Review of Amino Acid Nutrition and Digestibility in Shrimp: A Step Forward Toward the Formulation of Cost-Effective Feeds

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Abstract

Knowledge of nutrient digestibility coefficients for individual ingredients and the requirement of digestible nutrients for a defined production target, allows nutritionists to formulate diets that better match animals requirement. Significant information on the digestibility of nutrients, including amino acids from practical ingredients for pacific whiteleg shrimp (*Litopenaeus vannamei*), has been produced during the last years, allowing nutritionists to develop compound feeds that rely less and less on costly protein sources such as fish meal (FM). Fish meal has often been used as the protein source in commercial shrimp feed because of its excellent sources of nutrients, e.g., balanced amino acid profiles, essential fatty acids, and mineral content. However, in order to reduce feed cost, finding alternative protein sources to replace costly proteins such as FM is another major challenge facing nutritionists. Numerous research studies have demonstrated that substitution of FM with alternative protein sources in shrimp diets results in similar growth, survival, and feed conversion ratios, as long as nutrient composition, including amino acid profile, are balanced to cover animal requirements. We propose to review available data on amino acid recommendations and digestibility for whiteleg shrimp that will help making the process of least-cost formulation for shrimp more cost-effective.

Key words: Amino acids, methionine, amino acid digestibility, shrimp

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Review of available nutrient digestibility values in whiteleg shrimp

A major advantage of formulating diets in a digestible basis, is that it makes possible to ensure more predictable animal performance, when changing feed recipes due to changes in availability of feedstuffs and feedstuffs prices. Moreover, protein and amino acid digestibility coefficients of ingredients are needed for more accurate, environmentally friendly, and economical feed formulations. But for many years, the lack of information on amino acid digestibility has limited the switch from total into using digestible amino acid values in least-cost formulation. As a result, shrimp feed is still often formulated in terms of crude protein and amino acids content without considering the nutrient digestibility. The number of studies reporting nutrient digestibility, including amino acid digestibility has increased significantly during the last decade. Digestibility coefficients of dry matter (DM) and crude protein (CP), are by far the most commonly reported in shrimp. But information about amino acid digestibility in white leg shrimp is now available for several ingredients, including those commonly used as alternative protein sources to FM. Digestibility coefficients for individual essential amino acids, except tryptophan, have been reported for ingredients like blood meal (Villarreal-Cavazos *et al*., 2014, Liu *et al*., 2013), corn gluten meal (Yang *et al*., 2009; Liu *et al*., 2013), cottonseed meal (Liu *et al*., 2013), extruded soybean meal (Yang *et al*., 2009), feather meal (Villarreal-Cavazos *et al*. 2014), fermented soybean meal (Yang *et al*., 2009), fish meal of different origins and sources (Yang *et al*., 2009; Terrazas-Fierro *et al*., 2010; Liu *et al*., 2013), full fat soybean meal (Cruz-Suarez *et al*., 2009), meat and bone meal (Yang *et al*., 2009; Liu *et al*., 2013), peanut meal (Yang *et al*., 2009; Liu *et al*., 2013), plasma protein meal (Yang *et al*., 2009), pork by-product meal (Terrazas *et al.,* 2010; Villarreal-Cavazos *et al*., 2014), poultry by-product meal (Yang *et al*., 2009; Terrazas *et al*., 2010; Liu *et al*., 2013, Villarreal-Cavazos *et al*., 2014), rapeseed meal (Liu *et al*., 2013), different shrimp by-product meals (Yang *et al*., 2009, Terrazas-Fierro *et al*., 2010; Liu *et al*., 2003), soybean meal (Cruz-Suarez *et al*., 2009; Yang *et al*., 2009; Terrazas *et al*., 2010; Liu *et al*., 2013), soy protein concentrate (Cruz-Suarez *et al*., 2009), different squid meals (Terrazas-Fierro *et al*., 2010; Liu *et al*., 2013), and of different wheat products (Yang *et al*., 2009; Terrazas *et al*., 2010; Nieto-López *et al*., 2011). For

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many of these ingredients, also the digestibility of the non-essential amino acids is given. The digestible content of CP, lysine and methionine, of selected raw materials relatively to FM (taken as reference; 100%), is shown in Figure 1. Relatively to FM, digestible CP content is low in all of the ingredient analyzed with the exception of blood meal, feather meal and wheat gluten. Lysine and methionine contents are both limiting in feather meal, meat and bone meal, peanut meal, pork by-product meal, being in the case of feather meal and peanut meal severely limiting (<45%). Results found for feather meal illustrate well the existence of discrepancies between digestible CP and essential amino acid contents, and the need of moving away from using digestible or even available CP content as a criterion in the evaluation of ingredient quality. Digestible content of lysine is also limiting in corn gluten meal (<40%) and wheat gluten meal (< 45%), and that of methionine also limiting in soybean meal (<65%), blood meal (<80%), and slightly limiting in poultry by-product meal (90%). On the other hand, ingredients like blood meal and soybean meal have a relatively high digestible content of lysine, while corn gluten meal and wheat gluten meal have a relatively high digestible content of methionine. Regression of digestible CP content against digestible lysine or methionine showed no clear linear relationship, with a coefficient of determination of 0.63 and 0.36 found for CP vs lysine and CP vs methionine, respectively. Despite the limited number of measurements used to perform these analysis, the results highlight the limitations of using digestibility CP as a single criterion to define ingredient quality.

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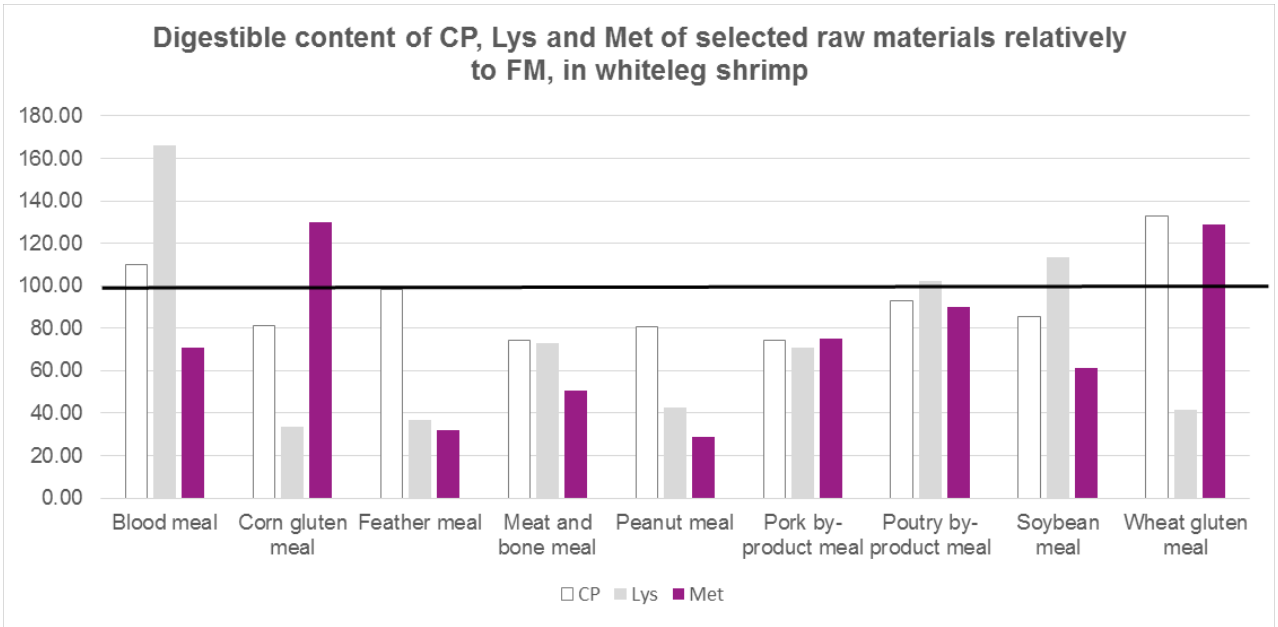

Figure 1. Digestible content of crude protein (CP), lysine (Lys) and methionine (Met) of selected raw materials relatively to fish meal (FM) in whiteleg shrimp.

Advances in the amino acid nutrition of shrimp

The slow feeding behaviour of crustaceans such as, for example, whiteleg shrimp, may result in a long residence time of the feed in water and thus of nutrients being dissolved or leached out. A major challenge that shrimp nutritionists are presented with is, thus, to find valid strategies to minimize leaching losses. Nutritionists, feed manufacturers and farmers have long recognized this issue and the need to improve feed stability in water so that wasting of nutrients due to physical deterioration is minimal. Besides the obvious economic losses, leaching of nutrients and in particular of amino acids and other nitrogen-compounds is long recognized to lead to eutrophication of the water and thus negatively impacting the environment. It is in this context that Evonik Industries started in 2008 an R&D project with the objective of developing a second generation methionine source for shrimp, prawn and other crustaceans. Such a product would remain sufficiently stable in water reducing leaching, and would be digested as slowly as protein-bound amino acids,

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improving protein synthesis. From several different molecules developed, the dipeptide DL-methionyl-DL-Methionine (or *DL*-Met-Met for short) was selected for its exceptional physical and chemical characteristics. The mixture of four different methionine stereoisomers (*DL*-Met-Met, *LD*-Met-Met, *DD*-Met-Met and *LL*-Met-Met) confers unique characteristics to this product –branded AQUAVI® Met-Met - due to its extremely low water solubility when compared to other methionine sources available in the market. Most importantly all four different stereoisomers were shown to be effectively cleaved by fish and crustacean digestive enzymes to free D- and L-Methionine, in several *in vitro* digestion experiments (Figure 2). This seems to agree with data obtained in Atlantic salmon (Sveier *et al*., 2001; Facts and Figures 1620), rainbow trout (Kim *et al*., 1992) and in hybrid striped bass (Keembiyehetty and Gatlin III, 1995), showing that D- and/or DL-Methionine is at least as effective as L-Methionine. The next step was to evaluate the efficacy of AQUAVI® Met-

Met by following a two-step systematic evaluation approach:

1) Studies under clear water/controlled conditions for an accurate evaluation of the AQUAVI® Met-Met efficacy,

2) Studies under green water/field conditions for a more practical oriented evaluation of Met-Met application in commercial feeds optimized to producer-specific conditions.

First studies were conducted to compare the effectiveness of AQUAVI® Met-Met and DL-Methionine in regard to shrimp overall performance (Facts and Figures 1623; Facts and Figures 1624; Fox *et al*., 2012; Lemme *et al*., 2012). Although DL-Methionine and AQUAVI® Met-Met are both efficiently utilized by whiteleg shrimp, significant differences in final body weight and specific growth rate (SGR) are seen when comparing both methionine sources. Altogether, data show that AQUAVI® Met-Met is about 2 times (200%) more efficient in promoting growth of shrimp than DL-Methionine.

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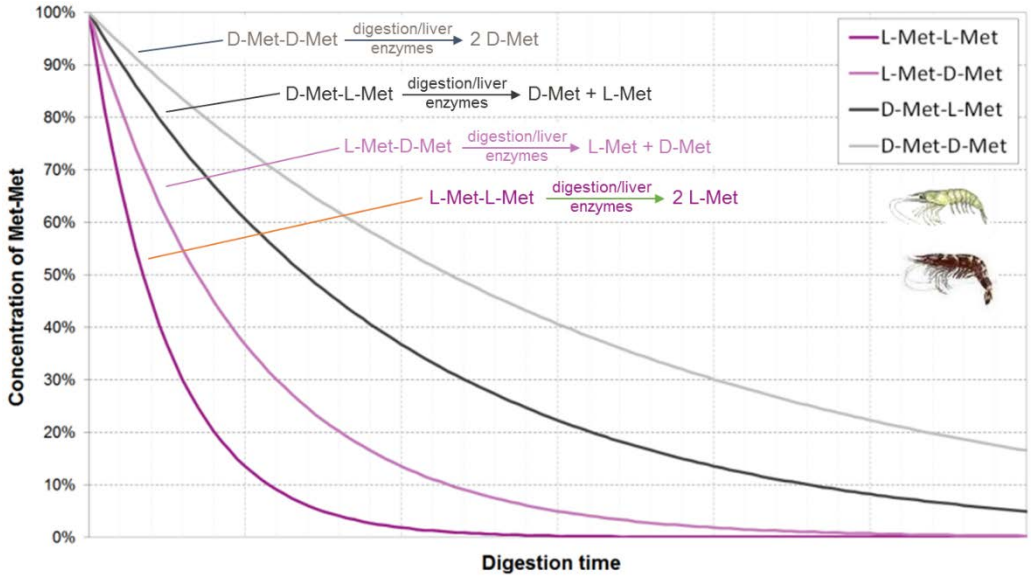

Figure 2. Cleavage kinetics for the four different *DL*-Met-Met stereoisomers (*in vitro* study; unpublished data).

Provided with evidence that AQUAVI® Met-Met is highly effective in covering methionine requirements of shrimp, the efficacy of this novel methionine source to reduce FM in whiteleg shrimp was evaluated (Facts and Figures 1625). AQUAVI® Met-Met proves to be a key element in formulating cost-effective reduced FM diets for whiteleg shrimp. Similar performance as a feed including 26% FM can be achieved with FM10% feeds supplemented with 0.19-0.28% DL-Methionine or 0.09% AQUAVI® Met-Met (Facts and Figures 1625).

The impact of natural food productivity when defining methionine recommendations and applying them to practical diet formulation in shrimp, was also evaluated. In fed-based aquaculture ponds, marine shrimp can be raised under various levels of intensification, from 10 to more than 120 shrimp/m^2. In these confined environments, phytoplankton productivity is the common dominant ecological factor. Microscopic algae typically can make up the base of the aquatic food chain, contributing to the abundance of a variety of shrimp food items, such as prey (polychaetes, amphipods, copepods, foraminifera, nematodes, molluscs), and other plant and organic matter in

various stages of decomposition, including microbial flocculated material. Although the precise relative contribution of pond food to shrimp growth is not completely understood, it is recognized as an important dietary component for farm-raised shrimp. This idea was corroborated in a recent study comparing responses of shrimp grown under two different rearing systems: flow-through (close to clear water conditions) and static green water systems (close to green water conditions) (Facts and Figures 1626). This study indicated that in systems where natural food productivity is scarcer or stocking densities are higher, an increase of about 20% of dietary methionine plus cysteine (Met+Cys) in a total basis, might be required to sustain maximum growth of shrimp. Furthermore, shrimp performance was shown to respond exponentially to graded levels of AQUAVI® Met-Met, with a dietary Met+Cys content of 1.05% (1.15 % dry matter) being required to reach 95% of maximum body weight. That AQUAVI® Met-Met significantly improves growth performances of shrimp grown under green water system was further corroborated by a study conducted under pond production conditions in India (Facts and Figures 1627). In this study, shrimp performance has also responded exponentially to increasing doses of AQUAVI® Met-Met, with a dietary methionine and Met+Cys content of, respectively, 0.72% (0.78% dry matter) and 1.16% diet (1.25% DM) being required to reach 95% of maximum weight gain. Overall, results demonstrate that AQUAVI® Met-Met significantly improves growth performances of shrimp grown under green water conditions, corroborating data produced under clear water conditions (Facts and Figures 1623, 1624, 1625). Although available data is not yet sufficient to determinate the impact of natural food on the Met+Cys specifications of shrimp feed, it supports the idea of adjusting the Met and Met+Cys dietary contents to the specific conditions of the farm.

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References

Cruz-Suárez, L.E., Tapia-Salazar, M., Villarreal-Cavazos, D., Beltran-Rocha, J., Nieto- López, M.G., Lemme, A., Ricque-Marie, D., 2009: Apparent dry matter, energy, protein and amino acid digestibility of four soybean ingredients in white shrimp *Litopenaeus vannamei* juveniles. Aquaculture 292, 87–94.

Facts and Figures 1620. Atlantic salmon respond equally well to both DL-Methionine and L-Methionine supplementation.

Facts & Figures 1623: AQUAVI® Met-Met is more effective than DL-Methionine in whiteleg shrimp: Study at Texas A&M University, US. 2015. http://feed-additives.evonik.com/product/feed-additives/en/services/technical-literature/Pages/default.aspx

Facts & Figures 1624: AQUAVI® Met-Met is more effective than DL-Methionine in whiteleg shrimp: Study at South China Sea Fisheries Research Institute, China. http://feed-additives.evonik.com/product/feed-additives/en/services/technical-literature/Pages/default.aspx

Facts & Figures 1625: AQUAVI® Met-Met is effective to reduce fish meal from 26% to 10% in shrimp feeds: Study at South China Sea Fisheries Research Institute, China. http://feed-additives.evonik.com/product/feed-additives/en/services/technical-literature/Pages/default.aspx

Facts & Figures 1626: Evaluation of the natural food productivity on the response of shrimp to AQUAVI® Met-Met: Study at Labomar, Brazil. http://feed-additives.evonik.com/product/feed-additives/en/services/technical-literature/Pages/default.aspx

Facts & Figures 1627: Response of whiteleg shrimp to increasing levels of AQUAVI® Met-Met under pond culture conditions: Study at TamilNadu Fisheries University, India. http://feed-additives.evonik.com/product/feed-additives/en/services/technical-literature/Pages/default.aspx

Fox, J.M., Lawrence, A.L., Lemme, A., Patnaik, S., 2012: Effect of methionine source and dietary inclusion level on growth and survival of juvenile *Litopenaeus vannamei*. Aquaculture America, February 29-March 2, Las Vegas, United Sates.

Keembiyehetty, C.N. and Gatlin D.M. III, 1995: Evaluation of different sulfur compounds in the diet of juvenile sunshine bass (*Morone chrysops*♀ x *M. saxatilis*♂). Comparative Biochemistry and Physiology 112A: 155-159.

Kim K.I., T.B. Kayes and Amundson, C.H., 1992: Requirements for sulfur amino acids and utilization of D-methionine by rainbow trout (*Oncorhynchus mykiss*). Aquaculture 101: 95-103.

Lemme A., Hei-Zhao L., Niu J., Yi-Fang C., Gao W., Kobler C., 2012: Impact of supplementation of a novel methionine source on growth performance of Pacific white shrimp, *Litopenaeus vannamei*, compared to DL-Methionine. XV International Symposyum of Fish Nutrition and Feeding, June 4-12, Molde, Norway.

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Liu, X.-H., Ye, J.-D., Kong J.-H., Wang K., Wang A.-L., 2013: Apparent Digestibility of 12 Protein-Origin Ingredients for Pacific White Shrimp *Litopenaeus vannamei* North American Journal of Aquaculture, 75:1, 90-98.

Nieto-López, M., Tapia-Salazar, M., Ricque-Marie, D., Villarreal-Cavazos, D., Lemme, A., Cruz-Suárez, L.E., 2011: Digestibility of different wheat products in white shrimp *Litopenaeus vannamei juveniles*. Aquaculture 319: 369–376.

Sveier, H., Nordås, H., Berge, G.E., Lied, E., 2001: Dietary inclusion of crystalline D- and L-methionine: effects on growth, feed and protein utilization, and digestibility in small and large Atlantic salmon (*Salmo salar* L.). Aquaculture Nutrition 7:169-181

Terrazas, M., Roberto, C., Ibarra L., Goytortúa, G., (2010): Coeficientes de utilización digestiva aparente de materia seca, proteína y aminoácidos esenciales de ingredientes terrestres para el camarón del Pacífico *Litopenaeus vannamei* (Decapoda: Penaeidae). Revista de Biologia Tropical 58 (4): 1561-1576.

Terrazas-Fierro, M., Civera-Cerecedo, R., Ibarra-Martínez, L., Goytortúa- Bores, E., Herrera-Andrade, M., Reyes-Becerra, A., 2010: Apparent digestibility of dry matter, protein, and essential amino acid in marine feedstuffs for juvenile whiteleg shrimp *Litopenaeus vannamei*. Aquaculture 308:166–173.

Villarreal-Cavazos, D.A., Ricque-Marie, D., Peña-Rodríguez, A., Nieto-López, M., Tapia-Salazar, M., Lemme, A., Gamboa-Delgado, J., Cruz-Suárez, L.E., 2014: Ciencias Marinas 40(3): 163–172.

Yang, Q., Zhou, X., Zhou, Q., Tan, B., Chi, S., Dong, X., 2009: Apparent digestibility of selected feed ingredients for white shrimp *Litopenaeus vannamei*, Boone. Aquaculture Research 40, 1–9.

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