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Aquatic animal nutrition and feeding for sustainable aquaculture production

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Abstract

Over the last decade, the world has witnessed spectacular growth in the aquaculture industries of many developing countries. It is unequivocally agreed that global aquaculture production will continue to increase, and much of this will occur in the developing countries of Asia and Africa, through the expansion of semi-intensive, small-scale pond aquaculture. Nutrition and feeding play a central and essential role in the sustained development of aquaculture and, therefore, feed resource continues to dominate aquaculture needs. This paper reviews a number of specific issues in the fields of aquatic animal nutrition and feeding which are critical for sustainable aquaculture production in both industrialized and developing countries. While discussing the nutrient requirement of fish under farming conditions, the possibility of accessing existing databases on nutrient requirements is examined, along with their application for establishing general nutritional principles. Particular emphasis is placed on understanding the contribution of naturally available food in semi-intensive aquaculture and its role on the development of on-farm feed management strategy.

Keywords: Aquaculture. Feed, Nutrition, Amino acids, Macronutrients.

Introduction

Aquaculture was known in Roman Empire and China 2000 years ago as ancient farming practice (Balon 1995; Dunham et al., 2000). However, in last few decades and since 1980s aquaculture industry has grown and developed dramatically into worldwide activity producing a huge quantity for the market. On the other hand, marine capture fisheries reach the plateau or decrease and the population of the world is increasing) (Dunham 2004). The estimated number of finfish throughout the world is about 28500 species inhabiting oceans, estuaries, rivers, streams, lakes and ponds and about 40% of these fish are freshwater species and particularly existing in the subtropical and tropical regions (Huntingford et al., 2012). The main criterion that determines the appropriateness of certain species for aquaculture is the growth rate and production under rearing conditions (Pillay et al., 2005). Thus, in fish farming (aquaculture), nutrition is critical because feed typically represents approximately 50 percent of the variable production cost. Fish nutrition has advanced dramatically in recent years with the development of new, balanced commercial diets that promote optimal fish growth and health. In aquaculture, like in all animal production operations, the parameters involved in nutrition management must be evaluated in order to strike a balance between commercial, environmental, and quality considerations (FAO 2020). This industry seeks to deliver social and economic advantages while also producing a very fresh food supply (Tadese et al., 2021). It is critical to underline that the growth of aquaculture activities is inextricably linked to fish nutrition, which has a direct impact on product quality. In this context, aquaculture necessitates nutrition optimization in order to properly develop fish for the aim of generating high-quality meals(Hasan 2001). The use of artificial feeds in aquaculture, on the other hand, is dependent on an understanding of fish feeding behavior and nutritional requirements. The objective is to supply high-quality nutrients. The purpose is to provide fish with high-quality nutrients in a physically acceptable condition.

1.1 Nutritional requirements of fish in aquaculture

Fish diets must contain all of the essential nutrients and energy required to support the physiological demands of growing fish. Amino acids, fatty acids, vitamins, minerals, and energy macronutrients are all essential elements for fish (proteins, fats, and carbohydrates). Protein is required in the diet to get amino acids, which are then utilized to build new proteins or sustain existing proteins in tissues, with surplus protein being turned into energy. In the diet, lipids offer necessary fatty acids as well as energy. In fish, lipids are crucial structural components of membranes and serve as precursors of steroid hormones and prostaglandins. Furthermore, lipids influence the quantity of unsaturated fatty acids in fish., but their ability to use dietary carbohydrates for energy varies depending on the species and their natural diet. Carbohydrates may provide energy to fish, although their capacity to do so varies depending on the species and their natural diet. Vitamins are chemical molecules that are essential for fish survival, growth, and development. The fish are unable to produce the vitamins required by their diet. Minerals are classified into two types based on demand: microminerals and microminerals. They are crucial in the formation of functional groups of enzymes and hormones, as well as in the control of protein production.

1.2 Digestibility of nutrients

Nutrient digestibility in the diet can affect aquaculture, production efficiency and environmental impact. The bioavailability or digestibility of the diet is the proportion of nutrients in the food that is digested and absorbed by the fish. Data on digestibility and available digestible energy of food ingredients in fish diets are essential for optimizing food formulations. Poorly digested foods lead to limited growth and high nutrient excreta, which pollute the environment. Therefore, nutrient digestibility and nutrient and waste retention potential must be considered for efficient and sustainable animal production when reviewing food formulations. Fish have the ability to use lipids for energy, saving protein for deposition and growth, so the inclusion of lipids in diets for fish is important for both growth and energy. Most commercial foods today are formulated to increase growth performance by exploiting the effect of protein savings by high-energy lipids, allowing most of the dietary protein to turn into flesh.

2. Fish nutrition, feeds, and health

Fish require organic and inorganic compounds which are represented by macro and micronutrients for their energy, maintain, growth, reproduction, immunity and so on; the macronutrients comprised proteins, carbohydrates and lipids meanwhile the micronutrients encompass vitamins, minerals, attractants etc. Some metabolic processes and growth depend on fish obtaining adequate supplies of certain indispensable nutrients that cannot be synthesized de novo and must be acquired from the diet. If the diet lacks or has deficient amounts of, one or more of the indispensable nutrients, the fish will exhibit some symptoms. Such some of them may include reduced FI and growth, metabolic disorders, irregular development, body color and the display of unusual behavior [4].

2.1 The function of dietary macronutrients in fish nutrition

The main component in fish feed is the protein because it offers the indispensable and dispensable (AA) to synthesize body protein and in part delivers energy for maintenance (Gan et al., 2012). Besides, of important and the most expensive constituent of diets for cultured species, proteins are the building material for the fish growth and perform a vast variety of biological functions playing a key role in virtually all the biological process in the body (Cyrino2008). In addition, they are important for the gene expressions regulation, enzymes, and hormones (Steffens 1988)[11]. Carbohydrates also are a main organic component of animals and presented in the fish body in small quantities. This class of macronutrient involves sugars (glucose) and their polymers (glycogen). Fish can synthesize carbohydrates from AA and fatty acids (FA), so they are not essential nutrients (Huntingford et al., 2012).

Lipids can separate into polar lipids (phospholipids) which are played structural roles and neutral lipids responsible for energy storage (triacylglycerol forms) and esters. Likewise, all fatty acids FA play the roles mentioned above, meanwhile, some specific ones have important roles in the regulation and control of metabolism, and sufficient lipid/FA should be satisfied gross energy and specific requirements for critical functional essential FA, sterol and phospholipids (Lee 2015).

3. Extruded feed

The extrusion processing is a combination of moisture, mechanical shear, pressure, and temperature, it has been used for almost a century in the food industry and its consequences in chemical and physical changes, such as the reduction of the size of ingredient particle, gelatinization of starch and enzymes inactivation (Cheng et al., 2003). This technique of feed production usually improves the plant proteins digestibility (Srihara P, Alexander J 1984). However, the extruded feed costs 10 to 15% more compared to conventional pelleted feeds (Nates 1984). Studies carried out to investigate the effect of extruded feed in the diets showed that the extrusion might diminish the contents of anti-nutritional factor such as lectin, cyanogenic glycosides and the inhibitors (trypsin, protease, and inhibitors) (Adamidou et al., 2009; Barrows 2007; Francis 2001; Drew 2007), and enhance the protein utilization(Gaylord2008).

4. Amino acids

All proteins contain groupings of the same set of 20 AA, most of which have little or no inherent biological activity in their free form. Of the 20 amino acids found in proteins, (in some species), 10 are not synthesized by animals and so must be acquired via the diet (Huntingford et al., 2012).

4.1 Utilization of amino acids

The AA utilization can be affected by several factors, such as the chemical structure of the AA, biological factors and diet composition (NRC 2011). The availability of AA and especially when it provides jointly with carbohydrate regulates and gives a greater increase in the synthesis of proteins (Bender 2012). The fish feeding behaviors are categorized mainly by alerting, appetitive and consummatory phase, the latter phase consisting food intake and either rejection or ingestion and the AA are efficient stimulants for each of these phases (Houlihan 2001). The main substances can be produced after catabolism processes of amino acids by animals are rather simple organic compounds such as nitrate, nitrite, urea, uric acid, ammonium salts and purines) and the excess of AA during the fed state for proteins synthesis requirements are not stored but are catabolized (Lovell 1989). The deamination of the most amino acids takes place in the liver and their carbon skeletons are used for ketogenesis and gluconeogenesis or to meet the energy requirements of the liver, meanwhile the branched chain of some other AA is mainly transaminated in skeletal muscle and The AA oxidation is determined by habitual protein intake and slightly changed with intake alteration (Bender 2012).

4.2 The function of amino acids

Besides the main function as a required component for the polypeptides and other nitrogenous substances synthesis, they have five essential roles in the regulation and nutrition of the animals; these major roles can be played in the cell signaling, antioxidative defense, chemical sensing, epigenetic regulation and transcription and protein modifications, in addition, these nutrients play other roles in the growth, development, survival, disease prevention, and some disorders treatment (digestive, muscular, reproductive and cardiovascular systems) (Wu G 2013). Likewise, organisms can synthesize from amino acids important biologic products such as feathers, scales, antibodies, enzymes, and hormones (Lee 2015). Fafournoux, Bruhat(2000) stated that the amino acids could play clearly, jointly with hormones, a key role in the control and modification of gene expressions at the levels of transcription and stability of mRNA. They are essential for fish as energy substrates, for and metabolic pathways regulation (Andersen et al., 2016). In the following figure (Fig 1-1), Wu (2009) summarized the possible roles of amino acids.

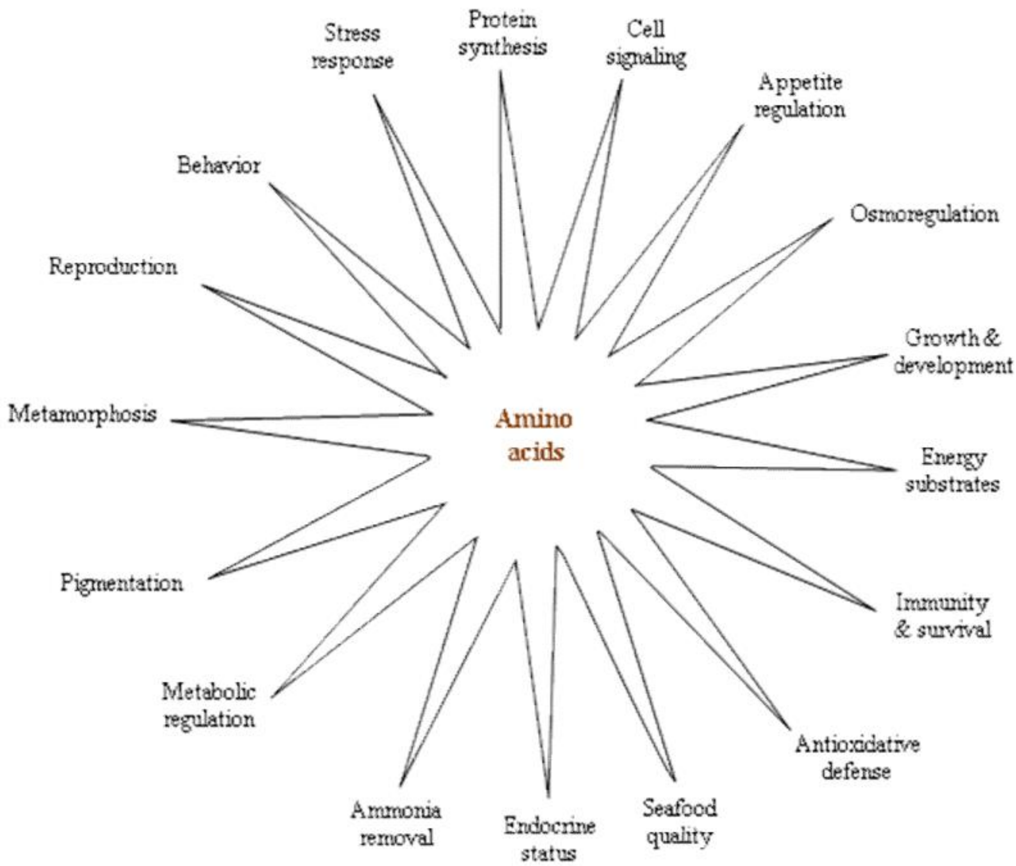

Fig. 1-1 AA functions in growth, development, and health of fish, adopted from adopted from Li, Mai (2008).

4.3 Essential amino acids (EAA) requirement of fish

The studies carried out to grasp the requirement estimation of fish on 10 indispensable amino acids revealed varied significant findings because of the experimental design, scope and methodological approaches used, whether for freshwater species such as tilapia, common carp, channel catfish, salmon, Indian major carp, rainbow trout and so on or marine species such as, sea bream, sea bass, flounder, turbot and others(NRC 2011). Cowey (1994) stated that the important particular factor in the studies of amino acids requirement. The maintenance requirements estimated by "A nonlinear mixed modeling approach" for the majority of EAA represent a small proportion of global requirements (less than 10%) with significant exceptions for phenylalanine and histidine and cannot be assumed equal for all AA (Acton 2013).

4.4 Limiting amino acids

Limiting AA of proteins are EAA present in the low amount compared to the requirement for protein total utilization for tissue protein synthesis. In general, legumes and animal proteins are limited by their content of methionine and cysteine, while the cereal proteins are limited by their content of lysine (Bender 2012). EAA synthesized from aspartate and required in non-ruminant animal diets are lysine, methionine, and threonine and the major crops such as soybean, corn, and rice are low in at least one of this three AA (Singh 1999).

The requirement of fish for lysine is ranging from 40-50 g/kg dietary protein of most fish species, for the methionine the value is ranging from 20 to 30 g/kg dietary protein and for threonine in the range of 20-50 g/kg dietary protein, and it's difficult to offer any explanation of the lack of agreement on these requirement values (D'Mello 2003).

4.5 Efficiency of dietary crystalline amino acids (CAA) utilization

The addition of CAA in the diets are directly absorbed by the small intestine; and the findings of some studies have been carried out with human and animals such as pigs, chicken and rats indicated that the CAA acids have high nutritional values when they are supplemented to deficient diet on those amino acids, on the other hand, the supplementation of the latter with the appropriate amount is safe for the animal in general (Wu G 2013). The CAA utilization in the aquafeed becomes more and more important because of the cost of the latter which is reduced with biotechnology progress and the huge production and availability and secondly, they can meet the requirement of EAA profiles when they added to others proteins sources in the diets for fish and shrimp in the case of fishmeal substitution (NRC 2011).

Nutrition and health

Several research studies have been conducted to determine the nutritional requirements of fish and shellfish (Elfina Azwar et al., 2022; C. Silva et al., 2012; Nina et al., 2014). Another area of study in aquaculture nutrition that has garnered substantial interest is the use of plant and animal by-products as fishmeal alternatives in fish feed (Kathryn et al., 2004). Unfortunately, the primary focus of these research was on improving growth, feed efficiency, and overall health.

Before adopting new immunostimulant techniques, there is a clear need to improve the stability of immunostimulants, micronutrients, and oral vaccines, particularly under subtropical and tropical conditions, as well as nutritional information related to the effective use of vaccines and/or chemotherapy.Additionally, boosting health via good diet would not only lessen the need for chemotherapy but would also assist in the avoidance of catastrophic disease outbreaks.

Toxic and antinutritional factors (blocking effective nutrient assimilation) found in plant ingredients, nutritional imbalances in formulated feed, adventitious toxic factors, toxic compounds formed during feed storage and processing, and other factors can all have a negative impact on the health of cultured species and increase susceptibility to disease. Although this information is documented, and adequate measures during feed formulation and processing can reduce the risk (Devresse et al., 1997), further study is needed to create better techniques to reduce such adverse consequences.

Conclusion

Many developing countries' aquaculture industries have expanded considerably in the recent decade. Aquaculture has so made significant contributions to food security and poverty alleviation. Global aquaculture production is predicted to increase further, adding to these demands. Feed supplies continue to dominate aquaculture needs since nutrition and feeding are so crucial to successful aquaculture. Much of the increased aquaculture production in Asia and Africa will very definitely be achieved through the expansion of semi-intensive, small-scale pond culture; hence, feed resource availability and cost may be significant restrictions for such development. In the near future, fish meal will remain the primary component in intensive aquaculture of marine carnivorous species, although there may be potential for limited use of animal by-products as alternate protein sources. As intensive aquaculture increases, aquaculturists must carefully analyze the impact of nutrient loading on the aquatic environment and use both science and judgment to prevent such issues. Furthermore, a careful balance should be maintained between the environment, health/disease resistance, and feed usage so that the system does not decline, lowering market value and customer confidence.

References

Acton QA. Amino Acids—Advances in Research and Application: 2013 Edition:Scholarly Editions; 2013.

Adamidou S, Nengas I, Henry M, Grigorakis K, Rigos G, Nikolopoulou D, et al. Growth, feed utilization, health and organoleptic characteristics of European seabass (*Dicentrarchus labrax*) fed extruded diets including low and high levels of three different legumes [J]. Aquaculture, 2009, 293(3-4):263-71.

Andersen S, Waagbø R, Espe M. Functional amino acids in fish nutrition, health and welfare [J]. Frontiers in bioscience (Elite edition), 2016,8:143-69.

Balon EK. Origin and domestication of the wild carp, *Cyprinus carpio*: from Roman gourmets to the swimming flowers [J]. Aquaculture, 1995, 129(1-4):3-48.

Barrows FT, Stone DA, Hardy RW. The effects of extrusion conditions on the nutritional value of soybean meal for rainbow trout (*Oncorhynchus mykiss*) [J]. Aquaculture, 2007,265(1-4):244-52.

Bender DA. Amino acid metabolism: John Wiley & Sons; 2012.

C. Silva, E. Yáñez, M.L. Martín-Díaz, T.A. DelValls,assessing a bioremediation strategy in a shallow coastal system affected by a fish farm culture – Application of GIS and shellfish dynamic models in the Rio San Pedro, SW Spain,Marine Pollution Bulletin,Volume 64, Issue 4,2012,Pages 751-765,ISSN 0025-326X,

Cheng ZJ, Hardy RW. Effects of extrusion processing of feed ingredients on apparent digestibility coefficients of nutrients for rainbow trout (*Oncorhynchus mykiss*) [J]. Aquaculture nutrition, 2003,9(2):77-83.

Cowey C. Amino acid requirements of fish: a critical appraisal of present values [J]. Aquaculture, 1994,124(1-4):1-11.

Cyrino JEP. Feeding and digestive functions in fishes: CRC Press; 2008.

Drew M, Borgeson T, Thiessen D. A review of processing of feed ingredients to enhance diet digestibility in finfish [J]. Animal Feed Science and Technology, 2007,138(2):118-36.

Dunham RA, Majumdar K, Hallerman E, Bartley D, Mair G, Hulata G, et al. Review of the status of aquaculture genetics. Aquaculture in the Third Millennium Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand2000. 137-66.

Dunham RA. Aquaculture and Fisheries Biotechnology: Genetic Approaches: CABI Pub.; 2004.

Elfina Azwar, Wan Adibah Wan Mahari, Hajar Rastegari, Meisam Tabatabaei, Wanxi Peng, Yiu Fai Tsang, Young-Kwon Park, Wei-Hsin Chen, Su Shiung Lam,Progress in thermochemical conversion of aquatic weeds in shellfish aquaculture for biofuel generation: Technical and economic perspectives,Bioresource Technology,Volume 344, Part A,2022,126202,ISSN 0960-8524,

Fafournoux P, Bruhat A, Jousse C. Amino acid regulation of gene expression [J]. Biochemical Journal, 2000,351(Pt 1):1.

Francis G, Makkar HP, Becker K. Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish [J]. Aquaculture, 2001,199(3-4):197-227.

Gan L, Liu YJ, Tian LX, Yang HJ, Yue YR, Chen YJ, et al. Effect of dietary protein reduction with lysine and methionnine supplementation on growth performance, body composition and total ammonia nitrogen excretion of juvenile grass carp,*Ctenopharyngodon idella* [J]. Aquaculture Nutrition, 2012,18(6):589-98.

Gaylord TG, Barrows FT, Rawles SD. Apparent digestibility of gross nutrients from feedstuffs in extruded feeds for rainbow trout, Oncorhynchus mykiss [J]. Journal of the World Aquaculture Society, 2008,39(6):827-34.

Hasan, M.R. 2001. Nutrition and feeding for sustainable aquaculture development in the third millennium. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery& J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 193-219. NACA, Bangkok and FAO, Rome.

Houlihan DF, Boujard T, Jobling M, Wiley I. Food intake in fish. 2001.

Huntingford F, Jobling M, Kadri S. Aquaculture and behavior: John Wiley & Sons; 2012.

Kathryn R Mahaffey,Fish and shellfish as dietary sources of methylmercury and the ω-3 fatty acids, eicosahexaenoic acid and docosahexaenoic acid: risks and benefits,Environmental Research,Volume 95, Issue 3,2004,Pages 414-428,ISSN 0013-9351,

Lee C-S. Dietary nutrients, additives and fish health: John Wiley & Sons; 2015.

Li P, Mai K, Trushenski J, Wu G. New developments in fish amino acid nutrition: towards functional and environmentally oriented aquafeeds [J]. Amino Acids, 2008,37(1):43-53.

Lovell T. Nutrition and feeding of fish: Springer; 1989.

Nates SF. Aquafeed formulation. 2016.

Nina Bilandžić, Marija Sedak, Maja Đokić, Ivana Varenina, Božica SolomunKolanović, Đurđica Božić, Mate Brstilo, Branimir Šimić,Determination of zinc concentrations in foods of animal origin, fish and shellfish from Croatia and assessment of their contribution to dietary intake,Journal of Food Composition and Analysis,Volume 35, Issue 2,2014,Pages 61-66,ISSN 0889-1575,

NRC. Nutrient requirements of fish and shrimp: National academies press; 2011.

Pillay TVR, Kutty MN. Aquaculture: principles and practices. 2005.

Singh BK. Plant amino acids: biochemistry and biotechnology: CRC Press; 1999.

Srihara P, Alexander J. Effect of heat treatment on nutritive quality of plant protein blends [J]. Canadian institute of food science and technology Journal, 1984,17(4):237-41.

Steffens W. Utilization and suitability of methanol grown bacteria biomass for raising rainbow trout (Salmo gairdneri) [J]. ArchivfuerTierernaehrung (German DR), 1988.

Wu G. Amino acids: biochemistry and nutrition: CRC Press; 2013.

Wu G. Amino acids: metabolism, functions, and nutrition [J]. Amino Acids, 2009,37(1):1-17.

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