DEVELOPMENT OF DISSOLVED OXYGEN CONTROL SYSTEM FOR INDOOR PRAWN CULTURE

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The thriving achievement of this research is belongs to all involved parties. It needs continuous effort, tough sacrifice, progressive supports and effective relationship. Hence, the synergized contributions among related personals and organizations were the key to the success of this research. Starting from KUiTTHO's staffs, my family, LKIM staffs, technical providers from product vendors and even Malaysian Government, everyone had played vital roles and contributions. Indeed, the ultimate satisfaction and pride of this research shall be ours and our country, and hopefully it can benefits to all humankind.

ABSTRACT

Prawn farming industry is now evolving to intensive and super intensive system. Both systems require more automation than traditional methods for a better prawn production management. Automation helps to increase the profits and revenues as well. Waste, such as cycle time and redundant energy could be decreased to the minimum level. Water quality control is one of the vital factors in prawn production which needs automated system. In this research, dissolved oxygen as one of the influential parameters in water quality control had been focused. A system was designed to sustain the dissolved oxygen concentration in prawn culture tank automatically. This system responded to the concentration in real time and activated the aeration process to increase the dissolved oxygen concentration to the set limit. Five tests were executed to ensure this system is reliable and reasonable to be used. It consists of functionality test, variables tests, energy consumption test and aeration efficiency test. The results showed that it can operate well and less energy consumed compared to typical aeration practice. However, the aeration efficiency was quite good because of the aerator's design. Solutions and suggestions was drafted for a better system performance.

ABSTRAK

Industri penternakan udang kini telah berkembang kepada sistem intensif and super-intensif. Kedua-dua sistem ini memerlukan lebih pengautomatan berbanding kaedah tradisional untuk pengurusan penternakan yang lebih baik. Automasi dilihat dapat membantu meningkatkan keuntungan dan pulangan dalam industri ini. Selain itu, pembaziran dari segi masa kitaran (cycle time) dan tenaga juga dapat diminimumkan. Kawalan kualiti air adalah salah satu faktor utama dalam industri penternakan udang yang memerlukan sistem berautomasi. Dalam penyelidikan yang dijalankan ini, kajian ditumpukan kepada parameter oksigen terlarut. Satu sistem telah direkabentuk untuk mengekalkan kandungan oksigen terlarut di dalam tangki penternakan udang secara automatik. Sistem ini mampu bertindakbalas dengan mengesan kandugan oksigen terlarut dan mengaktifkan pengudaraan (aeration) bagi meningkatkan kandungan oksigen terlarut kepada aras yang dikehendaki. Untuk memastikan sistem ini boleh berfungsi dan berbaloi untuk digunakan, lima ujikaji telah dijalankan ke atasnya. Ujikaji-ujikaji ini termasuklah kebolehgunaan sistem, ujian terhadap pembolehubah, ujian penggunaan tenaga dan ujian kecekapan pengudaraan. Keputusan ujikaji-ujikaji tersebut telah menunjukkan sistem ini mampu berfungsi dengan baik dan lebih menjimatkan tenaga berbanding amalan pengudaraan yang biasa dilakukan oleh penternak udang tempatan. Walaubagaimanapun, kecekapan pengudaraan yang dicapai kurang memberansangkan berasaskan kepada faktor rekabentuk aerator. Beberapa penyelesaian dan pandangan telah dikeutarakan untuk menghasilkan sistem yang lebih baik.

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LIST OF SYMBOLS & ABBREVIATIONS

%	Percent
μm	Micro Meter
°C	Degree Celsius
Ø	Diameter
ω	rotational speed in rpm
v	voltage
AC	Alternate current
ADC	Analogue – Digital converter
BP	Barometric pressure
C_m	Measured DO concentration
C_s	Saturated DO concentration
cm	Centimeters
CO_2	Carbon dioxide
DO	Dissolved oxygen
DC	Direct current
E(s)	Error signal
G(s)	Gain
$G_c(s)$	PID transfer function
ha	hectare
hr	hour
H_2O	Water
K_P	Process transfer function
K_S	Feedback transfer function
kPa	kilo Pascal
k_{La}	oxygen transfer coefficient
kWhr	kilowatt hour
kgO_2	kilogram Oxygen

L	Litre
m	Meters
mm	Millimeters
m^2	meter square
m^3	meter cubic
mg/L	milligram per litre
mmHg	millimeter mercury
O_2	Oxygen gas
OTR	Oxygen Transfer Rate
OD	Oxygen deficit
ppt	parts per thousand
ppm	parts per milion
PL	post larvae
PLC	Programmable logic controller
PID	Proportional – Intergrated – Derivative
USD	United States Dollar
RM	Malaysian Ringgit
SAE	Standard Aeration Efficiency
SOTR	Standard Oxygen Transfer Rate
T_{water}	Water temperature
T_{room}	Room temperature
U(s)	Desired value/input signal
V	volume
V_{emf}	Electromotive force
W(s)	Manipulated variable
Y(s)	Actual value/Output signal

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CHAPTER 1

INTRODUCTION

1.1 Research background

Prawn farming is one of the major businesses in aquaculture industry in Malaysia. High demand in domestic and global market had accelerated the prawn production exponentially. In achieving those requirements, prawn farmers increase their production by creating more and more prawn pond, either earthen pond or the indoor culture tank. This man made pond has many problems because it is out of the shrimp's nature. There are a lot of factors must be considered to acquire good shrimp growth as well as the shrimp quantity. Some of these factors are water quality, feeding rate and methods, prawn diseases and predators threat. Water quality is one of the most influential factors for prawn farming (World Bank *et al.* 2002). There are several parameters must be controlled to obtain suitable quality of water. Examples of these parameters are the pH value, ammonium capacity, dissolved oxygen (DO), water temperature, salinity and turbidity. In the natural prawn's habitat, those parameters are controlled in a natural ecosystem. However, for prawn farming which occupy man made pond or culture tank, several mechanisms are required to perform the right match of those parameters. For instance, aeration is important for sustain dissolved oxygen level, liming is essential to neutralize the acid intensity and water filtering is vital for maintain ammonium level inside the water.

This research concentrates on the control system which maintains the level of dissolved oxygen in the indoor prawn culture tank. Prawn culture in water tank and inside closed area is very common practice nowadays. It becomes current trend for prawn farmers because prawn can be cultured intensively and in a controlled condition. Basically, tank prawn culture is classified as intensive or super intensive culture. The stocking density is very high, which can be up to 200 to 250 PL/m^2 (Kungvankij, P et.al 1986). One of the hazardous problems caused by tank prawn farming is the dissolved oxygen depletion. High post larvae stocking density demand more dissolved oxygen. Hence, support aeration is essential to sustain the dissolved oxygen level.

Many traditional tank or indoor prawn farming use manual method of dissolved oxygen readings and aeration activation. It consumes a lot of time and inefficient for a big number of culture tanks. Dissolved oxygen sensor normally is quite expensive. Typical brands for single probe dissolved sensor with its reading meter and data logger can cost from RM 2,000.00 to RM10, 000.00 in Malaysian markets. This factor affects intensive prawn farmers to obtain only few dissolved oxygen sensors. Depending on the sensing method, definite reading can be achieved after several seconds to minutes. Total cycle time for dissolved oxygen reading might be increased as the number of culture tank increase. Meanwhile, for cautious purpose, most of the prawn farmers will activate the aeration for a long period to ensure secure dissolved oxygen inside tank. This aeration might take few hours (World Bank *et al.* 2002). Such of this continuous electric supply is not practical to transfer oxygen into the water because it results to the supersaturated oxygen concentration. Consumed time and inefficient electricity utilization both are the reasons of why this research is being conducted. Boyd, C.E (1998) had acknowledged that aerators operated by DO sensors used 62% less than those operated by timers, and 80% less electricity than aerators operated manually. The expensive DO sensors caused many companies as well as higher educational institutions do research and invent new and cheaper sensor as well as systems to overcome the current requirements.

1.2 Objectives

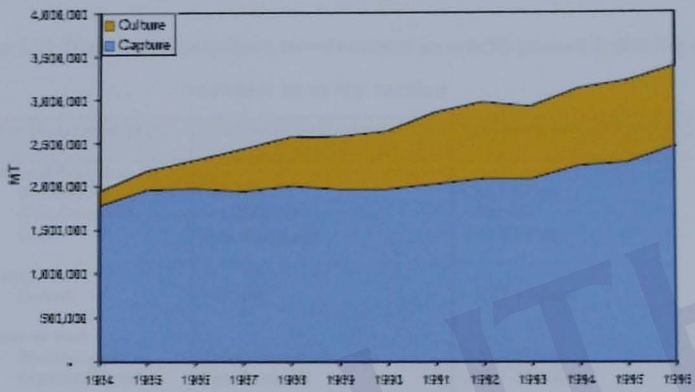
This study proposed a research in developing a system that controls the dissolved oxygen level in indoor prawn culture tank. The specific objectives which this research carried out described as follows:

1. To develop a dissolved oxygen control system with DO sensor and controller application.
2. To investigate the behaviour of DO inside research area.
3. To study a minimum energy consumption suitable for prawn culture with optimum DO level.
4. To study the aeration efficiency by analyzing the Oxygen Transfer Rate (OTR) and Standard Oxygen Transfer Rate (SOTR).

1.3 Importance of the study

Aquaculture industry in Malaysia was commercialized since late 70's and 80's (World Bank *et al.* 2002) and is expected to be aggressively expanding due to Ninth Malaysia Plan. Recently, Malaysian prime minister announced that Malaysian government plans to provide very attractive package and incentives to encourage Malaysian to participate in agro-technology and aquaculture industry (World Bank *et al.* 2002). It is reported that the plan includes raw material aid such as formulated feed, prawn juveniles (post larvae) and disease control chemicals. Emphasizing to the massive development on local aquaculture was made because of the increment of world demand on food and foreign exchange earnings (Philips, M.J. *et al.* 2002) for developing countries. A case study report was carried out by World Bank (World Bank *et al.* 2002) shows that the trend of aquaculture shrimp for world increase higher rather than the incremental of captured shrimp (Figure 1.1). Table 1.1 reveals the annual breakdown of the figure to compare the production growth of aquaculture industry and the shrimp captured activity. From this table, we can predict that the aquaculture industry has a big potential for the future as the increasing of the human population.

Figure 1.1 : World Shrimp Production from Capture and Culture



Source: World Bank *et al.* 2002

Table 1.1: World Production of Shrimp: Wild catch and aquaculture (1000s of MT)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Catches	1,947	2,043	2,107	2,149	2,381	2,440	2,554	2,629	2,749	3,034	3,081
Aquaculture	659	813	867	823	847	932	926	911	974	1,133	1,021
Sum	2,606	2,856	2,974	2,972	3,228	3,372	3,480	3,540	3,723	4,167	4,102

Source: FAO Aquaculture statistics, 200[illegible]

Source: World Bank *et al.* 2002

The written global factor in table 1.1 above is only one of the major reasons of why this research is very important. The significant of this research also include technical aspect such as the development of new technology in aquaculture engineering. Water quality control is one of the most influential factors to be considered in term of the technical aspect (D' Abramo *et al.* 2003), such as in this research; the dissolved oxygen control. Research on water quality plays an important role in hatchery, farming and distributing activity (the related revenue can be seen in Table 1.2) especially in intensive farming (Jayamanne, 1986). Basically, it combines several engineering disciplines such as engineering control, material science and fluid engineering to handle problems such as system design, control system and operation management in those activities (Widmer, *et al.* 2006 and Smith, *et al.* 2002) Novel sensing and control methods as well as flexible actuation mechanism are among the continuously developed technologies regarding to the water quality control.

Table 1.2: Number of workers involvement in world prawn industry and its revenue in every section

Actors in the marked chain	Number of people involved	Value of product (in US$)
PL and Feed Providers		
Hatchery PL	100,000	US$ 1 billion
Wild Caught PL	> 1,000,000	5,000,000
Feed	Few thousands	US$ 1 billion
Producers		
Farmers	300,000	> US$ 4 billion
Processor to Port		
Processing plants	Several thousands	US$ 6 billion
Exporters/Importers	Few thousands	US$ 7-10 billion
Importing Countries		
Distributors	Few thousands	Add 3-7% to product
Wholesalers	Several thousands	Add 5-12% to product
Retailers	> 100,000	Add 15-50% to product
Consumers	>1,000,000,000	US$ 50-60 billion

Source: World Bank *et al.* 2002

Those new technologies are very helpful in achieving good prawn production rate. According to the research goal, the importance of water quality research, such as dissolved oxygen control for indoor intensive prawn farming system is obvious and become trend for recent researchers. In addition, another problem occurred to the major prawn producers is the usage of chemicals for grow out activities. For example, EC had rejected shrimp from Vietnam and China because the discovery of chloramphenocal inside the exported shrimp (Philips, M.J. *et al.* 2002). This factor also catalyses to the development of this research, whereby Malaysia can be one of the chemical free prawn producing hubs for global market. As the conclusion, this research is very essential because it relate to humankind's indigent – the food. In fact, it also incorporates with the development of new technology and knowledge, cost reducing programme and healthy reason. Thus, it is our duty in university and excellent centre to overcome these problems by reducing the capital cost via more efficient, economic and sustainable system.

1.4 Scope of the study

Limited provided time had scaled down the research by excluding studies of the other parameters such as salinity, barometric pressure and air flow which are totally affecting the oxygen transfer rate. Different salinity will cause different oxygen absorption rate and so on with barometric pressure. In this case, freshwater was used as well so that the salinity can be fixed at 0 ppt. Air flow is important because it create wave and wave is a natural method of aeration. This research was carried out in a closed room where the ambient temperature and air flow were controlled, so that they can be neglected. Furthermore, current prawn rearing research trend was the intensive or super intensive culture inside closed area, rather than open earthen pond.

Aeration mechanism has many types and forms. Each type has different oxygen transfer rate capability. In this research, single self designed paddlewheel was used. The paddlewheel blade's size had been downsized to be adapted into the research tank and experiment rig. As this paddlewheel rotates in the tank, drag force by the water to paddlewheel blade cause the occurrence of load. This load determines the tork of the motor. High tork could reduce paddlewheel rotational speed. To increase the rotating speed, power must be increased. It means that paddlewheel design also had interrelation with power consumption. Again, in this research, several parameters had been fixed. We concentrated on one blade design with specific water volume. Therefore, the gained data on tork, paddlewheel speed and power consumption were based on this design only. It was considered that the location of the paddlewheel and the sensor as one point of aeration for the real culture tank which is bigger in size.

1.5 Project management

Figure 1.2: Project Flow Chart

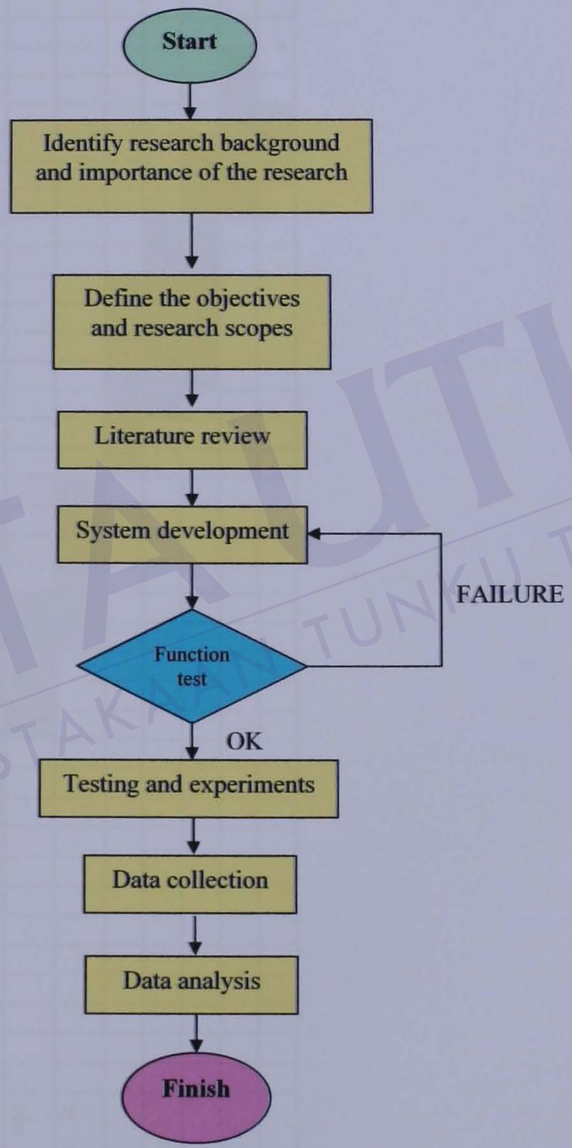


Table 1.3 : Project Schedule

Event/Activity	March				April				May				June				Jul				Aug				Sept				Oct				Nov				Dec			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Problem statement	■	■	■	■	■																																			
Literature and information sourcing					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																				
Purchasing equipment						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																				
Design system and draft framework													■	■	■	■	■																							
System assembly & fabrication works																■	■	■	■	■	■																			
System testing																						■	■	■	■	■	■	■												
Experimental works																								■	■	■	■	■	■	■										
Data collection																									■	■	■	■	■	■	■	■	■							
Data analysis																															■	■	■	■	■	■				
Writing report																																■	■	■						

CHAPTER 2

LITERATURE

The structure of literature review for this research consists of six major topics. These topics are inquired to gain more information on the background problems of the research and choice of solutions to achieve the objectives. First topic discusses the coined idea of this research and the importance of the studies. Information was collected by perusing journals and technical papers, site visits, discussion with expertise and attending seminars. The second literature is about the fundamental of the studied area itself; the dissolved oxygen. As the above mention in the first chapter, the main objective of this research is to develop a system that operates aeration without human intervention by using DO sensor and controller. Hence, the solution selection to the suitable system development requires information on aeration which is the process to transfer oxygen gas into dissolved oxygen in water, the dissolved oxygen sensor for measuring purpose, control system and communication of the system. The summary of this literature can be read in Table 2.1 next page. The literature of this dissertation was arranged in such way in this chapter to ease the reader to understand of why this topic was selected and what the choices for the solutions are.

Table 2.1: Summary of Literature Review

no	General topics	Summary	References
1.	Prawn farming (Importance of research and problem statements)	• Global demand on food • New technologies development in aquaculture industry • Problems in prawn farming • Introduction to prawn and shrimps • Prawn farming system • Current trend on prawn farming • Specific problems with current prawn farming system	• World Bank *et al.* 2002 • Kugvanji,P., *et al.* 1986 • Boyd, C.E., 1998 • D'Abramo *et al.* 2003 • Jayamene, S.C.,1986 • Widmer, *et al.* 2006 • Smith *et al.*, 2002 • Philips, *et al.*, 2002 • FAO tech reports, 1982 • ACE, 2003 • World Bank *et al.* 2002 • Philips, *et al.*, 2002 • FAO tech reports, 1982 • ACE, 2003
2.	Dissolved oxygen	• Fundamental of dissolved oxygen • Importance of dissolved oxygen • Effect of dissolved oxygen to prawn	• Eutech instruments • Erlich instruments • Shogo Ueno *et al.*, 1982 • Rosas *et al.*, 1997 • Turmel *et al.*, 1998 • Drapco *et al.*, 2000 • Pruder, 1983 • Yuquan, li, *et al.*, 2006
3.	Aeration	• Aeration concept • Aeration function • Current types of aeration • Measurement of aeration efficiency	• Boyd, C.E., 1998 • Kirke, *et al.*, 1996 • Peterson *et al.*, 2002 • Fast, *et al.*, 1999 • Peterson, *et al.*, 2001 • Cancino, *et al.*, 2004 • Cancino, 2004 • Burris *et al.*, 2002

4.	Dissolved oxygen sensor	• Measurement fundamentals • Advantages and limitations of sensing methods	• Chuquan, *et al.*, 1991 • Campbell*et al.*, 2004 • Martinez Manez, *et al.*, 2005 • Glazer, *et al.*, 2004 • Rommel, 2004 • Clarke, *et al.*, 1996
5.	Control system	• Control system theory • Type of controller (PID, fuzzy, neural networks) • Real time control system • Distributed control system (DCS) • Block diagram for the designed system	• Dorf, *et al.*, 1998 • Glaser, *et al.*, 1989 • Stolen, 1999 • Yang *et al.*, 2002 • Qing Li, *et al.*, 2004 • Hwang, *et al.*, 1999
6.	Communication system	• System response analysis • The importance of communication system in industry • Types of communication system • Selection of suitable system	• Middaugh, *et al.*, 1993 • Mahalik, *et al.*, 1995 • Romero, *et al.*, 2003 • Rheg, *et al.* 1999 • Valearet, *et al.*, 1997 • Dukovic, *et al.*, 1995

2.1 Introduction to Prawn Farming

Prawn and *shrimp* are *crustaceans' subphylum* which is mostly aquatic animals with a hard skin (an exoskeleton) over a segmented body (Figure 2.1) (Museum Victoria, 2006). In Southeast Asia, the difference between shrimp and prawns is based on size, with larger shrimp being called prawns (*Wikipedia*). In United States, prawn refers to freshwater shrimp (D'Abramo et.al 2003) while in Europe and Australia prawn term is mostly used (*Wikipedia*). Technical Report from FAO (1982) classifies prawn as the *freshwater* crustacean and shrimp refers to *saltwater* or *brackish water* or *brine water* crustacean. In this thesis, we consider prawn as shrimp.

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