IMPROVEMENT OF FORMULATED FEEDS AND FEEDING MANAGEMENT IN INTENSIVE AQUACULTURE

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Abstract
Aquaculture plays a vital role in achieving some of the Millennium Development Goals by offering employment opportunities, reducing malnutrition and increased incomes for Africans. However, aquaculture in Africa is practised on a lower scale compared to the rest of the world and is characterised by low input and low production output. Production can be increased substantially by embracing a technological shift from extensive to intensive systems of production as is the trend in developed countries. Feed quality is a major determinant of successful intensification of aquaculture because culture animals can be confidently grown to optimal harvest size and not left to chance. Feed costs are relatively high and account for over 70% of the total cost of production in intensive culture system. To solve this problem, most fish feed based research has focused on inexpensive ingredients to minimize feed costs; however, these ingredients have a direct impact on the pellet quality. Pellet quality with respect to both water stability and physical form, is of considerable importance for aquatic animals. Therefore, improvements in feed formulation using different binders to improve water stability and optimize pellet size for a given size/age of culture animal will enhance growth, minimise feed wastage and reduce production costs. However, such developments alone may not necessarily provide high returns because feed wastage depends on feeding management and in this regard, the improvements to both feed formulation and feeding management practices are both critical in intensive aquaculture. This paper is based on the studies of the author on improvement of feeds and feeding management in intensive aquaculture used in Australia as a model that can be adapted for adoption in Africa. Lessons learned from this research are directly implementable in Africa since they are developed in a tropical setting like most parts of Africa leading to the development, growth and expansion of aquaculture in Africa (South Africa).
Keywords: intensive aquaculture, feed formulation, feed management, Africa

Introduction

Aquaculture is the farming of aquatic organisms and plants in freshwater, brackish-water and seawater environments. Aquaculture has traditionally played a vital role in most of Millennium Development Goals such as offering better nutrition (Gabriel *et al*., 2007), creating livelihood opportunities (Zulfikar, 2001) and reduces some of the disease mostly for rural communities (Gabriel *et al*., 2007). Africans are second to Asians in terms of the importance of fish in their diet, with 17.4% of total animal protein intake from fish (compared to 25.7% in Asia) (Brummett *et al*., 2008). Fishery systems are under threat from upstream activities and overfishing because of growing population and unsustainable management practices, there is a considerable potential to expand aquaculture in Africa in order to reduce pressure on wild stock and improve food security.

Status of Aquaculture

Compared to agriculture that has a long history, aquaculture is a young industry but growing fast globally which is also true for Australia (Fig 1) (Food and Agriculture Organisation of the United Nations (FAO), 2012).

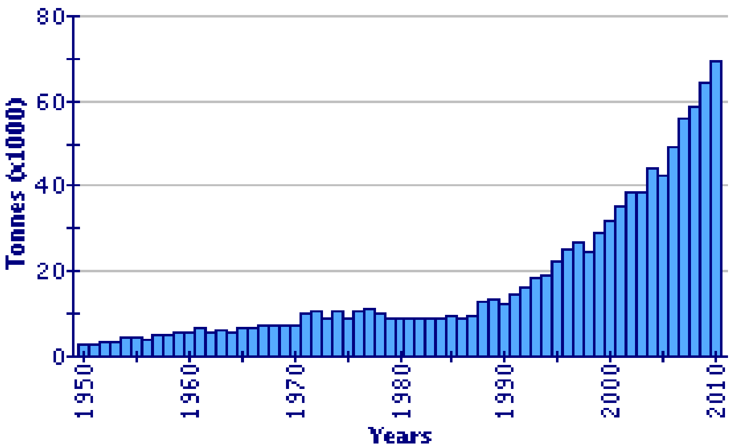
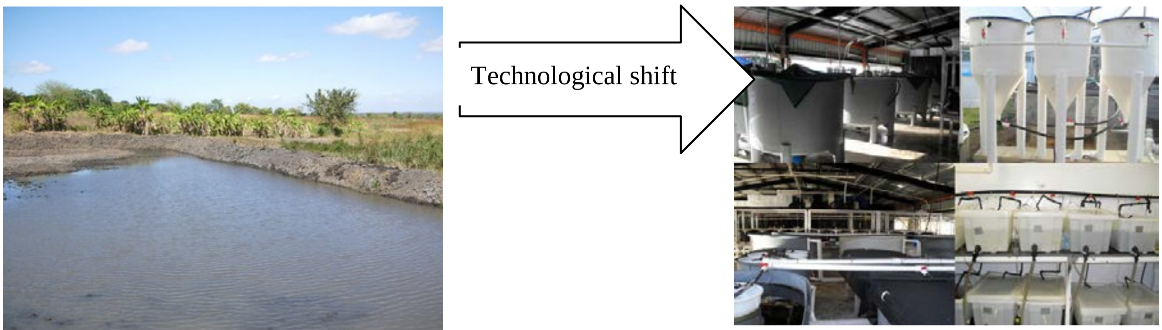


Fig 1: FAO (2012) Fishery Statistics, Aquaculture production in Australia

According to FAO (2012) global aquaculture production continues to be dominated by Asia with China taking a lead. Asia contributed 89% of global aquaculture production while Africa contributed only 2% in 2010 (FAO, 2012). The low contribution to global aquaculture production from Africa is attributed to the lower scale of production compared to the rest of the world (Gabriel *et al*, 2007). In addition Africa still rely on imported feed ingredients and fish feeds from other countries which makes fish farming expensive and also lack a long history of aquaculture, unlike Asia (Gabriel *et al*, 2007). In China for example, the aquaculture industry goes back thousands of years and has not only become an important industry but has also become part of the culture.

In comparison to African aquaculture as a whole, South Africa's contribution has remained disconcertingly low; accounting for less than 1% of the total African aquaculture production. Opportunities for aquaculture are often overlooked because South Africa is perceived as being a dry, water-scarce country with limited water resources (Hoffmann *et al*., 2000). The aquaculture systems that are generally used range from extensive to semi-intensive with relatively limited fish yields. The situation is further exacerbated because of increasing competition for land and water with other users. Therefore, if water is scarce or when land is not readily available, development of improved, *i.e.* technological shift from extensive to intensive systems (Fig 2) of production may be an efficient means to increase production of aquaculture.



Extensive aquaculture

Intensive aquaculture systems used at James Cook University (Australia)

Fig 2: Technological shift of extensive to intensive aquaculture systems

Overview of the project

The overall trend in global aquaculture is towards increased intensification of culture methods. The success of intensive aquaculture is highly dependent on the availability of nutritionally complete and cost effective formulated feed (Goddard, 1996). On the other hand, even a nutritionally-balanced diet with poor water stability will quickly become nutritionally impoverished as a result of nutrient loss through leaching and will not support optimal growth of the cultured animals. In turn, while the use of high-quality feed may not necessarily provide high returns, improvements to feed management practices can significantly increase returns if the feed is utilized efficiently by cultured animals.

Therefore, to sustain intensive aquaculture binders should be used to improve water stability of pelleted aquaculture feeds, optimise pellet size for easy handling, and optimise feed consumption which will enhance growth of the cultured animals and minimise feed wastage. It is hypothesized that with good water stability, optimal pellet size and the effective feed management practices, performance of intensive aquaculture systems will be improved and this will support development, growth and expansion of aquaculture in Africa (South Africa).

How to sustain Intensive Aquaculture?

<u>Identifying cost effective alternative ingredients in feed formulation</u>

The rapid expansion of intensive aquaculture has accelerated the search for alternative feed ingredients to replace fish meal. Since Australia has a strong aquaculture Research and Development skill base and good aquaculture nutrition research infrastructure, in 1993 Australia established Fish Meal Replacement (FMR) subprogram. Thereafter, FMR continued as the Aquaculture Diet Development (ADD) subprogram to develop least-cost aquafeed in which fish meal was partially or completely replaced since 1996 across a broad range of aquaculture species. In collaboration with aquaculture farmers and aquafeed manufacturers, the developed new aquafeeds were tested and the laboratory findings validated under on-farm conditions.

Agricultural ingredients include high quality soybean meal to cereals like wheat and rice (Allan, 2000) already used to replace fish meal in aquafeeds (Allan, 2007). Animal by-products such as bloodmeal, meat and bone meals are widely available and can be very useful ingredients, however, concern with exotic diseases like bovine spongiform encephalopathy (or Mad Cow Disease) has reduced use of meat products in feed formulation (Australasian Agribusiness Services, 1993) for animals that might be exported in other countries such as Japan and Europe (Allan, 2007). Furthermore, the hindering use of animal by-product on feed formulation is the practice of rendering processors to 'take what's left' which contributes to inconsistent composition as compared with vegetable protein source (Allan, 1997). Since animal by products has been banned in other countries and with variability of composition a lot of research has been done on vegetable based feed formulation.

Digestibility, price and availability of a given ingredient are major regulators of which ingredients can be considered for potential inclusion in intensive aquaculture feeds (Allan *et al*, 2000); however, the effect of pellet quality, pellet size and feeding intervals using chosen ingredients is always neglected.

<u>Pellet quality</u>

Pellet quality with respect to both stability in water and physical form, is of considerable importance for aquatic animals. High water stability is defined as retention of physical pellet integrity with minimal disintegration and nutrient leaching during immersion prior to consumption. Inadequate pellet stability would lead to nutrient loss (D'Abramo and Robinson, 1989), reduced attractiveness of the diet after remaining in water for some time, and disintegrated (Sáez-Royuela *et al*., 2001; Ahvenharju and Ruohonen, 2005). Economically, nutrient leaching results in considerable financial loss and leads to poor growth performance of the cultured animals because the full nutritional benefits of a carefully formulated diet are not realized and poor water quality results from increased nutrient content. Pellet quality is critical for cultured aquatic animals and for this reason there have been several strategies to improve pellet stability and physical form in water.

<u>Use of binders and concentrations to improve pellet quality</u>

One of the strategies to improve pellet quality is the diet extrusion method in which the ground food mixture is cooked by the addition of steam and compressed through a pellet die. However, the manufacturing procedure to improve water stability for the pellet alone is usually inadequate for proper binding. More recently research has focused on incorporating suitable processing technology with various artificial binders at different concentrations to improve quality of formulated diets (D'Agaro and Lanari, 2004, Rescoe *et al*., 2005; Volpe *et al*., 2008; Volpe *at al*., 2011). However, it is currently impossible to conclude that a certain binder and concentration is better than another with respect to water stability (Volpe *at al*., 2011; Paoucci *et al*., 2012), because diet water stability and physical form are also influenced by the choice of ingredients, method of pellet manufacture and pellet size tested.

Do cost effective ingredients affect pellet quality?

Behnke (2010) presented an overview highlighting that as research assessing inexpensive feed ingredients as potential replacements for fishmeal is ongoing, greater inclusion of such ingredients tends to create problems with pellet quality. Diet ingredients can have a direct influence on the effectiveness of binders (Dominy and Lim, 1991) and their concentration (Durazo-Beltrán and Viana, 2001). For example, Lim and Cuzon (1994) reported that ingredients that are hard to grind or have little or no binding properties, such as rice and oat hulls, may result in pellets with poor water stability. More than 42% inclusion level of soybean in diets significantly decreased the water stability of resulting pellets (Lim and Dominy, 1990). Furthermore, when using fish by-products as a major protein source, for more binding, alginate has to be supplemented by the addition of food sequestrants (International Specialty Products (ISP), 2004) because high levels of calcium and/ or other multivalent cations present in fish by-products, prematurely reacts with alginate causing unwanted thickening of the diet mixture (Meyer *et al.,* 1972; Wolf, 2004). However, such supplementation is less necessary when fish meal is totally replaced (Meyer *et al.,* 1972) by other protein sources.

Binder concentration is also affected by diet ingredient. For example, Durazo-Beltrán and Viana (2001) found that pellet stability increased as binder (alginate) level decreased to 0.5 % for formulated diets containing fish meal, whereas in the treatment using fish silage as the protein source, stability increased as alginate level was increase to 1.6 %. The presence of binders is essential in the formulation of aquatic animal diets. Diets containing too little binder may not be adequately water stable, resulting in deterioration of water quality and loss of valuable dietary nutrients (Wolf, 2004). On the other hand, high concentrations of binding agents result in reduced nutritional value due to the replacement of nutrients by binding agents, potential difficulties with ingestion and digestion, and these issues are also likely to result in increased feed cost (Hashim and Maat Saat, 1992; Durazo-Beltrán and Viana, 2001; Moond *et al*., 2004; Paoucci *et al*., 2012). Therefore, since the use of binders also influence feed cost it is important to determine the optimal level of binders to maximize the nutritional value of the diets in which they are used.

Pellet size also affects pellet quality

Pellet size is another important factor affecting the stability and physical form of feeds in water since other research indicates that water stability has a direct correlation to pellet size (Obaldo and Tacon, 2008), so generally, the larger the pellet the more stable it is. Poor water stability of small pellets is reported to result from the increased surface area to volume ratio compared to larger pellet sizes (Obaldo and Tacon, 2008). Additionally, although crumbling large pellets to produce pellets of a desired size is a practical and simple method for manufacturing crustacean feed, stress cracks result during this process has also been reported to contribute to poor water stability as compared to the use of appropriate dies size for desire pellet sizes (Obaldo and Tacon, 2008).

Feeding behavior to be considered when formulating feed and feeding management

Pellet size affect feeding behavior

Each species has its particular feeding behavior in response to different pellet sizes and this need to be considered when formulating pelleted aquaculture feeds in order to maximise feed consumption. If an animal is not fed with an 'ideal' pellet size, more energy and time is required to capture the pellet with consequent nutrient loss. D'Abramo (2002) mentioned that although large filter feeding fish and crustaceans can consume small particles of feed, more energy and time is required to capture an equivalent weight of these smaller particles with a consequent reduction in feed efficiency. A broad series of fish species (Goldan *et al*., 1997) and crustaceans (Sheppard *et al*, 2001) have been used to show that there is a direct relationship between animal size and food pellet size; as the size of the cultured animal increases the pellet size must also increase to retain nutritional efficiency. Therefore, the ideal food particle or pellet size must be determined and taken into account for each species individually as many show divergent feeding behaviors at different developmental stage. However, even when presented with food pellets of an ideal size, uneaten food pellets in aquaculture settings (waste feed) represents a financial loss and also contributes significantly to water quality degradation (De Silva and Anderson, 1995). Therefore, the optimal feeding strategies of ideal pellet size will also plays a role in maximising feed consumption at minimal waste, i.e. appropriate ration size is another important consideration when developing an optimal feeding regime for aquaculture animals.

Feeding management affect feeding behavior

An understanding of feeding behavior, which may vary with the developmental stage (size) of the cultured animals, is a prime factor in improving feed management in intensive aquaculture systems. Unlike land animals, excess food pellets cannot be retrieved from the water used to culture aquatic animals and therefore, the manner in which food is distributed to any aquaculture system can dramatically influence the performance of a given feed formulation. However, scientific feeding strategies have remained practically unchanged since the 1980's and have been adopted by farmers with a believe that more frequent feeding leads to a faster growth of cultured animals and better food conversion efficiency (Carvalho and Nunes, 2006). This strategy is derived from assumption that aquatic animals in the wild eat continuously. This perception misled most researches and farmers because the high quality and consistency of formulated feed compared to natural feed, eliminates the need for repeated feeding. Furthermore, feeding more often in a highly intensive culture system becomes labour-intensive and may require installation of expensive automatic feeders. Conversely, feeding less often may result in less growth and this can also represent an economic loss. Therefore, since feeding strategies are species-specific (Hossain *et al*., 2001), farmers need to understand feeding behavior of the cultured animal to obtain a balance between rapid fish growth and optimum use of the supplied feed.

Conclusion

Scarcity of information on both formulated feed and feed management in intensive aquaculture has contributed to the slow pace at which aquaculture is advancing in Africa. Both feed formulation and feeding management are expected to play a central role in sustaining the development of intensive aquaculture on the continent. Feed cannot be retrieved from the water of aquaculture systems so the potential ways to reduce production costs include development of pellets with optimal water stability, and ideal size (which may vary with the developmental stage of the culture animal), which is provided to the animals at optimal feeding intervals based on knowledge of the feeding behavior and developmental stage of the particular cultured animal. Both feed formulation and feeding management are not mutually exclusive particularly when a balance between maximum growth, high production and reduced labour costs is an objective. Therefore, aquaculture farmers need training and close interaction with researchers on both feed formulation and feeding management in intensive aquaculture in order to improve and sustain aquaculture production in Africa. The findings of this study will be used to sustain intensive aquaculture in Africa.

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