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Dissolved Wastes in Recirculating Aquaculture System (RAS): Management through the Dietary Modifications

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ABSTRACT

Recirculating aquaculture system (RAS) is a highly promising system for intensive aquaculture. This system along with hydroponics is pertinently adopted by the fish farmers today as there are scarcity for land and water. The major issue in maintain RAS is the feed and faecal waste, which give rise to generate dissolved and undissolved organic and inorganic load in RAS. Nitrogen (N) and phosphorous (P) in metabolic waste produced by fish are the significant dissolved waste. The suspended solids from the feed and faecal matter are the second most culprit. Both wastes are removed using different filters. Mechanical filtration combined with subsequent biological filtration is the typical strategy for managing wastes in this enclosed system. The feed used in RAS is the primary source for the release of dissolved wastes such as ammonia, nitrite, phosphate etc., Thus, the feed should be formulated in such a way that it produces low nitrogenous and phosphorus wastes. Use of technological interventions in feed technology and incorporation of additives to enhance feed digestibility, physical structure and protein energy ratio should be considered while developing feed intended to use in RAS.

INTRODUCTION

Recirculating aquaculture system (RAS) is an enclosed fish farming system where water is replaced only to the extent of loss caused due to evaporation and cleaning. This aquaculture system supports intensive practices with the benefits of a controlled environment, least space, and water requirement for sustained production. High production of 60 MT fish from 1/6th ha from RAS has been reported, which is much better than the conventional aquaculture of 3-10 MT per ha (DAHDF, 2017). Feed accounts for 40-60% of the production costs in aquaculture systems, with protein sources accounting for a significant proportion of this cost (Fotedar, 2004). Usually, 80% or more of the feed is consumed, but 10 to 20% of the feed goes unconsumed and released to the culture system (Boyd and Tucker, 2014). Almost 40% of consumed feed remains undigested and released as faecal matter. With new commercial fish feeds, fish retain only ~40 percent of the phosphorous content. In RAS, nitrogen (N) and phosphorous (P) in metabolic waste produced by fish are the origins of dissolved waste. Ribeiro (2006) demonstrated that commercial feed composition of 28% crude protein had nitrogen and phosphorus content of about 5.24% and 1.14% respectively of dry weight matter.

Dissolve wastes in RAS

The wastes in terms of dissolved N and P in RAS comes from the feed as the metabolic rate of fish is a function of temperature due to the poikilothermic nature of fish. The feed is given in RAS usually accounts for 3-4 percent of body weight in warmer temperature and 1-2 percent of the body weight per day when the RAS is held at a cooler temperature for the same species. The waste production is given a percentage of the feed per day and generally ammonia excretion accounts for 2-3 percent of the feed fed per day. However, there is a lack of knowledge of waste generation for different fish species, and it has not been well quantified in RAS. For example, the data for striped bass show that for every kg of feed fed, they produce 0.03 kg of ammonia, 0.3 kg solid waste, and use 0.2 kg of oxygen (Colt, 1986).

Phosphorus (P) release in RAS

The aqua-feed need to be formulated & prepared in such a way that minimises P excretion. Consequent eutrophication of the water requires the replacement of fish meal with low-P protein sources (Lall, 1991). Reduction of phosphorous level in feed without impacting growth, feed efficiency, and health is a key to the development of low pollution diets for RAS systems. The use of high protein ingredients that have a high percentage of digestible phosphorus may reduce the unavailable P concentration of the feed (Cho et al., 1994). However, reducing dietary phosphorus levels involves modifying feed ingredients such as fish meal to reduce bone content can be followed (Babbitt et al., 1995). There has been rising attention paid to replacing fish meals in practical feeds with plant or grain by-product materials because of the decreasing supply / rising price of fish meals in recent years, its relatively high phosphorus content (Tacon and Silva, 1997). The increasing availability of phosphates in feed ingredients involves using supplements such as phytase to hydrolyse phytate phosphorus in plant feed ingredients, making it available to fish (Riche and Brown, 1996). Phosphorus in salmon and trout feed contributed by fish bones in fish meal, phytate phosphorus in various plant protein sources, and phospholipids in fish and plant oils (Hardy, 1995). The form of phosphorus in the fish meal is mostly hydroxyapatite, which is not efficiently utilised by fish (NRC, 1993). Citric acid and some other dietary acidifiers have been shown to improve the performance of weaning pigs (Ravindran and Kornegay, 1993), and citric acid was shown to improve the availability of some minerals in fish meal. Phosphorus levels in faeces of fish fed a diet with 5% citric acid were approximately half of that of fish fed the control diet (0% citric acid) in the rainbow trout trial (Sugiura, 2000). The increasing availability of phosphates in feed ingredients involves using supplements such as phytase to hydrolyse phytate phosphorus in plant feed ingredients, making it available to fish (Riche and Brown, 1996). Goda et al. (2007) reported that supplementation of microbial phytase at 1000 FTU kg-1 level has demonstrated to be efficient for increasing dietary phosphorus supply for Nile tilapia fingerlings, thereby reducing the phosphorus effluent from aquaculture facilities.

Nitrogen (N) release in RAS

The nitrogenous waste such as ammonia, nitrite and nitrate produced in the RAS are also a concern for fishes reared under this system, although later is less toxic and has the least concern. The ammonia excreted accounts around 60 to 70 % of the nitrogen consumed by the fishes need to be converted into the nitrate through nitrification using bacteria. The nitrate which is less toxic also needs to be removed from RAS for its sustainability and environmental issue. Another unit considered is the conversion of nitrate into nitrogen through the denitrification process. The use of anaerobic denitrification to remove nitrate has not yet widely applied in RAS due to its efficacy and complexity (Pungrasmi et al., 2016). Efficient protein sparing (using sub-optimal protein and incorporating the right amount of non-protein resources for energy) & incorporation of activated charcoal in the feed (Mabe et al., 2018) are some of the solutions for the reduction of ammonia excretion in the RAS system. Numerous studies have shown that decreasing dietary DP/DE ratio by increasing dietary non-protein energy content results in an increase in N retention efficiency and a decrease in the dissolved nitrogenous waste (DNW) of numerous fish species in RAS (McGoogan & Gatlin, 2000).

Dietary strategies to reduce dissolved nitrogen waste

The major strategies are to manage the level of crude protein incorporation in the feed is providing the correct ratio to reduce feed wastage. Also, enhanced feeding frequency reduces feed wastage. The protein energy ration, more specifically digestible protein to digestible energy (DP:DE) ratio should be maintained to reduce the release of ammonia from protein catabolism. This will also reduce the load on the biofilter. When DP: DE ration is optimal, protein-sparing by non-protein ingredients will be maximal, which allows the inclusion of only a sub-optimal level of protein in the feed. Low leaching and good water stability will also reduce feed nitrogen release from the bacterial degradation of the wasted protein. Fish life stage and water quality also affect the feed wastage by influencing the form and quality of feed.

Table 1: Some of the supplements offer the possibility of increasing digestion and/or absorption efficiency of minerals

Dietary supplements	Mode of action	Reference
Cholecalciferol (vitamin D3)	Increase P, Ca and Mg absorption as calcitriol or 1,25(OH)2D	Breves and Schröder (1991)
Citric acid	Chelate mineral ions. Acidifier in weaning pig diets aid gastric digestion	Ravindran and Kornegay (1993)
Sodium citrate	Chelate mineral ions	Cuche et al. (1976)
NaCl	Increase Na-dependent active transport of P in the intestinal brush border	Cross et al. (1990)

Dietary strategies to remove phosphorus waste

The principal strategy is to improve the digestibility of phytate phosphorus. The release of un-absorbed phosphorus in the form of phytate causes environmental degradation of phytate and produce phosphorus release. The mineralisation of aquatic flora and fauna releases phosphorus. However, in RAS, the major source of phosphorus is feed and faecal waste. Enhanced phosphorus absorption by the addition of phytase enzyme can reduce the release of phosphorus to the environment. Also, a reduction in the inclusion of the non-digestible mineral salts containing phosphorus, such as high inclusion of fish meal or bone meal, is not recommended to control phosphorus release.

CONCLUSION

The recirculating aquaculture system is the upcoming intensive aquaculture where the land and water are a scarcity. Currently, species like trout, salmon, catfishes, tilapia, striped- seabass etc., are cultured in the RAS system. It offers crucial advantages over open pond culture. These include higher production on a limited supply of water & land, fully environmental control, flexibility to locate production facilities near large fish markets, effortless harvesting, and quick disease control.

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