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Editorial

An overview of feeding strategies and challenges in tropical aquaculture

Estrategias de alimentación y retos de la acuicultura tropical

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Abstract
Feeding accounts for more than 50% of the operating costs of commercial tropical aquaculture species such as tilapia and shrimp, while costs are difficult to estimate for emerging species, such as snooks and native cichlids, which are still under biotechnological development. Optimizing diets and feeding practices is essential to ensure the profitability and sustainability of the growing aquaculture industry. Specialized diets for critical stages such as reproduction and larval rearing are costly but justified by improved offspring quality and larval growth. However, the lack of specific feeds for emerging species forces the use of generic diets, such as those developed for tilapia or trout, which may not meet optimal nutritional requirements. This approach limits the productive evaluation of these species and, in the long term, the development of specific diets for commercialization. Dietary improvements include new ingredients and technological processes that increase efficiency, reduce costs, and minimize environmental impact. For example, the inclusion of animal meals has improved the acceptability of diets for carnivorous species. However, the design of feeding protocols remains challenging, particularly for larvae where live feed is common but costly. Genetics and environmental management are determining factors in the production performance of commercial species. In Mexico, the limited genetic acclimatization of imported tilapia has led to challenges such as diseases and stress episodes that affect growth and discourage investment. Integrating biotechnologies such as probiotics and prebiotics has shown benefits in the integrated management of the culture, reducing stress, improving feed efficiency, and reducing environmental impact. It is necessary to emphasize the generation of informed strategies that consider local resources and global information to minimize environmental and social risks and promote responsible and sustainable aquaculture that balances economic, social, and environmental benefits.
Keywords: Aquaculture feed, emerging species, sustainability, biotechnologies, integrated crop management.

Resumen: La alimentación representa más del 50% de los costos operativos en especies comerciales de acuacultura tropical como tilapia y camarón, mientras que, en especies emergentes como el robalo y las mojarras, aún en desarrollo biotecnológico, los costos son difíciles de estimar. Es crucial optimizar dietas y prácticas alimenticias para garantizar la rentabilidad y sostenibilidad de la industria acuícola en crecimiento. El uso de alimentos especializados para etapas críticas, como la reproducción y la cría de larvas, implica costos elevados, pero se justifica por la mejora en la calidad de la progenie y el crecimiento de larvas. Sin embargo, la falta de alimentos específicos para especies emergentes obliga a usar dietas genéricas, como las diseñadas para tilapia o trucha, que pueden no satisfacer las necesidades nutricionales óptimas. Este enfoque limita la evaluación productiva de estas especies y, a largo plazo, el desarrollo de dietas específicas para su comercialización. Las mejoras en las dietas incluyen nuevos ingredientes y procesos tecnológicos que buscan aumentar la eficiencia, reducir costos y minimizar el impacto ambiental. Por ejemplo, la inclusión de harinas de origen animal ha mejorado la aceptación de dietas para especies carnívoras. Sin embargo, el diseño de protocolos alimenticios sigue siendo un reto, particularmente para larvas, donde el uso de alimento vivo es común pero costoso. La genética y el manejo ambiental son factores determinantes en el rendimiento productivo de especies comerciales. En México, la limitada aclimatación genética de la tilapia importada ha generado desafíos, como episodios de enfermedades y estrés, que afectan el crecimiento y desincentivan la inversión. La integración de biotecnologías como probióticos y prebióticos ha demostrado beneficios en el manejo integral del cultivo, reduciendo el estrés, mejorando la eficiencia alimenticia y disminuyendo el impacto ambiental. Es necesario destacar la generación de estrategias informadas que consideren tanto recursos locales como información global para minimizar riesgos ambientales y sociales, promoviendo una acuicultura responsable y sostenible que equilibre beneficios económicos, sociales y ecológicos.
Palabras clave: Alimentación en acuacultura, especies emergentes, sostenibilidad, biotecnologías, manejo integral de cultivos.

Editorial

The economic impact of feed use at all stages of production on aquaculture investment is well known. Feed costs are estimated to represent more than 50% of operational production costs for commercial species in the tropics, such as tilapia and shrimp. In contrast, for emerging species, such as snooks and cichlids native to southern Mexico, there are still gaps in biotechnological development, making it difficult to estimate precisely. However, developing efficient diets and feeding practices is of great value in maintaining the profitability of the culture and the interest in entrepreneurship in the face of a growing and competitive aquaculture industry (Montoya-Camacho *et al.* 2016).

The parameters and scope of aquaculture production units are determined by the species' biological characteristics and the environmental conditions created for the culture. In farms dedicated to reproduction and seed production, the use of special feeds for broodstock and larvae generally includes the use of live, fresh feeds of high nutritional quality, which can be expensive but whose use is justified to improve the quality of spawning, survival and growth of larvae. On the other hand, the aim is to achieve sufficient nutritional quality to meet the needs of the target species at a reasonable cost that maximizes profitability. The incorporation of new ingredients, processing forms, and complementary products to improve feed utilization and reduce wastage has been explored to meet these premises. Therefore, research into the variables that control the efficiency of diets in species and the development of technologies to make processing processes more efficient and reduce the environmental impact of their waste are current and key issues for the advancement of aquaculture.

Introducing species into commercial aquaculture has created new challenges; it is difficult to determine how many species are being researched for aquaculture for food, ornamental, or raw material production (Fotedar *et al.* 2011). Given the importance of studying digestive physiology, nutritional inputs, and other issues due to their impact on the economics of farming, the transition from research to commercial practice of a species can be a slow and bumpy road. Much information has been generated on nutritional requirements, digestive physiology, and practical diets, but the commercial application of species-specific diets has not yet progressed for several reasons. The most important of these relate to the feed companies' economics, the globalization of trade, and the profitability of a new diet. It is necessary to start from a base production volume defined by the machinery capacity of the production plants, the frequency of consumption, and, therefore, the fact that the diet already has customers who demand the product in order to make it attractive to the manufacturer through a secure purchase. However, although some research centers may be able to produce a certain volume of products, more is needed and is costly.

The lack of specific diets for species with known nutritional requirements and those under research has meant that the first approach to growth trials has to be with diets designed for other species, which means there is no certainty that the production performance will be acceptable on the way to incorporation into a commercial crop. One of the advantages of globalization and the availability of a wide

range of balanced diets is the ability to conduct trials with diets designed for neighboring species or species with similar feeding habits. In this regard, we can point to the case of *Atractosteus tropicus*, a species whose requirements at different stages of development are known but whose diets are not commercially available (Márquez-Couturier *et al.* 2006). This is due to a very limited regional market; most production takes place on small family farms, and feed demand is low. Currently, culture is based on commercial diets for tilapia, from hatchery production to grow-out. A few decades ago, only commercial diets for carnivorous fish such as trout were used at the beginning of the culture. The high cost of this feed had a major impact on the production price and the final product. It was the only option then due to the lack of acceptance of tilapia feed since the high soy content made it unpalatable to this carnivorous fish. However, in recent years, new technological processes and the use of ingredients such as poultry, beef, and pork meal, which are profitable in producing tilapia feed on a global scale, have provided an alternative that allows its use in *A. tropicus* culture.

Current diets' versatility and cost attractiveness allow a first approach towards productive evaluation of emerging and regional species but do not solve the underlying problem of lack of knowledge of diet design and the possibility of full feasibility evaluation as candidates for commercial culture. On the other hand, the development of feeding protocols in the case of fish larvae represents a challenge where the problems of availability of balanced diets and aspects of the behavior of the specimens converge, which generally requires the use of live food, the availability and cost of which can hinder the activity.

For commercial aquaculture species such as tilapia, where a wide variety of commercial feed brands are available and have been derived from extensive commercially useful research, questions about the diets used and the productive performance of the cultures are common. In many cases, poor performance may be due to other variables, such as the genetic composition of the seed and acclimatization to the location. The number of adequately acclimatized strains is still limited in Mexico, where tilapia arrived in the 1960s but where tilapia culture has not been intensively developed for a long time. The importation of foreign broodstock has long not produced the expected results and may also be the origin of disease outbreaks that have affected the industry. It appears that the differences in results are largely due to a combination of factors where the environmental conditions of the culture affect the utilization and use of dietary energy. Highly selected genetic variants for growth, evaluated with non-locally available diets and different management conditions, can create stressful situations that lead to disease development and changes in growth performance, leading to disappointment for investors. Therefore, in the industry's future, decision-makers must consider such variables in strategic investment plans to make investments safe and profitable.

Biotechnologies, such as the incorporation of probiotics and prebiotics, are increasingly in demand to understand processes that benefit crops (Hai 2015). These strategies are combined with improved nutrient utilization, inhibition of competitive diseases, stress reduction, and efficient handling of waste and effluents, to name a few. Ultimately, this practice leads to integrated management of the farming system from an ecosystem perspective,

where the interaction of its elements improves production outcomes by positively affecting the welfare of the farmed organisms. This also positively impacts the environment by reducing pollution and disease risk to the farmed species and non-target species in the surrounding areas. The understanding of ecosystem management of larval cultures, where the use of balanced diets is complemented by the management of other environmental elements such as the presence of algae and food such as protozoa and rotifers, has gained momentum as it provides a less stressful growth environment for the larvae (Kittaka, 1997). Such management may require the study of native food species in the ecosystem where the species of interest develop, adding a degree of complexity but with a greater chance of success.

Faced with these current and future challenges for aquaculture feeds, the organizations and people involved need to take greater responsibility in decision-making. These choices must be based on globally available information. However, they must also encourage the generation of knowledge about local resources and the feasibility of their use, thereby reducing environmental and social risks. A more responsible aquaculture will only be achieved by adopting strategies that inform producers and government officials in their decisions so that the impact of the activity is positive in economic, environmental, and social terms.

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