3 m height	20 l	6
Aerator and LHO	Cylinder, 50cmϴ x 180cm height	19 desimeter^{3} air/sec	6
Oxygenator	Quad 40, SeQual Oxygenator	15 standard l o^{2}/min	2
Sandfilter	Triton TR 100, 80 kg sand substrate	22 m^{3}/hr	6
Biofilter	Cylinder, 100 cmϴ x 200 cm height	1.0-1.5 kg polystyrene microbead 4000-6000 m^{3} specific surface area	6
Pump	Pentair Pinnacle, 1.5 kWh motor Pentair Pinnacle, 1.0 KWh motor Pentair Pinnacle, 0.5 kWh motor	30 m^{3}/hr or 8 l/sec 18 m3/hr or 5 l/sec 15 m3/hr or 4 l/sec	5 2 1
Pipes	70 mmϴ PVC, 8 orifice holes	6 l/sec	

3.5.2 Species selection

Seabass is a native species in Malaysia. It is a euryhaline species and can be farmed either in fresh and brackish water. It grows best in culture environment as shown in Table 5 (Tookwinas and Charearnrid 2008). Seabass is the leading marine finfish species being cultured in Malaysia because of the availability of juvenile from artificial breeding in hatcheries (Mohd. Fariduddin 2006). and its rapid growth rate. It could grow to 3-5 kg in 2 years in the wild (Tookwinas and Charearnrid 2008).

The species has an established market in the Malaysia, including live fish for seafood restaurant. The ex-farm price of seabass in Malaysia is RM 12-14 per kg. However the price of live fish delivered to both the domestic and export market is RM 25-30 per kg (Mohd. Fariduddin 2006).

Table 5: Physio-chemical properties of water suitable for seabass culture in Malaysia

Water parameter	**Range**
Dissolved oxygen	4.0-8.0 mgl
Salinity	10-31 ppt.
pH	7.5-8.3
Temperature	26 -32^{0}C
Turbidity	≤10 ppm
Ammonia nitrogen	≤0.02 ppm

Source: Tookwinas and Charearnrid 2008

3.5.3 Site selection

The propose site is Sematan, approximately 105 km northwest of Kuching, the capital of Sarawak that has a population of 600,000 people. Sematan has supporting infrastructure facilities such as a good road to Kuching, electricity and water supplies and a telecommunications system. Sematan is situated on the coast of the South China Sea as shown in the map in Figure 4.

Figure 4: Map of Sarawak showing the location of the proposed RAS farm in Sematan (Source: Microsoft Encarta 2008).

The general parameters of the water at the South China Sea, the source of water for the proposed farm is shown in Table 6. The water parameters are similar to the physio-chemical properties of sea water suitable for seabass culture as shown in Table 5.

Table 6: Water parameters for RAS farm in Sematan

Parameters	Average
Salinity	30 ppt.
Temperature	29 ^{0}C
Dissolved oxygen	6.5 mgl
PH	7.7
Turbidity	≤10 ppm

Source: Syarikat 2008.

4 RESULTS

4.1 Pre-stocking performance test results

4.1.1 Standard oxygen transfer rate (SOTR)

The facility has three units of 0.09 kWh air blowers for the aeration system and the air blowers are operating simultaneously. Measurements of the air volume were done using the Pitot-Tube measurement. The aerator delivers 19 l/s air volume at a flow rate of 1 l/s, the gas liquid ratio is 19:1.

Two tests were conducted for each system. (The test bypasses the biofilter, but for identification purposes, the system is referred to as with and without biofilter). The test for the system without biofilter which was done at a flow rate of 1.2-1.3 l/s, reached 100% DO saturation at 10.3 mg/l after 10 minutes compared to 15 minutes at a flow rate of 0.90-0.95 l/s for the other system. The SOTR and standard aerator efficiency (SAE) of the system at different flow rates and different starting oxygen saturation levels are shown in Table 7.

Table 7: SOTR and SAE at different flow rates

Test flow rate (l/s)	Starting saturation	System	SOTR MgO^2/sec	SAE gO^2/kWh
DO 1a – 1.3	55%	Without biofilter	22.1	295
DO 1b 1.2	55%	Without biofilter	20.3	270
DO2a 0.95	44%	With biofilter	10.4	138
DO 2b 0.90	50%	With biofilter	12.2	162

The test results indicate that the higher the flow rate, the more efficient the aerator is in transferring oxygen.

Data for the aerator efficiency tests and calculation for the coefficient of oxygen transfer, SOTR and SAE are in Appendix 8a, 8b and 8c.

4.1.2 Carbon dioxide removal

Two tests were conducted for each system. With a gas to liquid ratio of 19:1 and vertical column of 0.37 m diameter x 0.9 m height filled with a bio polypropylene ring for gas liquid interface, the aerator efficiency in removal of relative carbon dioxide is estimated at 70% (Timmons *et al*. 2004). The results of the carbon dioxide removal test are shown in Table 8.

Table 8: Results of the carbon dioxide removal test on the system.

	Carbon dioxide removal test 1			
	Flow rate: 0.5 lit/sec			
Time	**PH**	**Temp °C**	**Salinity**	**CO_2 (mg/L)**
Before	7.7	10.3	20	1.92
0 min	6.41	10.3	20	23.97
After 15 min	7.25	11.2	20	3.00
After 45 min	7.6	11.8	20	1.43
	Carbon dioxide removal test 2			
	Flow rate : 1.5 lit/sec			
Time	**PH**	**Temp °C**	**Salinity**	**CO_2 (mg/L)**
Before	7.98	10.6	26	**1.36**
0 min	6.65	10.8	26	12.66
After 15 min	7.73	11.4	26	1.43
After 45 min	7.86	12.2	26	1.03

The levels of carbon dioxide in the water source before addition of 25 ml sulphuric acid were 1.92 and 1.36 mg/L. By adding acid, the Total Carbon equilibrium is shifted from Bicarbonate (HCO_3) to Carbon dioxide (CO_2). The CO_2 concentrations after acid addition were 23.97 and 12.66 mg/L respectively. After 45 minutes of aeration, the CO_2 levels were back to 1.43 and 1.03 mg/L for Test 1 and 2. Both levels were below the level for incoming water source, which indicated that the aerator were able to remove the rise in CO_2 concentration that result from the change in equilibrium of Total Carbon in the water by adding acid and also CO_2 that is present in the incoming water source.

4.2 Operation performance test results

4.2.1 Water exchange rate

Arctic charr were reared in the culture tanks from 22 January 2008. The water flow rate for both systems was set at 30 l/minute. However, the fresh water intake rate was 12 l/minute for the system without biofilter and 0.5 l/minute for the system with biofilter. At that intake rate, the volume of water needed per day was 17.3 m^3 for the system without biofilter, a 1000% water exchange rate per day, whereas the system with biofilter exchanges 40% of the water volume daily.

4.2.2 Delivery of dissolved oxygen

The average daily level of DO delivered to both systems was 10.5 mg/l. There was no difference in DO levels in the water for recirculation for both systems, as shown in Figure 5. However, there was a slight difference in the average daily oxygen consumption between the two systems as shown in Figure 6. The average daily oxygen consumption for the system without biofilter was 2.06 mg/l compared to 1.80 mg/l for the other system. The slight difference was due to a different amount of feed consumed by the fish. The data for delivery and consumption of oxygen are in Appendix 9.

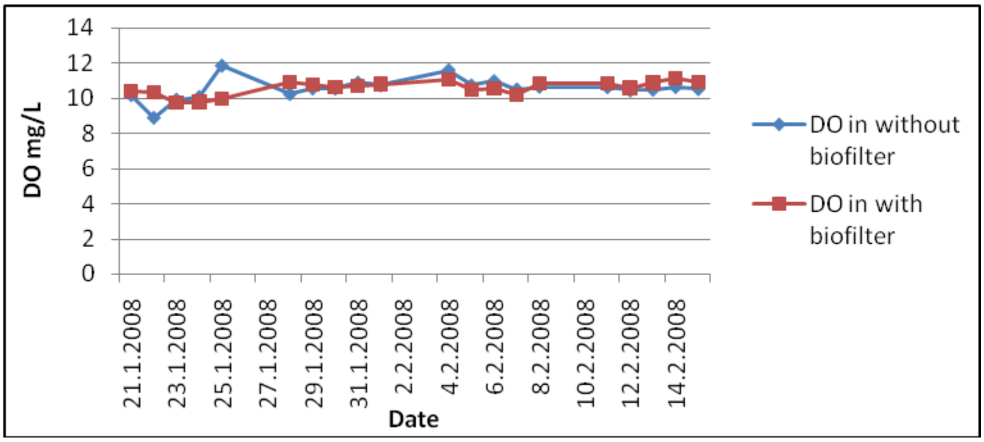

Figure 5: DO level in reused water during operation in both systems as explain above.

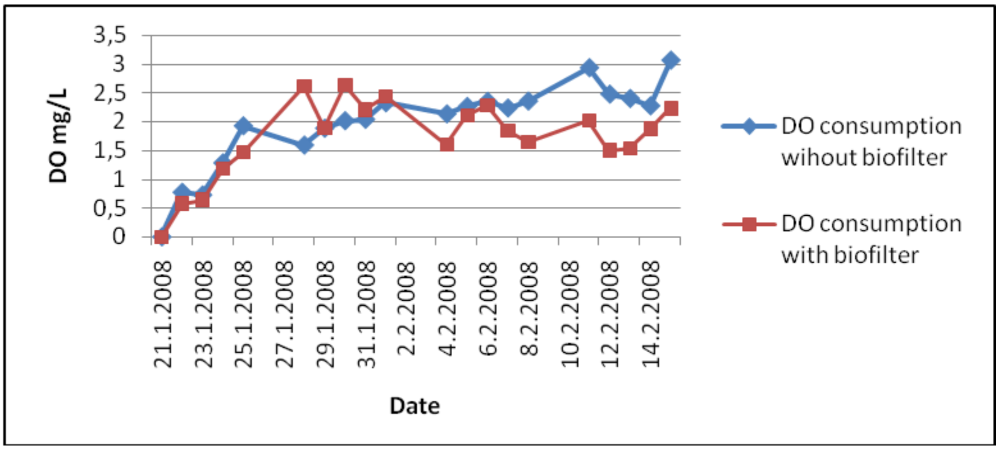

Figure 6: DO consumption during operation in both systems as explain above

4.2.3 Carbon dioxide removal

The average CO_2 level in the two tanks for the system without biofilter was 3.20 mg/l whereas the average CO_2 in the reused water that has been aerated was 2.01 mg/l. This indicates that the system had remove 1.19 mg/l of CO_2 that was produced as a result of fish metabolism.

For the system with biofilter, the average CO_2 level in the two tanks was 3.10 mg/l. The average CO_2 in the aerated water for reused water was 1.87 mg/l. This means that the system had removed 1.27 mg/l of CO_2 from the water in the culture tanks.

Based on the average CO_2 level and the average quantity of CO_2 removal, there is no difference in the performance of the system in removing carbon dioxide, even at different water exchange rates. The levels of CO_2 for both systems are below 5 mg/l, the safe level for salt water aquaculture (Figures 7 and 8).

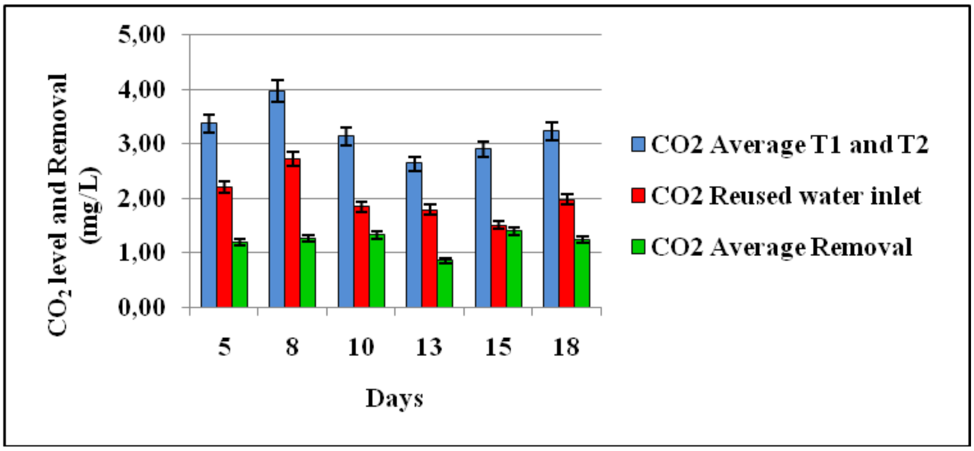

Figure 7: Dissolved CO_2 level and removal quantity in the system without biofilter as explain above

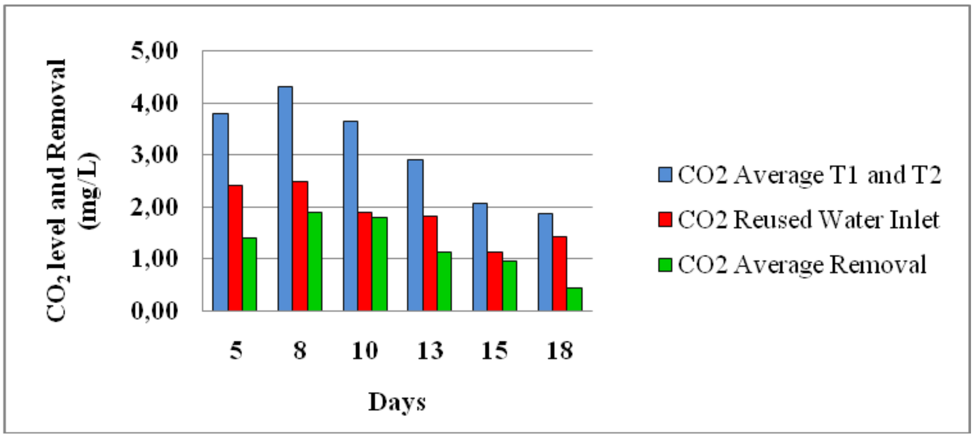

Figure 8: Dissolved CO_2 level and removal quantity in the system with biofilter as explain above

Data for the CO_2 level and removal quantity of CO_2 are in Appendix 10.

4.2.4 TAN removal

The system without biofilter relied on 12 l/minute of new water intake to remove ammonia. The average TAN level for this system was 0.286 mg/l. However, the average TAN level in the system with biofilter was 1.051 mg/l. The difference was big, as could be seen in the different levels of TAN plotted on a bar graph having a similar scale (Figures 9 and 10).

The quantity of TAN removal is the difference between TAN in the culture tank outlet and TAN in the water for reuse. The quantity is 0.020 mg kg^{-1}min^{-1} using 12 l/minute of new water. The system with biofilter has a negative removal of TAN from day 13 onwards. The quantity of TAN in the reused water is higher than TAN in the tank outlet water. The data from this study could not categorically explain why but it could be due to insufficient production of TAN for the nitrification process in the biofilter, or TAN that is in the sandfilter. However, the TAN levels for both systems were at safe levels, less than 3 mg/l which is considered critical for fish in similar environments.

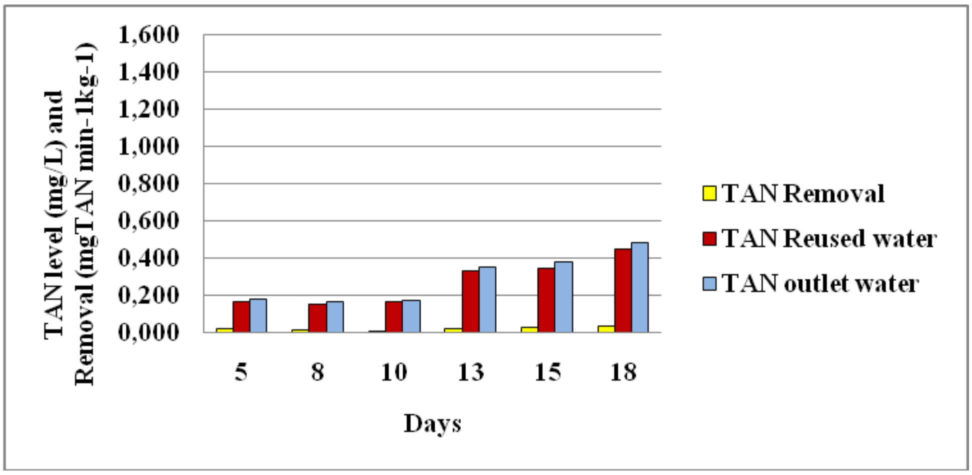

Figure 9: TAN level and removal quantity in the system without biofilter as explain above.

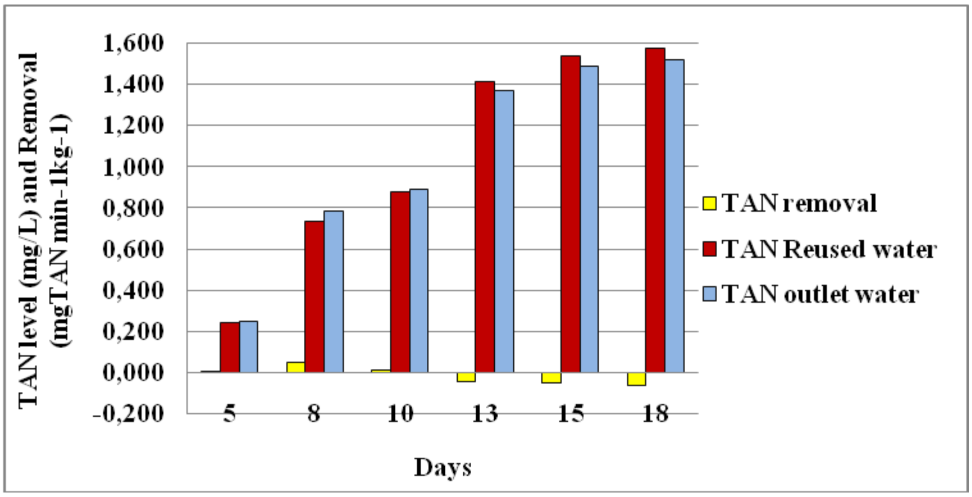

Figure 10: TAN level and removal quantity in the system with biofilter as explain above

As shown in Figures 9, 10, 11 and 12, TAN and NH_3-N levels increased with time. This was due to the rise in metabolic waste in relation to increased feed consumption by fish after a week.

Data for the TAN levels and removal quantities in both systems are in Appendix 11.

The more critical measurement for fish growth is the unionised ammonia nitrogen, NH_3-N. The level of NH_3-N in the culture tanks had been low at less than 0.005 mg/l for the system without biofilter and 0.015 mg/l for the other system. These levels did not exceed 0.025 mg/l, the maximum level for Arctic charr culture. However, the NH_3-N level in the inlet for recirculating water almost reached the critical point for the system with biofilter from day 15 to 18. This study has not identified the cause(s) for this abnormality due to insufficient time.

Figures 11 and 12 show the levels of NH_3-N during the period. To show the magnitude of the differences, the bar graphs are drawn on the same scale. This indicates that there was a significant difference in NH_3-N levels between the two systems.

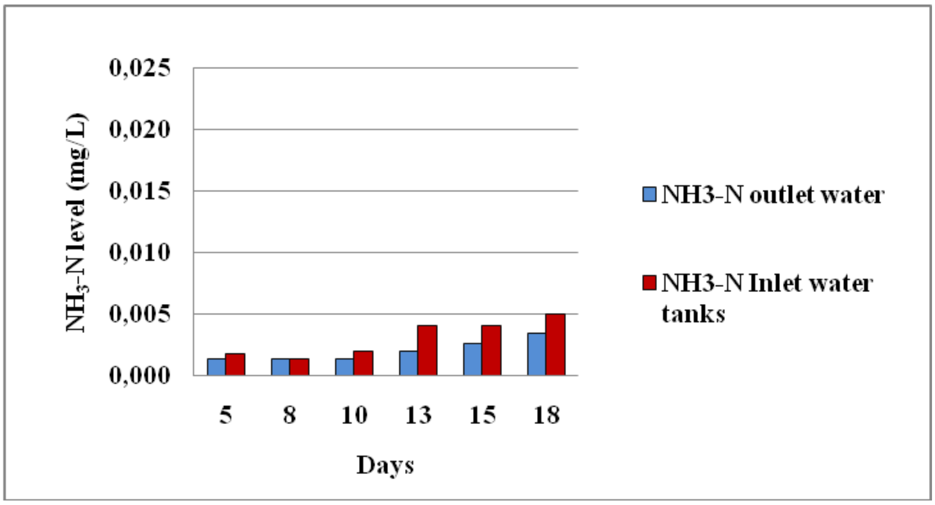

Figure 11: NH_3-N level in the system without biofilter at 10 times water exchange daily as explain above.

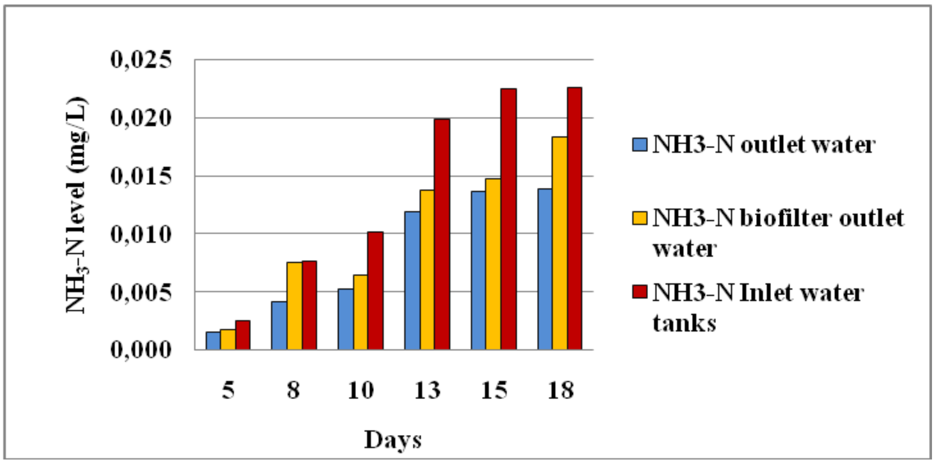

Figure 12: NH_3-N level in the system with biofilter at 0.4 times water exchange rate per day as explain above.

Data for the levels and removal of NH_3-N is in both systems are in Appendix 12.

4.2.5 Removal of solids

Self removal of solid wastes, the uneaten feed and faeces from the culture tank was efficient. However, wastes that deposit in the joints of the discharge pipe from the culture tanks to the reservoir tank need to be removed daily. The wastes that accumulate in the sedimentation tank need to be flushed out manually. The effluents that accumulate in the sandfilter need to be flushed out by a backwashing process.

4.3 Financial feasibility

4.3.1 Break-even analysis

The estimated variable cost of production is RM 7,400.00 per metric ton of seabass. Selling the fish at RM 16,000.00 per metric ton, the net profit contribution is RM 8,600.00 per metric ton

The break-even analysis using assumptions on variables and fixed costs of production and sales prices shows the simple break-even quantity is 10.5 t (Figure 13). However, the total break-even quantity for the project is 21.3 t per year. A calculation for the total break-even quantity is shown Appendix 13.

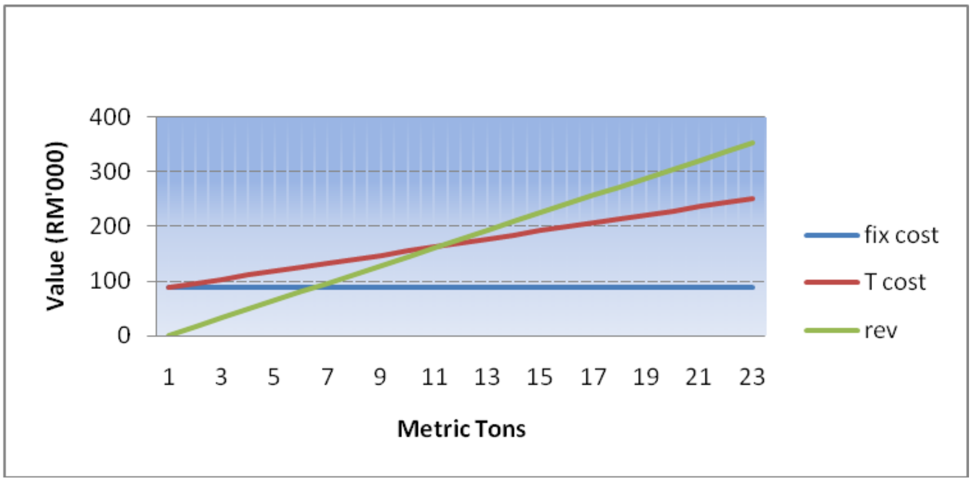

Figure 13: Simple break-even quantity based on variables and fixed costs of production

4.3.2 Operation gain or loss

Based on the operation statement in Appendix 14, the operating surplus or the earning before interest tax depreciation and amortisation (EBITDA) of the project is at RM 105,000.00 annually from the third year of operation. However, the annual total operation gain or loss after deducting depreciation ranges from negative RM 62,000.00 in the first year to surplus RM 80,000.00 from the sixth year onwards. After annuity payment, the net profit of the project over a 10 year period is RM 330,000.00. The projection of annual operation gain or loss and net profit of the project are shown in Figure 14.

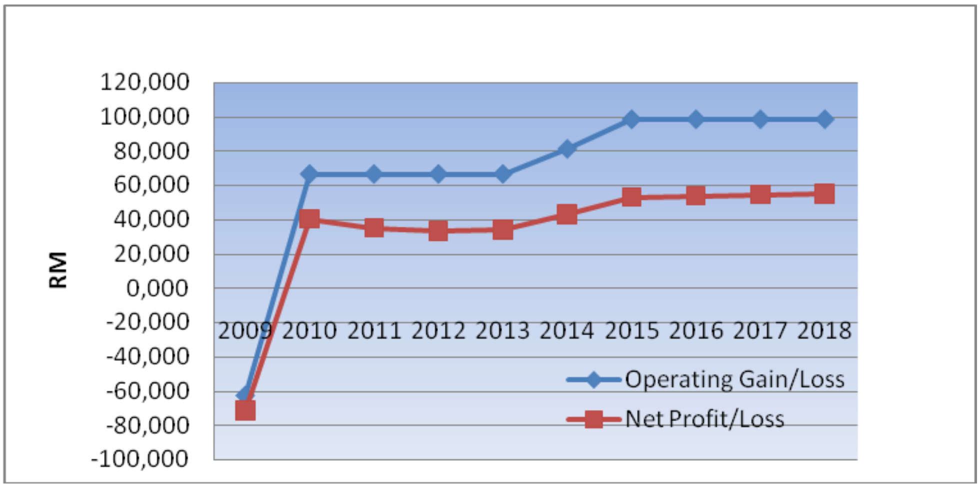

Figure 14: Projection of annual operation gain/loss and net profit/loss from 2008-2018

4.3.3 Net present value and internal rate of return

Total capital refers to the capital obtained by loans from financial institutions and equity is the amount contributed by the owners or shareholders of the project. The project had an NPV of total capital at RM 112,000.00. However, the NPV for equity of the shareholder is higher at RM 158,00.00. This positive NPV indicates that the project is profitable over a 10 year period even though it shows negative NPV of total cash flow until the sixth year. The NPV net cash flow of total capital and NPV net cash flow of equity are shown in Figure15.

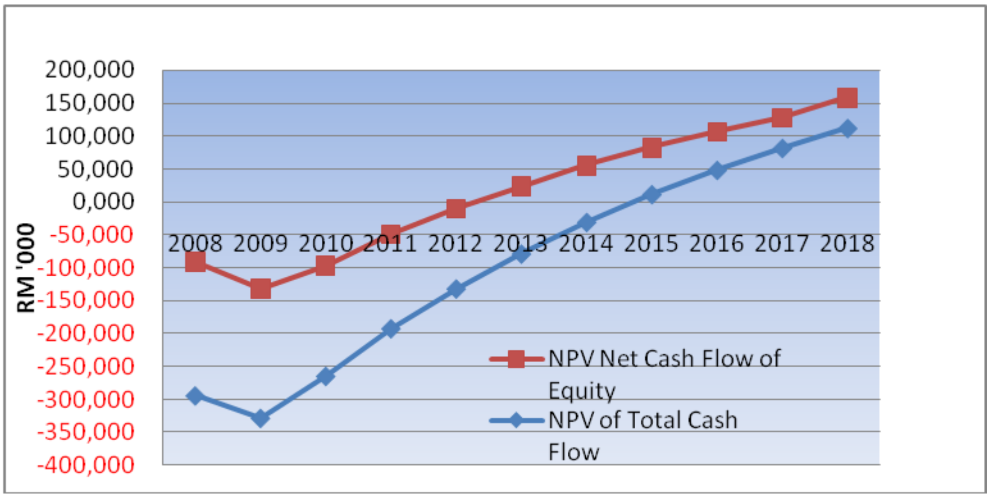

Figure 15: NPV of net cash flow of the total capital and equity from 2008-2018

The IRR is 17% and 30% for total capital and equity respectively in the 10^{th} year as shown in Figure 16 and the assumption and result worksheet in Appendix 15. It is above the loan interest at 4% and also above the marginal attractive rate of return (MARR) at 10%. (The MARR is based on the expectation that the project will generate ≥10% return on investment or other alternative investments in Malaysia). If the IRR is less than the MARR at 10%, then the project is not viable. The NPV of the project is ≤ RM 0.00 if the IRR is ≤10%.

The data for the IRR of net cash flow of total capital and equity are in the cash flow worksheet (Appendix 16).

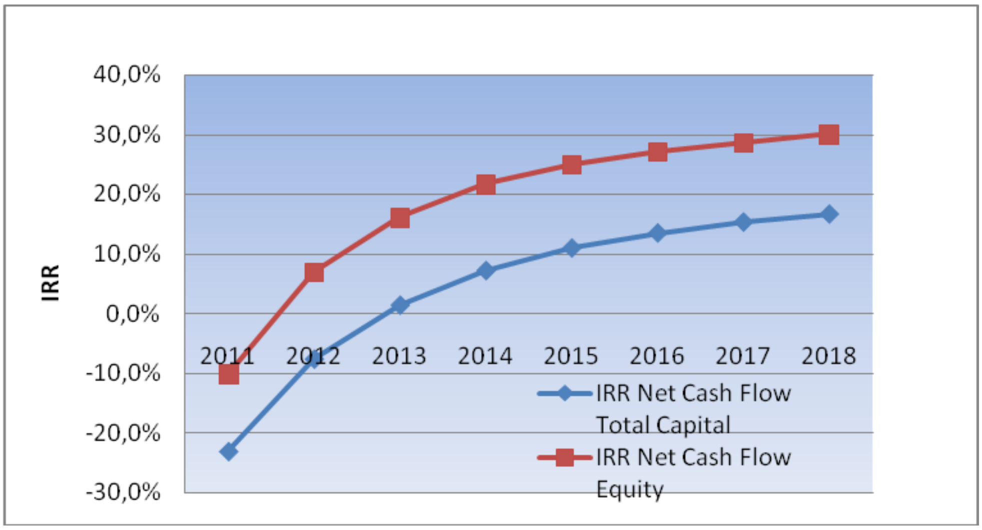

Figure 16: IRR of net cash flow of total capital and equity of the project

4.3.4 Sensitivity analysis

This project is sensitive to drops in selling price and production quantity. The NPV of total capital drops from RM 112,000.00 to RM 20,000.00 at RM 15.00/kg and to RM 41,000.00 at 95% production quantity. The NPV of total capital rises to RM 200,000.00 if the price increases to RM 17.00 per kg of fish and production quantity rises to 24 metric tons annually.

The parallel lines for the NPV of total capital and NPV of equity means changes in selling price and production quantity has similar effects to both NPV of total capital and NPV of equity. This also means that the NPV of total capital increases or decreases proportionately to the increase or decrease in NPV of equity due to changes in selling price as shown in Figure 17 and also increases or decreases in production quantity as shown Figure 18.

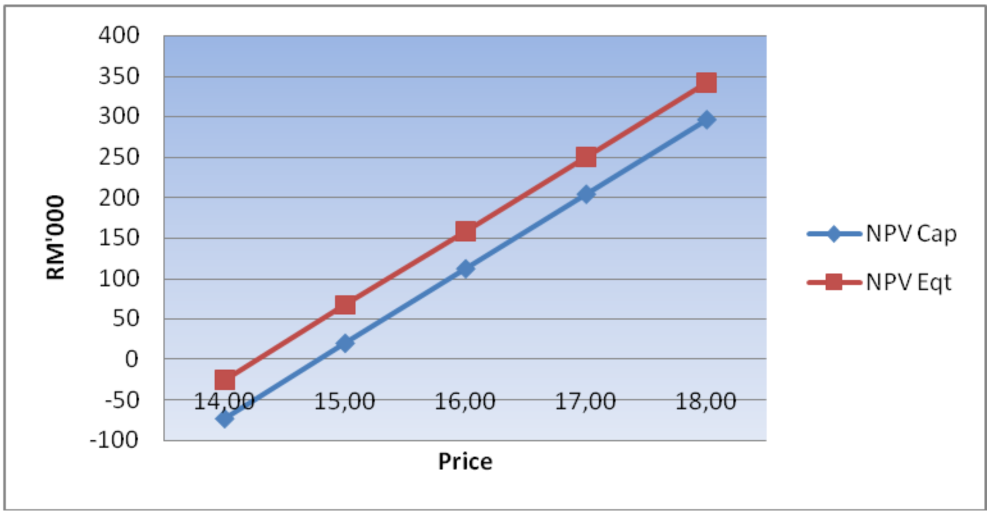

Figure 17: Impact of change in selling price on NPV of total capital and NPV of equity

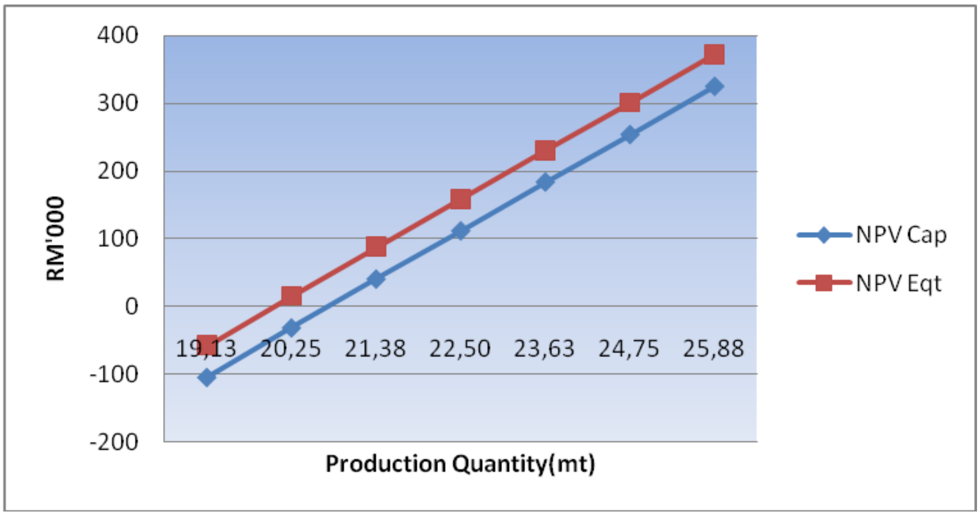

Figure 18: Impact of change in production quantity to NPV of total capital and NPV of equity

In terms of costing, a 10% increase in cost of operation led to a drop in the NPV of total capital by RM 122,000.00 from RM 112,000.00 to negative RM 10,000.00. The NPV rises by RM 113,000.00 to RM 225,000.00 for a 10% reduction in cost (Figure 19). However, the working capital, i.e. the funds needed to sustain the project before full production and sales is achieved, increased from RM 60,000.00 to RM 75,000.00 for a 10% increase in costs of operation and reduced to RM 50,000.00 for a 10% reduction in costs of operation.

The effects of changes in operation costs on the NPV of total capital and the NPV of equity is similar in proportion and value. This is indicated by the parallel lines of the NPV of total capital and of equity in Figure 19.

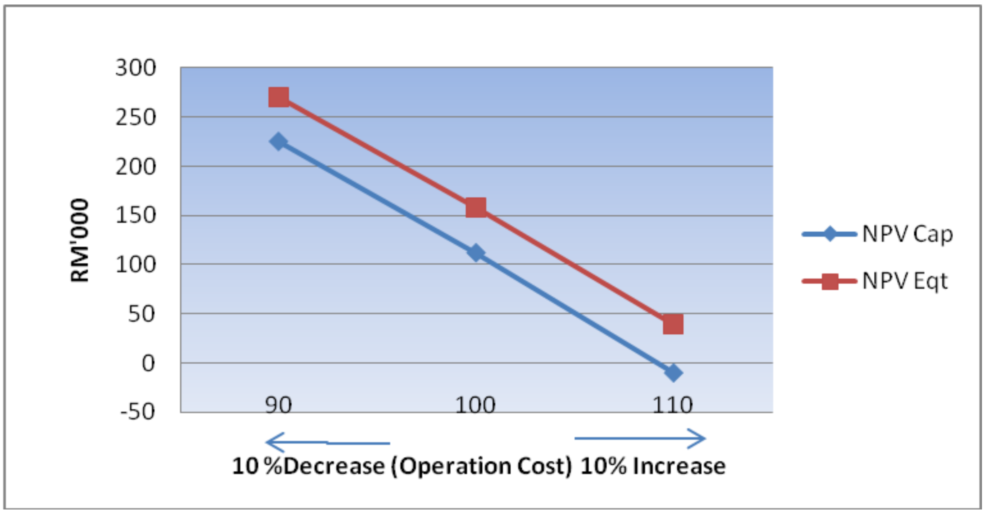

Figure 19: Changes in proportion and value of NPV of total capital and equity due to increases or decreases in operation costs

Based on the NPV of total capital at RM 112,000.00, this project could sustain operations at a ≤RM 1.00/kg drop in selling price, a ≤5% drop in production quantity and a <10% increase in production costs. The project will have negative NPV if price drops to RM 14.00 per kg or production quantity drops to 20 metric tons and costs of production increase by 10%.

At 17% IRR of total capital, it could also be concluded that the project could only sustain operations at a ≤RM 1.00/kg drop in selling price, a ≤5% drop in production quantity and a <10% increase in production costs. The impact of changes in price, production quantity and costs of operation on IRR is shown in Figures 20, 21 and 22.

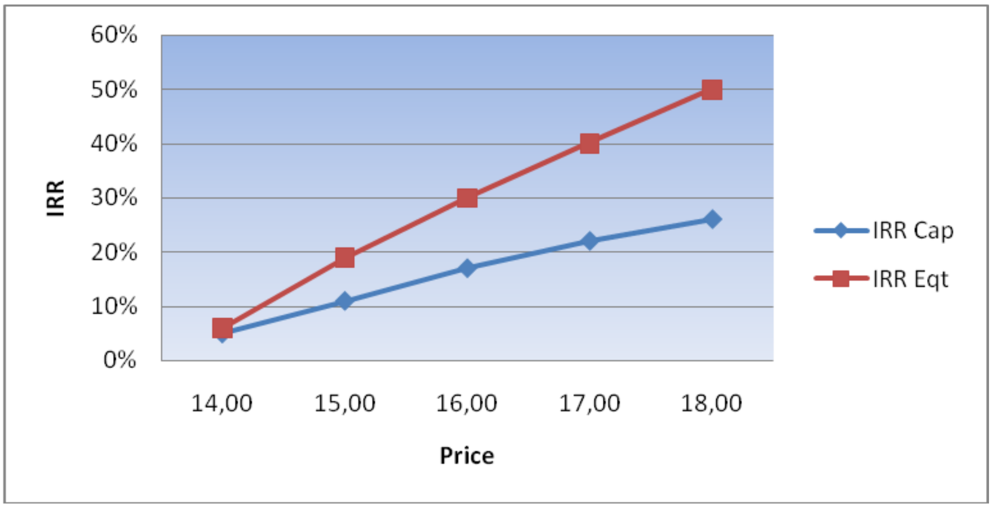

Figure 20: Impact of changes in price on IRR of total capital and equity.

Figure 20 shows that the effects of changes in selling price are different for the IRR of total capital and the IRR of equity. The increase in IRR of equity is much higher than the increase in IRR of total capital if selling price rises to RM 17.00 or RM 18.00 per kg. This means the equity owner gets a higher return on equity than the return on investment for total capital. The equity owner also gets higher returns compared to the return on investment for total capital if production quantity increases as shown in Figure 21 and costs of operation decrease as in Figure 22.

However, the steeper curve means that the equity owner will be more adversely affected by the drop in sales price, production quantity and increase in operation costs as shown in Figures 20, 21 and 22.

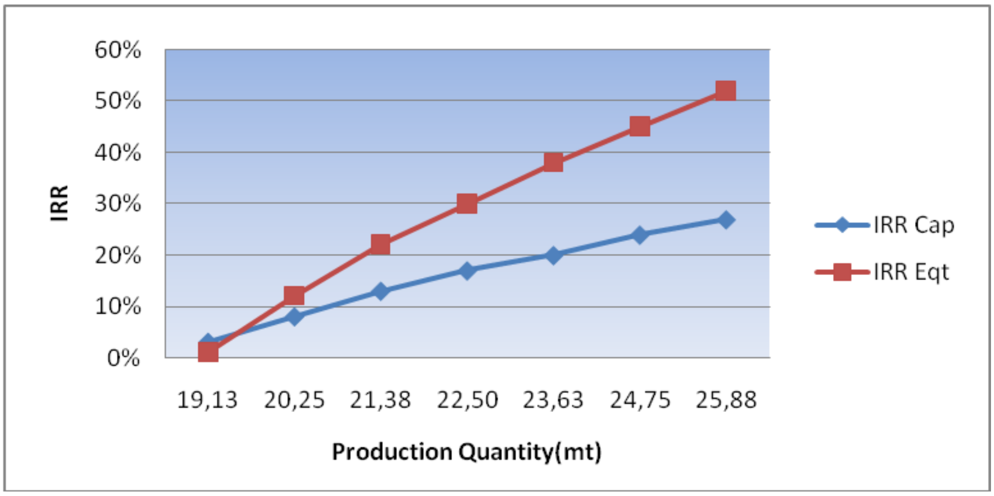

Figure 21: Impact of changes in production quantity on IRR of total capital and equity.

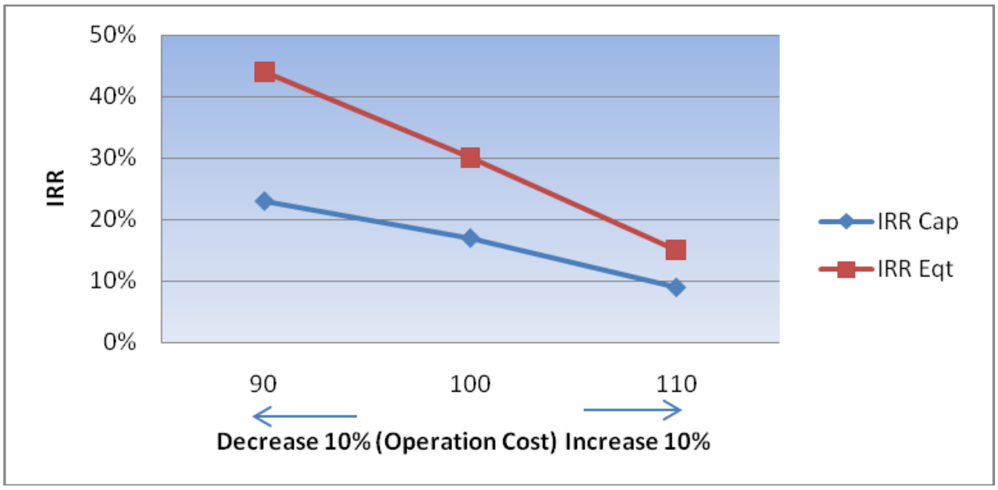

Figure 22: Impact of increase or decrease in operation costs on IRR of total capital and equity

4.3.5 Comparison of cost efficiency and profit margin

The average cost of operation at full capacity is RM 11,300.00 per t. Since the selling price is RM 16,000.00 per t, the profit margin is RM 4,700.00 or 41.5% of the average cost of operations. Based on the study by Hutchinson *et al.* (2004) on the economics of RAS producing barramundi (*Lates calcarifer*) in Australia, the average cost of production ranges from AU $6,640.00 to AU $7,080.00 per t. Selling at AU $9,400.00 per t, the profit margin ranges from 32% to 42%.

For tilapia production in the United States of America, Timmons *et al.* (2002) suggest that production costs should not exceed US $3,680.00 per t. Selling at US $4,780.00 (at the time), the profit margin is 30%.

It is not possible to relate the production costs by just converting the value of the currency to Malaysian Ringgit due to the difference in buying and selling price. However, a comparison could be made on the percentage of the profit margin. Based on the above information for the cost of production and profit margin in Australia and the USA, the percentage of the profit margin for this project is within a similar range.

5 DISCUSSION

5.1 Technical feasibility

The SOTR ranges from 10.4- 22.14 mgO^2/second indicated that the aerator and LHO system are technically capable of delivering sufficient oxygen for fish consumption at a flow rate of 1.0-1.5 l/second and a gas to liquid ratio of 10-15:1. This was proven by the average dissolved oxygen for both systems, which was constant at 10.5 mgO^2/l during three weeks of operation. With the oxygenator, the system achieved 115% dissolved oxygen saturation.

The aeration system was able to keep carbon dioxide concentration levels below 5.0 mg/l which are lower than the acceptable levels of 7-10 mg/l for salt water aquaculture.

Critical to successful operation of RAS is the ability to remove TAN and NH_3-N. The biofilter system was able to keep TAN at below 3.0 mg/l and NH_3-N at 0.025 mg/l in the culture tanks. However, due to short duration for data collection, this study was not able to identify the cause(s) for the abnormality in TAN and NH_3-N levels in the reused water for the system with biofilter.

The water exchange rate at 10 times daily requires a relatively high volume of water for a system without biofilter in the scale-up farm. Further study or trials are needed to determine the right exchange rate based on the storage facility and cost of pumping even though the selected site has abundant water for recirculation.

In general, the project experiment went well as both systems were functioning in the environment at the facility. Despite the abnormality in TAN and NH3-N levels in the system with biofilter, it is technically feasible to apply the design of both systems in a scale-up RAS farm in Malaysia.

5.2 Financial feasibility

This study had documented, where possible, the justifications behind the assumptions by giving sources to estimations of costing, expectations of production quantity and references to the financial variables. These documentations are necessary in order to be transparent and attach credibility to the assumptions and establish confidence or faith in the outcome of the study.

The sensitivity analysis shows the magnitudes of the changes to the profitability indicators both in pessimistic and optimistic scenarios. The organisation could evaluate the project better and assess the risk of funding the project under different scenarios. For this project, it is sensitive to ≥RM 1.00/kg drop in selling price, ≥5% drop in production quantity and ≥10% increase in production costs.

The decision whether to proceed with setting up an RAS farm producing seabass at Sematan depends on the specified criteria set by the organisation, for example a project must achieve an IRR based on the expected return on investment and the NPV of cash inflows corresponding to the expected IRR. If the decision criteria are set at IRR 10%, thus achieving positive NPV in cash inflows at the end of the planning horizon, this project should proceed.

If the project proceeds, the organisation needs to focus on the uncertainty factors that are within their control such as production costs and production quantity to enhance profitability. The organisation could also influence the price of fish products by producing according to the quantity and quality demanded of the market to increase revenues and reduce financial risk.

6 CONCLUSION

This study has enabled acquisition of fundamental knowledge on how to design the system, calculate technical specifications of water treatment components, test the efficiency of the component and conduct a feasibility study of setting a bigger system in Malaysia. The knowledge and experience gained will be useful in planning, designing and operating an RAS farm because application of knowledge in designing the system, water quality management and financial prudence will have to be coordinated before profit can be realised.

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Note *: Source of costing and estimation in Appendix 6 and 7.

APPENDICES

Appendix 1

(a) 4 culture tanks

(b) Reservoir tanks

Appendix 2

(a) Sedimentation tank

(b) Pump and sandfilter system

Appendix 3

(a) Combined aerator and oxygenator Unit

(b) Polypropylene bio ring for gas liquid interface in the aerator

Appendix 4

(a) Polystrene microbead for biofilter substrate surface area

Biofilter tank

Appendix 5

Specification of project component at Saudarkrokur

Component	Size/Model	Capacity
Culture Tank	Octagonal, ±100cm x 80 cm	750 l
Reservoir Tank	Circular, 68cmϴ x 64 cm height	230 l
Settling Tank	Circular, 25cmϴ x 30 cm height	15 l
Aerator and LHO	Cylinder, 37cmϴ x 180cm height	19 desimeter^3/sec
Sandfilter	Triton TR 60, 40 kg sand substrate	14m^3/hr
Biofilter	Cylinder, 68cmϴ x 150cm height	492 m^3 substrate surface area
Pump	Pinnacle 75, 0.55kWh motor	14m^3/hr or 4 l/sec
Pipes	40mmϴ PVC, 4 orifice holes	0.48 liter/sec

Appendix 6

Costing summary of scale-up RAS farm in Malaysia

	Investment Cost	Quantity	Unit Price RM	RM	Sources/Rationale
1	Building and Utilities (1200m2)	1	Lump sum	45.000	Estimation
2	Culture Tanks 15 mt	6	6.500	39.000	ATR Aquafarming/adjusted
	10mt	6	5.000	30.000	ATR Aquafarming/adjusted
	5mt	3	3.000	9.000	ATR Aquafarming/adjusted
3	Circulation Tanks 3mt	5	2.000	10.000	ATR Aquafarming/adjusted
	1.5mt	1	1.500	1.500	ATR Aquafarming/adjusted
	0.2mt	6	200	1.200	Estimation
4	Storage Tanks 20mt	3	8.000	24.000	ATR Aquafarming/adjusted
5	Pumps 1kWh	2	1.700	3.400	www.nextag.com
	0.75kWh	5	1.400	7.000	www.nextag.com
	0.5kWh	1	1.200	1.200	www.nextag.com
	Sumbersible 0.5kWh	2	1.600	3.200	www.nextag.com
6	Oxygenator-Quad 40	2	6.000	12.000	www.sequal.com
7	Sandfilter-Triton 60	6	3.100	18.600	www.preisroboter.de
8	Biofilter	6	1.800	9.600	www.solar-components.com/adjusted
9	Aerator and LHO	6	2.000	12.000	Estimation
10	Pipes and valves	Lump sum	6.000	6.000	Estimation
11	Generator -Voltmaster 15kW	1	15.000	15.000	www.generatorjoe.net/price/adjusted
12	Water Quality Equipment	Lump sum	8.000	8.000	Estimation
13	Office Equipment	Lump sum	8.000	8.000	Estimation
				263.700	Sum of all costing

Appendix 7

Operation cost and assumption of scale-up RAS farm in Malaysia

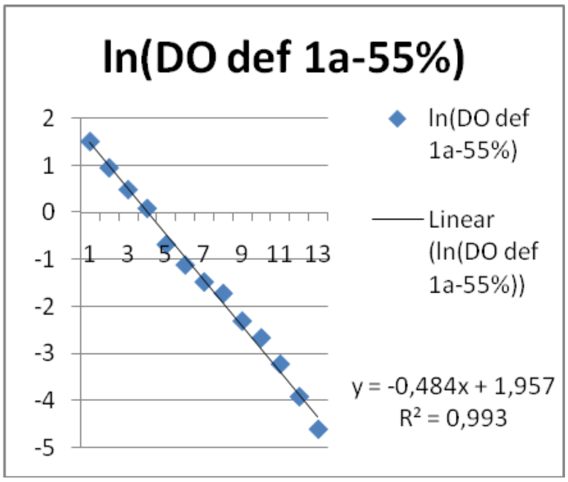
	RM	RM	Source/Rationale
	monthly	Annually	
Fixed Cost *			
Salary	6.000	72.000	Calculated estimation
Administration	500	6.000	Calculated Estimation
Maintainence	500	6.000	Estimation
Others	300	3.600	Estimation
		87.600	Sum of Fixed Cost
Variable Cost*			
Juvenile 30,000 pcs x RM1.4/pc		42.000	MFDA/ adjusted
Feed FCR 1.2 x RM3.5/kg		94.500	MFDA/adjusted
Electricity-4800kWh/month	1.600	19.200	Calculated rates.(Syarikat Sesco Bhd)
Water	400	4.800	Calculated estimation(Kuching Water Board)
Marketing and Transportation	500	6.000	Calculated estimation
		166.500	Sum of Variable Cost
Assumption (Based on: Hutchinson *at el.*)			
Survival Rate	80%		Industrial Benchmark
Market Size	1 kg/pc		Industrial Benchmark
FCR	1.2:1		Industrial Benchmark
Price/kg	RM 16		Fariduddin, 2006

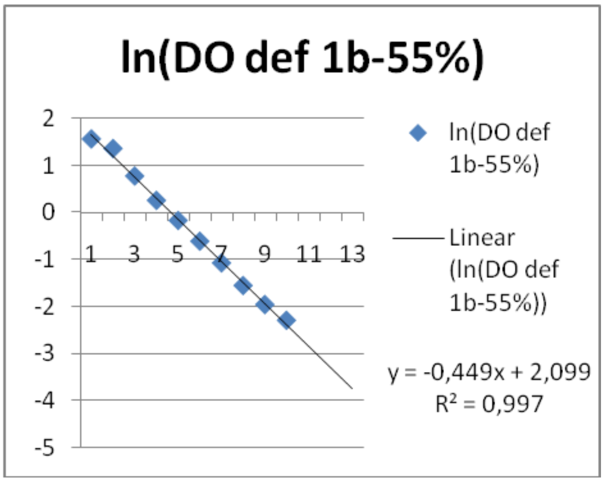
Notes*: Fixed Cost and Variable cost : these are based on basic budgeting process and assumption. The amounts are based on Malaysian pricing.

Appendix 8a

Result of Aerator Efficiency Test 1a and 1b

Time	DO 1a	DO def	ln(DO def)	DO 1b	DO def	ln(DO def)
0	5.67	4.57	1.5195132	5.67	4.72	1.5518088
1	7.63	2.61	0.95935022	6.55	3.84	1.3454724
2	8.60	1.64	0.49469624	8.28	2.11	0.7466879
3	9.24	1.10	0.09531018	9.16	1.23	0.2070142
4	9.73	0.51	-0.6733446	9.61	0.78	-0.2484614
5	9.91	0.33	-1.1086626	9.91	0.48	-0.7339692
6	10.01	0.23	-1.469676	10.11	0.28	-1.2729657
7	10.06	0.18	-1.7147984	10.24	0.15	-1.89712
8	10.14	0.10	-2.3025851	10.31	0.08	-2.5257286
9	10.17	0.07	-2.65926	10.35	0.04	-3.2188758
10	10.20	0.04	-3.2188758	10.37	0.02	-3.912023
11	10.22	0.02	-3.912023	10.38	0.01	-4.6051702
12	10.23	0.01	-4.6051702	10.38	0.01	-4.6051702
13	10.24	0	#NUM!	10.39	0	#NUM!
14	10.24	0	#NUM!	10.38	0.01	-4.6051702
15	10.24	0	#NUM!	10.37	0.02	-3.912023
16	10.23	0.01	-4.6051702	10.36	0.03	-3.5065579

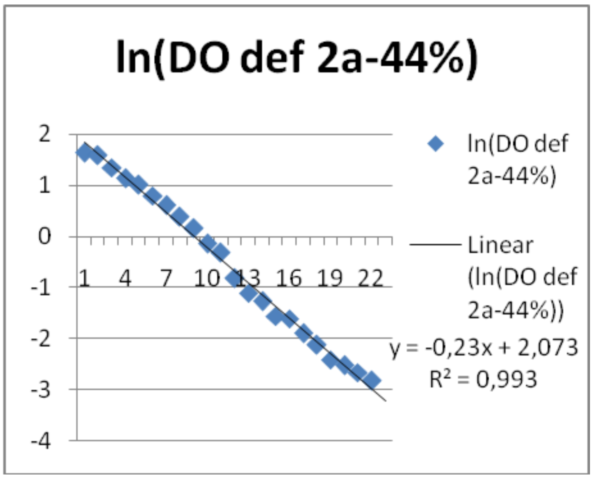


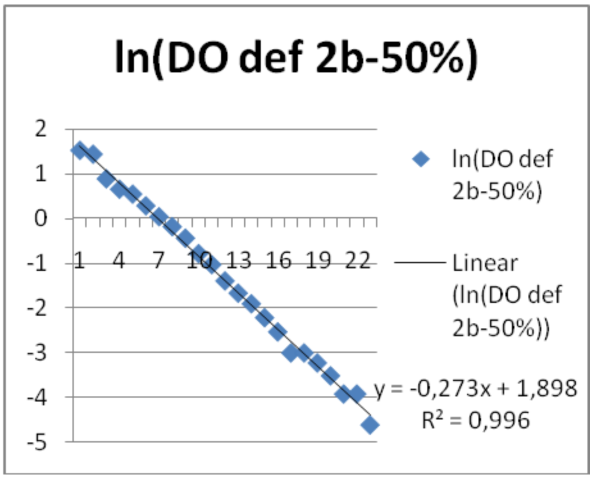


Appendix 8b

Time	DO 2a	DO def	ln(DO def)	DO 2b	DO def	ln(DO def)
0	4.39	5.11	1.631199404	5.15	4.62	1.53039471
1	4.63	4.87	1.583093937	5.51	4.24	1.44456327
2	5.66	3.84	1.345472367	7.3	2.45	0.89608802
3	6.4	3.1	1.131402111	7.83	1.94	0.66268797
4	6.76	2.74	1.00795792	8.03	1.74	0.55388511
5	7.28	2.22	0.797507196	8.43	1.34	0.29266961
6	7.66	1.84	0.609765572	8.72	1.05	0.04879016
7	8.02	1.48	0.392042088	8.93	0.84	-0.1743534
8	8.32	1.18	0.165514438	9.12	0.65	-0.4307829
9	8.63	0.87	-0.139262067	9.31	0.46	-0.7765288
10	8.77	0.73	-0.314710745	9.41	0.36	-1.0216512
11	9.06	0.44	-0.820980552	9.52	0.25	-1.3862944
12	9.17	0.33	-1.108662625	9.58	0.19	-1.6607312
13	9.22	0.28	-1.272965676	9.62	0.15	-1.89712
14	9.29	0.21	-1.560647748	9.66	0.11	-2.2072749
15	9.3	0.2	-1.609437912	9.69	0.08	-2.5257286
16	9.35	0.15	-1.897119985	9.72	0.05	-2.9957323
17	9.38	0.12	-2.120263536	9.72	0.05	-2.9957323
18	9.41	0.09	-2.407945609	9.73	0.04	-3.2188758
25	9.42	0.08	-2.525728644	9.74	0.03	-3.5065579
19	9.43	0.07	-2.659260037	9.75	0.02	-3.912023
20	9.44	0.06	-2.813410717	9.75	0.02	-3.912023
21	9.47	0.03	-3.506557897	9.76	0.01	-4.6051702

Result of Aerator Efficiency Test 2a and 2b





Appendix 8c

Calculation of Oxygen Transfer Coefficient, SOTR and SAE

1a. K_La_T = ln(DO def i)-ln(DO def ii)÷t ii-ti/60 =Slope of ln(DO def)=0.484x60=29.04/hr^{-1}

Adjusted to 20 ^OC, K_La_{20} = 29.04÷1.024^{-11} = 38.18 gO^2/hr^{-1}
Volume of water = 0.23 m^3, C_{s20}=9.08
SOTR = (K_La_{20})(C_{s20})(V)(10^{-3}) = 38.18 x 9.08 x 0.23 x 10^{-3}(to convert kg to g if necessary)
=79.72gO^2/hr, 1328mgO^2/min, 22.14mgO^2/sec
SAE = 79.72gO2/hr÷0.27 kW (of the 3 air blower) =295gO^2/kWh

1b. K_La_T = ln(DO def i)-ln(DO def ii)÷t ii-ti/60=Slope of ln(def)=0.449x60=26.94/hr^{-1}

Adjusted to 20 ^OC, K_La_{20} = 26.94÷1.024^{-11} = 34.98 gO^2/hr^{-1}
SOTR = (K_La_{20})(C_{s20})(V)(10^{-3}) = 34.98 x 9.08 x 0.23 x 10^{-3}
=73.06gO^2/hr, 1217mgO^2/min, 20.29mgO^2/sec
SAE = 73.06gO2/hr÷0.27 kW (of the 3 air blower) =270gO^2/kWh

2a. K_La_T = ln(DO def i)-ln(DO def ii)÷t ii-ti/60=Slope of ln(Ddef)=0.23x60=13.8/hr^{-1}

Adjusted to 20 ^OC, K_La_{20} = 13.8÷1.024^{-11} = 17.9 gO^2/hr^{-1}
SOTR = (K_La_{20})(C_{s20})(V)(10^{-3}) = 17.9 x 9.08 x 0.23 x 10^{-3}
=37.38gO^2/hr, 623mgO^2/min, 10.39mgO^2/sec
SAE = 37.38gO2/hr÷0.27 kW (of the 3 air blower) =138gO^2/kWh

2b. K_La_T = ln(DO def i)-ln(DO def ii)÷t ii-ti/60=Slope of ln(def)=0.273x60=16.38/hr^{-1}

Adjusted to 20 ^OC, K_La_{20} = 16.38÷1.024^{-11} = 21.27 gO^2/hr^{-1}
SOTR = (K_La_{20})(C_{s20})(V)(10^{-3}) = 21.27 x 9.08 x 0.23 x 10^{-3}
=44.42gO^2/hr, 740mgO^2/min, 12.34mgO^2/sec
SAE = 44.42gO2/hr÷0.27 kW (of the 3 air blower) =165gO^2/kWh

Appendix 9

Delivery and Consumption of Dissolved Oxygen (mg/L)

Without Biofilter					With Biofilter		
Date	DO Rec	DO out Ave	Cons Ave		DO Rec	DO out Ave	Cons Ave
21.1.2008	10.2	10.21			10.4	10.4	0
22.1.2008	8.9	8.13	0.77		10.36	9.78	0.58
23.1.2008	9.95	9.23	0.72		9.77	9.14	0.63
24.1.2008	10.10	8.84	1.26		9.80	8.65	1.15
25.1.2008	11.89	9.99	1.9		9.97	8.53	1.44
28.1.2008	10.26	8.72	1.54		10.95	8.42	2.53
29.1.2008	10.58	8.75	1.83		10.8	8.98	1.82
30.1.2008	10.57	8.61	1.96		10.63	8.09	2.54
31.1.2008	10.92	8.93	1.99		10.71	8.58	2.13
1.2.2008	10.76	8.48	2.28		10.82	8.47	2.35
4.2.2008	11.63	9.54	2.09		11.08	9.53	1.55
5.2.2008	10.76	9.54	1.22		10.5	8.47	2.03
6.2.2008	11.01	8.69	2.32		10.59	8.39	2.2
7.2.2008	10.53	8.32	2.21		10.19	8.41	1.78
8.2.2008	10.68	8.34	2.34		10.87	9.27	1.6
11.2.2008	10.65	7.72	2.93		10.84	8.88	1.96
12.2.2008	10.47	7.99	2.48		10.60	9.15	1.45
13.2.2008	10.51	8.1	2.41		10.90	9.42	1.48
14.2.2008	10.66	8.37	2.29		11.15	9.33	1.82
15.2.2008	10.55	7.45	3.1		10.96	8.79	2.17

Appendix 10

CO$_2$ Level and Removal (mg/L)

Without Biofilter	5 days	8 days	10 days	13 days	15 days	18 days
CO2 (mg/L) T1	3.34	3.97	2.90	2.38	2.99	3.37
CO2 (mg/L) T2	3.39	3.97	3.38	2.91	2.83	3.09
CO2 Average T1 and T2	3.37	3.97	3.14	2.64	2.91	3.23
CO2 Reused water inlet	2.21	2.72	1.84	1.80	1.51	1.98
CO2 Removal T1	1.16	1.26	1.07	0.58	1.47	1.36
CO2 Removal T2	1.23	1.29	1.59	1.14	1.33	1.11
CO2 Removal Average	1.2	1.3	1.3	0.9	1.4	1.2
CO2 Removal Rate(%)	120	127	133	86	140	124
With Biofilter						
CO2 (mg/L) T1	3.91	4.43	3.66	2.84	2.03	1.80
CO2 (mg/L) T2	3.67	4.22	3.63	2.99	2.09	1.93
CO2 Average T1 and T2	3.79	4.32	3.65	2.92	2.06	1.87
CO2 (mg/L) Water Inlet tanks	2.42	2.49	1.90	1.82	1.14	1.44
CO2 Removal T1(mg/L)	1.54	2.02	1.83	1.06	0.92	0.37
O2 Removl T2(mg/L)	1.29	1.77	1.79	1.20	0.98	0.51
CO2 Removal Average	1.42	1.89	1.81	1.13	0.95	0.44
CO2 Removal Rate(%)	142	189	181	113	95	44

Appendix 11

TAN Level and Removal (mg/L)

Days	5 days	8 days	10 days	13 days	15 days	18 days
Without Biofilter	0.181	0.164	0.171	0.359	0.383	0.496
TAN outlet water	0.171	0.163	0.168	0.343	0.368	0.468
Average Removal rate	0.176	0.163	0.170	0.351	0.375	0.482
TAN Inlet water tanks	0.161	0.149	0.163	0.331	0.347	0.447
TAN Removal	0.020	0.016	0.008	0.028	0.035	0.049
	0.011	0.014	0.005	0.012	0.021	0.021
	0.016	0.015	0.007	0.020	0.028	0.035
Removal Rate TAN (%) in LRS	2.0	1.5	0.8	2.8	3.6	4.9
	1.0	1.4	0.5	1.2	2.1	2.1
Average TAN Removal Rate (%)	1.5	1.5	0.7	2.0	2.8	3.5
With Biofilter						
TAN outlet water	0.251	0.779	0.890	1.369	1.483	1.511
	0.251	0.790	0.893	1.378	1.494	1.529
	0.251	0.784	0.891	1.373	1.489	1.520
TAN Inlet water tanks	0.246	0.734	0.877	1.416	1.537	1.577
TAN Removal Rate by biofilter	0.006	0.047	0.013	-0.049	-0.055	-0.068
	0.005	0.058	0.016	-0.039	-0.044	-0.050
	0.005	0.052	0.015	-0.044	-0.050	-0.059
Removal Rate TAN (%) in RAS	0.5	4.5	1.3	-4.7	-5.4	-6.6
	0.5	5.6	1.6	-3.8	-4.3	-4.8
Average TAN Removal rate (%)	0.5	5.1	1.4	-4.3	-4.8	-5.7

Appendix 12

NH$_3$-N Level and Removal (mg/L)

Without Biofilter *	5 days	8 days	10 days	13 days	15 days	18 days
NH3-N outlet water	0.001	0.001	0.001	0.002	0.003	0.003
	0.001	0.001	0.001	0.003	0.003	0.003
	0.001	0.001	0.001	0.003	0.003	0.003
NH3-N Inlet water tanks	0.002	0.001	0.002	0.004	0.004	0.005
With Biofilter*						
NH3-N outlet water	0.001	0.004	0.005	0.012	0.014	0.014
	0.001	0.004	0.005	0.012	0.014	0.014
	0.001	0.004	0.005	0.012	0.014	0.014
NH3-N Inlet water tanks	0.003	0.008	0.010	0.020	0.022	0.023
NH3-N biofilter outlet water	0.002	0.008	0.006	0.014	0.015	0.018
Biofilter*(Water exiting the Biofilter itself, not reaching the 2 different tanks)						
TAN	0.240	0.724	0.868	1.449	1.556	1.652
NH3-N	0.002	0.008	0.006	0.014	0.015	0.018
NO2-N	0	0	0	0	0.33	0.825
NO3-N	0	0	0	0.22	0.66	1.10

Note : There are 2 systems being tested i.e with biofilter and without biofilter

Appendix 13

Calculation of Total Break Even Quantity(BEQ)

Production	**22.500 kg**
Variable Cost/Kg	**RM7.40**
Fixed Cost/Kg	**RM3.90**
Price	**RM16.00**

Profit Requirement = ±10% of Total Financing
Annuity payment = Loan Repayment + Dividend + Tax

Net Profit Contribution(NPC)

NPC = Price/kg -VC/kg = RM8.60

Total BEQ

Total Fixed Cost + Profit Requirement + Annuity Payment ÷ NPC

RM87,600 + RM35,000 + RM60.000 = RM182,600 ÷ RM8.60 = ±21.250 kg

Appendix 14

Simulated Operations Statement of scale-up RAS farm in Malaysia

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	**Total**
Operations Statement													
Sales(ton)			7.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	210
Sale Price/ton			16	16	16	16	16	16	16	16	16	16	
Revenue			120.000	360.000	360.000	360.000	360.000	360.000	360.000	360.000	360.000	360.000	3,360
Variable Cost	7		65.500	166.500	166.500	166.500	166.500	166.500	166.500	166.500	166.500	166.500	1,564
Fixed Cost	4		87.600	87.600	87.600	87.600	87.600	87.600	87.600	87.600	87.600	87.600	876
Diverse Taxes	0.000%												0
Operating Surplus(EBITDA)			-33.100	105.900	105.900	105.900	105.900	105.900	105.900	105.900	105.900	105.900	920
Inventory Movement			10.000										
Depreciation			39.405	39.405	39.405	39.405	39.405	24.805	7.600	7.600	7.600	7.600	252
Operating Gain/Loss			-62.505	66.495	66.495	66.495	66.495	81.095	98.300	98.300	98.300	98.300	677
Interest and loan mgmt fee		2.266	9.064	9.064	7.931	6.798	5.665	4.532	3.399	2.266	1.133	0.000	49.850
Profit before Tax		-2	-71.569	57.431	58.564	59.697	60.830	76.563	94.901	96.034	97.167	98.300	627.920
Loss Transfer	0	-2.266	-73.835	-16.403	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Taxfree Dividend	0%												
Taxable Profit(tax base)		0.0	0.000	0.000	42.161	59.697	60.830	76.563	94.901	96.034	97.167	98.300	625.654
Income Tax	20%	0	0	0.000	8.432	11.939	12.166	15.313	18.980	19.207	19.433	19.660	125.131
Net Worth Tax	0.00%												
Profit after Tax		-2	-71.569	57.431	50.132	47.758	48.664	61.251	75.921	76.827	77.734	78.640	502.789
Dividend	**30%**	0.0	0.000	17.229	15.040	14.327	14.599	18.375	22.776	23.048	23.320	23.592	172.307
Net Profit/Loss		-2.266	-71.569	40.202	35.092	33.430	34.065	42.875	53.145	53.779	54.414	55.048	330,500

Appendix 15

Simulated Assumptions and Results of scale-up RAS farm in Malaysia

		2008		**Discounting Rate**		**10%**		
Investment:		RM		**Planning Horizon**		**10**	**years**	
Buildings		76.000						
Tanks	100%	114.700		-	-	**Total Cap**	**Equity**	
Equipments		73.000		**NPV of Cash Flow**		**112.357**	**158.963**	
Total		**263.700**		**Internal Rate**		**17%**	**30%**	
Financing:								
Working Capital		60.000		**internal Value of Share Capital/Equity**			**4.4**	
Total Financing		323.700		**after 10 years**				
Equity		30%						
Loan Repayments	100%	8	years					
Loan Interest	100%	4%						
Operations:			**2009**	**2010**	**2011**	**2012**	**2013**	
Sales Quantity	100%		7.5	22.5	22.5	22.5	22.5	mt/year
Sales Price	100%		16.000	16.000	16.000	16.000	16.000	RM/ton
Variable Cost	100%	7.4	RM/kg					
Fixed Cost	100%	3.9	RM/kg					
Inventory Build-up			**10.000**					
Debtors	15%	of turnover						
Creditors	15%	of variable cost						
Dividend	30%	of profit						
Income tax	20%	of profit						
Loan mng fee	1%	of Loan Drawdown						
Depre Tanks	10%							
Depre equip	15%							
Depre others	20%							

Appendix 16

Simulated Cash Flows of scale-up RAS farm in Malaysia

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Cash Flow												
Operating Surplus(EBITDA)	**0**	**-33.100**	**105.900**	**105.900**	**105.900**	**105.900**	**105.900**	**105.900**	**105.900**	**105.900**	**105.900**	**920.000**
Debtor Changes (Acc Rec)		**18**	**36**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**54.000**
Creditor Changes (Acc Pay)	**-**	**10**	**15**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**25**
Cash Flow before Tax	**0**	**-41.275**	**85.050**	**105.900**	**105.900**	**105.900**	**105.900**	**105.900**	**105.900**	**105.900**	**105.900**	**890.975**
Paid Taxes	**-**	**0**	**0.000**	**0.000**	**8.432**	**11.939**	**12.166**	**15.313**	**18.980**	**19.207**	**19.433**	**105.471**
Cash Flow after Tax	**0**	**-41.275**	**85.050**	**105.900**	**97.468**	**93.961**	**93.734**	**90.587**	**86.920**	**86.693**	**86.467**	**785.504**
Interest	**2.266**	**9.064**	**9.064**	**7.931**	**6.798**	**5.665**	**4.532**	**3.399**	**2.266**	**1.133**	**0.000**	**52.116**
Repayment	**0.000**	**0.000**	**28.324**	**28.324**	**28.324**	**28.324**	**28.324**	**28.324**	**28.324**	**28.324**	**0.000**	**226.590**
Net Cash Flow	**-2.266**	**-50.339**	**47.663**	**69.646**	**62.346**	**59.972**	**60.878**	**58.865**	**56.330**	**57.236**	**86.467**	**506.798**
Paid Dividend		**0.0**	**0.000**	**17.229**	**15.040**	**14.327**	**14.599**	**18.375**	**22.776**	**23.048**	**23.320**	**148.715**
Financing - Expenditure	**60.000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**60.000**
Cash Movement	**57.734**	**-50.339**	**47.663**	**52.416**	**47.307**	**45.645**	**46.279**	**40.490**	**33.554**	**34.188**	**63.146**	**418.083**

Appendix 17

Simulated Balance Sheet of a scale-up RAS farm in Malaysia

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Assets												
Cash Account	0	**57.734**	**7.396**	**55.058**	**107.474**	**154.781**	**200.426**	**246.705**	**287.194**	**320.748**	**354.937**	**418.083**
Debtors(Acc Rec)	15%	**0.0**	**18.000**	**54.000**	**54.000**	**54.000**	**54.000**	**54.000**	**54.000**	**54.000**	**54.000**	**54.000**
Stock(inv)	0	**0.000**	**10.000**	**10.000**	**10.000**	**10.000**	**10.000**	**10.000**	**10.000**	**10.000**	**10.000**	**10.000**
Current Assets		**57.734**	**35.396**	**119.058**	**171.474**	**218.781**	**264.426**	**310.705**	**351.194**	**384.748**	**418.937**	**482.083**
Fixed Assets		**263.700**	**224.295**	**184.890**	**145.485**	**106.080**	**66.675**	**41.870**	**34.270**	**26.670**	**19.070**	**11.470**
Total Assets		**321.434**	**259.691**	**303.948**	**316.959**	**324.861**	**331.101**	**352.575**	**385.464**	**411.418**	**438.007**	**493.553**
Debts												
Dividend Payable		**0.0**	**0.000**	**17.229**	**15.040**	**14.327**	**14.599**	**18.375**	**22.776**	**23.048**	**23.320**	**23.592**
Taxes Payable		**0.00**	**0.000**	**0.000**	**8.432**	**11.939**	**12.166**	**15.313**	**18.980**	**19.207**	**19.433**	**19.660**
Creditors(Acc Pay)	15%	**0**	**9.825**	**24.975**	**24.975**	**24.975**	**24.975**	**24.975**	**24.975**	**24.975**	**24.975**	**24.975**
Next Year Repayment		**0**	**28.324**	**28.324**	**28.324**	**28.324**	**28.324**	**28.324**	**28.3**	**28.3**	**0.0**	**0.0**
Current Liabilities		**0.0**	**38.149**	**70.528**	**76.771**	**79.566**	**80.064**	**86.987**	**95.055**	**95.554**	**67.729**	**68.227**
Long Term Loans		**226.590**	**198.266**	**169.943**	**141.619**	**113.295**	**84.971**	**56.648**	**28.324**	**0.000**	**0.000**	**0.000**
Total Debt		**226.590**	**236.415**	**240.471**	**218.389**	**192.861**	**165.035**	**143.634**	**123.379**	**95.554**	**67.729**	**68.227**
Equity	0	**97.110**	**97.110**	**97.110**	**97.110**	**97.110**	**97.110**	**97.110**	**97.110**	**97.110**	**97.110**	**97.110**
Profit & Loss Balance	0	**-2.266**	**-73.835**	**-33.633**	**1.460**	**34.890**	**68.955**	**111.831**	**164.975**	**218.755**	**273.168**	**328.216**
Total Capital		**94.844**	**23.276**	**63.477**	**98.570**	**132.000**	**166.065**	**208.941**	**262.085**	**315.865**	**370.278**	**425.326**
Debts and Capital		**321.434**	**259.691**	**303.948**	**316.959**	**324.861**	**331.101**	**352.575**	**385.464**	**411.418**	**438.007**	**493.553**
		0.0	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**