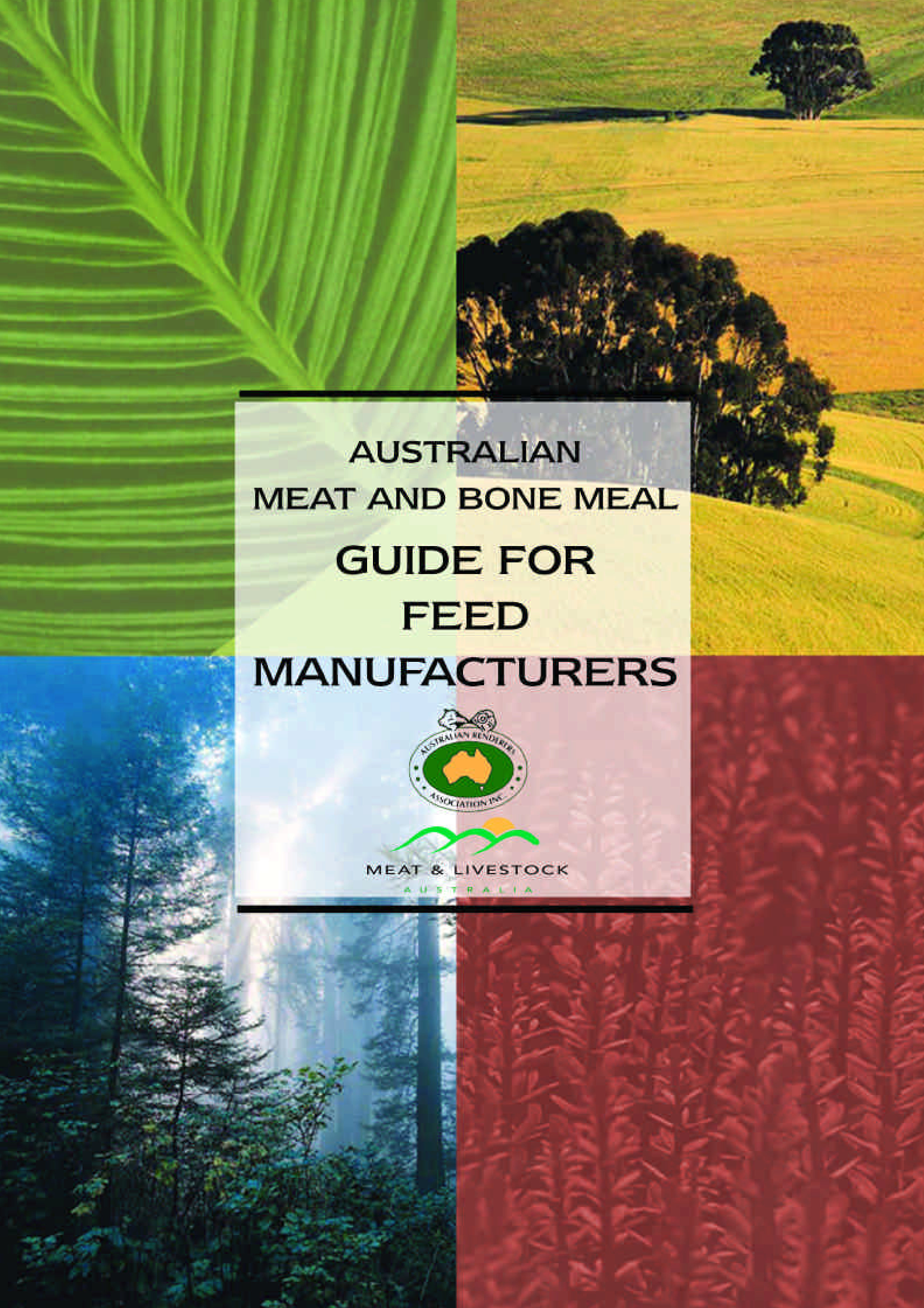

AUSTRALIAN MEAT AND BONE MEAL GUIDE FOR FEED MANUFACTURERS

AUSTRALIAN RENDERERS ASSOCIATION INC.

MEAT & LIVESTOCK AUSTRALIA

GENERAL INFORMATION

Australian Meat and Bone Meal Guide for Feed Manufacturers

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Further Information:

This publication provides a summary of data and recommendations relating to Australian MBM. It is not intended to provide an exhaustive review of the use of MBM. Additional technical information, including relevant reference sources used within this publication are available from the document entitled Australian Meat & Bone Meal Nutritional Technical Review. This document provides greater discussion relating to published research work and its application to the use of MBM in animal feeding. This document is available through Meat & Livestock Australia.

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AUSTRALIAN MEAT & BONE: IN GENERAL

Introduction

Meat and Bone Meal (MBM) is the product obtained by rendering, drying and grinding of mammalian tissues and bones from animals produced for human consumption, exclusive of hair, wool, hide, except where it is naturally adhering to heads and hoofs. The recycling of these materials into MBM provides a source of high quality nutrients for use in animal feeds.

This document provides a summary of relevant issues and data, together with recommendations of the use of Australian MBM in animal feeding.

MBM Processing Systems

Australia has a variety of rendering systems designed to process meat industry co-products into valuable ingredients for the animal fed industry.

A survey of 114 Australian renderers in 1996 sought details of equipment used, types of raw materials and heat treatments. The following information is a summary of the principal rendering systems used in Australia based on this survey:

Number of Australian rendering establishments using the principal rendering systems

Type of rendering	Number of plants
Batch dry rendering	60
Continuous dry rendering	43
Wet rendering	19

Source: ARA

There are an estimated 110 rendering plants operating 122 different rendering systems

Batch Rendering

A total of 60 establishments use batch dry rendering and 29% used a pressure cycle. These plants are mostly small and most do not export but there are several larger plants that can supply pressure cooked meal if required by customers.

Continuous Dry Rendering

A total of 43 establishments operate continuous dry rendering. Most use the Keith or Stampco tube-cluster type of rendering vessels. Four establishments use disc-type rendering vessels.

Wet rendering

A total of 19 establishments operate wet rendering systems. These include:

- Stord wet pressing system with disc drier
- MIRINZ low temperature rendering with cascading rotary or disc drier
- Alfa Laval with cascading rotary or batch cookers to dry meal
- Pfaudler with cascading rotary

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Effectiveness of Heat Treatments

Australia's rendering plants generally use non-pressure systems unless they are manufacturing product for a market which specifically requires a pressure cycle (such as EU). Investigations of continuous dry rendering systems without pressure treatment have shown that spore forming bacteria can be inactivated without pressure treatment at end point temperatures of 110-115°C.

Australian rendering heat treatments are equal to or exceed model rendering systems that have been shown to be effective in inactivating spore forming bacteria. The Australian Standard for Hygienic Rendering of Animal Products (AS 5008:2001) requires plants to verify that their process inactivates spore-forming bacteria. Plants complying with this Standard are regularly audited to ensure these conditions are met.

Australian rendered product is predominantly produced from non-pressure lower temperature plants which are less likely to damage amino acid quality but provide quality assured and safe ingredients for use in animal feeds.

Quality Assurance

Australian renderers have been at the forefront of developing quality assurance to improve the integrity and ever increasing standards for food safety.

The Australian Renderers Association launched its Code of Practice in 1994 with the first companies becoming accredited shortly after. The code has been upgraded a number of times subsequently and in 2001 provided the basis for the Australian Standard for Hygienic Rendering of Animal Products (AS 5008:2001).

The Standard encompasses quality assurance components relevant to rendering reflected under ISO 9002 guidelines. It also requires application of Hazard Analysis and Critical Control Point (HACCP) methods.

This standard to which all producers will be required to comply, establishes clear rules to ensure:

- Documented procedures and processes are in place to assure the production of safe rendered product
- Construction of facilities provides safe and hygienic processing and prevents contamination of product.

The standard incorporates two levels of microbiological safety. Firstly a validation that the heat process used destroys pathogens and secondly that the process is monitored by means of regularly sampling and testing for the absence of Salmonella.

Surveys of the incidence of Salmonella are undertaken by industry to measure MBM producer compliance. Individual companies are regularly audited by independent third party auditors to ensure they comply with the standard.

Individual companies are regularly audited to ensure compliance with the Standard. Those that comply are given an ARA accreditation number which may be provided to customers to ensure product received is produced according to the conditions of the standard.

In addition, the Standard of the Australian Renderers Association have developed two other initiatives:

- Formal training of plant operators and management in safe and hygienic rendering techniques (over 400 rendering plant personnel have been accredited in hygienic production of rendered animal products), and
- Bi-annual industry International Symposiums focussed on improvement to quality for its customers.

Both have contributed to significant changes to product hygiene and quality.

Australian producers of MBM were the first to adopt ISO 9000 principles and formally train plant personnel in product safety. Their record of achievement is enviable.

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Microbial Presence

The raw materials used to produce MBM contain various levels of micro-organisms and the rendering process is used to destroy these potentially harmful pathogens.

Vegetative Bacteria

Vegetative bacteria are relatively sensitive to heat. All are effectively destroyed in the rendering process. The processing temperatures used in rendering of between 115-135°C are more than sufficient to kill Salmonella and other vegetative bacteria.

Spore-Forming Bacteria

Spore-forming bacteria are more resistant to heat processing. Experiments on continuous dry rendering equipment have shown that spores of Clostridium sporogenes, a particularly heat resistant spore, inoculated into rendered material were inactivated when the temperature reached 110-115°C.

Salmonella may recontaminate MBM after it has been cooked during handling and storage; this is however equally likely with other raw materials such as grains and vegetable protein meals.

A review of Salmonella epidemiology recognised that raw materials such as soybean meal are often contaminated with Salmonella and that the focus placed upon Salmonella in MBM is greater than the risk analysis would warrant. The analysis of review is presented below.

Incidence of Salmonella in Feed Ingredients

	Country				
Ingredient	**Netherlands**	**Germany**	**USA**	**Canada**	**United Kingdom**
Animal Proteins	6%	6%	56%	20%	3%
Vegetable Proteins	3%	26%	36%	18%	7%
Grains		3%		5%	1%
Fish Meal				22%	22%

Source: Hamilton, 2002

The moisture level of meat meal between 4 and 10% provides too little moisture to support microbial growth. Salmonella found within MBM is not stable and does grow, over time the level of Salmonella present declines, work completed identified that MBM samples found to be positive for Salmonella declined in percent positive samples by 2% per week from the time of manufacture. MBM once cooked and dried is not a suitable medium for Salmonella growth and recontamination post rendering does not foster increases in contamination through Salmonella growth.

Published data on Salmonella levels in raw materials identifies all raw materials as being potential sources of Salmonella. The relative risk of Salmonella contamination within the finished feed is based upon the level of incidence and the inclusion level of that ingredient within the finished feed. Shown below are risk factor calculations for a feed formulation based upon the data shown above.

Relative Risk of Salmonella Contamination in Complete Feed

	Salmonella		
Ingredient	**Amount in formula %**	**Incidence %**	**Risk Factor Range**
Grain	66.9	1.0-5.0	.669-3.345
Vegetable Meal	24.9	7.0-36.0	1.743-8.964
Fish Meal	2.2	22	0.484
Meat Meal	3.0	3.0-56.0	.09-1.68

Source: Hamilton, 2002

The greatest Salmonella risk is found from use of raw materials such as grains and vegetable protein meals with higher inclusion levels. Even when MBM is taken as having a potentially high incidence, it remains a lower risk due to its lower inclusion rate than vegetable protein meals.

The significance of Salmonella within feed relative to other sources of Salmonella has been identified. The results shown below found feed to be a significantly lower reservoir of Salmonella when compared to other associated farm sources.

Reservoirs of Salmonella Contamination on Illinois Swine Farms

Reservoir	Number samples	% Positive
Employee footwear	93	17.2%
Cats	22	13.6%
Drinking water	33	12.1%
Mice/rodents	59	10.2%
Floor material	471	7.9%
Flies	95	7.4%
Feed	100	2.0%

Source: Weigal et al. 1999

The use of pelleting and the temperature and pressure generated within the conditioning chamber and die face have been recognised for many years as being capable of reducing Salmonella levels contained within feed raw materials. These feed processing techniques together with use of organic acids have been demonstrated to effectively produce feeds free of Salmonella even when the raw materials in use are identified as containing Salmonella.

Bovine Spongiform Encephalopathy (BSE)

BSE is a chronic degenerative disease that affects the central nervous system of cattle. Since the initial disease identification in the United Kingdom in 1996, the disease has been identified within other European countries, Japan in 2001 and Canada in 2003. Due to the incubation period of 2-8 years, disease identification is delayed, the disease is however not easily passed from animal to animal and is not considered contagious.

Australia is free of BSE and all other transmissible spongiform encephalopathy (TSE) such as Scrapie and Chronic Wasting Disease. The European Commission (EC) publishes an assessment of the geographic BSE risk (GBR) for countries. Australia has received the highest GBR Level 1 rating, meaning the EC considers that in Australia "it is highly unlikely that domestic cattle are (clinically or pre-clinically) infected with the BSE agent".

The GBR Level 1 rating provides the highest level of assurance to countries importing Australian MBM that it is produced in a BSE-free country.

The key measures Australia has taken to ensure it remains BSE free are:

1. Strict quarantine controls and restrictions on imports of live animals, genetic material and animal feed stuffs;
2. Implementation of a ban on the feeding of mammalian protein to ruminants; and
3. Initiation of a TSE surveillance program involving comprehensive monitoring which meets the endorsed World Organisation of Animal Health (OIE) code on BSE.

Freshness

MBM contains fat which is largely in a saturated form and can be subject to oxidative rancidity. Oxidation is the degradation process that occurs at the double-bond in the glyceride structure, because presence of double-bonds infers unsaturation, then naturally the more unsaturated a fat, the greater the chance of rancidity. The initial step in rancidity is the formation of free radicals which become susceptible to attack by atmospheric oxygen (and mineral oxides) which form unstable peroxide free radicals.

The practical control mechanism to prevent rancidity is through the use of antioxidants which function as free radical acceptors. Under extreme environmental conditions and where MBM is held for longer periods in storage and transport, antioxidants are used as a means of protecting MBM from rancidity.

Biogenic Amines

Biogenic amines are the breakdown products of amino acids found in a range of foods including fish, cheese, wine, beer, processed meat, chocolate and fruit. Biogenic amines are found in animal protein meals such as MBM, fish meal and poultry meal.

Micro-organisms containing decarboxylase enzyme convert free amino acids into biogenic amines by decarboxylation. Lysine and histidine are converted into cadaverine and histamine while ornithine, glutamine and arginine are the precursors for putrescine. The production of biogenic amines in MBM requires the presence of bacteria containing decarboxylase enzyme, free amino acids and conditions which favour microbial growth. The rendering process uses temperatures which eliminate microbes and reduces moisture content which results in a stable meal product. The critical period is between animal slaughter and the initiation of the rendering process. Minimising this time period and correct storage and handling of raw materials are essential in reducing biogenic amine levels.

Biogenic amines are broken down in the digestive tract of animals by the enzymes mono-amino-oxidase and di-amino-oxidase. Pigs have a greater capacity to breakdown biogenic amines. Their impact upon poultry only occurs when high concentrations exceed the digestive enzymes capacity to break them down.

Experimental trials have demonstrated that biogenic amines added to poultry diets at very high levels impact upon liveweight gain and bird health. However other work has been unable to find any affect of biogenic amines on performance. These contradictory results have not clearly identified that biogenic amines found at typical levels within MBM are sufficient to reduce bird performance. The level of biogenic amines are however considered to be a good indicator of the quality of MBM and renderers have responded to nutritional concerns by adopting processing techniques to reduce biogenic amine occurrence.

An Australian study analysing 1,445 samples for biogenic amines in animal by-product meals has been completed. The table below identifies results of this work.

Mean concentration and range of putrescine, cadaverine and histamine in Australian by-product meals between 1994 and 1997

Sample type	No. of samples	Putrescine(mg/kg)	Cadaverine(mg/kg)	Histamine(mg/kg)
Fish meal	78	102 (7-102)	220 (11-1340)	570 (<5-1620)
Poultry meal	387	82 (7-1320)	121 (<5-1350)	19(<5-167)
Meat meal	835	21 (<5-695)	29 (<5-680)	10(<5-258)
Feather meal	120	31 (5-267)	42 (<5-159)	5(<5-90)
Blood meal	25	13 (<5-223)	7 (<5-280)	4(<5-36)

Source: den Brinker, 2003

These results identify MBM as having lower levels of biogenic amines than levels found in fish meal and poultry meal. Renderers of products with higher levels of biogenic amines have responded in changing processing techniques to manufacture MBM with lower levels of biogenic amines.

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Chemical Residues

Australia has one of the best track records in the world for producing high quality beef and sheep meats which are chemical residue free. Australian beef and lamb is exported to all points of the globe and it must meet exacting standards in countries such as Japan and the USA. As part of the slaughter process of cattle and sheep to produce beef and sheep meats, the rendering industry utilises by-products to produce MBM. The same animals producing chemical residue free status beef and sheep meats also result in chemical residue free MBM.

Australian livestock producers take a positive stance with respect to chemical use and this translates into chemical residue free MBM. The fact that Australia has stringent controls on the use of agricultural chemicals and a meat testing programme to identify potential chemical residues offers a major benefit to users of Australian MBM.

Proximate Analysis of MBM

MBM is primarily considered as a high protein raw material which also has added value in supplying energy, minerals and vitamins. Because MBM is derived from animal tissues, it has been used for many years as a reliable source of amino acids. Because of the variation in the combination of raw materials being rendered, differences arise in the proximate analysis of MBM. Due to the increase in the number of sheep and cattle being supplied for human consumption and an increase in the volumes of raw materials and MBM resulting, there has been an increase in the consistency of MBM being supplied from Australian renderers. There has also been a tendency for the abattoir industry to move towards single-species plants. This has also resulted in greater consistency of product from individual processors. MBM is manufactured to meet a number of market requirements and the table below defines specifications for Australian MBM.

Specifications of Australian MBM

	45% MBM	48% MBM	50% MBM	55% MBM
Crude Protein	45% Min	48% Min	50% Min	55% Min
Fat	15% Max	15% Max	15% Max	15% Max
Moisture	10% Max	10% Max	10% Max	10% Max
Ash	38% Max	37% Max	32% Max	30% Max

Source: NACMA, 1998

The crude protein content of meat and bone meal is specified for products being supplied, the majority of Australian MBM is supplied as a minimum 50% crude protein (as fed basis), the protein content is usually between 50% and 52% protein. Some renderers are implementing systems to fractionate MBM into higher protein (55-60%) lower ash material which is formulated for application in aquaculture feeding.

The National Research Council (NRC) defines proximate analysis data upon which their more detailed specifications (such as amino acids) are based. The following is their data.

Nutrient composition of MBM as defined by the NRC 1994

Crude Protein	50.4%
Fat	10.0%
Moisture	7.0%
Calcium	10.3%
Phosphorus	5.1%

Protein Quality

Protein consists of amino acids which form complexes which gives proteins their individual characteristics and properties. These amino acids contain nitrogen at a constant ratio so that analysing raw materials nitrogen content allows a calculation of protein content to be made. Based upon animal proteins containing 16% nitrogen, crude protein is calculated by multiplying the nitrogen content by 6.25.

MBM has high levels of essential amino acids. The amino acid content has a high correlation with the protein content of MBM.

Pepsin Digestibility

Protein quality can be evaluated using in vitro enzyme digestibility assays. The commonly used pepsin digestibility test has been in use since the 1950's. This analysis is based upon incubating the sample with a single proteolytic digestive enzyme pepsin, undigested protein is separated from released amino acids and peptides. The basis of the assay is to mimic the conditions of a chicken's stomach within a glass flask. The resulting calculation of digestible protein has provided an estimate of animal protein quality. It is of note that the pepsin digestibility assay is not recommended for use in assessing vegetable protein meals and complete feeds due to the carbohydrate complexes which limit the capacity of a single enzyme assay.

The official test calls for the use of a pepsin concentration of 0.2%. Alternate lower pepsin concentrations have been shown to provide greater sensitivity in predicting in vivo protein and amino acid quality of animal protein meals. Alternate non-standard methods utilise 0.02%, 0.002% and 0.0002% pepsin concentrations. The use of lower concentration pepsin is reported to be superior in identifying differences between meat meal sources and the impact of heat treatment upon digestibility. The more dilute pepsin concentrations result in lower digestibility results. Difficulty has been found in correlating pepsin digestibility to in vivo feeding trial digestibility results; this has provided a reduced confidence in the use of the test.

The major advantage of pepsin digestibility assays is the use of a relatively simple, rapid and low cost assay. It continues to be used as a means of discriminating between high and low results. Inadequate grinding and incubation, results in low assay results which underestimate the samples digestibility. The assay is further limited through the use of a single enzyme when the animals digestive tract in a complex system with multi-enzymes.

Utilising 0.2% pepsin within the assay, pepsin digestibility for Australian MBM will be in the range 85-92%, with some specialised MBM achieving higher digestibility. The Australian standard requires all MBM to be manufactured and supplied with a minimum 85% pepsin digestibility.

Multi-enzyme Assays

The use of a combination of enzymes has been used to assess in vitro digestibility for a wider range of protein sources. This assay is based upon incubating samples with a combination of trypsin, chymotrypsin and peptidase; the resulting decline in pH is measured, this being found to correlate with protein digestibility in vivo.

Potassium Hydroxide Protein Solubility Assay

This is a chemical assay which measures the solubility of protein when samples are mixed with 0.2% KOH. The assay was developed for use with vegetable protein meals to measure over processing and protein damage caused by heat. When applied to soybean meal, canola meal and sunflower meal, protein solubility is correlated with in vivo digestibility.

Studies have identified that the KOH protein solubility assay is not significantly correlated with MBM in vivo protein digestibility. Although this test is widely used within the North American feed industry, it is not recommended for use in assessing MBM quality.

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Total Amino Acids

MBM is an excellent source of amino acids. Amino acid analyses are completed using acid hydrolysis, followed by ion-exchange chromatography. Because tryptophan is destroyed and methionine and cystine are partially destroyed by acid hydrolysis, these amino acids are determined in separate analyses. Amino acid analysis is difficult and complicated, requiring laboratory expertise and precision which is limited to a number of specialist laboratories operating in the world. Companies supplying synthetic amino acids have retained facilities capable of providing ongoing amino acid analytical services.

Amino Acid Recommended Levels in MBM:

	Recommended
Lysine (%)	2.75
Methionine (%)	0.68
Cysteine (%)	0.50
Met + Cys (%)	1.18
Threonine (%)	1.70
Tryptophan (%)	0.30
Isoleucine (%)	1.45
Leucine (%)	3.20
Valine (%)	2.30
Histidine (%)	1.10
Arginine (%)	3.50
Glycine (%)	6.75
Serine (%)	2.00
Glycine + Serine (%)	8.75
Phenylalanine (%)	1.80
Tyrosine (%)	1.20
Phe + Tyrosine (%)	3.00
Aspartic acid (%)	3.75
Glutamic acid (%)	5.85
Proline (%)	4.20
Alanine (%)	3.80

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Ash Content

The ash component of MBM is principally the mineral derived from bone, together with lesser amounts of minerals contained within animal tissues which are rendered. Bone supplies approximately 99% of the calcium and 80% of the phosphorus found within MBM, whereas 30% of the magnesium is found in non-bone component of the ash. Bone is made up largely of calcium phosphate in an organic complex. Within MBM, calcium and phosphorus are generally within the ratio 2:1.

Macro Mineral content of MBM compared to soybean meal.

Mineral	50% MBM	48% Soybean Meal
Calcium	10.3%	0.27%
Phosphorus	5.1%	0.62%
Magnesium	1.12%	0.30%
Sodium	0.70%	0.02%
Potassium	1.45%	1.98%
Chlorine	0.69%	0.05%
Sulphur	0.50%	0.44%

Source: NRC, 1994

MBM is characterised as a protein meal which supplies a highly available source of phosphorus. Unlike plant materials, MBM does not contain phytic acid which binds phosphorus reducing its availability.

The level of trace minerals supplied by MBM is compared against other raw materials in the table below.

	Iron (mg/kg)	Manganese (mg/kg)	Copper (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)
MBM	606	17	11	0.31	96
Soybean Meal	176	86	20	0.27	55
Canola Meal	142	49	6	1.10	69
Wheat	39	34	6	0.33	40
Sorghum	45	15	5	0.20	15

Source: NRC, 1998

MBM supplies additional quantities of iron and zinc relative to other raw materials.

Fat Content

The amount of fat within MBM provides a valuable source of energy for animal feeding. Work completed has provided the data below relating to the phospholipid, cholesterol and fatty acid profile from 27 analysed Australian MBM samples.

Phospholipid, cholesterol and fatty acid profile of Australian MBM samples, data on an as fed basis.

Gross Energy MJ/kg	Ash %	Crude Protein %	Total Lipid %	Total PL %	PC %	Cholesterol %
17.38	27.07	55.39	11.14	0.75	0.46	0.16

Fatty acid data results expressed as g of fatty acid/100g of MBM

16:0	18:0	18:1n-9	18:2n-6	SFA	MUFA	Total
3.37	3.00	4.51	0.60	7.21	5.16	12.56

Source: NRC, 1998 Source: Smith et al. 1999

Total PL = Total phospholipid
PC = Phosphatidylcholine

SFA = sum of saturated fatty acids
MUFA = sum of mono-unsaturated fatty acids

The gross energy results of 17.38 MJ/kg (4154 kcal/kg) compares favourably against 16.74MJ/kg (4000 kcal/kg) found by other researchers.

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Effect of Processing upon MBM Quality

Excessive heat applied to proteins reduces the availability of heat sensitive amino acids. This effect has been identified across a range of protein sources including soybean meal, canola, sunflower and MBM.

Heat treatment can result in three types of nutritional damage:

1. Total destruction of amino acids,
2. Maillard or browning reactions where free lysine reacts with certain types of sugars such as sucrose, fructose, stachyose and raffinose. Soybean meal contains considerable quantities of soluble sugars and is very susceptible to Maillard reactions during heat treatment. This effect in MBM is less pronounced than in oilseeds due to the low carbohydrate and reducing sugar content of MBM.
3. Cross linking between amino acids, this being found in soybean meal and MBM. Cross linked amino acids such as lysinoalanine formation from lysine and lantionine formation from sulphur amino acids, particularly cytiene.

It can be seen that all protein meals, both animal and vegetable sources, are sensitive to heat treatment. Heat is required to reduce anti-nutritional factors such as trypsin inhibitor in soybeans and gossypol in cotton. Heat is an essential component in the manufacture of MBM; the critical factors affecting protein quality are the degree of heating and the length of time this heat is applied.

The Australian rendering industry utilises lower temperature continuous cookers, with ambient air pressure. Conditions recognised as providing a gentler heating of protein are where temperature remains below 125°C at zero psi pressure and for minimal time periods. In contrast, processing MBM at 133°C and 3 bars of pressure for 20 min, as required by the EC treatment directive, significantly reduces amino acid digestibility.

Australian MBM is not required to be manufactured under the EC treatment conditions (unless products are produced for export to the EU) as Australia is free from BSE. This provides a significant benefit to users of Australian MBM due to its higher protein quality as it has been manufactured using lower temperature and pressure conditions.

Digestibility Co-efficients of Selected Amino Acids in Meat and Bone Meal as Reported in the Literature Since 1984

Amino Acid	1984	1989	1990	1995	1997	2000
Lysine %	65	70	78	92	71	87.5-92
Threonine %	62	64	72	89	-	80.2-88.9
Tryptophan %	-	54	65	-	70	86.4
Methionine %	82	-	86	91	-	87.4-92
Cystine %	-	-	-	71	-	76.4

Source: Pearl, 2002

A review of published data relating to MBM shows an improvement over time in defined amino acid digestibility co-efficients. This improvement is recognising the increased performance of renderers and the equipment and conditions under which MBM is manufactured. Most of the original digestibility work in the 1980's and early 1990's was completed using MBM sourced from batch cookers using high temperature, time and pressure conditions. More recent research work has shown MBM manufactured under the correct conditions provides amino digestibilities in excess of 90%.

MBM Supply of Nutrients in Animal Feeding and Recommended usage rate.

POULTRY

Introduction

MBM is a valuable raw material which can be used in all classes of poultry feeding. MBM is principally considered as a protein source, but also supplies valuable levels of energy and minerals.

Energy

The gross energy supplied within MBM has been analysed to be in excess of 4000 kcal/kg. Energy content is directly related to the energy supplied from the fat and protein components of MBM.

The metabolisable energy (ME) content of MBM has in recent years undergone considerable reworking, this resulting from views that the published NRC energy levels appear too low.

Several papers have been published which identify higher levels of ME when MBM is included in test diets at more practical levels. This work has demonstrated that a typical 50% protein MBM, containing 10% fat supplies more ME than is identified within NRC 1994:

Metabolisable energy recommendation for MBM:

2500 kcal/kg or 10.46 MJ/kg for broiler chickens
2700 kcal/kg or 11.30 MJ/kg for laying hens.

Amino Acids

MBM is recognised as being an excellent source of amino acids, the concept of utilising available amino acids recognises that amino acids consumed by the animal are not completely digested and metabolised. Methods to determine amino acid availability are various and include both in vitro and in vivo analyses, the commonest approach is to utilise digestibility studies.

MBM produced under low temperature conditions such as those practiced within Australia results in the supply of a protein source with high digestibility levels, this exceeding 90% for lysine and methionine. The table below provides recommended amino acid digestibility co-efficients for MBM feeding in poultry.

Ileal Digestible Amino Acid co-efficients for Australian MBM.

	Chick. Dig. Coeff. (%)	Adult Dig. Coeff. (%)
Lysine	77	81
Methionine	84	85
Cysteine	55	58
Met + Cys	69	74
Threonine	69	79
Tryptophan	75	78
Isoleucine	75	84
Leucine	76	85
Valine	73	83
Histidine	76	80
Arginine	76	84

Minerals

The term biological availability is often applied to the mineral phosphorus, it is implied that bioavailability is a measure of the degree to which a phosphorus source can support the physiological processes of the animal. Comparative assays have commonly been used to measure phosphorus availability relative to individual phosphate sources, in this way some raw material sources can be assessed as having a relative bioavailability exceeding 100%.

Research work has been completed demonstrating the biological availability of phosphorus from MBM is equivalent to that supplied from dicalcium phosphate when fed to poultry.

The principle form of phosphorus from plant raw materials is phytate phosphorus. Phytate combines with calcium, phosphorus, magnesium, zinc and manganese making them largely indigestible when consumed by animals. Phytate phosphorus in plant materials generally exceeds 70% of the phosphorus content.

Calcium and Phosphorus content of 50% MBM.

Mineral	50% MBM	Range
Calcium	10.3%	8-12%
Phosphorus	5.1%	4-6%
Available phosphorus	5.1%	4-6%

Poultry recommendations for use

MBM has been widely used as a poultry raw material for many years. Within Australia due to its ready availability, the poultry industry has commonly used MBM at levels of up to 10% inclusion in broiler and layer rations.

It is recommended that when feed formulations are based upon digestible amino acids, the following maximum inclusion levels of MBM can be used for poultry rations.

Poultry Type	Maximum Usage Rate
Broiler Starter	8%
Broiler Grower/Finisher	10%
Layer	10%
Turkey	10%

PIG

Introduction

Animal by-products have been important raw materials in the feeding of pigs for the last 100 years. MBM was the first supplement added to all grain rations for pig feeding and it demonstrated value for balanced ration feeding. MBM has been recognised as an excellent source of protein, energy, calcium and phosphorus. The volume of published work relating to MBM is significant and this report assists in defining the key nutritional attributes of MBM as it relates to pig feeding.

Energy

Data relating to dietary energy content of feed ingredients is required to allow formulation of pig feed diets.
The pig industry utilises a number of definitions of energy:

- Gross energy (GE) being the result of combustion of the feed, with use of a bomb calorimeter to measure the energy released.
- Digestible energy (DE) which is the energy left after energy is lost in faeces.
- Metabolisable energy (ME) accounts for energy lost in faeces, urine and digestive gases.
- Net energy (NE) is equivalent to ME less an increment for heat generated through digestion.

NE provides data most closely relating to how the animal utilises nutrients for production, it is however the most difficult to measure. DE is relatively easier to measure in pigs and considerably more DE data is available on raw materials. Recommended energy figures for Australian MBM are shown below.

	Energy MJ/kg	Content (kcal/kg)
DE	11.30	(2700)
ME	10.9	(2605)
NE	9.10	(2175)

Amino Acids

Considerable debate has taken place relating to the difference between digestibility and availability of amino acids in pig feeding, much of this being generated through Australian research work completed by Ted Batterham at Wollongbar Research Station. This work used slope-ratio assays to determine the utilisation of ileal digestible lysine in heat damaged proteins. Batterham was able to demonstrate that it is possible for amino acids to be digested and absorbed in forms that are not utilised by the animal.

The Australian work has been verified in overseas research, this clearly demonstrating that MBM produced under low temperature conditions, such as those practiced within Australia, results in the supply of a protein source with high digestibility levels, this exceeding 90% for lysine and methionine. Batterham concluded that:

- Digestibility was similar to availability for high quality feedstuffs, digestibility overestimates availability for low quality ingredients which have been heat damaged.
- It is possible to produce high quality MBM provided pressure is avoided and the final end point temperature does not exceed 125°C.

Nutritionists need to adopt the digestible amino acid values for MBM relative to their own database and the supply of MBM. Where MBM in use is known to be sourced from a manufacturer utilising low temperature rendering equipment, the higher digestible amino acid data shown below can be utilised. Where rendering conditions are unknown, use of the average MBM data is more applicable.

Ileal digestible amino acid and available lysine co-efficients for Australian MBM.

	Pig Dig. Coeff. (%) Average* MBM	Pig Dig. Coeff. (%) High Quality** MBM
Lysine	77	92
Avail. Lysine	75	90
Methionine	77	91
Cysteine	51	71
Met + Cys	67	84
Threonine	74	91
Tryptophan	73	90
Isoleucine	78	96
Leucine	78	96
Valine	76	94
Histidine	76	94
Arginine	85	96
Phenylalanine	78	93

* Average MBM utilises Degussa AminoDat 2.0 digestibility co-efficients

** High quality MBM utilises digestibility co-efficients derived from Batterham (1992) and Wang and Parsons (1998).

Minerals

There is considerably more work completed studying phosphorus bioavailability from MBM in poultry than in pigs. The NRC defines MBM phosphorus bioavailability as being 90%.

Increasing MBM particle size has been indicated as reducing the availability of P within pig diets. The specification for Australian MBM is for 98% to pass through a 10 mesh (2mm) screen, MBM of this particle size has a high bioavailability for its calcium and phosphorus content.

Recommended calcium and phosphorus content of 50% MBM.

Mineral	50% MBM	Range
Calcium	10.3%	8-12%
Phosphorus	5.1%	4-6%
Available phosphorus	4.6%	4-6%

Pig recommendations for use

Within Australia due to its ready availability, the pig industry has commonly used MBM at levels of up to 10% inclusion in pig rations. This level of feeding is considerably higher than that practiced in North America and Asia, where greater reliance is placed upon the use of vegetable protein meals in combination with feed phosphates.

In the feeding of early weaned pigs, use of MBM is restricted due to the inclusion of higher digestible ingredients such as whey and skim milk powders, fish meal and blood meal. Maximum usage of MBM within grower, finisher and breeding pigs is higher as shown below.

Recommended maximum usage levels of MBM within pig feeds.

Pig Type	Maximum Usage Rate
Early Weaner	5%
Weaner	8%
Grower/Finisher	10%
Breeder	10%

AQUACULTURE

Introduction

Aquaculture has been the fastest growing food production sector for more than a decade. Growth is however dependant on fish meal derived from capture fisheries, which is virtually static in volume available for use. The need to replace fish meal in aquaculture is recognised internationally.

Energy

Both protein and lipids are the available energy sources for fish. Energy concentration is the prime nutritional consideration in formulating fish diets. Lipid is the key energy source but there is also a key relationship between energy and protein.

Recommendation:

The levels of digestible energy quoted by NRC (12.2-13.3 MJ/kg) seem low when compared to more recent Australian studies. This discrepancy would seem related to ash and protein content of the MBM. The following recommendations are related to MBM protein and ash content.

- **Low ash (<28%) and high protein (>55%) MBM: DE = 13.7-14.1 MJ/kg**
- **Higher ash (>28%) and lower protein (>50%) MBM: DE = 12.2-13.3 MJ/kg.**

Amino Acids

The level and balance of amino acids required by fish is most likely to be met by proteins akin to fish i.e. fishmeal. The ability of other protein sources to meet the essential and total amino acid needs of a particular aquatic species depends on requirement and digestibility factors.

Excess dietary protein is generally catabolised preferentially over carbohydrates and fats and used for energy. It is important to formulate diets with care and to minimise cost of overuse of protein.

Recommendation:

The amino acid digestibility co-efficients vary by fish species. For crustaceans nutritionists should use an amino digestibility factor of 55-57%, whilst for omnivorous and carnivorous species the digestibility factors are substantially higher between 75% and 85%.

Minerals

Calcium and phosphorus are directly involved in the development and maintenance of the skeletal system. Fish however absorb calcium from their environment and rely entirely on calcium present in water during dietary deprivation.

Phosphorus must however be supplied in the diet at varying levels depending on the fish species and the phosphorus form and availability. Feed ingredients such as fish meal and MBM contain relatively high levels of phosphorus, this coming from the bone component. Plant materials although lower in phosphorus content have the phosphorus stored as phytate-phosphorus which reduces phosphorus digestion and adds to the load of excreted phosphorus.

Availability of phosphorus from plant proteins is generally poor. MBM however has good digestibility and care is needed to ensure that excess is not provided in the diet from MBM and excreted as a potential pollutant. For this reason when using higher inclusions of MBM a lower ash MBM should be selected. This also has the advantage of higher protein levels.

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Aquaculture recommendations for use

There are a number of variables which require consideration when selecting the best level of inclusion of MBM in fish diets. The most important of these are:

- Species being fed, and
- MBM specification with reference to crude protein and ash levels.

Varying levels of substitution of MBM for fish meal are achievable, resulting in a significant reduction in diet cost. The maximum replacement of fish meal with MBM is recommended as:

- Carp, tilapia and perch (fresh water omnivorous) 75-100%
- Barramundi (warm water carnivore) 100%
- Trout and salmon (cold water carnivores) 25%
- Prawn and shrimp (crustaceans) 25%

PETFOOD

Introduction

Dogs are classified as omnivorous-carnivores and cats true carnivores. As domesticated animals they are dependant on their owners to provide the essential nutrients they require: failure to do so may result in deficiency symptoms, disease or death. Both also have a relatively high requirement for protein at maturity.

The criteria for selection of the best and most nutritious ingredients are a little different to diets for pigs and poultry, being based more on palatability, appearance and nutritional completeness and balance.

Energy

Cats are true carnivores and do not tolerate high carbohydrate diets. Together with the protein content, MBM is an important source of energy for pet foods.

Diets containing MBM are highly digested, MBM has proven to be of high nutritive value compared to fresh meat with rendering not affecting the MBM digestibility.

Amino Acids

Although companion pets are for most of their life mature, protein is needed to replace the natural turnover of epithelial surfaces, hair and other body tissues and in secretions. Additional protein is needed for growth, pregnancy, lactation and wound healing. The protein quality in terms of amino acid profile and digestibility are therefore most important. Animal proteins generally have a more balanced amino acid profile, with a greater proportion of essential amino acids and better digestibility than plant proteins. Plant proteins are identified as having a number of drawbacks, these being presence of anti-nutritional factors (lectins, tannins, trypsin inhibitors, oligosaccharides) and their impact upon digestion within pet foods. Dietary protein in excess of the body's requirements is converted to fat and stored as adipose tissue.

Cats exhibit a number of nutritional peculiarities and require a higher level of protein than other mammals. They are sensitive to arginine-deficiency diets and also have a specific need for the amino-sulphonic acid taurine.

Published data on amino acid digestibilities for various raw materials fed to cats and dogs is limited. Data which is available indicatates that MBM is highly digested, amino acid digestibility co-efficients being in the range 80-90%.

Minerals

Macro and trace minerals are essential in the diets of pets. Their functions include bone and teeth growth and maintenance, blood clotting, nerve and muscle function, enzymes, acid-base balance, electrolytes, pigmentation and blood and hormonal function.

The likelihood of deficiencies are relatively low and while generally ash levels in the finished feed for dogs is only in the order of 4 to 5%, frequently ash levels may exceed this requirement. There is no apparent relationship between excess dietary ash and clinical disease in dogs. High dietary ash may however compromise diet quality.

The ash content of MBM plays an important part in the mineral nutrition of the dog. As the ash content between different suppliers may vary it is important that these levels are known when formulating diets.

This factor is also important when formulating cat food. Indeed quite high levels can be utilised for low ash meat meal. Magnesium is the mineral of the most concern in cat nutrition, low ash MBM which supplies lower levels of magnesium are preferred for cat foods.

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Palatability

A significant effort on diet formulation by commercial pet food manufacturers is focussed on palatability. If a diet is not ingested it does not provide nutrients to the animal.

Palatability is said to be influenced by many factors including food texture, composition, ingredients, smell, taste, temperature, past experience of the animal, heat treatment, etc.

The owner's perception of the diet is another important criteria as it strongly determines repurchase. Such attributes may include consistency, colour, smell and appearance.

MBM is generally known to have a positive palatability affect in pet food diets.

Where MBM is stored or not used expeditiously it is generally advisable to add anti-oxidants to preserve fat quality and flavour.

Labelling

An important criteria in the selection of raw materials is the ability to use the origin of the material on product labels. The levels of inclusion to enable use of the name depend on the laws or regulations of the particular jurisdiction.

Commonly Australian MBM is beef (bovine), lamb (ovine) or possibly mixed species. Where this aspect is important a specification should be requested with the supplier.

Allergenic reactions are often identified in diets containing soybean protein and also wheat and beef. For such reasons ovine meal has become popular as a major ingredient in any "hypoallergenic" foods as they are less frequently associated with such adverse reactions. Australia is the major supplier of ovine meals to the world market.

Petfood recommendations for use

Typically levels of 20-25% MBM inclusion in dog foods are used depending on other raw materials available. The life stage of the pet is also important, whether growing, pregnant or lactating.

In cat diets the levels of inclusion will depend on the ash content of the MBM. For low ash MBM (<20%) higher levels can be used again dependant on the choice and availability of alternative raw materials.