Replacement of fishmeal with poultry byproduct meal and meat and bone meal in shrimp, tilapia and trout diets

Y. Yu
Asia Regional Director
National Renderers Association, Inc.
Hong Kong

Abstract

Meat and bone meal (MBM) and poultry byproduct meal (PBM) are logical candidates for substituting fish meal in diets for carnivorous and omnivorous aquacultural species, for reasons of product of animal origin, nutritional composition, and price and supply advantages over fish meal (FM). Evaluation for effectiveness of substitution should be largely based on matching of digestible amino acids content and the requirement of the target species, and the growth performance from the feeding trials. Supplementation of crystalline amino acids is recommended when amino acids imbalance has arised. Results of most feeding trials indicate that replacement of FM with MBM and PBM has minimal effect on feed consumption, survival rate, carcass composition and taste characteristics for white shrimp, tilapia and trout. Optimum FM replacement rates for MBM and PBM in shrimp, tilapia and trout diets are 50, 60, 50% for MBM, and 70, 80, 80% for PBM. The recommended inclusion rates of MBM and PBM in shrimp, tilapia and trout are 15-20, 6, 20% for MBM, and 18-25, 8, 25% for PBM. Diets must be formulated with sufficient essential fatty acids.
Key words: Poultry byproduct meal, meat and bone meal, fishmeal substitution, shrimp, tilapia, trout.

Introduction

Global consumption of shrimp and fish has been increasing steadily during the past decade as result of economic growth and expanded aquaculture production. One of the limiting factors for future growth in aquaculture is the supply and price of fishmeal (FM), which has been predicted unfavorably for the aquafeed industry. Additionally, there is a perceived inefficiency from catching fish, making it into fishmeal and then feed back to fish. Nutritionists worldwide have been searching for effective FM substitutes. Plant source proteins are logical choice for replacing FM in diets for herbivorous and omnivorous species, but animal protein sources such as poultry byproduct meal (PBM), and meat and bone meal (MBM) are clearly preferred alternatives to FM in carnivorous species. With few exceptions, most carnivorous species are high value sea foods such as shrimp and trout. The purpose of this paper is to review the feeding trials conducted for evaluation of PBM and MBM as FM substitute is shrimp, tilapia and trout diets.

Nutritional Composition

Both PBM and MBM are byproducts from livestock and poultry slaughtering operations. The rendering processes and condition employed by US and Canadian renders are sufficient in destroying most pathogenic microorganisms (such as salmonella, clostridium, canbylobaster, and AI virus), and yet are able to have a minimum effect on digestibility of key nutrients such as lysine. Federal law in US and Canadian prohibits renders in accepting and processing of animals infected with specific diseases such as BSE and AI. Typical composition of PBM, MBM and FM are listed in Table 1. PBM is similar to FM in composition except being slightly lower in some amino acids. Meat and bone meal is somewhat lower in some amino acids content, and higher in mineral, as compared with FM. Significant variations on composition of these protein meals have been frequently reported, and could be largely due to variability in raw material composition and quality.

Table 1. Proximate and amino acids composition of MBM, PBM and FM

	MBM[1]	PBM[2]	FM[3]
Crude protein %	50	58 – 65	64.6
Crude fat %	10	12	7.9
Calcium %	8.8	4	3.93
Phosphorus %	4	2	2.55
Ash	25 – 35	10 – 18	16
Gross energy (Kcal/kg)	3850	4900	4500
Arginine	3.25	3.94	3.68
Histidine	.84	1.25	1.56
Isoleucine	1.55	2.01	3.06
Leucine	2.99	3.89	5
Lysine	2.6	3.32	5.11
Methionine	.63	1.11	1.95
Phenylalanine	1.63	2.26	2.66
Threonine	1.75	2.18	2.82
Tryptophan	.28	.48	.76
Valine	2.16	2.51	3.51
Crystine	.41	.66	.61
Tyrosine	1.34	1.56	2.15

[1]Meat & bone meal

[2]Poultry byproduct meal

[3]Fish meal

Protein and Energy Digestibility

Protein (PD) and energy (ED) digestibility of PBM, MBM, and FM are given in Table 2. Fish meal and PBM are generally highly digestible in protein (>88%) and energy (> 80%), while MBM is reported to be about ten percentages lower in PD and ED than that of FM. Digestibility reported with shrimp are scarce and are equal in PD as found in fish but are about five percentages lower in ED, compared with data obtained from fish.

Table 2. Apparent protein and energy digestibility of meat and bone meal, poultry byproduct meal and fish meal by fish and shrimp

	MBM[1]	PBM[2]	FM[3]
Fish [4]			
Protein Dig. %	83	88	90
Energy Dig. %	73	82	86
Shrimp[5]			
Protein Dig. %	82	90	91
Energy Dig. %	69	76	81

[1]Meat & bone meal

[2]Poultry byproduct meal

[3]Fish meal

[4]Literature value from trout, salmon, Japanese seabass and striped bass.

[5]Literature value from P. monodon and *L. vannamei*

These digestibility values suggest that PBM could be used in aquafeeds to a level similar to FM, but the use of MBM may need to be limited for water quality consideration.

Amino Acids Digestibility

Amino acids (AA) digestibility data of MBM, PBM, and FM measured from fish (trout, silver perch, rockfish, gilthead seabream) and shrimp are listed in Table 3. The relative ranking in AA digestibility of the three animal protein meals is similar to that for crude protein. Again, caution should be exercised when using relatively high levels (> 10%) of MBM in aqua feeds, unless the diet is supplemented with crystalline amino acids such as lysine and methionine. Literature provides no reliable digestibility data of PBM measured from shrimp.

Table 3. Apparent essential amino acids digestibility of meat and bone meal (MBM), poultry byproduct meal (PBM) and fish meal (FM) by fish and shrimp

	Apparent digestibility (%)											
	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val	Cys	Tyr
Fish												
MBM[1]	81	87.5	80.7	85.7	86.3	89.6	83.6	85.5	71.	81.5	66.5	88.6
PBM[2]	88.7	86.7	83.5	85.8	89	92.6	84.3	87.1	97	83.9	78	87
FM[3]	92.6	91.8	90.8	94.7	93.3	94.6	91.7	93	74.5	93.4	88	94
Shrimp												
MBM[4]	44.9	59.3	56.4	55.1	61.6	64.3	55.9	51.7		53.3	35	74.3
PBM												
FM	93.1	92.8	90.2	90.5	94.8	92.7	90.1	91	-	90.5	85.1	100

1. Average value from trout (Bureau, 1998), silver perch (Allan etal. 2000), and rockfish (Lee, 2002)
2. Average value form trout (Hardy and Cheng 2002) silver perch (Allan etal. 2000), and gilthead seabream (Lupatsch etal. 1997)
3. Average value from trout (Hardy and Cheng, 2002), silver perch (Allan etal. 2000), and rockfish (Lee, 2002)
4. Smith, D. M. 1995

Digestible amino acids (DAA) profile *vs.* requirements

Other than feeding trials, the comparison between digestible amino acids profile of a protein ingredients and the amino acids requirements (i.e. ideal protein) of the target species is the most effective tool in evaluating the usefulness of that particular ingredients, provided that data on amino acid composition and digestibility are reliable and accurate. Table 4 lists the digestible amino acids content in MBM, PBM and FM. Calculations were done for fish and shrimp by applying separate digestibility values. These digestible amino acids profile (Table 4) are compared with the requirements of tilapia, trout, and shrimp (Table 5). Both MBM and PBM have similar limiting DAA for tilapia (Ile, Thr, Trp, Met + Cys), with tryptophan being the most limiting DAA.

Table 4. Digestible amino acids content in meat and bone meal, poultry byproduct meal, and fish meal

	Meat & bone meal		Poultry Byproduct meal	Fish meal	
Digestible amino acids	Fish	Shrimp	Fish & shrimp	Fish	Shrimp
Arginine	2.63[1] (6.3)[2]	1.56 (3.75)	3.5 (6.14)	3.41 (6)	3.43 (6.04)
Histidine	.74 (1.8)	.53 (1.27)	1.08 (1.9)	1.43 (2.5)	1.45 (2.55)
Isoleucine	1.25 (3)	.93 (2.24)	1.68 (3)	2.78 (4.9)	2.76 (4.86)
Leucine	2.56 (6.2)	1.76 (4.23)	3.34 (5.9)	4.74 (8.3)	4.53 (7.97)
Lysine	2.24 (5.4)	1.74 (4.1)	2.96 (5.2)	4.77 (8.4)	4.84 (8.52)
Methionine	.56 (1.35)	.44 (1.06)	1.03 (1.8)	1.85 (3.2)	1.81 (3.18)
Phenylalanine	1.36 (3.27)	.97 (2.33)	1.91 (3.4)	2.44 (4.3)	2.4 (4.2)
Threonine	1.5 (3.6)	.97 (2.33)	1.9 (3.3)	3.03 (5.3)	2.57 (4.52)
Trytophan	.2 (.48)		.47 (.8)	.57 (1)	
Valine	1.76 (4.23)	1.23 (2.96)	2.11 (3.7)	3.28 (5.8)	3.18 (5.6)
Cystine	.27 (.65)	.15 (.36)	.52 (.9)	.54 (1)	.52 (.92)
Tryosine	1.69 (2.86)	1.07 (2.57)	1.36 (2.4)	2.02 (3.5)	2.15 (3.78)

1. % as is basis
2. % of digestible protein

The imbalance in DAA would suggest that the maximum fish meal substitution rate in tilapia diet is 50% for MBM and 80% for PBM. Similar comparison for trout reveals that both MBM and PBM can meet the DAA requirement to a very high level (80 to 100%). However, due to relatively low digestibility values measured with shrimp, the maximum FM replacement rate for MBM in shrimp diets is only 40% and 75% for PBM. The most limiting DAAs for shrimp were methionine plus cystine. Value presented for shrimp are for reference only since amino acid digestibility values are scarce and variable. More data are needed in this area.

Growth response from fish meal substitution by meat and bone meal and poultry byproduct meal

White Shrimp (L. *vannamei*)

Weight gain response of white shrimp to FM protein substitution with MBM is shown in Fig. 1. Contrary to the calculated maximum substitution rate based on limiting DAA (Table 5), white shrimp can maintain a highly satisfactory weight gain (i.e. ~ 90% of FM control diet) at 100% FM substitution. This discrepancy is probably due to under estimation of AA digestibility of MBM in shrimp. When weight gain response was plotted against the actual inclusion rate of FM (Fig. 2), it appears that white shrimp can grow fairly well with a FM inclusion rate as low as 10- 20 %, plus about 20% inclusion rate of MBM in the diet. However, high level of FM replacement with MBM generally resulted in a three to five percentages loss in feed efficiency (Fig. 3). Literature data indicate that FM substitution with MBM has no significant effect on mortality, carcass composition, and taste characteristics.

Fig. 1. **Weight gain** response of white shrimp to fish meal substitution with Meat and Bone Meal (% Fish meal protein replacement)

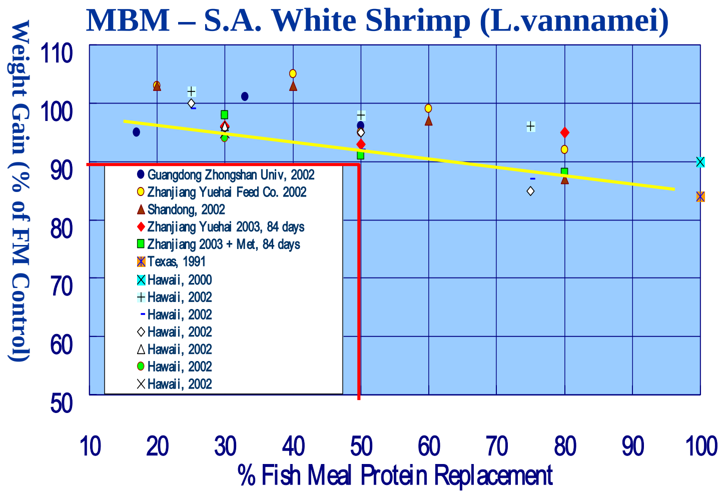


Fig. 2. **Weight gain** response of white shrimp to fish meal substitution with Meat and Bone Meal (% Fish meal protein replacement)

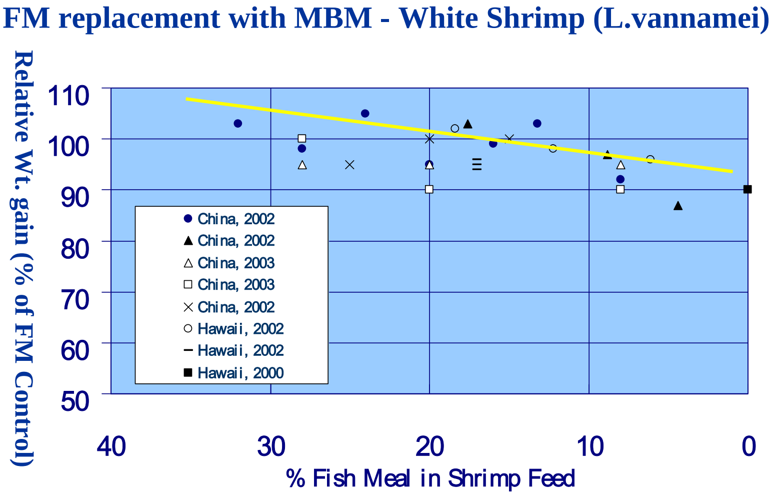


Fig. 3. **Feed efficiency** response of white shrimp to fish meal substitution with Meat and Bone Meal (% Fish meal in shrimp feeds)

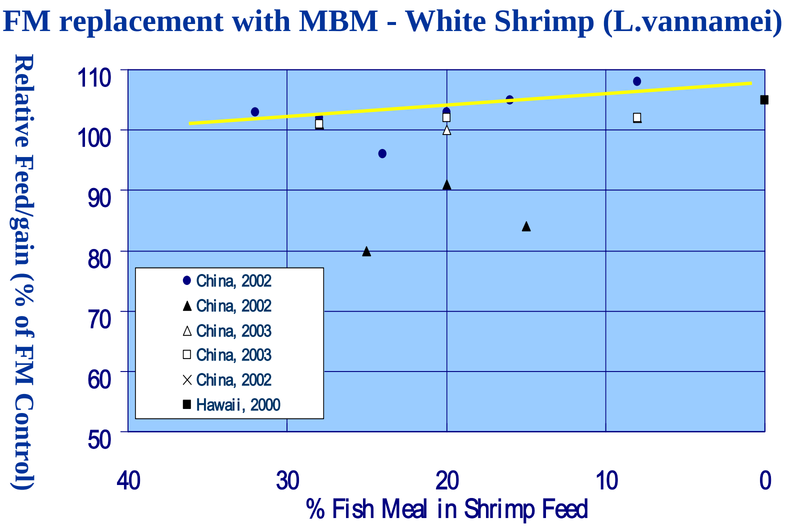


Table 5. A comparison between digestible amino acids content of meat and bone meal and poultry byproduct meal, and the requirement of tilapia and shrimp

Amino	Tilapia			Trout			Shrimp		
Acids	Tilapia	MBM	PBM	Trout	MBM	PBM	Shrimp	MBM	PBM
Arg	4.1	6.3	6.1	4.2	6.3	6.1	5.5	3.75	6.1
His	1.7	1.8	1.9	1.6	1.8	1.9	2.1	1.27	1.9
Ile	3.1	3	3	2	3	3	3.4	2.24	3
Leu	3.4	6.2	5.9	3.6	6.2	5.9	5.4	4.23	5.9
Lys	4.6	5.4	5.2	4.8	5.4	5.2	4.8	4.1	5.2
Thr	3.8	3.6	3.3	2	3.6	3.3	3.6	2.33	3.3
Trp	1.0	.48 (48%)	.8 (80%)	.6	.48 (80%)	.8	.8	-	.8
Val	2.8	4.23	3.7	2.2	4.23	3.7	4	2.96	3.7
Met + Cys	3.2	2	2.7	2.4	2	2.7	3.6	1.42 (39%)	2.7 (75%)
Phe + Tyr	5.6	6.13	5.8	5.3	6.13	5.8	7.1	4.9	5.8

Amino acid with an underlined value is considered deficient in meeting the requirement, and number inside parenthesis is the percentage in meeting the requirement.

Results of fish meal substitution with PBM in terms of weight gain are shown in Fig. 4. Weight gain response is variable among different grades of PBM and is likely related to the low ash and flash dried PBM are equal to FM in supporting weight gain while pet food grade and feed grade PBM have a mild negative effect on shrimp weight gain (Fig. 5, 6, 7). When used in combination with PBM, FM inclusion rate could be reduced to about 10%.

Fig. 4. **Weight gain** response of white shrimp to fish meal substitution with Poultry byproduct Meal (% Fish meal protein replacement)

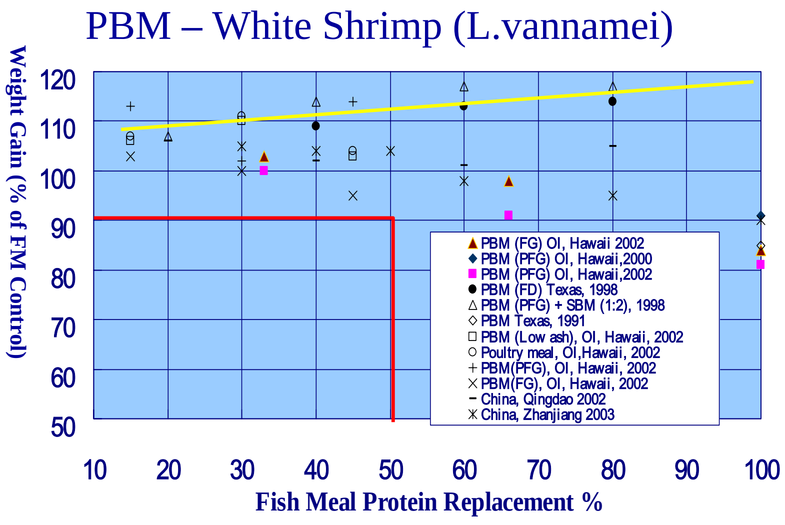


Fig. 5. **Weight gain** response of white shrimp to fish meal substitution with Low Ash Poultry Byproduct Meal (% Fish meal in shrimp feed)

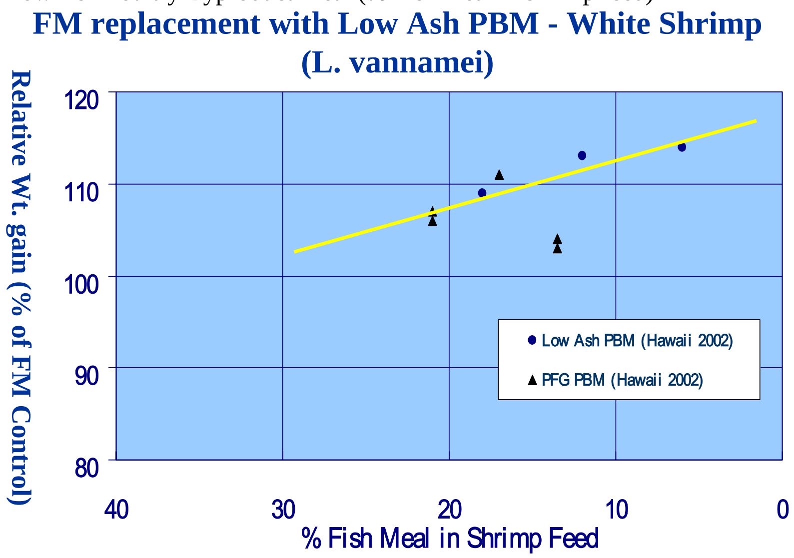


Fig. 6. **Weight gain** response of white shrimp to fish meal substitution with Pet Food Grade Poultry Byproduct Meal (% Fish meal in shrimp feeds)

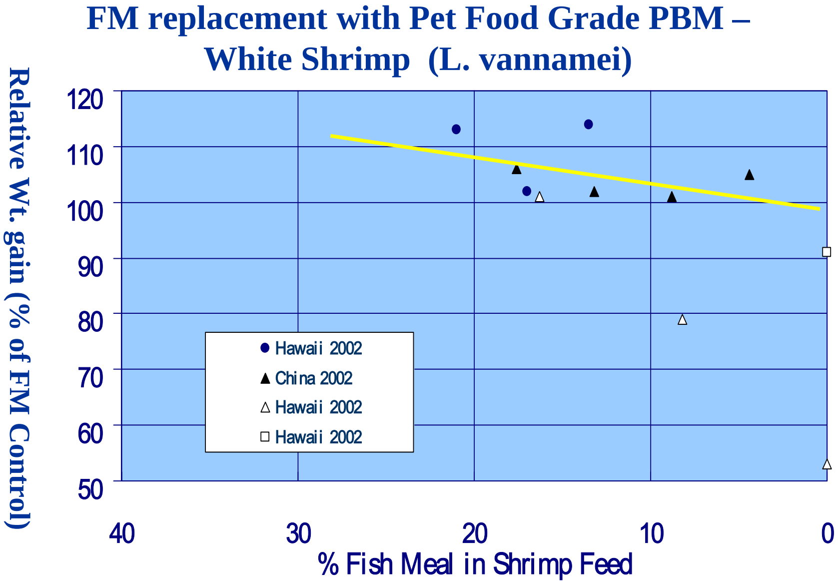
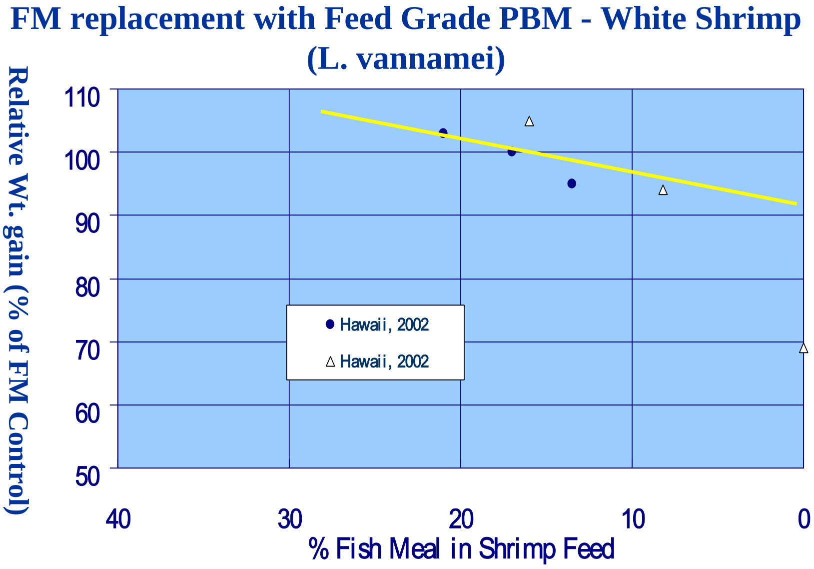
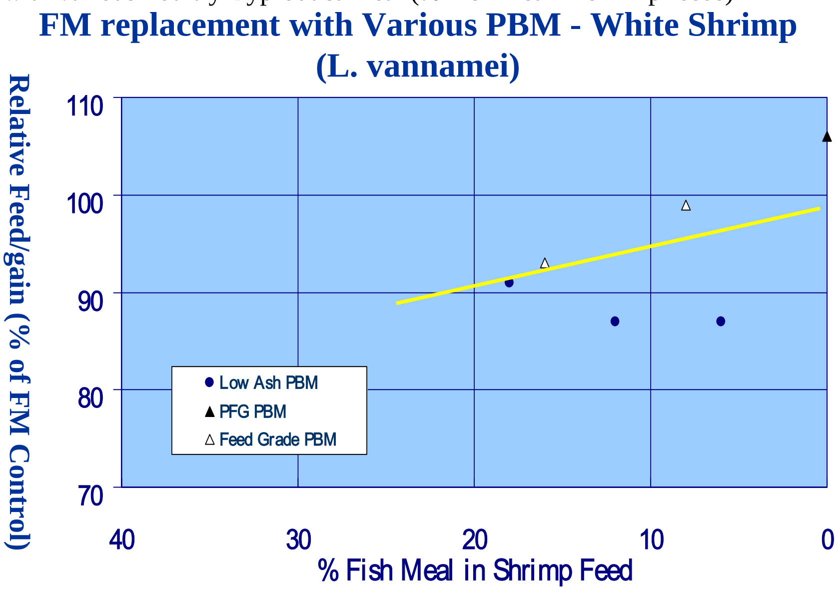


Fig. 7. **Weight gain** response of white shrimp to fish meal substitution with Feed Grade Poultry Byproduct Meal (% Fish meal in shrimp feeds)



Response in feed utilization was similar to that of weight gain (Fig. 8). Low ash and flash dried PBM actually improved the feed utilization compared with FM, but opposite was true for PFG or FG PBM with an average loss of about five percentages. Similar to the findings of MBM, substitution of FM with PBM did not affect mortality rate, carcass composition, or taste characteristics.

Fig. 8. **Feed Efficiency** response of white shrimp to fish meal substitution with various Poultry Byproduct Meal (% Fish meal in shrimp feeds)



Tilapia

Tilapia is generally considered as a omnivorous species and therefore does not require a high inclusion rate of FM or animal protein meal in the diet. Meat and bone meal can replace FM in tilapia diet up to 100% with an eight percentage loss in weight gain as compared with FM control (Fig. 9). Again, this disagrees with DAA calculation from Table 5. Factors other than DAA obviously can affect the growth performance of tilapia. However, the use of MBM at high rates will likely result in a loss of five percentages in feed utilization (Fig. 10). Studies done with PBM substitution for FM indicated no effect on weight gain of tilapia even at high levels of substitution (Fig. 11). Very limited data would suggest that feed efficiency will be negatively affected (~ 5%) by the PBM substitution (Fig. 12).

Fig. 9. **Weight gain** response of tilapia to fish meal substitution with meat and bone meal (% Fish meal in tilapia feeds)

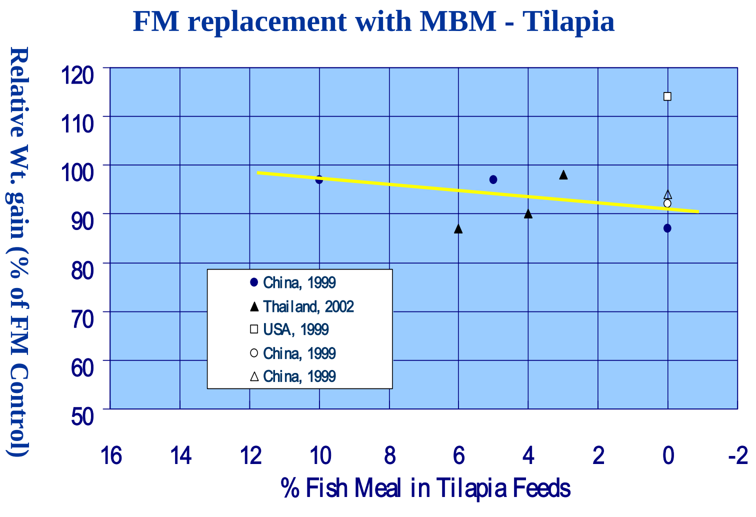


Fig. 10. **Feed efficiency** response of tilapia to fish meal substitution with meat and bone meal (% Fish meal in tilapia feeds)

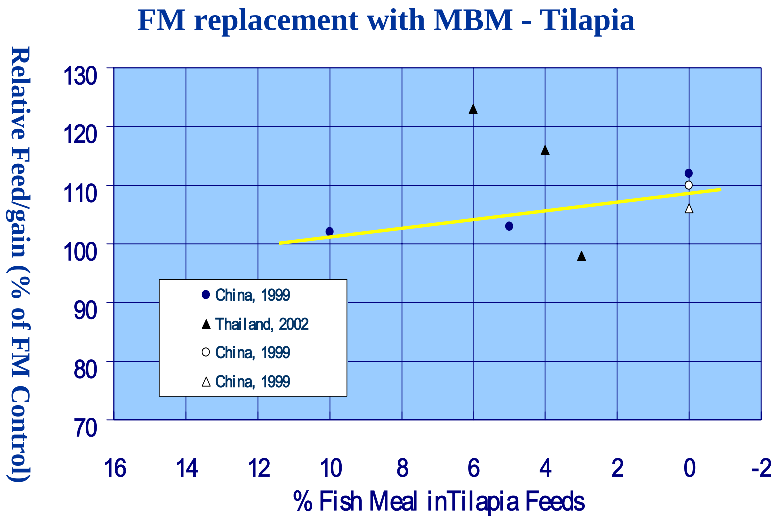


Fig. 11. **Weight gain** response of tilapia to fish meal substitution with Poultry Byproduct Meal (% Fish meal in tilapia feeds)

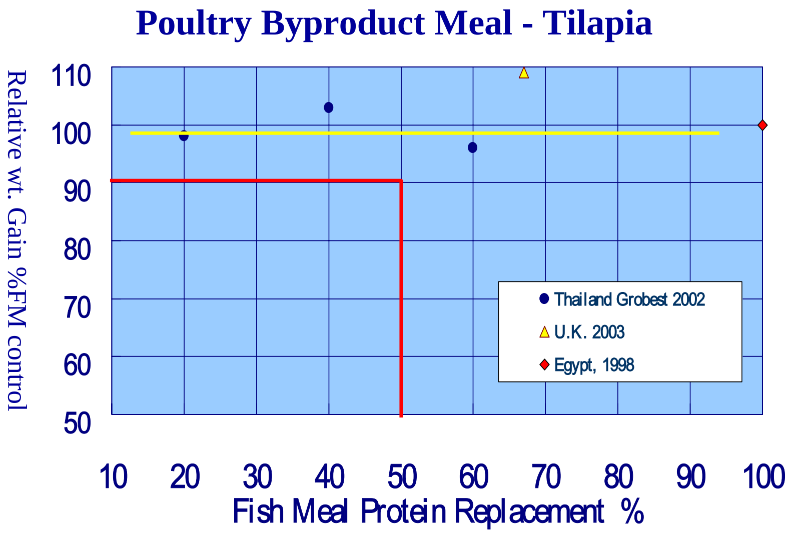
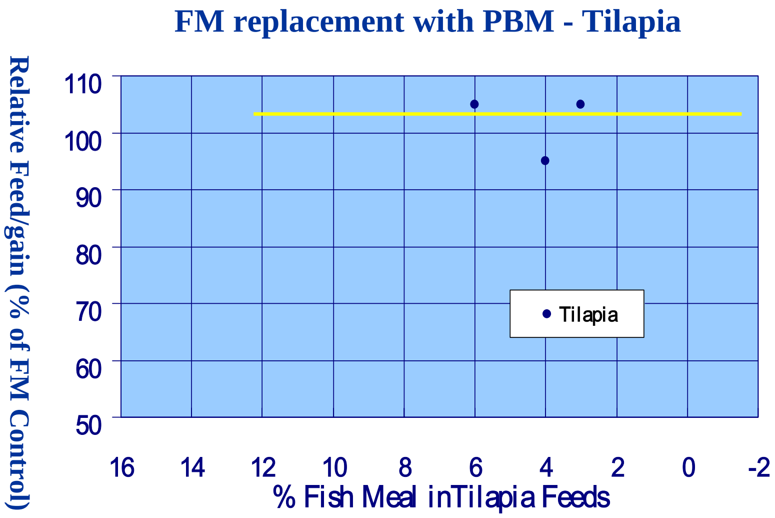


Fig. 12. **Feed efficiency** response of tilapia to fish meal substitution with Poultry Byproduct Meal (% Fish meal in tilapia feeds)



Trout

Weight gain response to replacement of FM with MBM and PBM is shown in Fig. 13 and 14.

Rate of fish meal substitution with MBM higher than 75% appears to cause noticeable decline in weight gain, which is also suggested from the DAA calculation (Table 5). However, high quality PBM can replace FM totally in trout feed without harming the performance provided crystalline lysine and methionine are supplemented to meet the requirements.

Fig. 13. **Weight gain** response of trout to fish meal substitution with meat and bone meal (% Fish meal in trout feeds)

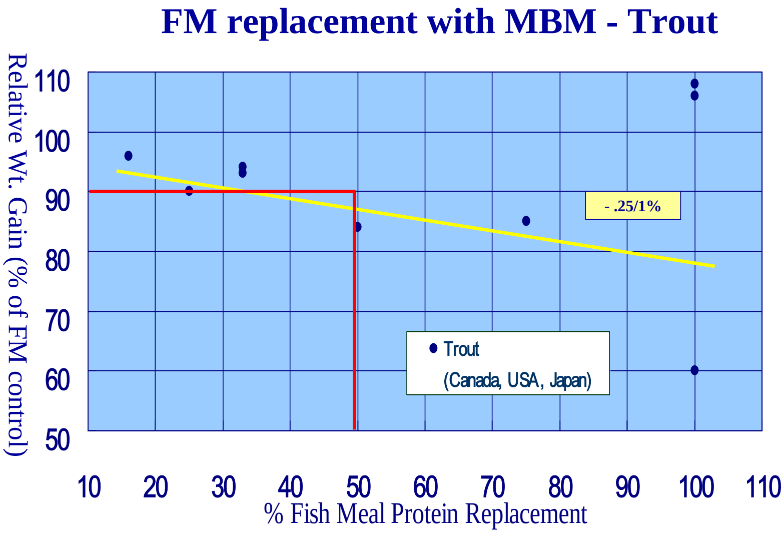
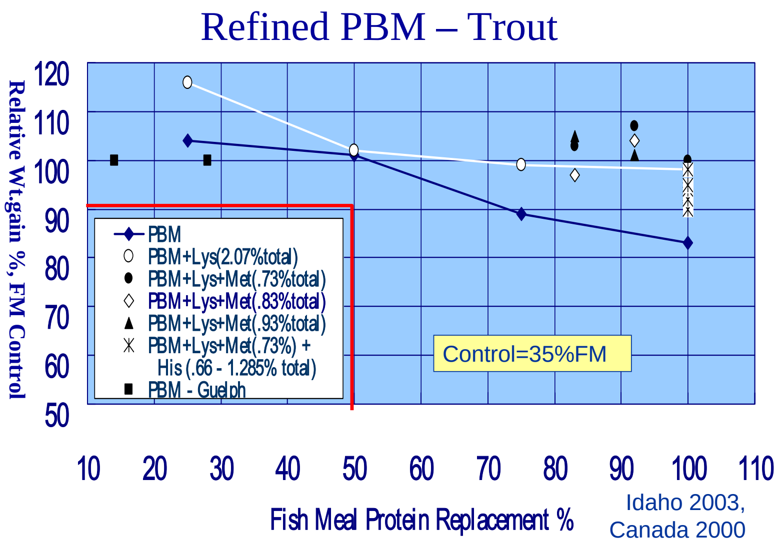


Fig. 14. **Weight gain** response of trout to fish meal substitution with Poultry Byproduct Meal (% Fish meal in trout feeds)



Recommended Rates of Substitution

The optimum FM replacement rate and dietary inclusion rate of MBM and PBM in shrimp, tilapia and trout diets are given in Table 6. These values are derived mainly from the findings of growth trials. At high rates of substitution, feed nutritionists should examine the amino acid balance, and consider the supplementation of synthetic amino acids if needed. Under the normal price relationship between FM, MBM, and PBM, substitution of FM with either MBM or PBM should substantially reduce the demand for FM and also the cost of feed and weight gain.

Table 6. Recommended fish meal protein replacement rate, and dietary inclusion rate of meat and bone meal and poultry byproduct meal in tilapia, trout and shrimp diet

	Optimum replacement Rate for FM[1]	Optimum dietary inclusion rate
	%	%
Tilapia		
MBM	60	6
PBM	80	8
Trout		
MBM	50	20
PBM	80	25
Shrimp (*L. vannamei*)		
MBM	50	15 – 20
PBM	70	18 – 25

Conclusions

Poultry byproduct meal has a nutritional composition and feeding value similar to that of fish meal for shrimp, tilapia and trout. Feed utilization may be reduced slightly (~5%) at high use rates. Meat and bone meal has a somewhat lower feeding value than PBM due to deficiency in amino acids content and digestibility. The optimum of FM replacement rate for MBM is about 50% for shrimp or trout, and 60% for tilapia. At high rates of substitution, amino acid balance and supplementation must be carefully examined. Diets should be formulated with adequate level of essential fatty acids, regardless the source of protein ingredient.

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