https://doi.org/10.32854/agrop.v14i1.1800

Protein Inputs of Animal Origin Used in the Substitution of Fish Meal in Aquaculture Feed

Godínez-Siordia, Daniel Enrique[1*]; Lorente-Adame, Rogelia Guillermina[2]; Ornelas-Luna, Ricardo[1]; Bernal-Ornelas, Iván Hummel[3]; Hinojosa-Larios, José Ángel[1]

[1]Universidad de Guadalajara, Departamento de Estudios para el Desarrollo Sustentable de Zona Costera; [2]Universidad de Guadalajara, Departamento de Ecología y Recursos Naturales [3]Junta Intermunicipal de Medio Ambiente para la Gestión Integral de la Región Norte (JINOR).

***Corresponding Author**: daniel.gsiordia@academicos.udg.mx

ABSTRACT

Objective: To highlight some studies carried out with alternative protein sources from byproducts of animal origin to replace fish meal (FM) in the nutrition of aquaculture species.

Design/Methodology/Approach: A search for new protein sources of animal origin was carried out and experimentally evaluated with species of aquaculture interest, employing an information search methodology through the analysis of metadata kept in databases throughout the World Wide Web.

Results: Advantages and disadvantages of including byproduct flours of animal origin in the diet of aquatic organisms are pointed out. However, for worldwide aquaculture it is essential to emphasize that this protein exchange should not affect aquatic ecosystems but rather mitigate the effects of environmental impacts and promote the sustainability of aquaculture.

Study Limitations/Implications: The results of incorporating flours of animal origin in substitution of FM in the diets of aquaculture species are experimentally indicated, while specifying that there are no reports indicating the transcendence of such substitution in commercially balanced meals.

Findings/conclusions: Each of the dietary alternatives described here works at certain nutritional levels, decreases costs and increases the digestibility index, allowing for better water quality by disposing less nitrogen into the aquatic environment, without sacrificing the quality of the diets or the energy content of the final products.

Key words: aquaculture, proteins, diets, byproducts.

INTRODUCTION

There is environmental legislation in Mexico for sustainable development in the agriculture, livestock, aquaculture, and fishing sector which aims at moving towards good production practices. A strategy to achieve this is to generate exploitation of natural resources by promoting a culture of transformation and reutilization of byproducts from industries of the primary sector that can be used as protein substitutes in diets formulated for aquatic species, on the premise of being as efficient as commercial diets, in addition to showing

Agroproductividad: *Vol. 14, Núm. 1, enero. 2021. pp: 89-93.*
Recibido: *agosto, 2020.* **Aceptado:** *diciembre, 2020.*

a reduction in production costs (Aurrekoetxea and Perera, 2002). In this research, several studies with alternative protein sources are analyzed, based on byproducts of animal origin used to replace fish meal (FM) for the nutrition of aquaculture species, thus revealing the potential for their implementation and ecological benefits.

MATERIALS AND METHODS

A meta-analysis was carried out relying upon databases in the World Wide Web through Information Sciences (IS), Information and Communication Technologies (ICT), in addition to library resources and Open Educational Resources (OER) (Michán, 2011). A structured and systematic integration of the information about the topic was conducted through consultation of articles in scientific journals and libraries, carrying out the retrieval, translation, meta-analysis, interpretation, and drafting of the material (Tinto, 2009; Michán, 2011).

RESULTS AND DISCUSSION

Byproducts of animal origin can offer a wide range of raw materials that exist anywhere in the world and which, after aminogram and toxicity tests, can be included in the formulation of balanced meals for almost any aquaculture species. Some of these inputs are mentioned next:

Shrimp Head Flour (SHF)

Shrimp heads are discarded in shrimp farming at processing plants; this byproduct has an amino acid profile similar to that of soybean flour (*Glycine max* L.) and FM (Espinosa *et al.*, 2015), with an average raw protein value of 50.72% (Belandria and Morillo, 2013), in addition to being a source of unsaturated fatty acids, minerals and carotenoids (Benitez, 2018). There are published studies about the physicochemical evaluation of oil obtained from shrimp heads where high concentrations of fatty acids were discovered, such as linoleic (C_{18}:2n_6), oleic (C_{18}:1n_9), and palmitic (C_{16}:0) acids, besides eicosapentaenoic (C_{20}:5n_3, EPA) and docosahexaenoic (C_{22}:6n_3, DHA) acids, with a mean astaxanthin content of 2.72 mg g^{-1}, which is a powerful antioxidant and nutraceutical agent (Núñez *et al.*, 2011; Navarro *et al.*, 2020). SHF also contains chemical-attractant molecules, thus allowing high palatability and being attractive for the consumer organism, managing to diminish FM from 5% and up to 30% when included in artificial food. This highlights that enriching a diet for shrimps with byproducts of the same shrimp industry allows for the improvement of the farm's efficiency, reaching greater survival and growth compared to the traditional ones (Benitez, 2018; Barbarito *et al.*, 2009; Pelegrin, 2013). Espinosa *et al.*, (2015) agrees that protein substitution of FM with SHF in the inclusion of feed for young totoaba (*Totoaba macdonaldi*) significantly improves the feed's digestibility with substitution levels of 30%.

Mollusk Entrails

Studies have been carried out with giant squid flour (*Dosidicus gigas*), to feed young marine fishes, such as Gulf corvina (*Cynoscion othonopterus*), showing high efficiency from obtaining greater yields in final weight and survival than in fish fed with the FM control diet (Madrid, 2014). In another experiment, Toyes (2016) developed diets based on scallop (*Pinna rugosa*) and giant squid (*D. gigas*) entrails to feed Pacific white shrimp (*Litopenaeus vannamei*). Its results demonstrated higher survival rates, between 18% and 21%, than those of the control diet, in addition to reporting a higher weight gain (35% and 50%) than the control diet, leading to the conclusion that incorporating flour of marine byproducts from cooked mollusks in the feed for shrimp as a substitute for FM increases consumption and growth in shrimps, in addition to decreasing the dietary condition factor (DCF). However, caution must be taken when using this kind of marine byproducts, since Benitez (2018) discovered that incorporating filtering mollusks such as the Catarina scallop (*Argopecten ventricosus*) in diets formulated for longfin yellowtail (*Seriola rivoliana*) had negative effects because the flour contained a marine toxin identified as okadaic acid, which affected the health of farmed fish and caused mortality. This toxin is produced by marine dinoflagellates of the genus *Dinophysis* spp and *Prorocentrum* sp, which accumulate in bivalve mollusks as a result of filtration and ingestion of these dinoflagellates in the ocean. If human beings consume these bivalves, affectations can be severe, given that the resulting pathology is diarrheic shellfish poisoning (DSP) caused by phycotoxins (Hernández, 2017).

Biological Ensilage

Biological ensilage is an affordable option that employs minimal technological infrastructure in its production; it is widely and mainly used with fishery byproducts (Salah *et al.*, 2014). Fish processing produces between 50% and 60%

waste, the main ones being: head, backbone, fins, skin, and entrails, which are employed in the formulation of diets for several animal species (Calderón *et al*., 2017). Delgado (2018) obtained 40% protein when using ensilage flour from the soft residues of Peruvian calico scallop (*A. purpuratus*), an input added in the ratio of between 2% and 10% to the diet of *L. vannamei* shrimp, thus discovering that these diets improve the organism's survival and weight gain. Carrasco (2016) used ensilage made of giant squid (*Dosidicus gigas*) entrails, tentacles and skin, concluding that it can be used as an alternative protein source to FM in diets formulated for *L. vannamei*. Cota (2018) designed a nutritional formula with giant squid (*D. gigas*) ensilage combined with soybean paste, coconut (*Cocus nucifera* L.) flour, and *Lactobacillus fermentum*, managing to obtain a nutritional profile of 44% protein, a meal which was evaluated in a bioassay with *L. vannamei* using a biofloc system. This author's results recorded greater growth in farmed shrimp, with more weight gain (39%), specific growth rate higher than 2.93% per day, 81% survival, and lower feed conversion of 1.5, thus concluding that this diet has strong viability to be applied in commercial farming.

Protein Hydrolysates

Enzymatic hydrolysis of proteins is the oxidation of organic matter to enzymatic degradation of different sized peptides. This process increases protein levels in diets, which will greatly determine their nutritional characteristics and use (Benítez *et al*., 2008). The quality (source), origin (safety), and type of proteolytic enzymes are key factors in the production of protein hydrolysates (Li and Kittikun, 2010; Zapata and Castañeda, 2017). Inputs such as eggs, meat, blood, entrails, and cereals are the most commonly used, while yeast or casein hydrolysates are used as source of fermentation for the growth of microorganisms (Benítez *et al*., 2008). Cárdenas (2014) indicated that fish hydrolysates show better nutritional and functional properties than those of whole fish or fish protein concentrate (FPC), without showing drawbacks such as elevated costs of protein raw materials used in fish diets, as well as FM scarcity in the international market (López, 2014). Carranza *et al*. (2018) researched the inclusion of hydrolyzed protein extract from tissues of weakfishes (*Cynoscion* sp.) and tilapia (*Oreochromis* sp.) in balanced meal for shrimp, where there was a favorable growth of 11% (weakfish hydrolysate) and 24% (tilapia hydrolysate). The greatest attraction was observed in shrimp fed with the balanced meal plus tilapia hydrolysate, in addition to having shown a specific growth rate (SGR) of 2.0% and a registered survival rate of 68% (with tilapia hydrolysate) and 71% (with weakfish hydrolysate), compared to the 52% survival rate obtained with balanced feed with FM. This demonstrated the effectiveness of including fish hydrolysates given the contribution of essential amino acids supplemented in diets for shrimp.

Livestock Industry

In the livestock industry there are meat processing byproducts, such as: bones, horns, hooves, tendons, some pieces of offal, blood and its constituents, all of which have a high nutritional value given their high protein content, complete profile of essential amino acids, and functional properties for the food processing industry (Barragán, 2013). There are studies showing their adequate implementation in aquaculture nutrition (Moutinho *et al*., 2017), whether individually or combined with other nutritional sources, since they have amino acids such as: isoleucine, lysine, and methionine, which are paramount for the development of aquatic species (Márquez *et al*., 2005). In this sense, blood meals (BM) have a greater potential given their high protein concentration, often higher than 85%. However, they have disadvantages for aquatic diets, since Villarreal *et al*. (2014), through studies conducted on the digestibility in diets for young *L. vannamei* based on several meat processing byproducts, determined that BM is the ingredient with most solubility in its amino acids in marine water, and it also has lower apparent digestibility coefficient of amino acids (65.3%), compared to that of FM (76.4%). Nevertheless, this raw material should not be completely dismissed, since it can be employed complementarily to the traditional diet and reinforced with fish oil, which in addition to having a high content of essential fatty acids, n-3 HUFAs, also enriches the diet and can reduce its lixiviation in marine water, thus creating a protective film on the feed particle as a stabilizing emulsion if it is used in larval diets for fish, crustaceans, or bull-frog tadpoles.

Poultry Industry

The poultry industry wastes most of the parts of the birds that are sacrificed, such as: carcasses, bones, legs, feathers, heads, and offal. Even when these byproducts are processed as poultry meal (PM) for flavoring or broth, they are not largely used as inputs in commercial diets for aquaculture species. Campos *et al*. (2017) conducted a bioassay with feather flour in young European seabass (*Dicentrarchus labrax*), managing to replace FM up to 76% with PM in its diets, thus concluding that there were no differences in growth or in survival from the fish fed with the control diet. Within tilapia farming, fermented poultry byproducts have managed to substitute FM from 20% to 80%, due to their kinetic characteristics, such as an increased activity in lipases and proteases, and due to their greater bioavailability and digestibility, in addition to a greater immune response (Dawood *et al*., 2020; Samaddar, 2018). Successful substitutions of up to 80% from FM by PM have been carried out in young *Oreochromis niloticus* (Hernández *et al*., 2010); however, when only chicken offal is used the final lipid content in the nutritional profile has increased, although the growth of young tilapia is lower than with the control feed based on FM (Alofa and Abou, 2019). Therefore, the additional implementation of essential fatty acids as a complement to the diets from these byproducts in various fish species is discussed (Barreto *et al*., 2016). Fish meal is the most commonly used input in dietary formulas for aquaculture, given the quality of its proteins due to the amino acid balance and concentration, combined with its high digestibility (Madrid, 2014). Obtaining raw material for its production has an environmental impact, because of overfishing of wild populations of sardines, herrings, and other forage and accompanying species that naturally appear as primary links in the trophic chains of marine environments, added to rising prices due to its growing demand and high operational costs of fishing and industrialization (Cota, 2018; Carranza *et al*., 2018). Commercial balanced meals for several aquatic species that are 100% manufactured on the basis of alternative sources to fish meal are not currently available in the market, which is why it is considered as an emergent market with high profitability index and necessary for the sustainability of aquaculture in Mexico. It is clear that when using byproducts as protein means, the environmental impact of otherwise wasted raw materials is reduced, so it is very important to promote a circular economy or "waste-free economy" in order to make the best use of byproducts branded as waste for the creation of new products and implementations. Mexico needs entrepreneurs with projects that are solely devoted to collecting all the waste of various food processing industries and its reconversion into diverse reusable inputs, not just for the food industry, but which can also be applied in the generation of biodiesel, biopolymers, and organic nano particles with different uses in various industries.

CONCLUSION

Each one of the dietary alternatives described here functions at certain nutritional levels, decreases costs, and increases the digestibility index. This allows improving water quality by disposing less nitrogen into the aquatic environment, without sacrificing the quality of diets or the energy contents of the final products.

REFERENCES

Alofa, S. & Abou, Y. (2019). A comparison between chicken viscera and housefly maggot cultured from this by-products for nile tilapia diets: growth performance, feed utilization and whole body composition. Asian Journal of Fisheries and Aquatic Research. 5(3): 1-12.

Aurrekoetxea, G. & Perera, M. (2002). Aprovechamiento de recursos pesqueros infrautilizados para la obtención de alimentos mejorados de peces de acuicultura. Boletín. Instituto Español de Oceanografía. 18(1-4): 87-93.

Barbarito, J. J., Fraga, C.I., Galindo, L. J., & Álvarez, C.J. (2009). Effect of shrimp head meal inclusion level in *Litopenaeus schmitti* juveniles diet. Revista de Investigaciones Marinas. 30(1):71- 78.

Barragán A.P. (2013). Estudio del plasma sanguíneo bovino para fermentación sumergida y sistemas alimentarios. Tesis de Doctorado, Universidad de Caldas, Manizales. Colombia. 39 p.

Barreto, F., Parés, S.G., Correa, R.G., Durazo, B.E. & Viana, M. (2016). Total and partial fishmeal substitution by poultry by- product meal (petfood grade) and enrichment with acid fish silage in aquafeeds for juveniles of rainbow trout *Oncorhynchus mykiss*. Latin American Journal of Aquatic Research. 44(2): 327-335.

Belandria, J.C., & Morillo, N.J. (2013). Perfil de aminoácidos y contenido de pigmentos en las harinas de residuos de camarón. Zootecnia Trop. 31 (1): 24-34.

Benítez, R., Ibarz, A. & Pagan, J. (2008). Hidrolizados de proteína: procesos y aplicaciones. Acta Bioquímica Clínica Latinoamericana. 42(2): 227-236.

Benitez, H. A. (2018). Valor nutricional de subproductos de origen marino en alimentos para juveniles de jurel *Seriola rivoliana* (Valenciennes, 1833). Tesis Doctoral, Centro de Investigaciones Biológicas del Noroeste, S. C. La Paz, B.C.S. México. 153 p.

Calderón, Q.V.,Churacutipa, M. M., Salas, A.,Barriga, S.M. & Araníbar, M.J.(2017). Inclusión de ensilado de residuos de trucha en el alimento de cerdos y su efecto en el rendimiento productivo y sabor de la carne. Revista de Investigaciones Veterinarias del Perú. 28 (2): 265-274. http://dx.doi.org/10.15381/rivep.v28i2.13055

Campos, I., Matos, E., Marques, A. & Valente, L. (2017). Hydrolyzed feather meal as a partial fishmeal replacement in diets for European seabass (*Dicentrarchus labrax*) juveniles. Aquaculture. 476: 152-159.

Cárdenas, L.J.L. (2014). Hidrolizados de Proteína de Pescado. Material Educativo. Recuperado de: https://dipa.unison.mx/posgradoalimentos/docentes/jose_luis_cardenas/materialdeapoyo/16-HidrolizadosdeProteinadePescado2014.pdf

Carranza, O., Velásquez, A. & Rivas, F. (2018). Análisis de la proteína hidrolizada extraída del tejido de la curvina y la tilapia en el alimento del camarón. Revista Ciencia y Tecnología. (22) 23-36. https://doi.org/10.5377/rct.v0i22.6437

Carrasco, C.H. (2016). Efecto del ensilado biológico de residuos de Dosidicus gigas sobre el crecimiento y factor de conversión alimenticio de *Litopenaeus vannamei*. Tesis de Maestría en Ciencias, Universidad Nacional de Tumbes, Tumbes, Perú, 53 p.

Cota, C. (2018). Alimentos con ensilados de calamar, soya y coco en la pre engorda de juveniles de camarón blanco (*Litopenaeus vannamei*) en un cultivo hiperintensivo con biofloc. Tesis de maestría en ciencias marinas y costeras, Universidad Autónoma de Baja California Sur, La Paz, B.C.S. México. 60 p.

Dawood, M., Magouz, I., Mansour, M., Saleh, A., Asely, E., Fadl, S., Ahmed, H., Al-Ghanim, K., Mahboob, S., & Al-Misned, F. (2020). Evaluation of Yeast Fermented Poultry By-Product Meal in Nile Tilapia (*Oreochromis niloticus*) Feed: Effects on Growth Performance, Digestive Enzymes Activity, Innate Immunity, and Antioxidant Capacity. Frontiers in Veterinarie Science. 6:516.

Delgado, G.K. (2018). Efecto de la inclusión de ensilado de residuos blandos de *Argopecten purpuratus* en la dieta sobre el crecimiento y supervivencia de *Litopenaeus vannamei*. Tesis de Ingeniero Pesquero, Universidad Nacional de Tumbes, Tumbes, Perú, 36 p.

Espinosa, C.D, Silva, L.A., García, E.Z., & López, A.M. (2015). Uso de harina de cabeza de camarón como reemplazo proteico de harina de pescado en dietas balanceadas para juveniles de *Totoaba macdonaldi* (Gilbert, 1890). Latin American Journal of Aquatic Research. 43(3): 457-465.

Hernández, C., Olvera, N.M. Hardy, R. Hermosillo, A., Reyes, C. & González, B. (2010). Complete replacement of fishmeal by porcine and poultry by-product meals in practical diets for fingerling Nile tilapia *Oreochromis niloticus*: digestibility and growth performance. Aquaculture Nutrition. 16(1): 44-53.

Hernández, C.J. (2017). Dinoflagelados y toxinas lipofílicas en bancos naturales de bivalvos al sur de la Bahía de La Paz, B.C.S., México. Tesis de Maestría en Ciencias, Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional, La Paz, B.C.S., México. 99 p.

Li, Y.W. & Kittikun, H. (2010). Protein hydrolysis by protease isolated from tuna spleen by membrane filtration: A comparative study with commercial proteases. LWT–Food Science Technology. 43 (1): 166-172.

López, M. J. (2014). Nutrición y Alimentación Piscícola, Editorial Universidad de Nariño, Pasto, Colombia.

Madrid, H.J. (2014). Efecto de la sustitución en dieta de harina de pescado con harina de productos de origen animal, en juveniles de corvina golfina, *Cynoscion othonopterus*. Tesis de Maestría en Ciencias, Centro de Investigación Científica y de Educación Superior (CISESE). Ensenada, Baja California, México. 50 p.

Márquez, E., Bracho, M., Archile, A., Rangel, L. & Benítez, B. (2005). Proteins, isoleucine, lysine and methionine content of bovine, porcine and poultry blood and their fractions. Food Chemistry. 93(3): 503-505.

Michán, L. (2011). Meta-análisis bibliográfico en la Web. Presentación. Recuperado de http://sistemas.fciencias.unam.mx/~layla/CLASE%20META-ANALISIS.pdf

Moutinho, S., Martínez, L. S., Tomás, V. A., Jover, C.M., Oliva, T.A., & Peres, H. (2017). Meat and bone meal as partial replacement for fish meal in diets for gilthead seabream (*Sparus aurata*) juveniles: Growth, feed efficiency, amino acid utilization, and economic efficiency. Aquaculture.468: 271-277.

Navarro, V.E., Ventura, J.M., Hernández, A.Y., Chávez, M.L., Martínez, J.L. Boone, V.D. & Cristóbal N. (2020). Carotenoids: properties and bioprotective effects. Journal of Bioprocess and Chemical Technology.14 (23):1-10.

Núñez, G.J.A, Sánchez, I.D.M, López, C.J., Paseiro, L.P., Sendón, R., Sanches, S.A.T., Costa, H.S., Aurrekoetxea, G.P., Angulo, I. & Soto, V.H. (2011). Evaluación físico-química de aceite pigmentado obtenido de la cabeza de camarón. Grasas y aceites. 62 (3): 321-327.

Pelegrin, E. (2013). Nuevas alternativas de dietas de bajo costo para el cultivo del camarón *Litopenaeus vannamei* en Cuba. Revista Electrónica de Veterinaria. 14(6):1-7.

Salah, M., Sajed, S. & Basim, M. (2014). Effects of fishmeal replacement with fish biosilage on some haematological and biochemical parameters in common carp *Cyprinus carpio* fingerlings. International Journal of Research in Fisheries and Aquaculture. 4(3): 112-116.

Samaddar, A. (2018). A review of fishmeal replacement with fermented biodegradable organic wastes in aquaculture. International Journal of Fisheries and Aquatic Studies. 6(6): 203-208.

Tinto, J. A. (2009). El meta-análisis como instrumento de búsqueda y selección de información. Una experiencia en el proceso de selección bibliográfica para el desarrollo de una tesis doctoral. Visión Gerencial. 8: 203-229.

Toyes, V. (2016). Aprovechamiento de subproductos marinos para la alimentación de camarón de cultivo y gallinas ponedoras. Tesis de Doctorado en Ciencias, Centro de Investigaciones Biológicas del Noroeste, S.C. La Paz, B.C.S. México. 184 p.

Villarreal, C. D., Ricque-Marie, D., Peña, R.A., Nieto, L.M., Tapia, S.M., Lemme, A., Gamboa, D.J. & Cruz-Suárez, E. (2014). Digestibilidad aparente de materia seca, proteína cruda y aminoácidos de seis subproductos de rastro en juveniles de *Litopenaeus vannamei*. Ciencias Marinas. 40(3):163-172.

Zapata, J., & Castañeda, C. (2017). Hidrolizados de pescado–producción, beneficios y nuevos avances en la industria. - Una revisión. Acta Agronómica. 66(3): 311-322.