A SEMINAR PAPER ON

Recirculating Aquaculture System

Course Title: Seminar

Course Code: FBE 598

Term: Summer, 2018

<u>Submitted to:</u>

Course Instructors	Major Professor
1. Dr. Md. Mizanur Rahman Professor BSMRAU 2. Dr. A. K. M. Aminul Islam Professor BSMRAU 3. Dr. Md. Rafiqul Islam Professor BSMRAU 4. Dr. Dinesh Chandra Shaha Assistant Professor BSMRAU	Dr. S. M. Rafiquzzaman Associate Professor Department of Fisheries Biology & Aquatic Environment

<u>Submitted by:</u>

Tasmiah Tabassom

MS Student

Reg. No.: 13-05-3022

Department of Fisheries Biology & Aquatic Environment

BANGABANDHU SHEIKH MUJIBUR RAHMAN AGRICULTURAL UNIVERSITY

SALNA, GAZIPUR 1706

Abstract

Intensification of aquaculture is the promising way to satisfy the protein demand of the increasing population worldwide. In intensive aquaculture, regulating the water quality parameters is the major challenge that have a direct effect on the growth performance of fish. This study was conducted to review the water quality parameters and growth performance of different fishes in Recirculating Aquaculture System (RAS) compared to different conventional aquaculture systems. As this is a review paper, so all the data were collected from secondary sources. Results found that, DO level was significantly higher (8.30mg/L) in RAS than the pond (7.28mg/L), temperature fluctuations was reduced in RAS compared to pond. Total suspended Solids (TSS), Chemical Oxygen demand (COD), Total Ammonium Nitrogen (TAN), Nitrite and Nitrate were significantly lower in the RAS compared to conventional aquaculture, which ensured the better water quality for fish production in high density. Mean weight gain was higher in Common Catfish of RAS (151.5g) than the fish of pond (142.7g). Gilthead Seabream reared in RAS showed 85% faster growth than the conventional net pen system. Specific growth rate (SGR) was found higher in Rainbow Trout, Crucian Carp, Pikeperch reared in RAS than other culture systems. Survival rate was higher in Crucian Carp raised in RAS than pond. Hepatosomatic Index (HSI), Crude protein, fat, ash content were higher in the fish muscle raised in RAS compared to other culture systems. From the above results, RAS showed best results for higher fish production compared to conventional aquaculture systems.

Key Words: TSS, COD, TAN, Mean Weight Gain, HSI, SGR, FCR.

TABLE OF CONTENTS

SL No.	Content	Page No.
01	Abstract	i
02	Table of contents	ii
03	List of Figures	iii
04	List of Tables	iv
05	Chapter 1: Introduction & Objective	01-03
06	Chapter 2: Materials & methods	04
07	Chapter 3: Review of findings	
	3.1: System components of RAS	05-08
	3.2: Condition of water quality parameters of the fish tank running by RAS	08-14
	3.3: Comparative growth performance of the fish reared in RAS and conventional aquaculture system.	15-21
	3.4: Present status of RAS adoption in Bangladesh	21-22
07	Chapter 4: Conclusions	23
08	References	24-26

LIST OF TABLES

Table no:	Table name	Page no.
01	Water quality standards for fish production	9
02	Effect of temperature on the periodic weight changes of fish in RAS and conventional culture system (control)	10
03	Average pH level in RAS and Pond culture	11
04	TSS value in RAS and Control pond	12
05	COD value in RAS and Control pond	12
06	SGR value of Rainbow Trout in RAS and FTS	17
07	HSI value of Pikeperch (*Sander lucioperca*) juveniles cultured in RAS and pond	19
08	Muscle composition of Crucian Carp (*Carassius auratus*) reared in RAS and pond culture system.	19
09	Muscle composition of Pikeperch (*Sander lucioperca*) reared in RAS and pond culture system.	20
10	FCR value of Crucian Carp (*Carassius auratus*) cultured in RAS and pond	20

LIST OF FIGURES

Figure no:	Figure name	Page no.
01	A commercial Recirculating Aquaculture System	8
02	Average DO level in RAS and pond	9
03	Temperature fluctuations in RAS and Pond culture	11
04	TAN fluctuations in RAS and Pond (David 2006)	13
05	TAN fluctuations in RAS and Pond (Roncarati et al.,2014)	13
06	Nitrite level in RAS and Pond culture	14
07	Nitrate level in RAS and Pond culture	14
08	Mean weight gain of the fish reared in RAS and Pond	15
9	Mean weight gain of the fish reared in RAS and Net pen system	16
10	Total weight gain of the fishes reared in RAS and Pond	16
11	SGR value of Crucian Carp cultured in RAS and Control pond	17
12	SGR value of Pikeperch (*Sander lucioperca*) juveniles cultured in RAS and Pond.	18
13	Survivability rate of Crucian Carp cultured in RAS and Pond system	18
14	FCR value of Rainbow Trout reared in RAS and FTS	21

Chapter 1

Introduction

1.1 General background

Aquaculture production has increased dramatically over the past five decades reaching 73.8 million tonnes of food fish harvested (FAO, 2016). Now it is the fastest growing food-producing sector, accounting for almost 50% of the world's food fish (FAO, 2006). It is predicted that more than an additional 40 million tonnes of aquatic food will be necessary by 2030 to maintain the current per capita consumption (FAO, 2006). 'Producing more food from the same area of land while reducing the environmental impacts requires what has been called sustainable intensification' was written in a recent review about the challenge of feeding 9 billion people. (Godfray et al., 2010) Here comes the significance of Recirculating Aquaculture System (RAS), which requires limited resource for greater production and provides environment sustainability. RAS is used for fish production where water exchange is limited and the use of biofiltration is required to reduce ionized and unionized ammonia level (Timmons et al., 2013). This system filters the water and makes it clean for recycling back through fish culture tanks. In RAS, more than 90% of the water is recirculated through a series of biological and mechanical filtration systems. New fresh and clean water is added to the tanks only to make up for losses through splash outs; evaporation and for those that is used to flush out waste materials. It represents a new and unique way to farm fish. In contrast of the conventional method of growing fish outdoors, this system rears fish at high densities, in indoor tanks with a "controlled" environment. The main benefit of RAS is the ability to reduce the need for fresh, clean water while still maintaining a healthy environment for fish. Clean water, dissolved oxygen, and optimal temperatures are required to ensure better growth. To be operated economically, commercial RAS must have high fish stocking densities, and many researchers are currently conducting studies to make RAS a viable form of intensive aquaculture (Andrew 2010).

1.2 Rationale

Bangladesh is a densely populated country with around 160 million people. Land is decreasing day by day with the increasing of population. Every year 1% of its land or 82900 ha of crop land and everyday 221 ha of land is losing in Bangladesh. Waterbodies have been decreased 17.66 %

and the river area has been decreased 52.44% from 1977 to 2010. (Islam 2011). In 2030, the population of Bangladesh will be over around 190 million when an extra 25% food will have to be produced (Islam 2011). But the additional harvests will have to be reaped from a much smaller area of cropland than is now available. Increasing aquaculture production horizontally is not possible due to the decreasing of land day by day. So, vertical expansion of fish production or indoor fish farming can be a good solution to meet the demand of increasing population. RAS is an indoor fish farming system that can bring a revolutionary change in our aquaculture production.

To increase fish production, intensification of fish culture is very important where the supplementation of feed is greater due to high stocking density than the conventional aquaculture. When there is abundance of feed, unfed residues gradually decompose in the water medium, consume oxygen and settle down on the bottom. This disturbs the physico-chemical parameters of water. Uneaten excess feed residues decrease the concentration of dissolved oxygen and increases the load of harmful metabolites and gases like carbon dioxide, ammonia, methane, hydrogen sulphide etc. (Datta 2012). This causes disease infestation in the culture system. RAS can face these issues in a promising way. In this technology high stocking density is achieved and water quality remains suitable for the fish production. RAS offers reduced water utilization (Verdegem et al., 2006). It also creats improved ways and opportunities for waste management and nutrient recycling (Piedrahita., 2003). It provides a better hygiene and disease management (Summerfelt et al., 2009; Tal et al., 2009) and biological pollution control (Zohar et al., 2005).

Another important challenge can be achieved by this technology, which is environmental sustainability. Environmental issues are ignored in Bangladesh while considering aquaculture practices but unfortunately the environment suffers the most. In aquaculture plenty of tons of water and exchange of that is needed periodically but in our country we have a very little or in most of the cases don't have any waste water treatment facility in hatcheries or culture farms. (Islam et al., 2017) That's why recycle of waste water or treat water before discharge to the nature is not possible till now. In most cases, the used water or wastage of aquaculture is being released to the natural waterbody or main river stream without any treatment which leads to the disease outbreak, invasion of undesired species or foreign species, imbalance in biodiversity and ecosystem. (Islam et al., 2017) Besides in our aquaculture a plenty of chemicals are being used and then these chemicals get discharged into the environment it also have adverse impact over the environment and its biodiversity. (Islam et al., 2017) In RAS, waste water is treated in filtration systems and the sludges found from this system can be used as a fertilizer which contains macro and micro nutrients specially high levels of nitrogen and phosphorus which potentially can be used to the land to fertilize crops (Campo et al.,2010). This is how this technology becomes environmentally sustainable. In spite of its environmentally friendly characteristics and the increasing number of countries applying RAS technology, its contribution to production is still small compared to other conventional culture systems like cages, flow-through systems or ponds. The slow adoption of RAS technology is due to the large initial capital investments required by RAS (Schneider et al., 2010). That's why High stocking densities and productions are required to be able to cover investment costs. This technique is very much relevant and required in commercial aquaculture sector where proper maintenance of water quality is a prime necessity. In RAS, water quality management plays a major role in fish production. RAS is a dynamic system in which the response of fish growth varies with changes in the water quality parameters, thereby monitoring and management of the culture is challenging for the entrepreneur or farmer.

1.3 Objectives:

Based on above facts the objectives of this review paper are-

1. To get acquainted with the system components of RAS,
2. To review the conditions of water quality parameters of RAS tank as well as the growth performance of the fishes produced in RAS,
3. To highlight the present status of RAS adoption in Bangladesh.

Chapter 2

Materials and methods

This seminar paper is exclusively a review paper. All the information has been collected from the secondary sources. During the preparation of the review paper, I went through various books, journals, proceedings, reports, publications, internet etc. relevant to this topic. I got suggestions and valuable information from my major professor and my course instructors. After collecting all the available information, I myself complied that collected information, and prepared this seminar paper.

Chapter 3
Review of findings

3.1 System components of RAS

System components of RAS technology must maintain five key processes and those are clarification, biofiltration, circulation, aerations, and degassing. Solids must be removed from the recirculating system through a clarification process. Dissolved organics and ammonia are then removed through a biofiltration process. The system must provide for circulation between the tank and filtration components. After filtration, both oxygen and carbon dioxide must be brought back into balance through the process of aeration and degasification. These five processes are essential to RAS success. Failure to address any of these five issues will ultimately lead to the downfall of any commercial RAS venture. (Malone, 2013)

3.1.1 Fish Tank

Sizing of fish tanks is based upon the density of fish. There are three common tank shapes which are circular tank, rectangular tank and raceway tank. The dominance of circular tanks in the RAS industry stems from their inherent structural and hydrodynamic nature. The walls of a circular tank are maintained in tension by water pressure and the walls are self-supporting. These properties allow circular tanks to be constructed out of relatively thin polyethylene plastic or sturdier fiberglass materials. The hydrodynamics of a circular tank helps in the rapid removal of suspended solids which makes it more efficient than other tanks. A circular tank with a center drain is naturally good at solids removal. The rectangular tank is prone to poor solids movement, but it is about 20 percent more efficient in floor space utilization than others. Raceway tanks would appear to be the perfect compromise between circular and rectangular. A third wall is centered along the tanks length to facilitate controlled circulation of water. This circulation is highly effective at movement of solids but it adds cost. (Malone, 2013)

3.1.2 Circulation component

The fish tanks and the filtration components are connected with the circulation loops. Recirculation flow rates can be 5 to 10 gallons per minute per pound of daily feed ration given to cultured fish. It varies among the system strategy. The major source of RAS energy consumption is the water pump or air blower which drives the circulation loop. If the circulation system failure occurs, it leads to a rapid deterioration in RAS tank water quality. Three common type of pumping systems are used and those are centrifugal, axial flow and airlift pumps. In most of the RAS applications, a centrifugal pump with high flow and low lift capacity is preferred to minimize energy consumption. Axial flow pumps are used on commercially larger scale RAS because this pumps have better pumping efficiencies than centrifugal pumps under low lift conditions (<10 feet or 3 m). Airlift pumps are capable of moving large volumes of water at extremely low lifts. The air injected to move the water also aerates and degasifies circulating water. (Malone, 2013)

3.1.3 Mechanical Filtration

Mechanical filtration of the outlet water from the fish tanks has proven to be the only practical solution for removal of the organic waste products. Today almost all recirculated fish farms filter the outlet water from the tanks in a microscreen fitted with a filter cloth of typically 40 to 100 microns. The drumfilter is by far the most commonly used type of microscreen, and the design ensures the gentle removal of particles. Water to be filtered enters into the drum and is filtered through the drum's filter elements. The difference in water level inside/outside the drum is the driving force for the filtration. Solids are trapped on the filter elements and lifted to the backwash area by the rotation of the drum. The rejected organic material is washed out of the filter elements and accumulates into the sludge tray. Reduction of the organic load of the biofilter. Making the water clearer as organic particles are removed from the water. (Bregnballe, 2015)

3.1.4 Biological Filtration

Biological filtration is the core part of RAS. It removes the finest particles .Nitrogen in the form of free ammonia (NH_3) is toxic to fishes, and needs to be transformed in the biofilter to harmless nitrate. Heterotrophic bacteria oxidise the organic matter by consuming oxygen and producing carbon dioxide, ammonia and sludge. Nitrifying bacteria convert ammonia into nitrite and finally to nitrate. The efficiency of biofiltration depends primarily on the water temperature in the system and the pH level in the system. For satisfactory nitrification rate, water temperatures should be maintained within 10 to 35 °C (most favorable around 30 °C) and pH levels between 7 and 8. (Bregnballe, 2015)

Biofilters are typically constructed by using different types of plastic media giving a high surface area per m^3 of biofilter where bacteria grows. The purpose of a well-designed biofilter is to create as high a surface area as possible per m^3 without packing the biofilter so tight that it will get clogged with organic matter under operation. High percentage of free space is essential for the water to pass through and to have a good flow, through the biofilter. A sufficient backwash procedure is a vital thing also. In recirculation systems, usually there are two types of biofilters based on plastic media used in there and those are fixed bed filters where the media is fixed and moving bed filters where the plastic media is moving around in the water by a current created by pumping inside the biofilter. These filters removes the microscopic organic material and leaves the water very clear. (Bregnballe, 2015)

3.1.5 Additional System Components

There are some additional components other than the basic system for getting better production. Those are aeration, degassing, temperature regulation, disinfection. Most recirculating systems use either a blown air or pure oxygen delivery system to ensure desired O_2 levels. The blown air systems is a simple system for oxygen addition and carbon di oxide stripping. (Bregnballe, 2015) The two most common disinfection devices are UV light and ozone treatment. UV light is commonly used because of its simplicity of setting up and operation. Ozone is viable in larger facilities that can support the cost of its installation and operation by a technically trained staff. (Malone, 2013). Water temperature in the culture system is the most important factor. Because the growth rate of the fish is directly related to the water temperature. If cooling by the use of intake water is limited a heat pump can be used to regulate the temperature. (Malone, 2013)

A new very worthwhile technology is being developed for the water quality monitoring and controlling. That is the multi-sensor system in which temperature, dissolved oxygen, pH, water level, and water flow rate are to be monitored continuously and well controlled. (Kolarevic, 2008) Input sensors from the different parameters checking equipment are connected with the microcontroller and the output signals are sent to the control devices (pumps, valves, heat pumps, etc.) to regulate them to their optimum condition. The proper monitoring of farming processes can optimize the resource utilization and expand its sustainability and profitability. Wireless sensor networks (WSN) are a promising option to perform this monitoring. Multi sensors in WSN are composed of simple electronic apparatuses. This multi sensor can monitor water quality parameters, tank condition, the feed sinking and fish swimming depth and velocity. (Parra et al., 2018)

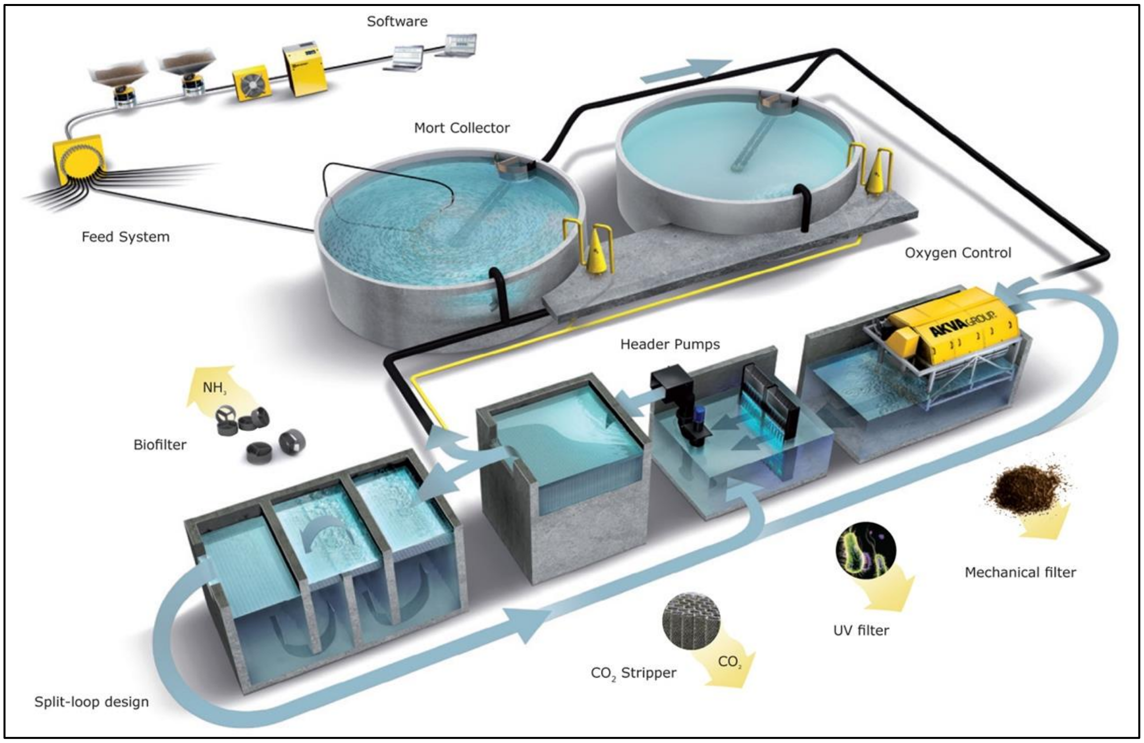

Figure1: A commercial Recirculating Aquaculture System (Source : http://www.akvagroup.com)

3.2 Condition of Water Quality Parameters of the fish tank running by RAS

Water quality reflects the overall capability of culture water to provide optimal growth conditions for the species of interest and that's why it is very important. The feeding behaviour of fish is strongly influenced by the environmental conditions, such as the water temperature, DO, TAN, and NO_2–N (Buentello et al., 2000; Meinelt et al., 2010; Pang et al., 2011). The RAS provides better environmental conditions year-round, contributes to the health of the fish and minimises the FCR, thus improving the feeding efficiency (D'Orbcastel et al., 2009). The effect of RAS showed significant results on various water quality parameters like dissolved oxygen (DO), pH, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Total Ammonium Nitrogen (TAN), Nitrite and Nitrate level of the fish tank which is described below.

Table 1: Water quality standards for fish production

Parameters	Acceptable Concentration
DO	>5 mg/L
pH	6.5-8.5
Temperature	>20°C for warm water species 15-20°C for cool water species
COD	20–30 mg/L
TSS	<80 mg/L
Nitrite (NO_2)	<0.02
Nitrate (NO_3)	0-100
TAN	0-0.2

(Source: Bhatnagar et al., 2013)

3.2.1 Dissolved Oxygen

Dissolved oxygen (DO) is arguably the most important water quality parameter for fish survival. Concentrations of oxygen are expressed as parts per million (ppm) by weight, or milligrams per liter (mg/L).

Roncarati et al., (2014) conducted a study to evaluate the growth performance and survival of common catfish, *Ameiurus melas*. 54,420 juveniles of 5.1 g were raised in two groups: Pond group, characterized by 3-1,000 m^2 ponds and RAS group composed by 3-2 m^3 indoor tanks functioning in closed recirculated system. Two groups of catfish were reared at two different densities (PN=15 fish/m^3; RC=1,570 fish/m^3) for 181 days. The main water physico-chemical parameters were monitored where it was found that the average DO level is significantly higher (8.30mg/L) in RAS than the pond DO level (7.28mg/L). (Figure 2) which is very beneficial for better fish production.

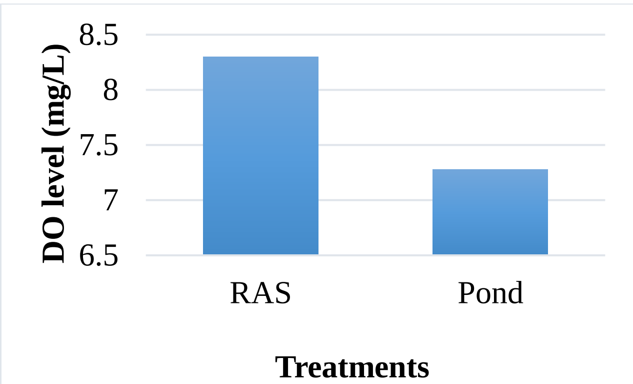

Figure 2: Average DO level in RAS and pond. (Source : Roncarati et al.,2014)

3.2.2 Water temperature

Water temperature affects the development and growth rates of fish as much as no other parameters does. Each species of fish has a temperature range it can tolerate. Within that range, there is an optimum temperature for growth and reproduction which may change as the fish grows**.** Increasing water temperature 10°C will double the metabolic rate of an organism, which correlates to higher food consumption and growth rate as well as an increased biological oxygen demand (BOD). David, 2006 conducted a study on European catfish *Silurus glanis* to increase water temperatures during winter months. The experiment was for 220 days. Fish were held in an enclosed housing where the water quality was maintained using a low-cost RAS treatment. For comparison, some fish were held in a separate system that was not enclosed and took place in an adjacent earthlined pond. The recirculating system achieved significantly higher water temperatures and it had a positive effect on total fish weight gain (Table 2).

Table 2: Effect of temperature on the periodic weight changes of fish in RAS and conventional culture system (control)

Days	Temperature of RAS (ºC)	Temperature of Control pond (ºC)	Total weight change (%) in RAS	Total weight change (%) in pond
60	12	9	5	0
80	8	3	2	0
100	8	8	1	0
120	10	7	1	0
140	10	6	2	-3
160	12.5	8	5	-2
180	23	10	18	2.5

(Source : David,2006)

Temperature fluctuation causes problem in fish feed uptake. Fish cannot adapt with the wide fluctuations of temperature. Roncarati et al., 2014 conducted a study to evaluate the growth performance and survival of common catfish, *Ameiurus melas*. A total of 54,420 catfish juveniles (5.1) were reared in two groups: Pond group, represented by 3-1,000 m^2 ponds; RAS group composed by 3-2 m^3 indoor tanks working in closed recirculated system. In these two groups, catfish were reared at two different densities (Pond=15 fish m^3; RC=1,570 fish m^3) for 181 days. The main water physico-chemical parameters were monitored and growth performances were evaluated. In the RAS treatment, water temperature was not characterised by any significant fluctuations. Water temperature was subjected to seasonal and daily fluctuations in the Pond basins (Figure 3).

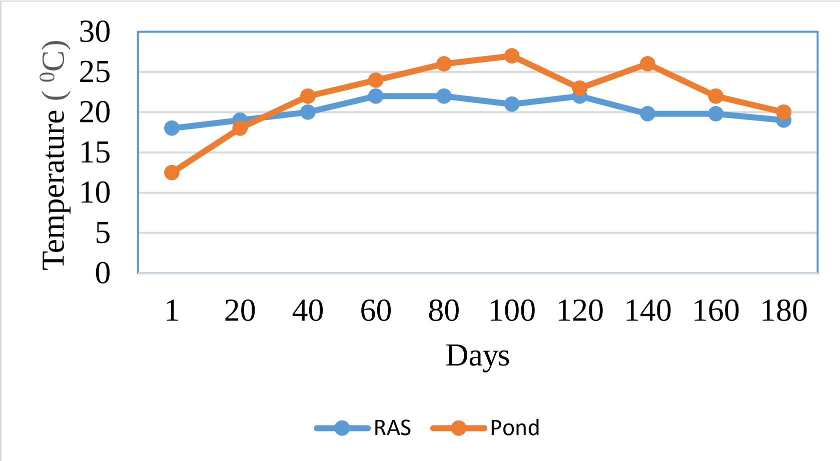

Figure 3: Temperature fluctuations in RAS and Pond culture. (Roncarati et al., 2014)

3.2.3 pH

pH is a very important parameter in aquaculture system. Sudden changes in pH can stress the culture animals. Fish have less tolerance of pH extremes at higher temperatures. Ammonia toxicity becomes an important consideration at high pH. Several studies monitored pH in both RAS and pond culture and no significant difference was found there (Table 3).

Table 3: Average pH level in RAS and Pond culture

Parameter	RAS	Pond	References
pH	7.67	7.65	Zhang et al.,2011
	7.99	7.78	Ronocarati et al.,2014

3.2.4 Total suspended Solids (TSS)

Suspended solids are particles that are large enough to be filtered out of the water by mechanical filtration (using a filter screen, sand filter, swirl separator, etc.) or can be settled out of the water column given sufficient “quiet” time. Suspended solids include colloidal (0.001 to 100 µm dia.) and settleable solids (>100 µm dia.). While increasing in TSS can have a negative effect across multiple scales of fish communities, from individual level (e.g., spawning success and fry emergence) to the system level (e.g., decreased species richness).

Zhang et al., 2011 conducted a study on the water quality and fish production of RAS, which showed significantly lower amount of TSS in RAS than Control pond (Table 4)

Table 4: TSS value in RAS and Control pond

Parameter	RAS	Control pond
TSS (mg/L)	55.2	72.5

(Source: Zhang et al., 2011)

3.2.5 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand or COD is a measurement of the oxygen required to oxidize soluble and particulate organic matter in water. Higher COD levels indicates a large amount of oxidizable organic material in water that will reduce DO levels. A reduction in DO can lead to anaerobic conditions, which is deleterious to fish health. Zhang et al., 2011 conducted a study on the water quality and fish production of RAS, which showed significantly lower amount of COD in RAS than Control pond (Table 5).

Table 5: COD value in RAS and Control pond

Parameter	RAS	Control pond
COD (mg/L)	7.3	12.8

(Source: Zhang et al., 2011)

3.2.6 Total Ammonium Nitrogen

Ammonia comes from the fish excretion and is dissolved in water. Some of the ammonia reacts with water to produce ammonium ions (NH^{4+}). The remainder is present as un-ionized ammonia (NH_3). Un-ionized ammonia is more toxic to fish than ionized ammonia and it varies with different parameters such as salinity, dissolved oxygen, and temperature. However, it is determined primarily by the pH of the solution. Such as, an increase of one pH unit from 7.0 to 8.0 increases the amount of un-ionized ammonia approximately 10-fold.

David, 2006 conducted a study on European catfish *Silurus glanis.* Which showed a higher TAN level (mostly above 0.3mg/L) in pond than RAS (mostly around 0.2mg/L) (Figure 4). As the standard level of TAN is 0 to 0.2 mg/L (Table 1), RAS showed the better water quality in case of TAN level.

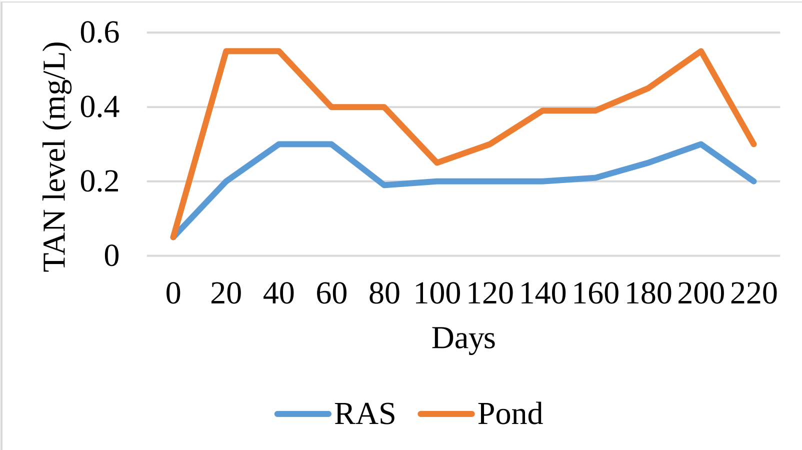

Figure 4: TAN fluctuations in RAS and Pond. (David, 2006)

Roncarati et al.,2014 conducted a study on the culture common catfish, *Ameiurus melas* in both RAS and pond and it also showed the higher level of TAN in pond (mostly above 4 mg/L) than RAS (mostly below 3mg/L) that is shown in Figure 5. From this result, it can be concluded that RAS significantly reduces the TAN level.

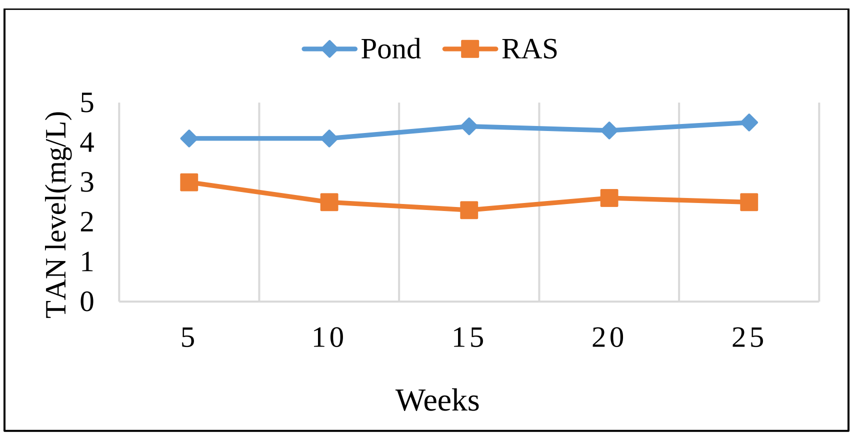

Figure 5: TAN fluctuations in RAS and Pond. [Roncarati et al., 2014]

3.2.7 Nitrite Nitrogen (N-NO_2)

Nitrite (NO_2^-) is the intermediate product of the oxidation of ammonia to nitrate, and it is toxic to fish at high levels. Nitrite poisoning causes Brown Blood Disease in fish body. Roncarati et al., 2014 conducted a study on the culture common catfish, *Ameiurus melas* in both RAS and pond and it showed the higher level of N-NO_2 in pond (0.075 mg/L) than RAS (0.02mg/L). From this result, it can be concluded that RAS significantly reduces the nitrite level.

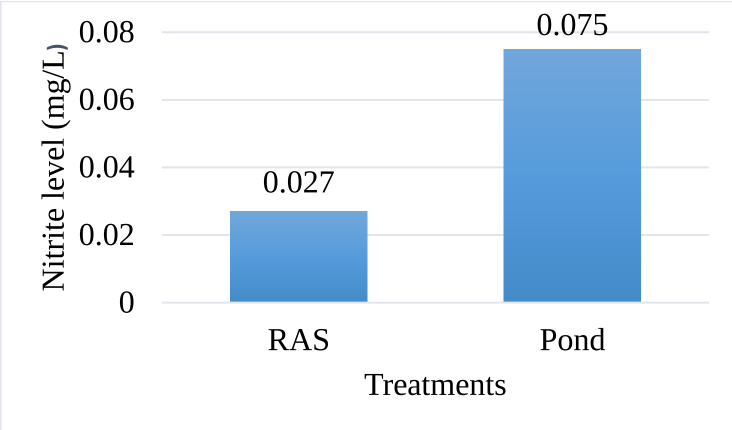

Figure 6: Nitrite level in RAS and Pond culture. (Roncarati et al., 2014)

3.2.8 Nitrate Nitrogen (($N\text{-}NO_3$)

Nitrate is the final product of ammonia in the nitrification process. Processing of nitrite to nitrate is generally done by *Nitrobacter spp*. in fresh water. Nitrate is relatively non-toxic to fish. Roncarati et al., 2014 showed the higher level of Nitrate in pond (around 4 mg/L) than RAS (mostly below 3mg/L). From this result, it can be concluded that RAS reduces the Nitrate level although both of the nitrate concentration is non toxic for fish health.

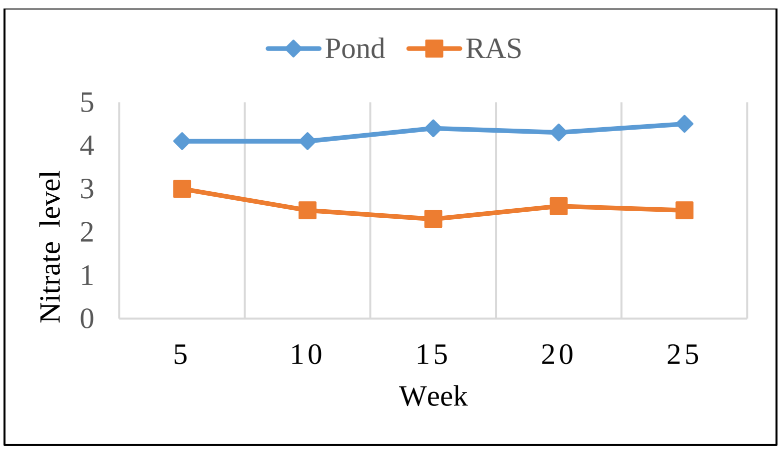

Figure 7: Nitrate level in RAS and Pond culture. (Roncarati et al., 2014)

All of above parameters showed that RAS keeps water quality better than the conventional aquaculture.

3.3 Comparative growth performance of the fish reared in RAS and conventional aquaculture system.

Better growth performance in high stocking density is the major challenge in RAS compared to other aquaculture systems. From different studies, significant results are found in the growth performance, survivability and body composition of the fishes reared in RAS compared to conventional aquaculture systems.

3.3.1. Mean weight gain (MWG)

Roncarati et al.,2014 conducted a study to evaluate the growth performance and survival of common catfish, Ameiurus melas. A total of 54,420 catfish juveniles (5.1) were reared in two groups: Pond group, represented by 3-1,000 m^2 ponds; RAS group composed by 3-2 m^3 indoor tanks working in closed recirculated system. In these two groups, catfish were reared at two different densities (Pond=15 fish m^3; RC=1,570 fish m^3) for 181 days. Though the stocking density of RAS was very much higher than the pond, result showed that the mean weight gain was higher in the fish of RAS (151.5g) than the fish of pond (142.7g) that is shown in Figure 8.

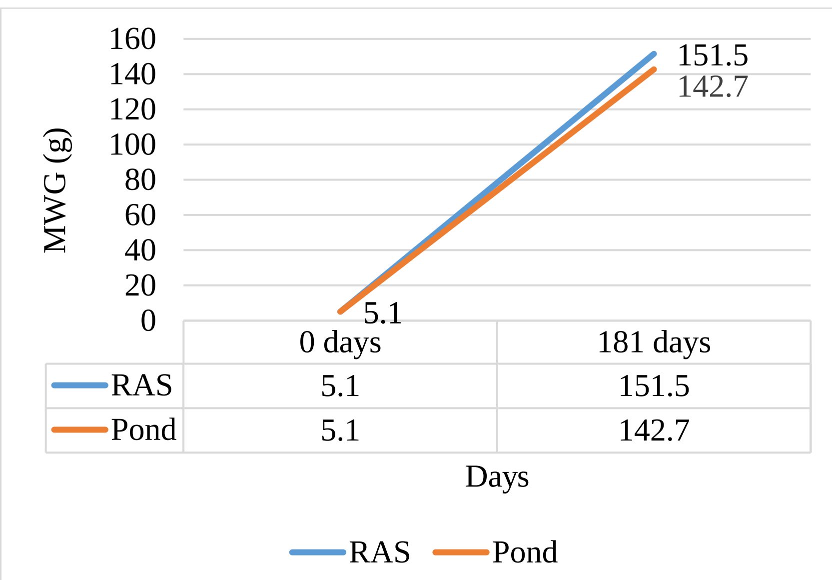

Figure 8: Mean weight gain of the fish reared in RAS and Pond. (Source: Roncarati et al., 2014)

Tal et al., 2009 conducted a study on the land based culture of Gilthead Seabream *(Sparus Aurata)* which showed 85% faster growth rate in land based or Recirculating culture system than the conventional net pen system. The mean initial weight of the fishes were 0.45g and it took 274 days to reach 450 g of mean weight in RAS. In conventional net pen system it takes usually 17 months. (Theodorou 2002)

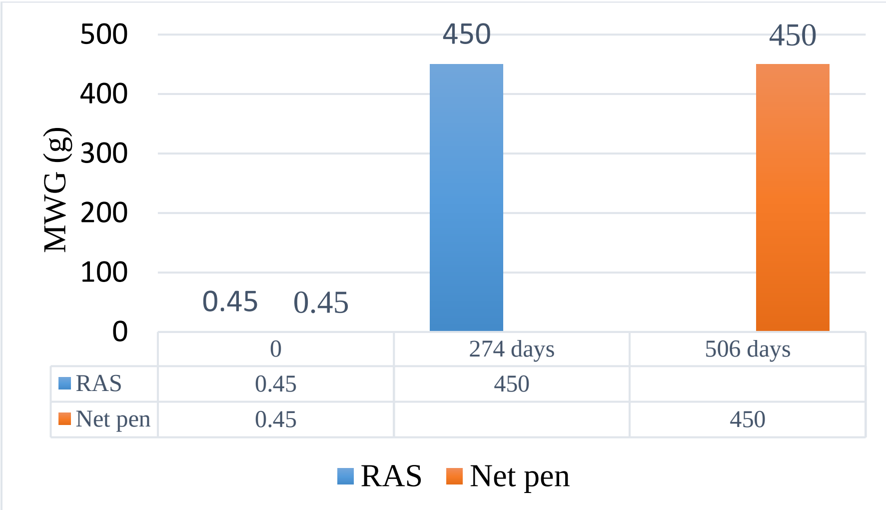

Figure 9: Mean weight gain of the fish reared in RAS and Net pen system. (Tal et al., 2009)

3.3.2 Total weight gain

Zhang et al., 2011 conducted a study on the water quality and fish production of RAS. In this study, it was found that after 1300 kg feed intake, total weight gain of pond was 706 kg. On the other hand, after 1250 kg feed intake produced 840 kg weight gain in RAS.

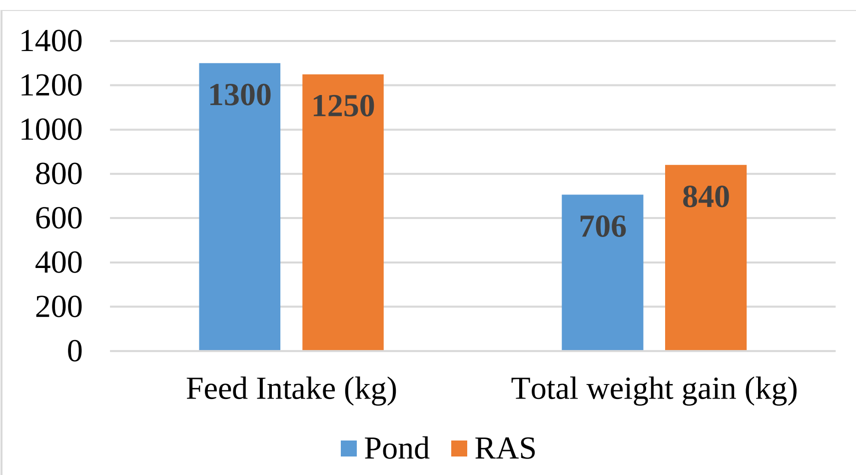

Figure 10: Total weight gain of the fishes reared in RAS and Pond. (Source: Zhang et al., 2011)

3.3.2 Specific Growth Rate (SGR)

Specific growth rate (SGR % per day) = $\frac{\text{LogW2 - LogW1}}{\text{Time}} \times 100$

Where, W_1 = Initial live body weight (g) at time T_1 (day)

W_2 = Final live body weight (g) at time T_2 (day)

D'Orbcastel et al., 2009 conducted a study on Comparative growth and welfare in Rainbow Trout reared in recirculating and flow through rearing systems (FTS). Reslts showed that final weight was 17% higher in RAS than in FTS. SGR value was higher in RAS than FTS (Table 6).

Table 6: SGR value of Rainbow Trout in RAS and FTS

Parameter	RAS	FTS
SGR (%)	0.85	0.68

(Source: D'Orbcastel et al., 2009)

Li et al., 2012 conducted a study on the effect of RAS on Growth Performance, Body Composition of Crucian Carp (*Carassius auratus*) which showed a slightly higher SGR value in RAS than in control pond (Figure 11).

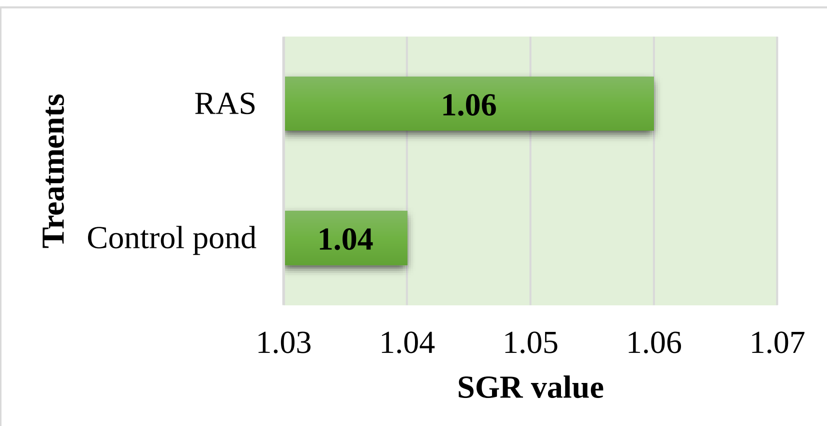

Figure 11: SGR value of Crucian Carp cultured in RAS and Control pond. (Li et al., 2012)

Policar et al., 2016 conducted a study on Comparison of production efficiency and quality of Pikeperch (*Sander lucioperca*) juveniles cultured in RAS and Pond. This study showed a higher SGR value in RAS (8%) than Pond (6.7%) which concludes that RAS ensures a better growth performance than pond (Figure 12).

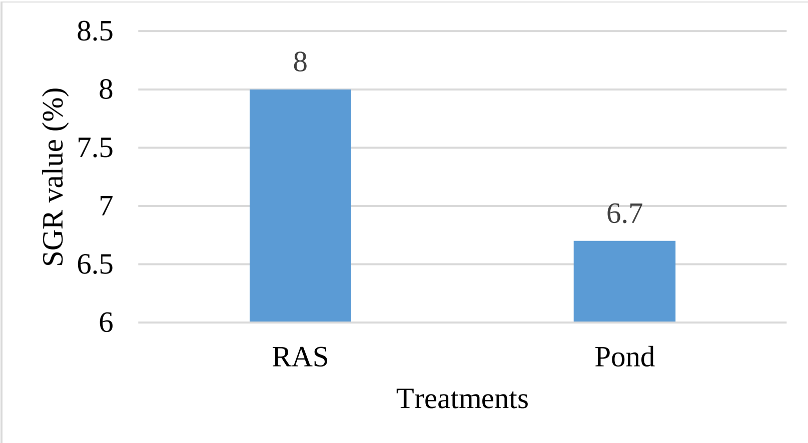

Figure 12: SGR value of Pikeperch (*Sander lucioperca*) juveniles cultured in RAS and Pond.

(Source: Policar et al., 2016)

3.3.3 Survivability

Li et al., 2012 conducted a study on the effect of RAS on Growth Performance, Body Composition of Crucian Carp (*Carassius auratus*) which showed a survivability rate in RAS which is 99.30% than the survivability rate in control pond (94.30%) (Figure 13).

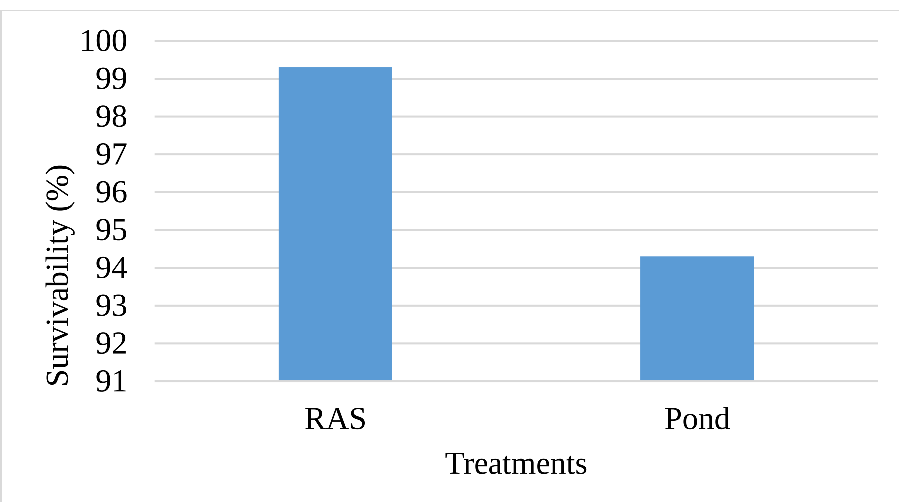

Figure 13: Survivability rate of Crucian Carp cultured in RAS and Pond system.

(Source: Li et al., 2012)

3.3.4 Hepatosomatic Index (HSI)

The ratio of liver and body weight is defined as HIS, which gives an indication on status of energy reserve of an animal. In a poor environment, fish usually have a smaller liver with less energy reserved in the liver.

Hepatosomatic index (HSI) = $\frac{\text{Liver weight (g)}}{\text{Body weight(g)}} \times 100$

Policar et al., 2016 conducted a study on Comparison of production efficiency and quality of Pikeperch (*Sander lucioperca*) juveniles cultured in RAS and Pond. This study showed a higher HSI value in RAS than Pond (Table 7), which concludes that fish RAS ensures a better environment for the fish than pond culture.

Table 7: HSI value of Pikeperch (*Sander lucioperca*) juveniles cultured in RAS and Pond

Parameter	RAS	Pond
HSI (%)	2	0.8

(Source: Policar et al., 2016)

3.3.5 Muscle Composition

Li et al., 2012 conducted a study on the effect of RAS on Growth Performance, Body Composition of Crucian Carp (*Carassius auratus*). Results showed a better quality of muscle composition in RAS than pond as the Crude protein, fat, ash level were higher in the fish cultured in RAS than pond and the moisture level was lower in the fish cultured in RAS than in pond.

Table 8: Muscle composition of Crucian Carp (*Carassius auratus*) reared in RAS and Pond culture system.

Muscle composition	RAS	Pond
Moisture (%)	70.48	73.45
Crude protein (%)	72.89	65.42
Crude fat (%)	13.73	16.09
Crude ash (%)	4.39	4.25

(Source: Li et al ., 2012)

Policar et al., 2016 conducted a study on Comparison of quality of Pikeperch (*Sander lucioperca*) juveniles cultured in RAS and Pond. This study also showed a better quality of muscle composition in RAS than pond as the Crude protein, fat, ash level were higher in the fish cultured in RAS than pond and the moisture level was lower in the fish cultured in RAS than in pond.

Table 9: Muscle composition of Pikeperch (*Sander lucioperca*) reared in RAS and Pond culture system.

Muscle composition	RAS	Pond
Moisture (g/kg)	732	789
Crude protein (g/kg)	172	158
Crude fat (g/kg)	58	20
Crude ash (g/kg)	38.9	37.2

(Source: Policar et al., 2016)

3.3.6 Feed Conversion Ratio (FCR)

FCR is the ratio of Total feed intake and total body weight gained by the organism. It means the unit amount of feed an organism requires to gain a unit of body weight is FCR. If the FCR is lower, it reduces the production cost as the fish is gaining expected weight from lower amount of feed intake.

$$\text{FCR} = \frac{\text{Total Feed consumption}}{\text{Total body weight gain of fish}}$$

Li et al., 2012 conducted a study on the effect of RAS on Growth Performance of Crucian Carp (*Carassius auratus*) which showed a higher FCR value of the fish cultured in Pond than RAS.

Table 10: FCR value of Crucian Carp (*Carassius auratus*) cultured in RAS and Pond

Parameter	RAS	Pond
FCR	1.42	1.63

(Source: Li et al., 2012)

D'Orbcastel et al., 2009 conducted a study on comparative growth perforfance of Rainbow Trout raised in RAS and flow through rearing systems (FTS). Results of this study showed that FCR value is lower in RAS cultured fish than FTS (Figure 14).

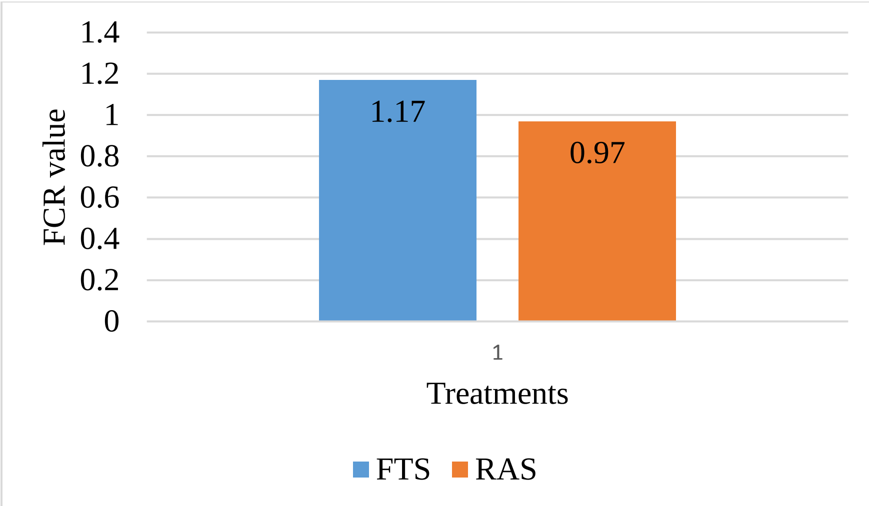

Figure 14: FCR value of Rainbow Trout reared in RAS and FTS. (Source : D'Orbcastel et al., 2009)

All of above parameters showed that RAS ensures better growth performance than the conventional aquaculture systems.

3.4 Present status of RAS adoption in Bangladesh

Bangladesh has adopted RAS technology in Fish culture. This technology is introduced in commercial fish farming in Bangladesh through a project named JAK-AGRO3 Aquaculture project. ABM Shamsul Alam, owner of Agro3 Fishery, has pioneered the indoor fish farming by installing RAS in Mymensingh in 2016. The project is expected to be economically profitable due to the less water requirement, low feed conversion ratio, healthy and uniform size fish production, high volume production and less mortality. Bangladesh Council of Scientific and Industrial Research (BCSIR) is the the leading state-run scientific research body. It comes second to Agro3 Fishery in installing a RAS at its headquarters recently in November 2016 for the purpose of research and demonstration. BCSIR has brought the RAS equipment from the Netherlands while Agro3 got those from Canada through a company named JAK International. (Ahmed, 2017) Another RAS fish farm named "Deshi Fish Farm" is established in Balirtek ferry ghat, Manikganj. Farm owner is Moshir Ahamed Majumder Swapan & Jahangir Alam. Pabda, Tilapia, gulsa fishes are cultivated here.

Agro3's indoor fish farm is set up eight-tank of RAS on 3,000 square ft. Agro3 proprietor Shamsul said compared to one to two kg of fish being produced per m^3 of water in an open pond he got 35kg of pabda per m^3 of water in his fish tanks, 60kg of hybrid catfish and up to 80kg of pangas per m^3. This farm has recently marketed the first batch of 500kg of pabda. Another 200kg of the Pabda fish are now ready to sale while a huge stock of gulsha fish (Mystus Cavasius) are also ready for sale in a month. Production cost is 200 tk per kg, selling price of pabda 600 tk per kg in the market, showing a sign of a profitable venture. (Ahmed, 2017)

The RAS facility of BCSIR is constructed on 1,800 square feet of land. BCSIR set 11 fish tanks with a maximum production capacity of 15 tonnes in 33,000 litres of water. It is aimed to produce demandable fish like tilapia, catfish and pabda. They expect to cultivate bhetki (Barramundi) in the next production cycle in this indoor fish farming facility. BCSIR sold the first batch of RAS fish (100kg of tilapia) to superstore Shwapno. According to the speech of Rezaul Karim, head of the Centre for Technology Transfer and Innovation (CTTI) at BCSIR , it's an innovative and promising technology for fish culture in Bangladesh. BCSIR will go for training, promoting, demonstrating and encouraging indoor fish farming. One of the goals of BCSIR in case of this technology will be cost minimisation. If this technology will become less costly, many fish farmers in Bangladesh will be able to start indoor fish farming. It costs 60 lacs BDT to import a RAS unit but if the bio-filter can be designed and developed here in Bangladesh, cost of a RAS unit will come down to 20 lacs BDT. Around 23 entrepreneurs have already shown interest in knowing about the RAS technology. (Ahmed, 2017)

Chapter 4

Conclusions

In conclusion, this study establishes a strong base for RAS fish culture with the aim of suitable water quality maintenance and better growth performance of fish.

- The system components are still in developing stage to make them more viable in commercial purpose and some additional component like multi sensor is being tried to develop to monitor the water quality parameter automatically and to take steps against any abnormal condition.
- All the water quality parameters like temperature, DO, pH, TAN, Nitrite, Nitrate, TSS, COD level showed significant result for higher production of fish in the RAS. The fishes raised in RAS showed significant growth performance in high stocking density. Mean weight gain, total production, specific growth rate, survival rate, hepatosomatic index were higher in RAS raised fish. The muscle of the RAS raised fish contains higher protein, fat, ash, which is beneficial for consumers' health. FCR was lower in the RAS, which reduces the production cost of feeding. Therefore, RAS can be an encouraging way of higher fish production for the growing population.
- In Bangladesh, RAS has been just introduced in 2016. Only two farms named Agro3 Fisheries in Mymensingh and Deshi Fish Farm in Manikganj are running this technology on commercial basis and getting their expected results in growth performance of fish. BCSIR is also running a RAS project for research and demonstration purpose with the aim of reducing the high initial investment cost and making this technology commercially profitable for the developing country like Bangladesh. Entrepreneurs, who are already running this technology or want to adopt this technology, are expecting to have training programs from government.

References

Bhatnagar, A., & Devi, P. (2013). Water quality guidelines for the management of pond fish culture. *International Journal Of Environmental Sciences,* 3(6). doi:10.6088/ijes.2013030600019.

Bregnballe, J. A Guide to Recirculation Aquaculture, An introduction to the new environmentally friendly and highly productive closed fish farming systems (2015 ed.). The Food and Agriculture Organization of the United Nations (FAO) and Eurofish International Organization. Retrieved from http://www.fao.org/3/a-i4626e.pdf

Buentello, J., Gatlin, D. M., & Neill, W. H. (2000). Effects of water temperature and dissolved oxygen on daily feed consumption, feed utilization and growth of channel catfish (*Ictalurus punctatus*). *Aquaculture,* 182(3-4), 339-352. doi:10.1016/s0044-8486(99)002744.

Campo, L. D., Iberra, P., Gutierrez, X., & Takle, H. (2010). Utilization of sludge from recirculation aquaculture systems. (Rep.). Norway: Nofima.

D'Orbcastel, E. R., Ruyet, J. P., Bayon, N. L., & Blancheton, J. (2009). Comparative growth and welfare in rainbow trout reared in recirculating and flow through rearing systems. *Aquacultural Engineering,* 40(2), 79-86. doi:10.1016/j.aquaeng.2008.11.005.

David, J. A. (2006). Water quality and accelerated winter growth of European catfish using an enclosed recirculating system. *Water and Environment Journal*, 20(4), 233-239. doi:10.1111/j.1747-6593.2006.00021.

Godfray, H. C., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Toulmin, C. (2010). Food Security: The Challenge of Feeding 9 Billion People. *Science,* 327(5967), 812-818. doi:10.1126/science.1185383.

Islam, M., & Islam, R. (2017). Impact of aquaculture and contemporary environmental issues in Bangladesh. *International Journal of Fisheries and Aquatic Studies,* 5(4), 100-107. Retrieved from www.fisheriesjournal.com.

Islam, Md Rahedul, and Md Zahidul Hassan. "land use changing pattern and challenges for agricultural land: a study on rajshahi district." *Journal of Life and Earth Science*, vol. 6, 2012, doi:10.3329/jles.v6i0.9724.

Kolarevic, J., Bundgaard, D., Kristin, B., Reiten, M., & Sather, B. S. (2008). Multi-sensor automated water quality monitoring and control system for continuous use in recirculation aquaculture systems [Scholarly project]. Retrieved October 17, 2016, from http://smoltproduksjon.no/Bilder/TidlKonf 2014/Kolarevic.pdf

Li, X., Li, G., Zhang, S., & Tao, L. (2013). Effect of recirculating aquaculture system (RAS) on growth performance, body composition and hematological indicators of Allogynogenetic Crucian Carp (*Carassius auratus gibelio*). *Advance Journal of Food Science and Technology,* 5(3), 348-355. doi:10.19026/ajfst.5.3269.

Malone, R. (2013). Recirculating Aquaculture Tank Production Systems, A review of current design practice. Retrieved from https://www.scribd.com/document/362454516/SRAC-Publication-No-453-Recirculating-Aquaculture-Tank-Production-Systems-A-Review-of-Current-Design-Practice-pdf.

Meinelt, T., Kroupova, H., Stüber, A., Rennert, B., Wienke, A., & Steinberg, C. E. (2010). Can dissolved aquatic humic substances reduce the toxicity of ammonia and nitrite in recirculating aquaculture systems? Aquaculture, 306(1-4), 378-383. doi:10.1016/j.aquaculture.2010.06.007.

Murray, F., Bostock, J., & Fletcher, D. (2014). Review of Recirculation Aquaculture System technologies and their commercial application (Rep.). University of Stirling.

Pang, X., Cao, Z., & Fu, S. (2011). The effects of temperature on metabolic interaction between digestion and locomotion in juveniles of three cyprinid fish (*Carassius auratus, Cyprinus carpio and Spinibarbus sinensis*). *Comparative Biochemistry and Physiology Part A:Molecular & Integrative Physiology*, 159(3), 253-260. doi:10.1016/j.cbpa.2011.03.013.

Parra, L., Sendra, S., García, L., & Lloret, J. (2018). Design and Deployment of Low-Cost Sensors for Monitoring the Water Quality and Fish Behavior in Aquaculture Tanks during the Feeding Process. *Sensors,* 18(3), 750. doi:10.3390/s18030750.

Piedrahita, R. H. (2003). Reducing the potential environmental impact of tank aquaculture effluents through intensification and recirculation. *Aquaculture,* 226(1-4), 35-44. doi:10.1016/s0044-8486(03)00465-4.

Policar, T., Blecha, M., Křišťan, J., Mráz, J., Velíšek, J., Stará, A., Stejskal, V., Malinovskyi, O., Svacina, P., Samarin, A. M. (2016). Comparison of production efficiency and quality of differently cultured pikeperch (*Sander lucioperca L.*) juveniles as a valuable product for ongrowing culture. *Aquaculture International,* 24*(6),* 1607-1626. doi:10.1007/s10499-016-0050-9.

Ahmed. R. (2017, February 9). Indoor farming: novel way to up fish yield. *Daily Star*. Retrieved February 14, 2017, from https://www.thedailystar.net/frontpage/indoor-farming-novel-way-fish-yield-135810.

Roncarati, A., Melotti, P., Mordenti, O. (2014). Comparison of Growth Performance of 'Common Catfish Ameiurus melas, Rafinesque1820', Reared in Pond and in Recirculating Aquaculture System. *Journal of Aquaculture Research & Development*, 05(02).doi:10.4172/2155- 9546.1000218.

S.D. (2012). Management of Water Quality in Intensive Aquaculture. Retrieved from https://www.researchgate.net/publication/259175404.

Schneider, O., Schram, E., Poelman, M., Rothuis, A., van Duijn, A., 2010. Practices in managing finfish aquaculture using RAS technologies, the dutch example. OECD workshop on advancing the aquaculture agenda, Paris, France, OECD.

State of World Aquaculture (Tech. No. 500). (2006). Rome, Italy: Food and Agriculture Organization of the United Nation.

Summerfelt, S. T., Sharrer, M. J., Tsukuda, S. M., & Gearheart, M. (2009). Process requirements for achieving full-flow disinfection of recirculating water using ozonation and UV irradiation. *Aquacultural Engineering,* 40(1), 17-27. doi:10.1016/j.aquaeng.2008.10.002.

Tal, Y., Schreier, H. J., Sowers, K. R., Stubblefield, J. D., Place, A. R., & Zohar, Y. (2009). Environmentally sustainable land-based marine aquaculture. *Aquaculture,* 286(1-2), 28-35. doi:10.1016/j.aquaculture.2008.08.043.

The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all. (2016). Rome: FAO.

Theodorou, J. A. (2002). Current and future technological trends of european Seabass-Seabream culture. *Reviews in Fisheries Science,* 10(3-4), 529-543. doi:10.1080/20026491051776.

Timmons, M. B., & Ebeling, J. B. (2013). *Recirculating Aquaculture* (3rd ed., p.3). Ithaca Publishing Company Publishers

Verdegem, M. C., Bosma, R. H., & Verreth, J. A. (2006). Reducing Water Use for Animal Production through Aquaculture. *International Journal of Water Resources Development,* 22(1), 101-113. doi:10.1080/07900620500405544.

Zhang, S. Y., Li, G., Wu, H. B., Liu, X. G., Yao, Y. H., Tao, L., & H. L. (2011). An integrated recirculating aquaculture system (RAS) for land-based fish farming: The effects on water quality and fish production. *Aquacultural Engineering,* 45, 93-102. doi:10.1016/j.aquaeng.2011.08.001.

Zohar, Y., Tal, Y., Schreier, H. J., Steven, C. R., Stubblefield, J., & Place, A. R. (2005). Commercially feasible urban recirculating aquaculture: Addressing the marine sector. *Urban Aquaculture,* 159-171. doi:10.1079/9780851998299.0159.