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Survey of the nutrient composition of meat meals and meat co-products with respect to their use as ingredients in aquaculture feeds

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CONTENTS

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EXECUTIVE SUMMARY

A survey has been carried out to determine the biochemical composition and hence the suitability of Australian meat meals for use in aquaculture diets, particularly in prawn diets. Twenty five renderers from 6 states supplied a total of twenty seven samples of meat meal and one sample of tallow for analysis.

Meat meal has the potential to be used as a major component in aquaculture diets for fish and prawns to replace or partially replace fishmeal (Williams et al., 1997). The aquaculture feed market could offer an outlet for tens of thousands of tonnes of Australian meat meal if feed manufacturing companies were to adopt recent research findings. However, the feed manufacturers are likely to specify maximum or minimum levels of some of the parameters that have been measured so that the required proportion of meat meal can be included in the diet formulation without compromising other dietary specifications.

There was great variation in the ash, crude protein and total lipid (fat) between the meat meals. To be used to the fullest extent as an ingredient in aquaculture feeds, a meat meal would have a low ash (< 20%), low fat (< 8%) and high crude protein (> 60%) content. The closer a meat meal approaches the above specifications the more likely it is to be included in a prawn feed formulation and the more of it that can be included in the diet. Though none of the meat meals analysed met these 'ideal' specifications, a number did approach them, while others could only be used at relatively low inclusion levels. To illustrate this point, a number of diets have been formulated with varying amounts of either of four hypothetical meat meals in which the ash content varied between 20 and 35% and the total lipid varied between 8 and 14%.

The cholesterol content of the meat meals was generally lower than anticipated and generally lower than found in fishmeal but substantially higher than in plant protein sources. The consequence of this is that where meat meal is used to replace fish meal in a diet formulation, there will be a corresponding reduction in dietary cholesterol that will need to be replaced with a supplementary source.

It will be difficult, if not impossible, for some renderers to produce a meat meal that meets the 'ideal' specifications for an aquaculture grade meat meal. However, it is important that they recognise the needs of the aquaculture feeds industry and the factors that limit the use of their particular meat meal. Even if a meat meal does not come close to the 'ideal' specifications, it can still be used in aquaculture feeds, albeit at lower inclusion levels. The meat meal might less expensive because of its high ash or fat content, but will be limited in its use in certain diet formulations. A key factor in establishing a supply link to a feed manufacturer is consistency of product. The feed manufacturer is far more likely to use a meat meal if assured that future consignments from that renderer will be of very similar proximate composition and quality.

BACKGROUND

In 1997, the world capture fisheries yielded 94.5 million tonnes of 'seafood' product (Tacon and Dominy, 1999). There has been little growth in these fisheries (0.2% since 1996 and only 1.5%/year since 1984) and this is unlikely to change. In contrast, aquaculture has been the fastest growing food production sector for more than a decade. However, the growth in the aquaculture production has been dependent on fishmeal derived from the capture fisheries.

Currently fishmeal is a major component of aquaculture diets where it constitutes between 25 and 50% of most diets and is the major protein source. The global fishmeal production in 1997 was about 6.2 million tonnes of which about 37% were used in aquaculture feeds (Tacon and Dominy, 1999). In 1998, the El Nino effect on fish stocks resulted in a decrease in fishmeal production to 4.74 million tonnes, leading to a 25% increase in the cost of fishmeal. There continues to be a worldwide increased demand for fishmeal, particularly for the high quality fishmeals used in aquaculture feeds. In 1997, 1.45 million tonnes of feed were used in

the production of 942,000 tonnes of farmed prawns (Tacon and Dominy, 1999), with most of the production occurring in the east and south-east Asian region.

The need to replace fishmeal in aquaculture diets is recognised internationally as a high research priority. There are marketing opportunities for protein-rich feed ingredients that can be shown to be viable alternatives to fishmeal in aquaculture feeds. Meat meal has the potential to be used as a major component in aquaculture diets for fish and prawns to replace or partially replace fishmeal (Williams et al., 1997). The aquaculture feed market could offer an outlet for tens of thousands of tonnes of Australian meat meal if feed manufacturing companies were to adopt recent research findings. However, the feed manufacturing and prawn farming industries need to be convinced of the cost-effectiveness of using meat meal in the diets in a commercial production environment. They will also have to be satisfied that the meat meal diets will not create markedly more waste in their ponds than is currently produced from conventional diets. Finally, they will have to assess the risk of any negative effect associated with market perceptions of bovine spongiform encephalopathy (BSE) arising from prawns fed diets containing meat meal.

INTRODUCTION

Research funded by the Meat Research Corporation and carried out within the FRDC Fishmeal Replacement Sub-program indicated that meat and bone meals (meat meals) can be used as a partial replacement for fishmeal in commercial prawn diets (Smith, 1995, 1997, 1999). Previous research using both aquarium tanks and cages deployed in a small prawn pond, demonstrated that meat meal could be effectively used at an inclusion of 300 g/kg of diet, provided that the remaining protein was of good quality and of marine origin (Smith, 1997). The apparent digestibility of dry matter, protein and energy in meat meals was found to be lower than that of fishmeals with *P. monodon* (Smith, 1995) and with the white shrimp, *P. setiferus* (Brunson et al. 1997). The lower digestibility of meat meal is likely to be mainly due to its higher ash content and to poor digestion of the protein in the bone particles. This suggests that where a significant proportion of dietary fishmeal is replaced with meat meal there will be an increase in faecal waste.

The meat meal used by Smith (1999) had high crude protein (59%) and low fat (10.9%) and ash (21.2%) contents. Because of these specifications, it could be used in the diet formulation at 300 g/kg without increasing the amount of dietary ash above an arbitrary limit of 15%. It could also be used at a high dietary inclusion with minimal disturbance to the fatty acid profile of the diets, that otherwise occurs with higher fat meat meals. The arbitrary limit of 15% ash was based on the effect of ash on water stability of the feed pellets and wear of the dies in the steam pellet press used in the commercial manufacture of feed pellets. It is unlikely that a dietary ash content of >15% would be considered acceptable by manufacturers using a steam pellet press.

To include a feed ingredient in a diet formulation, the nutrient composition of the ingredient must be known. The essential information is the dry matter (or moisture), crude protein, total lipid (or crude fat) and ash. Additional data on gross energy, cholesterol and phospholipid content are very useful to the feed formulator and can enable significant savings to be made in the cost of the diet. In this survey we have analysed 27 meat meal samples and one sample of tallow to quantify the above nutrients.

MATERIALS AND METHODS

Participating renderers

An initial invitation to Australian renderers to participate in this survey was made by Mr Denis Roberts of Venturetech Pty Ltd. acting on behalf of Meat & Livestock Australia. Twenty five companies (Table 1) supplied a total of twenty seven samples of meat meal and one sample of tallow for analysis.

Table 1. Companies that provided samples for analysis in the survey

Agpro By-products	Peerless Holdings Pty Ltd
Australia Meat Holdings Pty Ltd	Queensland Abattoir Corporation
Bindaree Beef Pty Ltd	Scone Fresh Meats Pty Ltd
Cargill Foods Australia	South Burnett Meatworks Co-op Assoc
Cowra Rendering Pty Ltd	Southern Meats Pty Ltd
Devonport City Abattoir	Sunland Meats Pty Ltd
Fletcher International Exports	Talloman
Geraldton Meat Exports Pty Ltd	Tatiara Meat Company
Harvey By-products	V & V Walsh Pty Ltd
Kilcoy Pastoral Company Limited	Vodusek Meats
Mudgee Regional Abattoir	Warrnambool Stockfeeds Pty Ltd
Nolan Meats Pty Ltd	Wodonga Rendering Pty Ltd
Northern Coop. Meat Company Ltd	

Chemical analyses

All samples were ground in a laboratory hammer mill, passed through a 1.00 mm mesh sieve and then thoroughly mixed before sub-samples were taken for analysis. While awaiting analysis the samples were stored at -20°C.

Dry matter and ash:

Dry matter content was determined from replicate samples of ~1 g. The samples were weighed into pre-baked (550°C) and pre-weighted crucibles with the weights being measured to ±0.0001 g. The samples were heated at 105°C in a fan-forced oven overnight. On removal from the oven, they were placed in a vacuum desiccator and left to cool to room temperature for one hour. They were then re-weighed to ±0.0001 g immediately after the vacuum in the desiccator had been released.

To determine the ash content, the dried samples and crucibles were placed in a muffle furnace and the temperature raised to 200°C for 2 hours then increased 550°C for 14 hours. The muffle furnace was then turned off and the samples allowed to cool inside the furnace until the temperature had reached approximately 100°C. The crucibles were removed from the furnace and allowed to cool to room temperature in a vacuum desiccator before weighing to ±0.0001 g.

Gross energy:

Gross energy was determined from a pelleted sample of meat meal (~1.0g) weighed to ±0.0001 g. The gross energy was determined by isothermal bomb calorimetry using a Leco AC200 Bomb Calorimeter that was calibrated using AR grade benzoic acid.

Crude protein:

Crude protein was determined as 6.25 x Total nitrogen. Samples of meat meal (~400mg) were weighed to ±0.0001 g, wrapped in nitrogen free paper and pelleted prior to analysis. Total nitrogen was determined by a combustion method (Sweeney, 1989) using an ELEMENTAR RapidN analyser. The instrument was calibrated using AR grade aspartic acid.

Total lipid:

Duplicate samples of ~5 g of the dried and finely ground meat meal was weighed to ±0.0001 g into a flask. A volume of distilled water was added to it that was equal to 4 times the mass of sample. The sample was allowed to rehydrate for 5 min before the addition of chloroform/methanol (2:1). The extraction with chloroform/methanol was carried out using the method of Bligh and Dyer (1959). The mass of lipid extracted from the samples (between 0.5 and 1.0 g) was weighed to ±0.0001 g.

Cholesterol:

A sample of ~2 g, weighed to ±0.0001 g, was saponified in a screw-capped test tube using 0.5mL 5O% w/v KOH and 2mL Ethanol (95%) at 80^{o}C with stirring for 1h (Kovacs, et al. 1979). On cooling, the cholesterol was extracted with hexane and made up volumetrically to 5 mL. An aliquot (0.5 to 1.5 mL) of the cholesterol extract and of the internal standard, cholestane, were combined and made to volume.

The analysis was carried out using an HP5890 capillary gas chromatograph (GC). The GC was fitted with a direct on-column injection port, an HP1 (non polar) column 50m x 0.2mm with retention gap (1m x 0.5mm), and a flame ionisation detector. A 0.15 µL sample was injected onto the column with hydrogen as the carrier gas. Separation was achieved with a

temperature program going from 90°C to 250°C at 15°C/min, then 250°C to 300°C at 4°C/min and finally held at 300°C for 7 min. Chromatographic data was collected and integrated using Waters Millenium software. The cholesterol content of the sample was quantified using a previously established response curve. Peak areas that were out of the range of the response curve were reanalysed using a more or less sample relative to the internal standard.

Phospholipids:

Phospholipids were determined from the chloroform/methanol (2:1) extracts taken to determine total lipid content of meat meal samples. The phospholipids were separated using a Waters HPLC system fitted with an evaporative light scattering detector (ELSD, Alltech). An Alltech Adsorbosphere HS Silica 3µ 100x4.6mm column was used with a solvent gradient system involving two solvents each comprising different proportions of isopropyl alcohol, hexane and water (Alltech Application Note #E0024). The ELSD was set with the drift tube temperature at 75°C and the gas flow rate of 2.1 L/min. Chromatographic data was collected using Waters Millenium software and the phospholipids were quantified from previously determined response curves. The content of all phospholipids identified have been quantified and combined to give the total phospholipid content of the sample. The phosphatidylcholine content of the samples has also been reported as it is the most abundant phospholipid in the samples.

Fatty acids:

Fatty acids were derivatised to their methyl esters (FAME) by the method of Van Wijngaarden (1967) and separated by capillary gas chromatography using split injection and helium carrier gas on a DB-23, 30m x 0.25mm fused silica column with a 0.25µm coating (J & W Scientific, Folsom, CA, USA). Column temperature was held at 140°C for 5 minutes and then elevated at 3°C/minute to 210°C where it was held until all FAME of interest had been eluted. FAME were quantified by comparison with the response of an internal standard (heneicosanoic acid). FAME were identified by comparing their retention times with those of authentic standards (Sigma Chemical Company, St Louis, MO, USA).

RESULTS

In reporting the results of the survey, samples have only been identified using a code number. Renderers will be advised individually as to what code number was allocated to their sample(s). The dry matter, gross energy, ash, crude protein, total lipid, total phospholipid, phosphatidylcholine and cholesterol contents of all the meat meals were determined (Table 2). A sample of tallow was also analysed and found to contain 0.236% cholesterol and no phospholipids.

The fatty acid content of each meat meal was determined and is reported in detail in Appendix A. However, to simplify this data, the most important fatty acids and groupings of fatty acids (i.e. the total saturated fatty acids (SFA), the total mono-unsaturated fatty acids (MUFA) and the sum of all fatty acids (Total)) are summarised in Table 3.

Table 2. Proximate, phospholipid and cholesterol composition (dry matter basis) of meat meal samples. (Total PL = Total phospholipid, PC = Phosphatidylcholine).

Ident No.	Dry Matter	Gross Energy	Ash	Crude Protein	Total Lipid	Total PL	PC	Cholesterol
	% sample	MJ/kg	%	%	%	%	%	%
111	97.8	18.0	29.3	54.2	13.6	0.59	0.36	0.157
112	96.0	18.3	25.3	64.3	9.7	0.67	0.40	0.160
113	96.3	16.7	32.0	55.2	8.4	0.58	0.37	0.146
114	96.6	18.1	27.1	58.6	12.0	1.01	0.54	0.209
115	97.2	16.6	33.3	58.1	8.7	0.75	0.46	0.109
116	97.9	19.3	21.8	65.2	10.4	0.90	0.57	0.160
117	94.4	17.2	31.3	58.3	10.6	0.81	0.49	0.107
119	96.9	15.6	37.2	53.2	8.3	0.59	0.37	0.177
120	97.5	16.1	35.8	50.1	12.6	0.48	0.32	0.121
121	93.0	16.4	33.9	54.1	10.2	0.94	0.55	0.132
122	95.9	17.1	31.7	58.0	8.9	0.42	0.28	0.208
123	94.0	23.2	14.6	59.1	19.7	1.70	1.07	0.487
124	95.8	18.1	27.1	61.9	10.8	0.68	0.42	0.105
125	97.9	19.6	23.0	63.1	12.7	0.88	0.52	0.140
126	94.5	17.2	32.4	57.1	11.3	0.65	0.40	0.098
127	94.3	20.4	20.0	47.2	15.1	0.79	0.47	0.171
128	95.0	15.7	35.5	51.9	10.1	0.62	0.40	0.066
129	98.0	18.5	25.4	62.3	9.5	0.82	0.49	0.166
130	97.0	17.4	30.4	56.5	10.8	0.63	0.38	0.145
131	96.4	19.7	22.8	59.9	13.5	0.72	0.43	0.188
132	97.0	15.6	35.4	54.8	9.5	0.72	0.44	0.110
133	94.7	22.9	11.2	76.4	13.7	1.84	1.29	0.416
134	94.7	19.1	26.5	58.4	11.1	0.89	0.60	0.205
135	96.3	17.5	30.9	53.4	11.7	0.40	0.25	0.145
136	93.6	20.8	22.6	57.2	17.7	0.59	0.35	0.287
137	97.5	18.6	27.6	58.4	13.0	0.63	0.38	0.114
138	96.0	15.1	37.4	52.2	8.6	0.52	0.34	0.091
Maximum	98.0	23.2	37.4	76.4	19.7	1.84	1.29	0.49
Minimum	93.0	15.1	11.2	47.2	8.3	0.40	0.5	0.07
Average	96.0	18.1	28.2	57.7	11.6	0.78	0.48	0.17
Std dev	1.5	2.1	6.7	5.7	2.8	0.33	0.23	0.10

Table 3. Summary of fatty acid data; results expressed as g of fatty acid/100g of meat meal on a dry matter basis. (SFA = sum of saturated fatty acids; MUFA = sum of mono-unsaturated fatty acids; Total = sum of all fatty acids identified in the sample).

Ident. No.	16:0	18:0	18:1n-9	18:2n-6	SFA	MUFA	Total
111	2.44	2.58	3.46	0.21	5.54	3.72	9.53
112	1.86	1.59	2.61	0.11	3.81	2.92	6.92
113	1.77	1.45	2.44	0.11	3.50	2.68	6.29
114	2.08	2.19	2.93	0.22	4.73	3.18	8.20
115	1.45	1.82	2.10	0.15	3.58	2.16	5.89
116	1.76	2.17	2.37	0.19	4.32	2.53	7.10
117	2.07	1.59	3.07	0.20	4.06	3.39	7.65
119	1.60	1.26	2.30	0.11	3.12	2.57	5.80
120	2.40	2.25	3.31	0.17	5.13	3.63	8.99
121	1.97	1.69	2.68	0.18	4.12	2.99	7.35
122	1.74	1.34	2.51	0.13	3.40	2.79	6.32
123	3.51	3.12	4.65	0.35	7.51	5.14	13.08
124	2.16	1.53	3.19	0.11	4.11	3.67	7.89
125	2.12	2.59	3.12	0.24	5.19	3.24	8.75
126	2.22	1.53	3.35	0.34	4.14	3.81	8.34
127	2.83	2.58	3.85	0.41	6.00	4.26	10.79
128	1.97	1.52	2.75	0.15	3.91	3.08	7.15
129	1.68	1.78	2.29	0.15	3.82	2.49	6.55
130	1.98	1.94	2.81	0.15	4.32	3.07	7.58
131	2.41	2.18	3.59	0.46	4.98	4.00	9.57
132	1.84	1.41	2.57	0.14	3.68	2.90	6.80
133	2.00	2.10	3.21	0.30	4.50	3.42	8.36
134	1.73	1.91	2.74	0.17	4.05	2.95	7.21
135	1.90	2.18	2.90	0.19	4.53	3.08	7.86
136	3.08	2.07	4.70	0.63	5.63	5.38	11.75
137	2.09	2.25	3.21	0.19	4.77	3.50	8.51
138	1.67	1.47	2.55	0.13	3.47	2.82	6.42
Maximum	3.51	3.12	4.70	0.63	7.51	5.38	13.08
Minimum	1.45	1.26	2.10	0.11	3.12	2.16	5.80
Average	2.09	1.93	3.01	0.22	4.44	3.31	8.02
Std dev.	0.46	0.46	0.66	0.12	0.95	0.75	1.75

DISCUSSION

Analysis of meat meals

This survey has enabled a comparison of the meat meals produced by a wide range Australian renderers, to be made using identical analytical methods and hence allowing true comparisons to be made. To ensure standardisation between meat meals, the percentage of ash, crude protein and total lipid are reported on a dry matter basis rather than on an 'as supplied' basis. As a result, these figures will be about 5% higher than when expressed on an 'as supplied' basis. In addition, the total lipid content of the meat meals, which was determined using a chloroform/methanol extraction, has a higher estimate of 'fat' content than the soxhlet extraction method, which is more commonly used in the feed industry. However, the chloroform/methanol extraction recovers a greater percentage of phospholipids than the soxhlet extraction method. As this study has included analyses to determine the phopholipid content of the meat meals, it was more appropriate to use a chloroform/methanol extraction. The net effect is that total lipid values will appear even higher than most renderers would expect from their own analyses.

All the samples were well dried with an average dry matter content of 96.0 ± 1.5 (mean ± SD); the range being from 93.0% to 98.0% (Table 2). The average sum of ash, crude protein and total lipid, expressed on a dry matter basis, for 25 of the 27 samples was 98.3 ± 1.5 (mean ± SD). The composition of two of the meat meals has been difficult to resolve as the sum of ash, CP and total lipid was markedly different from that of the other samples, being 94% and 83%. Both samples were reanalysed by two independent laboratories with close agreement and the possibility of an inaccurate analysis eliminated. The results suggest that there has been a significant inclusion of fibre or carbohydrate in the meat meal, possibly coming from the contents of the rumen pouch.

Cholesterol is an essential nutrient for prawns and as such must be provided in their diet. The cholesterol content of the meat meals was generally low with the average content being 0.17% (range 0.07 to 0.49%) (Table 2). In contrast, the cholesterol content of two fishmeals that were analysed at the same time was 0.42% and 0.45% respectively while plant proteins meals,

such as lupin and soybean meals, do not contain cholesterol but contain phytosterols which are poorly utilised by crustaceans. The phospholipid content in all the meat meals is also relatively low, 0.78% ± 0.33 (mean ± SD) when compared to fishmeal which contains about 3% total phospholipid. Hence, where meat meals are used to replace fishmeal in aquaculture diets, there will be a net decrease in the dietary cholesterol and phospholipids without additional supplementation of these nutrients.

Utilisation of meat meals

The objective of this survey was to review Australian meat meals to assess their suitability for inclusion in aquaculture diets, particularly in prawn diets. For a meat meal to be used to the fullest extent as an ingredient in aquaculture feeds, it should have a low ash (< 20%), low fat (< 8%) and high crude protein (> 60%) content. Though none of the meat meals analysed meet these 'ideal' specifications, a number did approach them. As a comparison, a good quality Peruvian fishmeal, analysed with the techniques used in this survey, contained 18.9% ash, 11.6% total lipid and 72.5% crude protein on a dry matter basis. A lower percentage of total lipid is specified for meat meals because the endogenous fat (or tallow) consists mainly of saturated fatty acids (SFA) and mono-unsaturated fatty acids(MUFA). Meat meals contain only a very small percentage of the nutritionally essential polyunsaturated fatty acids (PUFA) and none of the essential highly unsaturated fatty acids (HUFA).

The closer a meat meal approaches the above specifications the more likely it is to be included in a prawn feed formulation and the more of it that can be included in the diet. Each feed manufacturer is likely to have certain specifications for the maximum amount of ash and total lipid in a prawn diet, typically 15% for ash and 8 to 9% for lipid. They may also have specifications that ensure that the balance of fatty acids does not deviate more than a certain amount from that found in marine oils. These specifications may be in the form of a maximum allowable amount of SFA and minimum amounts of the essential HUFA, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). To illustrate this point, diets have been formulated with a meat meal component at varying inclusion levels. The dietary digestible crude protein and total lipid content of the formulated diets have been fixed at 35% and 9% respectively. Several scenarios have been drawn (Figures 1, 2 and 3) using four

hypothetical meat meals (Table 4) in which the ash content varied between 20 and 35% and the total lipid varied between 8 and 14%. The fatty acid composition of meat meals (Table 4) has been derived from results of the analyses carried out in this survey and is related to the total lipid content.

Table 4. Composition of hypothetical meat meals (% on dry matter basis) used to illustrate the effect of including meat meal in a prawn diet. SFA = total saturated fatty acids; MUFA = total mono-unsaturated fatty acids; EPA = eicosapentaenoic acid.

Meat meal	Ash	Crude Protein	Total Lipid	SFA	MUFA	EPA
MM A	20	63	14	5.5	4.0	0.0
MM B	25	60	12	4.5	3.4	0.0
MM C	30	57	10	3.8	2.9	0.0
MM D	35	54	8	3.1	2.3	0.0

Where meat is included in a prawn diet to replace some of the fishmeal, while the digestible crude protein and total lipid are kept constant, the ash in the diet will increase with increasing inclusion of meat meal (Figure 1). The higher the ash content of the meat meal, the more rapid will be the increase in ash content of the diets. As feed manufacturers generally set a limit on the maximum amount of ash in the diets, usually about 15%, a meat meal will only be included up to the point where the ash content meets this limit. As a result, high ash meat meals will be used at relatively low inclusion levels, and low ash meat meals will be used at correspondingly higher levels. The cost of the meat meal is likely to be influenced by the amount of ash in it. It may be more cost effective for a feed manufacturer to use a slightly higher ash meat meal if the intention is to use only relatively low inclusions in the diet formulations. However, low ash meat meals will be more attractive as ingredients because they allow greater flexibility in the diet formulations and contribute less to wear in the pelleting equipment.

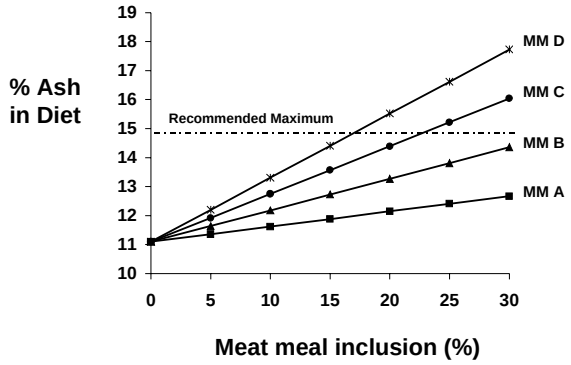

Figure 1. Changes in ash content of a prawn diet with increasing inclusion of four meat meals. Ash content of MM A = 20%, MM B = 25%, MM C = 30%, MM D = 35%.

Prawns do not tolerate high fat diets well, so the maximum amount of fat in most prawn diets is limited to about 9%. When meat meal is used to replace fishmeal in a prawn diet formulation, some fish oil that is present in the fish meal is removed from the diet and replaced with tallow that is endogenous in the meat meal. If the meat meal contains more fat than the fishmeal, the amount of supplementary fish oil in the diet formulation will also be reduced to maintain the total lipid at the specified maximum. The net effect is that the fatty acid profile of the dietary total lipid will change from one that approximates a marine oil towards that of tallow. The effect is that the saturated fatty acids will increase to the point where the proportion of saturated fatty acids to total fatty acids exceeds about 0.35 resulting in an unacceptable imbalance (Figure 2). At the same time the amount of marine oil will diminish resulting in a reduction in the amount of the essential fatty acids EPA and DHA in the diet to below an acceptable minimum (Figure 3). Hence, there will be a maximum amount of a particular meat meal that can be used in a prawn diet that will be defined by its total lipid content and fatty acid composition even if it contains very little ash.

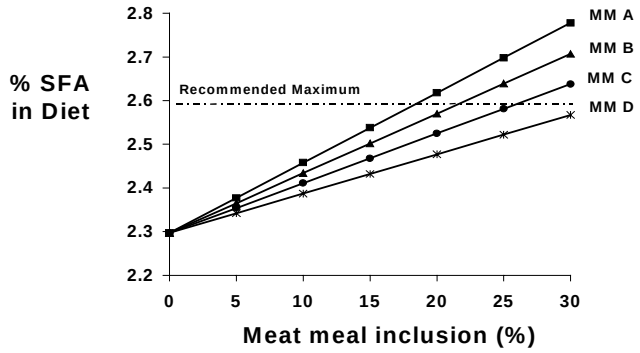

Figure 2. Changes in % total saturated fatty acids (SFA) in a prawn diet with increasing inclusion of four meat meals. SFA content of MM A = 5.4%, MM B = 4.6%, MM C = 3.8% and MM D = 3.1%.

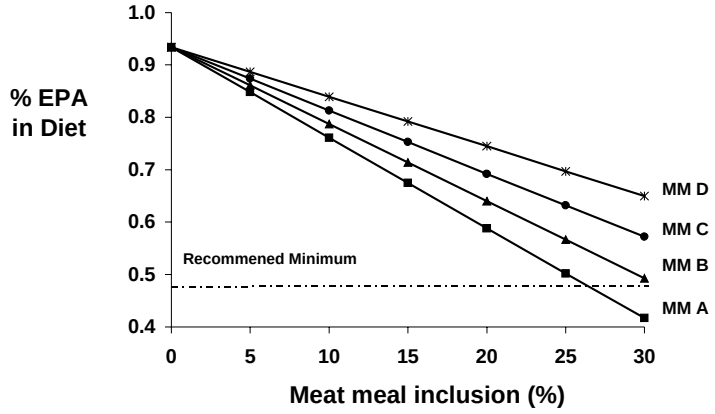

Figure 3. Change in percentage of eicosapentaenoic acid (EPA) in prawn diets with increasing inclusion of four meat meals. % EPA expressed on a dry matter basis. EPA content of all meat meals is 0%.

CONCLUSION

It will be difficult, if not impossible, for some renderers to produce a meat meal that meets the 'ideal' specifications for an aquaculture grade meat meal. However, it is important that the meat rendering industry recognises the needs of the aquaculture feed industry and the factors that limit the use of meat meals in aquaculture diets. Even if a meat meal does not come close to the 'ideal' specifications, it can still be used in aquaculture feeds, albeit at low inclusion levels. A meat meal containing more ash or fat than the ideal may have a useful price advantage but will be limited in its use in certain diet formulations. A key factor in establishing a supply link to a feed manufacturer is consistency of product. The feed manufacturer is far more likely to use a meat meal if they can be assured that future consignments from that renderer will be very similar in proximate composition and quality. A renderer that wants to be involved in the supply of ingredients to the aquaculture feed manufacturing industry must be prepared to make that commitment.

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APPENDIX A

Fatty acid composition of meat meals (g fatty acid/100 g of meat meal (dry matter basis). (Ratio = Total fatty acids/Total lipid)

Ident. N	14:0	14:1n-5	15:0	16:0	16:1n-7	17:0	18:0	18:1n-9	18:1n-7	18:2n-6	18:3n-3	20:4n-6	TOTAL	Ratio
111	0.27	0.00	0.07	2.44	0.17	0.17	2.58	3.46	0.09	0.21	0.06	0.00	9.53	70
112	0.21	0.04	0.05	1.86	0.19	0.11	1.59	2.61	0.09	0.11	0.04	0.04	6.92	71
113	0.19	0.00	0.00	1.77	0.16	0.09	1.45	2.44	0.08	0.11	0.00	0.00	6.29	75
114	0.27	0.00	0.06	2.08	0.14	0.13	2.19	2.93	0.11	0.22	0.07	0.00	8.20	68
115	0.14	0.00	0.05	1.45	0.07	0.13	1.82	2.10	0.00	0.15	0.00	0.00	5.89	68
116	0.20	0.00	0.05	1.76	0.10	0.14	2.17	2.37	0.07	0.19	0.06	0.00	7.10	68
117	0.25	0.00	0.05	2.07	0.22	0.11	1.59	3.07	0.10	0.20	0.00	0.00	7.65	72
119	0.18	0.00	0.00	1.60	0.18	0.09	1.26	2.30	0.09	0.11	0.00	0.00	5.80	70
120	0.27	0.00	0.06	2.40	0.20	0.14	2.25	3.31	0.13	0.17	0.07	0.00	8.99	71
121	0.29	0.00	0.05	1.97	0.19	0.12	1.69	2.68	0.12	0.18	0.00	0.05	7.35	72
122	0.19	0.00	0.04	1.74	0.17	0.09	1.34	2.51	0.11	0.13	0.00	0.00	6.32	71
123	0.58	0.06	0.10	3.51	0.25	0.20	3.12	4.65	0.19	0.35	0.00	0.07	13.08	65
124	0.25	0.07	0.05	2.16	0.29	0.12	1.53	3.19	0.12	0.11	0.00	0.00	7.89	73
125	0.23	0.00	0.07	2.12	0.11	0.17	2.59	3.12	0.00	0.24	0.08	0.00	8.75	69
126	0.24	0.04	0.05	2.22	0.27	0.10	1.53	3.35	0.16	0.34	0.06	0.00	8.34	74
127	0.35	0.04	0.07	2.83	0.25	0.17	2.58	3.85	0.12	0.41	0.06	0.05	10.79	72
128	0.27	0.05	0.05	1.97	0.19	0.11	1.52	2.75	0.09	0.15	0.00	0.00	7.15	71
129	0.21	0.00	0.05	1.68	0.12	0.10	1.78	2.29	0.08	0.15	0.05	0.04	6.55	69
130	0.23	0.00	0.05	1.98	0.16	0.11	1.94	2.81	0.10	0.15	0.05	0.00	7.58	70
131	0.23	0.00	0.05	2.41	0.21	0.12	2.18	3.59	0.19	0.46	0.07	0.05	9.57	71
132	0.28	0.05	0.06	1.84	0.19	0.10	1.41	2.57	0.10	0.14	0.04	0.04	6.80	72
133	0.20	0.00	0.06	2.00	0.10	0.15	2.10	3.21	0.10	0.30	0.07	0.07	8.36	61
134	0.22	0.00	0.05	1.73	0.10	0.14	1.91	2.74	0.11	0.17	0.05	0.00	7.21	65
135	0.24	0.00	0.06	1.90	0.11	0.15	2.18	2.90	0.06	0.19	0.06	0.00	7.86	67
136	0.29	0.06	0.06	3.08	0.42	0.13	2.07	4.70	0.21	0.63	0.07	0.04	11.75	66
137	0.23	0.00	0.06	2.09	0.15	0.14	2.25	3.21	0.13	0.19	0.05	0.00	8.51	65
138	0.18	0.03	0.04	1.67	0.15	0.10	1.47	2.55	0.09	0.13	0.00	0.00	6.42	75