Use of Rendered Terrestrial Animal By-products in Aquatic Feeds

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Abstract

The demand for high quality, palatable protein ingredients for aquatic feeds has grown along with the aquaculture industry. Although fishmeal continues to play a significant role, its generally high cost, variability of supply and limited scope for increased fishmeal production have led to interest in identification and development of alternative protein sources. Rendered animal by-products are produced in significant quantities and are available in a variety of forms, including meat and bone meals and poultry by-product meals.

A number of studies have shown that many of these by-products are suitable for inclusion in aquatic feeds in partial replacement of fishmeal. This paper reviews some of this research, with an emphasis on shrimp feeds. In general, rendered animal by-products can replace from 15 to 75% of fishmeal in diets for shrimp. Most of the published research on by-products was conducted in clean, flow-through water conditions, whereas shrimp are commercially cultured in outdoor ponds, where there is considerable opportunity for shrimp to supplement their diet with endogenous organic material (floc) from the culture environment. Under conditions of high floc availability, it has been found that rendered animal by-products may replace a significantly higher portion of fishmeal in diets for shrimp, without significant reduction of growth. Variability of the composition of the rendered material in by-products necessitates the profiling of incoming by-products before formulating to effectively use this material to meet the nutrient requirements of fish or shrimp.

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Introduction

Although it is often said that animals have a dietary requirement for protein, in fact animals require sources of balanced, available amino acids. Under culture conditions, it is important to ensure that feeds provide amino acids, and be acceptable (palatable) to the species they are targeted for within the culture environment. In general, sources of amino acids (protein) are among the most expensive components of aquaculture feeds. Ensuring that feeds provide the amino acids to animals in available and palatable form will reduce cost of feeding, improve farm efficiency and reduce pollution from feed.

Because of its good balance of amino acids, good digestibility and high palatability, high quality fishmeal is commonly used in commercially available feeds for many species of cultured fish and shrimp. The variable availability and generally high price of fishmeal of sufficiently high quality for many aquaculture applications has led to interest in identifying and developing alternative amino acid (protein) sources.

Advances in breeding, production and processing technologies have improved the efficiency of utilization of livestock for food. Even so, at least 40,000 tons of animal by-products are generated each week in the U.S.A. from slaughter houses, packing plants, supermarkets, butcher shops and restaurants. Food production in many countries is under strict supervision and the resulting by-products are of high quality. Rendered animal by-products include livestock and poultry carcasses plus offal, spent cooking fats and oils, fat trimmings, bones, and other meat and poultry processed materials.

These by-products contain significant levels of protein and oils and provide a ready source of nutritious, digestible animal protein and fat. The availability of by-products for inclusion in aquatic feeds provides feed producers with added flexibility in formulating feeds, and decreases dependence on fishmeal supplies.

The two main varieties of rendered terrestrial animal by-products are Meat and Bone Meals (MBM), which are obtained from cattle, swine and poultry, and Poultry By-product Meals (PBM) primarily derived from poultry meat meals, feather meals, and egg meals.

Research has demonstrated that several of these rendered by-products have utility in feeds for aquaculture (reviewed by Yu, 2004). This report summarizes some of these findings, with an emphasis on research conducted at the Oceanic Institute, Hawaii, U.S.A. In general, it is found that MBM and PBM may replace a considerable portion of the fishmeal used in feeds for shrimp and fish.

Use of MBM in shrimp feeds

Forster *et al.,* (2003) examined the use of MBM to replace fishmeals in diets for Pacific white shrimp (*Litopenaeus vannamei*). In this work, which was conducted at the Oceanic Institute, three products were tested: A. 35% beef, 35% pork, 30% poultry, B 90% beef, 5% pork, 5% poultry, and, C 50% beef, 50% pork. The results of an amino acid apparent digestibility trial and a growth trial

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were used to assess the nutritional quality of these products relative to a high quality fishmeal for shrimp.

The proximate composition and particle size distribution (Table 1), amino acid (Table 2) and mineral composition (Table 3) were determined for these meals. The amino acid levels as a percent of total amino acids of these MBMs compares favorably with the lysine requirement of *L. vannamei* established for lysine (Fox *et al.,* 1995), the recommended amino acid levels of Akiyama (1991), except for methionine and possibly phenylalanine and tryptophan, and with estimated requirements based on A/E ratios (based on lysine requirement determination (Fox *et al.,* 1995) and EAAI (Mente *et al.,* 2002), except possibly for isoleucine and phenylalanine.

Table 1. Composition and size distribution of three meat and bone meals (MBM-A. 35% beef, 35% pork, 30% poultry, MBM-B. 90% beef, 5% pork, 5% poultry, and MBM-C 50% beef, 50% pork)

	MBM-A	MBM-B	MBM-C
Moisture (%)	6.79	3.92	3.29
Crude Protein (%)	53.30	55.61	53.51
Crude Fat (%)	17.12	10.61	15.06
Ash (%)	19.00	24.09	22.28
Gross Energy (kJ/g)	19.50	17.80	19.00
Particle size range (μ)	488 (256-932)	355 (167-757)	500 (288-869)

Table 2. Essential amino acid profile of three MBMs, recommended values and estimated amino acid requirements for *L. vannamei*. Values are expressed as a percent of total amino acids. (MBM-A 35% beef, 35% pork, 30% poultry, MBM-B 90% beef, 5% pork, 5% poultry, and MBM-C 50% beef, 50% pork)

Amino acid	MBM-A	MBM-B	MBM-C	Recommended[1]	Estimated Requirement[2]
Arginine	7.6	7.6	7.5	5.8	5.0
Histidine	2.6	2.7	2.8	2.1	1.4
Isoleucine	3.8	4.0	3.5	3.4	3.9
Leucine	7.5	7.9	7.3	5.4	5.9
Lysine	5.9	7.0	6.0	5.3	5.2[3]
Methionine	1.8	2.2	1.9	2.4	0.5
Met + Cys	3.3	3.1	2.8	3.6	
Phenylalanine	4.2	4.3	3.9	4.0	4.1
Phe + Tyr	7.6	8.1	7.1	7.1	
Threonine	4.1	4.2	3.8	3.6	3.3
Tryptophan	0.7	0.8	0.7	0.8	0.7
Valine	5.7	5.4	5.3	4.0	3.8

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[1] Akiyama 1991

[2] Based on lysine requirement of 5.2% of crude protein (Fox *et al.,* 1995) adjusted by EAAI ratios (Mente *et al.,* 2002) according to Ogino (1980).

[3] Requirement value from growth trial (Fox *et al.,* 1995)

Table 3. Mineral content of three MBMs (MBM-A. 35% beef, 35% pork, 30% poultry, MBM-B. 90% beef, 5% pork, 5% poultry, and MBM-C 50% beef, 50% pork).

	MBM-A	MBM-B	MBM-C
P (%)	3.14	3.66	4.11
K (%)	0.42	0.26	0.50
Ca (%)	5.98	8.15	7.84
Mg (%)	0.14	0.21	0.17
Na (%)	0.68	0.44	1.65
Mn (mg/kg)	11.92	10.21	14.98
Fe (mg/kg)	470.33	872.60	998.78
Cu (mg/kg)	9.34	9.74	9.71
Zn (mg/kg)	56.43	119.91	81.29
B (mg/kg)	4.57	4.51	6.66

The apparent digestibility coefficients of diets containing each of these byproducts were determined *in vivo* using the indirect method. Chromic oxide was used as an indigestible marker and feces were collected using a settling container. Dry matter, crude protein (Table 4) and amino acid (Table 5) apparent digestibility coefficients were determined for the diets containing these MBMs. The apparent digestibility coefficients of crude protein (nitrogen) in diets containing each meal were in close agreement with the mean digestibility of individual amino acids. The control diet had the highest digestibility, with digestibility for MBM-A, MBM-B, MBM-C in decreasing order.

Table 4. Apparent digestibility coefficients of three MBM by shrimp (MBM-A. 35% beef, 35% pork, 30% poultry, MBM-B. 90% beef, 5% pork, 5% poultry, and MBM-C 50% beef, 50% pork). Values within a column with common superscripts are not significantly different (P>0.05; n=3).

Treatment	Dry matter (%)	Crude protein (%)
Control	78.46 a	92.63 a
MBM-A	74.25ab	87.84ab
MBM-B	68.08ab	85.08bc
MBM-C	63.60 b	81.04 c
SEM[4]	3.10	1.47

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[4] Standard Error of the Means

Table 5. Apparent amino acid digestibility coefficients of three MBMs by shrimp (MBM-A. 35% beef, 35% pork, 30% poultry, MBM-B. 90% beef, 5% pork, 5% poultry, and MBM-C 50% beef, 50% pork).

	Control	MBM-A	MBM-B	MBM-C
Arginine	94.4	88.2	86.3	81.5
Cystine	84.7	74.6	78.1	76.3
Histidine	91.3	89.9	85.9	83.2
Isoleucine	93.4	89.6	87.7	81.8
Leucine	93.4	89.0	87.0	81.0
Lysine	95.4	92.7	88.6	84.5
Methionine	92.4	91.0	86.7	81.5
Phenylalanine	92.5	88.3	86.7	81.7
Taurine	94.3	93.3	92.3	88.6
Threonine	90.3	85.7	82.8	76.9
Tryptophan	91.2	91.0	87.2	81.5
Tyrosine	90.9	87.8	85.6	80.3
Valine	92.5	86.8	85.4	79.6
Average	92.0	87.4	85.2	80.5

The nutritive quality of these meals was further determined using a growth trial conducted in a clean flow-through culture system, in which a series of diets (35% CP) containing a high quality fishmeal (Norse LT-94®) was replaced by 25, 50 and 75% of each of the three MBMs on an equal protein basis. The shrimp (*L. vannamei*) were stocked initially at 0.8 g and the animals were fed for 8 weeks.

Although there was considerable variability in the ability of each of these meals to promote growth of shrimp at higher levels of inclusion (Fig. 1), all three were able to replace at least 25% of the fishmeal. There was a general trend to reduced growth in the animals with increasing MBM above 25% fishmeal replacement, but this was not significant for MBM-B up to 75% of fishmeal replacement. It is possible that the specific combination of material used to produce the MBM (pork, beef, and poultry) may influence the nutritional quality of the final product. The relative rankings of these meals on the basis of shrimp growth was (from high to low) MBM-B, MBM-C, MBM-A. Note that MBM-A had the highest apparent digestibility. Clearly, the differences in the meals resulting in improved growth are not related to amino acid digestibility.

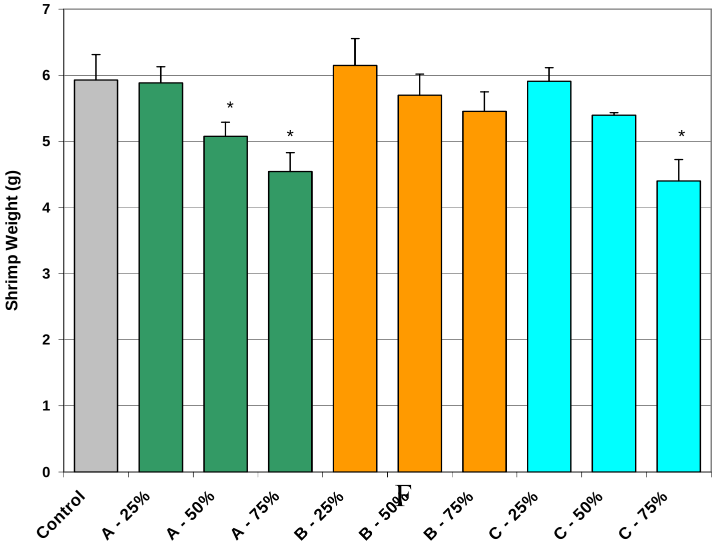

Figure 1. Final weight of shrimp fed diets containing three levels of three MBMs (Forster *et al.,* 2003). Values are means of three observations (error bars are standard deviations). Values with * are significantly different than the control (P<0.05).

Research by many groups has indicated the value of MBMs as ingredients in shrimp feeds. Williams *et al.,* (1997) reported that as much as 67% of Peruvian fishmeal (70.5% crude protein on a dry matter basis) could be replaced by MBM in black tiger shrimp (*Penaeus monodon*) diets under both laboratory and field conditions, without adverse effect on production. Tan *et al.,* (2005) found that up to 60% of fishmeal protein can be replaced by MBM with no adverse effects on growth, survival, FCR, PER and body composition of *L. vannamei* (Figure 2).

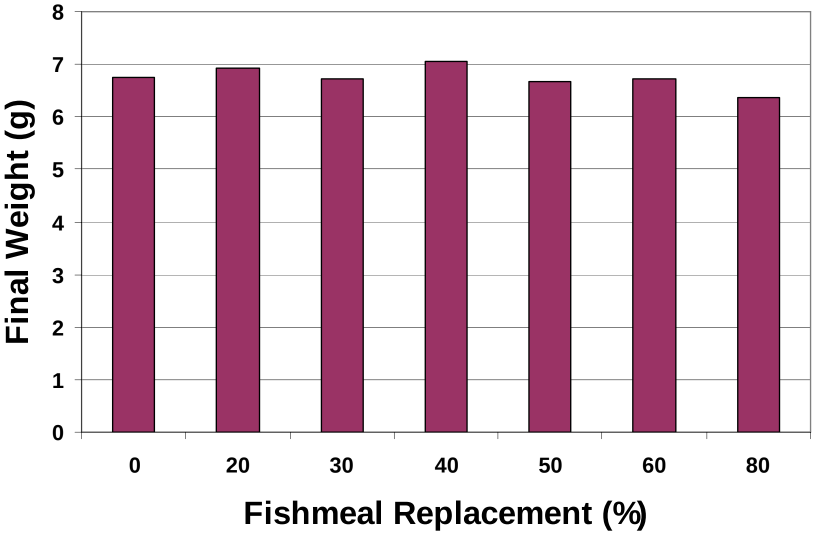

Figure 2. Final weight of shrimp fed diets containing up to 80% replacement of fishmeal by MBM (Tan *et al.,* 2005).

Research on Use of PBM in shrimp feeds

The utility of four poultry by-products, low ash poultry meal (LAPM), poultry bone meal (PBoM), pet food grade poultry meal (PFGM) and feed grade poultry meal (FGPM) were tested in diets for shrimp (*L. vannamei*) at the Oceanic Institute. Each of these products was included in diets (43% CP) in replacement of 15, 30 and 45% of high quality fishmeal (Norse LT-94®), on an equal protein basis. The initial weight of the shrimp was 0.7 g and the diets were fed for eight weeks in a clean, flow-through system. All the poultry meals were able to support growth of the shrimp at least at 15% fishmeal replacement with no loss in growth (Fig 3.). Three of the meals (LAPM, PFGM, PBoM) were able to support growth equivalent to the control at up to 45% fishmeal replacement.

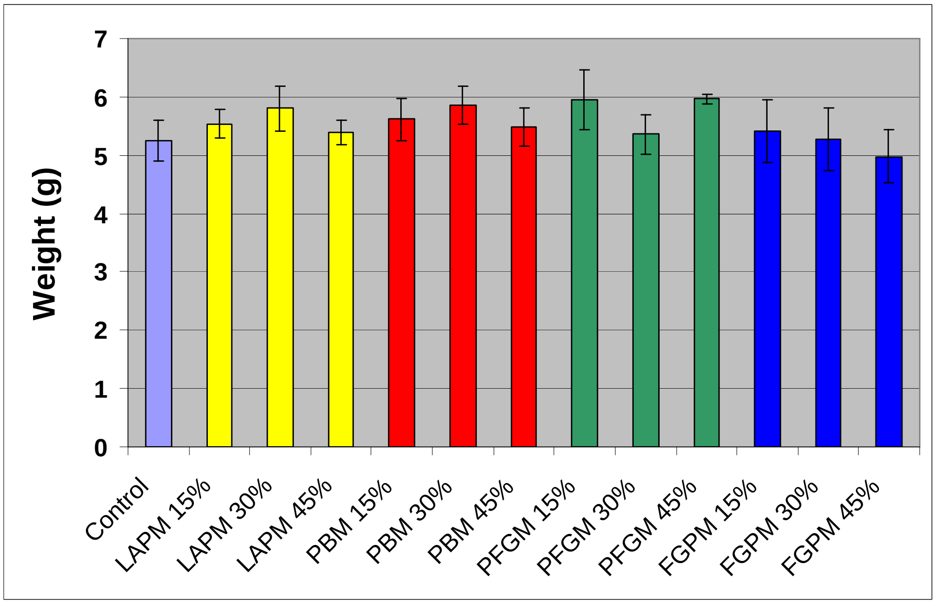

Figure 3. Weight after eight weeks of shrimp fed diets containing three levels of various poultry meals. Values are means of three observations (error bars are standard deviations).

These findings indicate that poultry byproduct meals can be effective ingredients for shrimp. The high variability of their nutritional quality indicates that care must be taken when selecting among different sources for use in feeds for aquatic animals, including shrimp.

The suitability of poultry meals as ingredients for aquatic feeds has been extensively studied and while there is some variability in the findings (Table 6), in general, poultry meals are able to replace at least 35% of fishmeal. Samocha *et al.,* (2004) indicated that fishmeal may be completely replaced in diets for shrimp by a co-extruded soybean and poultry by-product meal, while Alexis *et al.,* (1985) demonstrated complete replacement of fishmeal by a combination of poultry by-product meal and plant protein sources.

Table 6. Partial literature findings of the use of poultry by-products in aquaculture feeds

Species	Product	Replacement	Reference
L. vannamei	Poultry meals;	30–45 % of fishmeal[1]	This study
L. vannamei	Poultry by-product meal[2]	100 % of fishmeal	Samocha *et al.,* 2004
L. vannamei	Feather meal	33 % of fishmeal[3]	Cheng *et al.,* 2002a
L. vannamei	Poultry by-product meal	67 % of fishmeal	Cheng *et al.,* 2002b
L. vannamei	Poultry by-product meal[4]	80 % of fishmeal	Davis and Arnold 2000
L. vannamei	Poultry by-product meal; pet food grade	50-65% of fishmeal[5]	Cruz-Suarez, *et al.,* 2005
Oncorhynchus mykiss (rainbow trout)	Poultry by-product meal[6]	Total replacement	Alexis *et al.,* 1985
O. tshawytscha (chinook salmon)	Poultry by-product meal	50 % of herring meal	Fowler 1990
Labeo rohita (Indian carp)	Feather meal	50 % of fishmeal	Hasan *et al.,* 1997
Sparus aurata (gilthead seabream)	Poultry by-product meals	35-75% fishmeal	Nengas *et al.,* 1999
Carassius auratus gibelio (gibel carp)	Poultry by-product and meat and bone meals	50% fishmeal	Yang *et al.,* 2004

[1] High grade fishmeal (Norse LT-94®) was used.
[2] Product was co-extruded soy and poultry meal with egg supplement.
[3] Best results were obtained when diets were supplemented with the indispensable amino acids lysine and methionine. High grade fishmeal (Norse LT-94®) was used.
[4] Similar results were found for both a co-extruded soy/poultry meal and flashed dried poultry meal used to replace menhaden meal
[5] At 65% replacement there was significant reduction in feed consumption, and at 85% there was significant reduction in consumption and growth rate
[6] Diets contained combination of poultry by-product meal, carob seed germ meal and corn gluten meal

Shrimp culture under practical conditions

Most research on by-product meals in shrimp are conducted in indoor, clean water systems, with a controlled environment. Most shrimp production, however, is conducted in outdoor ponds with limited water exchange allowing establishment of a microbial community. By consuming elements of this community, shrimp are able to supplement their supply of nutrients. Because of this, feeds that perform poorly in indoor, clean water systems may be able to promote high shrimp productivity in microbial based outdoor culture systems.

A study was conducted to examine the ability of MBM and PBM to completely replace fishmeal in diets for shrimp under conditions similar to pond culture. Shrimp were grown under highly eutrophic conditions at the facilities of the Oceanic Institute. Three diets were fed to the shrimp: a control diet containing high quality fishmeal (Norse LT-94®), a diet with fishmeal replaced by MBM (55.6% CP; 10.6% CL), and a diet with fishmeal replaced by PBM (69.1% CP; 15.7% CL). The shrimp were grown in conditions of zero water exchange at a density of 50 animals/m^2 for 8 weeks in outside tanks (1,300 L volume), with only fresh water added to make up for evaporative loss.

Although not statistically significant (P>0.05), there was a tendency for lower final weight and lower FCR in the shrimp fed the MBM and PBM diets (Fig 4). This trial demonstrated that MBM and PBM can replace fishmeal in diets for shrimp under zero-water conditions, which is closer to actual pond conditions than is clean water, with little or no deleterious effect on growth and FCR.

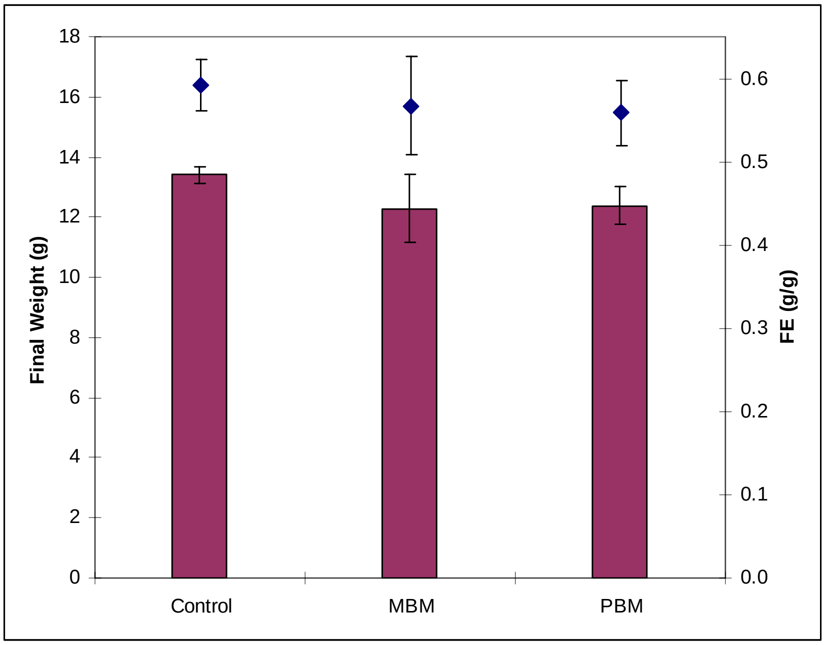

Figure 4. Final weight and feed efficiency of shrimp fed diets containing either fishmeal, MBM or PBM for 8 weeks in zero water exchange conditions. Values are means of three observations (error bars are standard deviations).

More recently, another trial under zero-water exchange conditions was undertaken at the Oceanic Institute in which MBM replaced fishmeal (menhaden meal) in diets (35% CP) for *L. vannamei* at 0, 25, 50, 75 and 100% on an equal crude protein basis. This trial was conducted under conditions similar to those of the previous trial. As in the previous trial, no significant effect (P>0.05) of fishmeal replacement by MBM was found among the shrimp at the end of this trial (Table 7), although there was a tendency for lower final weight in the shrimp fed the MBM diets, compared with the fishmeal control.

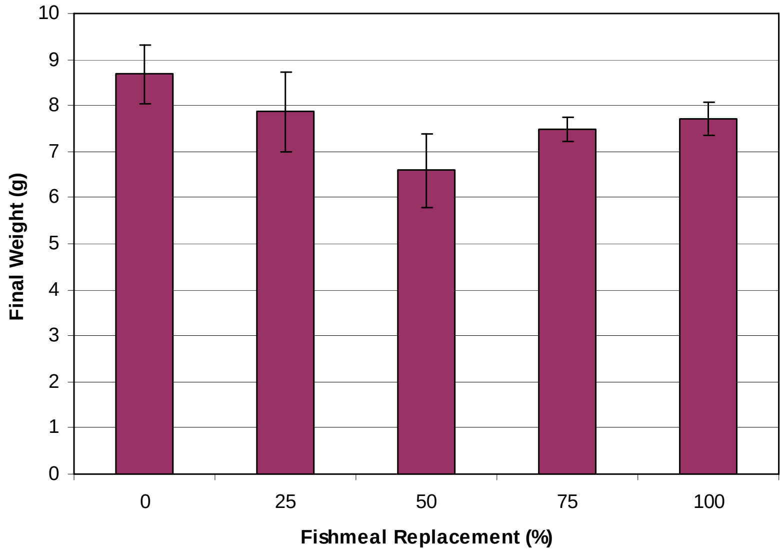

Figure 5. Final weight of shrimp fed diets containing meat and bone meal in replacement of fishmeal (menhaden meal) for 8 weeks in zero water exchange conditions. Values are means of three observations (error bars are standard deviations).

Table 7. Growth, final weight and survival of *L. vannamei* reared in under zero-water exchange conditions for 8 weeks fed diets containing 0, 25, 50, 75 and 100% replacement of fishmeal by meat and bone meal. Values are means of three replicate groups of shrimp.

Treatment	Growth (g/week)	sd	Final Wt (g/shrimp)	sd	Survival (%)	sd
0	0.96	0.08	8.68	0.63	94.3	2.1
25	0.86	0.10	7.86	0.86	95.7	0.6
50	0.71	0.11	6.60	0.80	94.0	1.0
75	0.81	0.03	7.49	0.27	94.0	3.6
100	0.84	0.05	7.70	0.36	90.0	4.6

Summary

- The reliance on fishmeal in feeds for many aquatic animals needs to be reduced.
- Several varieties of rendered terrestrial animal by-products are available in sufficient quantities to be useful to aquaculture.
- Good quality meat and bone meal and poultry meal can replace between 15 – 75% of fishmeal in feeds for many aquatic species.
- In feeds developed for shrimp reared in ponds, where there is significant opportunity for supplemental nutrient input from the environment, rendered by-products may replace nearly all of the fishmeal in shrimp feeds.
- The limitations to utilization of by-products appear to be related to high ash and possibly limiting amino acids.

- Variability of the composition of the rendered material in by-products necessitates the profiling of incoming by-products before formulating to effectively use this material to meet the nutrient requirements of fish or shrimp.

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References

Akiyama, D.M, Dominy, W.D., Lawrence, A.L. 1991. Penaeid shrimp nutrition for the commercial feed industry revised. In: D.M. Akiyama and R.K.H Tan, eds. Proceedings of the aquaculture feed processing and nutrition workshop, Thailand and Indonesia, Sept. 19-25. American Soybean Association, Singapore.

Alexis M.N., Papaparaskeva-Papoutsoglou, E., Theochari, V., 1985. Formulation of practical diets for rainbow trout (*Salmo gairdneri*) made by partial or complete substitution of fishmeal by poultry by-products and certain plant by-products. Aquaculture 50, 61–73

Cheng Z.J., Behnke, K.C., Dominy, W.D. 2002a. Effect of feather meal on growth and body composition of the juvenile Pacific white shrimp, *Litopenaeus vannamei*. Journal of Applied Aquaculture 12, 57-69.

Cheng, Z.J., Behnke, K.C., Dominy, W.D. 2002b. Effect of poultry by-product meal as a substitute for fish meal in diets on growth and body composition of the juvenile Pacific white shrimp (*Litopenaeus vannamei*). Journal of Applied Aquaculture 12, 71–83.

Cruz-Suárez, L.E., Nieto-López, M., Ricque-Marie, D., Guajardo-Barbosa, C. y Scholz, U. 2004. Uso de Harina de Subproductos Avícolas en Alimentos para *L. vannamei*. In: Cruz Suárez, L.E., Ricque Marie, D., Nieto López, M.G., Villarreal, D., Scholz, U. y González, M. Avances en Nutrición Acuícola VII. Memorias del VII Simposium Internacional de Nutrición Acuícola. 16-19 Noviembre, 2004. Hermosillo, Sonora, México. 215-236.

Davis, A.D., Arnold. 2000. Replacement of fishmeal in practical diets for the Pacific white shrimp, *Litopenaeus vannamei*. Aquaculture 185, 291–298.

Forster, I.P., Dominy W., Obaldo, L., Tacon, A.G.J. 2003. Aquaculture. Rendered meat and bone meals as ingredients of diets for shrimp *Litopenaeus vannamei* (Boone, 1931). Aquaculture 219, 655-670.

Fowler, L.G., 1990. Feather meal as a dietary protein source during parr-smolt transformation in fall chinook salmon. Aquaculture 89, 301-314.

Fox, J.M., Lawrence, A.L., Li-Chan. 1995. Dietary requirement for lysine by juvenile *Penaeus vannamei* using intact and free amino acid sources. Aquaculture 131, 279-290.

Hasan, M.R., Haq, M.S., Das, P.M., Mowlah, G., 1997. Evaluation of poultry-feather meal as a dietary protein for Indian major carp, *Labeo rohita* fry. Aquaculture 151, 47-54.

Mente, E., Coutteau, P., Houlihan, D., Davidson, I, Sorgeloos, P. 2002. Protein turnover, amino acid profile and amino acid flux in juvenile shrimp *Litopenaeus vannamei*: effects of dietary protein source. Journal of Experimental Biology 205, 3107-3122.

Nengas, I., Alexis, M.N., Davies, S.J. 1999. High inclusion levels of poultry meals and related byproducts in diets for gilthead seabream *Sparus aurata* L. Aquaculture 179, 13-23.

Samocha, T.M., Davis, A.D., Saoud, I.P., Debault, K. 2004. Sub Substitution of fish meal by co-extruded soybean poultry by-product meal in practical diets for the Pacific white shrimp, *Litopenaeus vannamei* Aquaculture 231, 197-203.

Tan, B., Mai, K., Zheng, S., Zhou, Q., Liu, L., Yu, Y. 2005. Replacement of fish meal by meat and bone meal in practical diets for the white shrimp *Litopenaeus vannamei*. Aquaculture Research 36, 439-444.

Williams, K.C., Allan, G.L., Smith, D.M., Barlow, C.G., 1997. Fishmeal replacement in aquaculture diets using rendered protein meals. In: Banks, G. (Ed.), Proceedings Fourth International Symposium of Australian Renderers' Association, 24-26 September, 1997, Australian Renderers' Association Inc., Sydney, Australia. pp. 13-26.

Yang, Y, Xie, S., Cui, Y., Lei, W., Zhu, X., Yang, Y., Yu, Y. 2004. Effect of replacement of dietary fish meal by meat and bone meal and poultry by-product meal on growth and feed utilization of gibel carp, *Carassius auratus gibelio*. Aquaculture Nutrition 10, 289-294.

Yu, Y. 2004. Replacement of fishmeal with poultry byproduct meal and meat and bone meal in shrimp, tilapia and trout diets. In: Cruz-Suarez, L.E., Rique Marie, D., Nieto Lopez, M.G., Villareal, D., Scholz, U. and Gonzalez, M. Avances en Nutricion Acuicola VII. 16-19 November, 2004. Hermosillo, Sonora, Mexico.