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Utilisation of the ash component of meat meal M.743

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Prepared by:
Venturetech Pty Ltd

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Denis W Roberts
Managing Director and Consulting Scientist.

1. Summary

1.1. Except for fertiliser and feed supplements the uses for the "ash fraction" of meatmeal are based on clean degreased bone that has been rendered separately. This raises the questions of whether ash fractions separated from meatmeal are suitable for the established uses and whether renderers should continue to cook bone and soft material together.

1.2. The analyses show that both crude and refined "ash fractions" of meatmeal appear to have excellent prospects for use as fertilisers. The crude "ash fractions" are closely aligned to traditional "blood and bone".

1.3. Both crude and refined "ash fractions" of meatmeal, appear to have excellent prospects for use as feed supplements in Australia and overseas.

1.4. The prospects for "ash fractions" in high grade gelatine and bone china may be promising for individual companies that arrange to process bones separately. The use of bone char in pigments seems to be insignificant from a "whole of industry" perspective. Its use in carburizing steel is at best steady and it is being phased out in the bleaching of raw sugar.

1.5. When ash fractions are used a fertiliser, its phosphorus and nitrogen are readily available, but can presumably be controlled by varying the degree of grinding and/or classification of the bone particles according to size.

1.6. The wholesale price of "blood & bone" of around $400 per tonne values the product at $260 per tonne above the chemical value of its constituents. While the total quantity sold (estimated at 6,000 to 8,000 tonnes per annum) may not be spectacular, it is significant, the price is excellent and so its vulnerable position should therefore be defended and if possible, expanded. The suggested means to defend and expand the market share of "blood & bone" are to make it more user friendly, for example by pelleting it, by deodorising it and by incorporating it into slow release products. To demonstrate and publicise its effectiveness. To promote its use among the most dedicated gardeners, especially the various plant and flower societies. Making samples available as raffle prizes and competition prizes at shows is a proven fertiliser promotion route.

1.7. The potential for ash fraction based fertilisers arises from the prospect of securing a share of the present 100,000 tonnes per annum base usage plus a share in its growth. A 15% share in the present market or 15,000 tonnes per annum should be feasible. It should be

realistic to suppose that ash fractions could secure 15% of the 10,000 to 15,000 tonnes per annum expansion of the organic fertiliser market growth.

1.8. This market would not develop passively. It would need to be actively developed and the products promoted. Since as with traditional "blood & bone" these products would to be pretty much generic there is good opportunity to reduce market development costs and improve its effectiveness by the rendering industry as a whole to a large extent.

1.9. The values for the ash fractions examined calculated on their mineral content alone ranged from $193 to $268. On their mineral contents plus the mean margin of $208 from the four proprietary fertilisers their calculated prices ranged from $401 to $476. On their mineral content plus the $266 margin that "blood & bone" secures in the market place their calculated prices ranged from $459 to $534.

1.10. While prices of $401+ per tonne for an ash fraction of meatmeal are attractive, particularly given that the low ash fraction would be sold into aquaculture for considerably more, it must be borne in mind that the figure represents a $100 per tonne increase in the prevailing prices for the established organic fertilisers already in the market place. The ash fraction "blood & bone" meals would therefore need to be marketed skilfully.

1.11. The animal feed industries use meatmeal almost as much on account of its phosphorus content as its protein content. Hence the main value of a phosphorus enriched meal would be based on its phosphorus content at a price of $2730 per tonne based on that of di-calcic phosphate of ~22% P at around $600 per tonne. To that at present would be added around $50 to $60 per tonne for its protein content of 31.2%.

1.12. Taking into account the phosphorus as well as the protein contents of the ash fractions examined on the basis of costing phosphorus on the equivalent of $600 per tonne of 22% P in di-calcic phosphate, and protein as 44% in solvent extracted soybean meal @ $500 per tonne, the feed values of the 4 fractions were respectively $667, $641, $708 and $727 per tonne. When the protein was discounted to 85% the value of soybean, the respective calculated values were $617, $588, $631 and $648 per tonne.

1.13. Applying the same calculations to meatmeal of 50% protein and 6% phosphorus gives it a theoretical value of $732 per tonne or $647 per tonne on the basis of assigning its protein a value 85% of soybean protein.

1.14. There no doubt are some valid reasons for the gross differences between the value of meatmeal calculated from the value of its individual constituents. Apart from the rendering industry not making its clients fully aware of the constituents, some of the reasons would be poor physical quality of meals, variations in quality and constituents and in particular the quality and variations in quality of the protein. However, to a considerable extent the low prices for the product must arise from its mix of constituents being unsuitable for some applications, of which aquaculture is one instance and poultry production would be another. The production of high ash meatmeal fractions would go a significant way towards overcoming the latter restrictions. **The ideal means of fractionating meatmeal would be by greater segregation of the raw materials in the first place.**

2. Summary of recommendations

2.1. Animal feeds

It is recommended that the animal feeds industry be the greatest priority target for market development of ash fractions of meatmeal on account of the prospects for price increases and the market size considering that:

i. There is an established market of 10,000 to 20,000 tonnes per annum in the animal feeds industry and likely to be 16,000 to 32,000 tonnes, for the ash fraction at around $2727 per tonne of phosphorus, or $286 per tonne for meal of 10.5% phosphorus;

ii. In addition there is a proportion of the existing 300,000 tonne domestic meatmeal market that would be open to use of the ash fraction in conjunction with another source of protein;

iii. The calculated values of the ash fraction (and indeed of normal meatmeal itself) taking into account its phosphorus, protein and fat contents are $230 to $450 per tonne above present prices and therefore constitute an impressive opportunity to increase profitability;

2.2. Joint industry action and fertiliser applications

It is recommended that the rendering industry pursue the opportunities for ash fractions commercially with an industry marketing plan in which marketing and promotional costs are shared, and in conjunction with research and demonstration to promote use of the fertilisers and to justify the premium prices sought for them considering that:

i. The existing market prices for "blood & bone" and proprietary organic fertilisers are $206 to $260 per tonne above the chemical value of their constituents, translating to attractive prices for the ash fractions examined of $401 to $534 per tonne;

ii. The make-up of the ash fractions would be attractive to horticulturalists on account of their relatively high nitrogen contents;

iii. The indicated market opportunity for such fertilisers of 15,000 tonnes per annum with annual growth of 1,000 to 2,250 tonnes;

iv. The $206 to $260 per tonne margin of price over chemical value of organic fertilisers constitutes a threat as well as an opportunity;

v. From a fertiliser point of view the chemical quality of protein is of no consequence, for example hair and hoof protein have the same value of that of lean meat;

2.3. Blood & bone development and marketing

It is recommended that promotion of traditional "blood & bone" be undertaken as a diversification step, to improve its price, to maintain its competitive position with respect to products such as "Dynamic Lifter". The present market for blood & bone is mainly separate from that for commercial organic fertilisers, but at $400 per tonne wholesale, which is competitive with the present stockfeed price, it is a position well worth defending by the rendering industry. This would ideally involve the rendering industry as a whole in conjunction with brand promotion.

2.4. Marketing to organic growers

It is recommended that promotion to commercial organic growers can be simplified by cooperating with the National Association for Sustainable Agriculture of Australia (NASAA). In the first place NASAA certifies fertilisers that meet its criteria for a fee of $400 to $550 and a 0.5% royalty on sales. Secondly, it can provide a list of its members. Thirdly, the products can be promoted through its newsletters, preferably by arranging editorial space in conjunction with advertising. It would probably be feasible to arrange for field trials to be conducted under NASAA auspices as well. Presumably NASAA newsletters or other journals could then be used as vehicles to authoritatively publicise the outcomes of the trials.

3. Introduction

The "ash fractions" of meatmeal are the fractions containing most of the bone.

Ash fractions may be produced by rendering the bones separately, the means by which Sample A was produced; or by using gravity and/or air techniques, the means by Samples B, C and D were produced. These methods rely on the density and air resistance differences in the soft meal and the bone fractions to give separations.

Sample B was produced using sophisticated machinery and Samples C and D with very simple apparatus from two different meatmeals.

The ash fractions contain significant proportions of protein (around 30% or more) on account of gelatine contained in the bone itself and on account of fines material adhering to the bone because of the presence of tallow.

4. Composition of the ash fraction

Table 1 shows typical results from the analyses of the ash fractions of meatmeals. *Sample A* is the material used in the fertiliser trials within this project and is produced by processing bone material separately from soft material in a low temperature rendering system. *Sample B* is ash fraction separated from a dry rendered meatmeal, it is material very free of soft meal and is probably near the ultimate of the ash fraction that can be separated out from meatmeal. *Samples C and D* are ash fractions crudely separated from two different meatmeals using very simple fractionation apparatus.

Table 1 showing results from analyses of 4 types of ash fractions of meatmeal

Parameter	Sample A	Sample B	Sample C	Sample D
Nitrogen	4.7	5.0	7.2	7.4
Protein (Nx6.25)	29.4	31.2	45	46.2
Ash	60	58.9	37.6	39.2
Calcium	23.7	24.4	8.3	9.1
Sodium	0.52	0.54		
Potassium	0.04	0.06		
Iron	18.3	26.2		
Copper	6.8	6.8		
Zinc	30.0	32.6		
Total Phosphorus (P)	12.2	10.5	6.82	6.78
Water soluble P	0.02	0.085	0.19	0.30
Citrate insoluble P	10.7	9.2	5.0	4.4
Citrate soluble P	1.48	1.22	1.63	2.08
"Available" P (total - citrate insoluble)	1.5	1.3	1.82	2.38

It is notable that the phosphorus contents of *Samples A and B* are about 40% and 20% respectively higher than in superphosphate, while those of *Samples C and D* are about 75% of superphosphate.

Samples C and D are well within the specifications for blood and bone for minimum nitrogen and total phosphorus contents, although neither of them achieve the minimum level of 2.5% for citrate soluble phosphorus specified under the notoriously perverse Victorian Fertilizers Regulations.

Table 2 Showing a typical amino acid profile of Sample B, fractionated from meatmeal.

Amino acid	% in bone fraction
Lysine	1.17
Methionine	0.26
Cysteine	0.21
Threonine	0.67
Tryptophan	0.18
Isoleucine	0.67
Leucine	1.30
Valine	0.91
Histidine	0.67
Arginine	2.25
Glycine	3.92
Serine	0.94
Phenylalanine	0.78
Tyrosine	0.55
Aspartic acid	1.46
Glutamic acid	2.05
Proline	2.89

5. Possibilities and characteristics of the 'ash' fraction

5.1. Industrial uses of bone

All of the established uses for bone, except feeds, currently use clean, degreased bones as their rawstock. It is reported (Appendix 1) that degreased bone releases phosphate more readily when it is used for fertiliser.

The fundamental differences between the bone fraction separated from meatmeal and the feedstock material for the industrial uses are that the separated bone fraction is neither clean nor degreased. Having been dry rendered, it has been severely cooked as well.

Bones from younger animals have higher collagen contents and those from older animals have higher mineral contents. The use of bones from pigs is limited by religious restrictions.

5.2. Gelatine

Cleaned, degreased bones can be treated with HCl to dissolve the mineral material to leave behind about 25% ossein, of which about 65% is bone gelatine. The phosphate produced can be precipitated out in various forms for use in dental fillings and synthetic ivory or for more mundane and lower value application. Indications are that bone derived phosphates are not used as extensively in dentistry as they were formerly. Phosphates appear to have been used in several dental and orthopaedic applications, but evidently as by-products of gelatine production and there is no evidence that the quantities are significant.

$600 per tonne is the indicated price for bone material of this type.

Production of glue is a sub-class of gelatine production.

5.3. Char

Cleaned, degreased bones are charred with air excluded at around 700°C to produce char. Sighting tests in this laboratory have shown that char produced in a laboratory furnace from even crudely separated ash fractions of meatmeal, as well as high purity fractions have bleaching ability. However, that is not to say that they are as effective as conventional char or that they do not have other deficiencies.

Char has been widely used for the bleaching of raw sugar, but that is being phased out. The last sugar refinery in Australia to use it will change to activated carbon by the end of the year. At one time most sugar refineries had their own bone charring plants and regenerated their own char. CSR had a large plant in Sydney. Pig bones are unsuitable for this use on account of religious reasons. Char is being eased out because it has to be conveyed while dry and so is messy. It has only around a 10% carbon content yet the whole 100% of its mass needs to be retorted for regeneration. Finally some sugar refineries are changing to extraction processes that do not require bleaching. Hence the use of bone char in the sugar industry has almost ceased.

5.4. Pigments

Pigment for inks can be produced from fresh char and char that has been spent in sugar refining. Char black used in inks gives an attractive lustre. There are no indications that the quantities used are great and it is not a large scale application.

5.5. Metallurgy

Char is used in pack carburizing of steel in which it seems to have advantages over other material in being suitable for control of the level of carburizing within some ranges. However, when contacted, BHP sales engineering were unaware of this, which indicates that the use is not widespread. References indicate that pack carburizing is generally being replaced by other carburizing methods because they are more efficient, and so it cannot be viewed as a dramatically expanding field of opportunity.

5.6. Bone china

Bone china is made with China clay and around 25% of calcined bone. A pure white colour in the calcined bone is of the utmost importance and it is evidently essential that the bones used be clean and free of grease as well as colour to be suitable for calcining. At least one meatworks in Australia studied the feasibility of producing bone for the purpose, but abandoned the proposal on account of the colour and degreasing questions in the light of the overall moderate level of profitability from producing it.

It is noteworthy that a common contaminant noticed in meatmeal is steel filings that would have unhappy effects on colour.

5.7. Abrasives

No indication was found of bone having been used as an abrasive.

6. Prospects and requirements for applications for ash fractions

6.1. Fertiliser

Phosphatic fertilisers are used throughout Australia on a massive scale and the price of phosphorus in superphosphate with about 9% phosphorus, sits at around $2000 per tonne. On phosphorus content then, the clean bone used in the fertiliser trials of this project, with 12.2% phosphorus, has a value of $240 per tonne.

One could reasonably expect that it should warrant a premium when used by organic growers who have no other source of readily available phosphorus available to them under the Australian National Standard for Organic and Bio-dynamic Produce. The same should apply to plant production in regions where leached phosphorus poses a pollution threat to waterways.

An important feature of this application is that bone fractions require no further treatment or purification since the nitrogen and trace minerals present in the meat fraction have high fertiliser values and any fat present is likely to have beneficial surfactant effects that would be likely to counter any anti-microbial effects from free fatty acids.

The issue of the 2.5% minimum level of citrate soluble phosphorus in blood and bone demanded by the Victorian regulations is a concern because such a level could not come from bone material and would have to be supplied by the "non-ash fraction".

The established awareness in horticulture of "blood and bone", the esteem in which it is held, its scarcity on account of the decline in the traditional method of producing it and the enforcing of minimum standards for it under the Fertiliser Regulations in Australia recently, the burgeoning of organic farming, environmental concerns over fertilisers combine to create a superb marketing opportunity for the ash fraction of meatmeal as "blood and bone".

There is no doubt that fertiliser offers the best large scale opportunity for the use of bone separated from meatmeal and the market prospects should be given the highest priority for examination.

The use of bone as fertiliser is discussed at length by J Y Langdon in Appendix 2 . He identifies potential application for bone as a phosphatic fertiliser in coastal New South Wales, Gippsland, North East Tasmania and parts of the South West of Western

Australia in conventional agriculture over a total of around 13m hectares. He excludes Northern Australia because it has not been evaluated in this connection.

He points out that among the factors that dictate the effectiveness of bone as a phosphate source are the soil hydrogen pool size, the moisture conditions, the buffering capacity of the soil, its cation exchange capacity and its adsorption capacity. The degree of aeration of soils is known to be another factor.

Bone seems likely to be an effective means of maintaining ongoing phosphorus levels in established systems, especially pastures. It may prove to have an availability similar to partially activated phosphate rock (PAPR).

Langdon sees the principle opportunities for bone as fertiliser in:

i. Organic farming.

ii. Environmentally sensitive areas where phosphate leached from more readily available sources can lead to eutrophication of waterways.

iii. As an alternative to poultry manure where heavy applications of it as a very cheap source of phosphorus can lead to pollution of groundwater with nitrate as well as phosphorus.

iv. In the production of cut flowers and leaves from Australian native and other plants such as Proteas that require phosphorus at low levels, but are extremely sensitive to it at moderate levels.

6.2. Animal feed supplements

Phosphate deficiency in cattle in the tropics is a worldwide and well documented problem. Although phosphate supplementation, where it is practiced in Australia tends to be done in the drinking water, it is a poor substitute for providing it in feed and bone meal is the ideal phosphorus source.

In most cases a crude ash fraction would be highly acceptable on account of the extra protein, the other minerals and the energy value of the fat.

Most of the cattle and know-how being used to boost beef and dairy production in tropical countries North of Australia are sourced from Australia and presumably the industries in these countries would be open to the use of such supplements. Indonesia would be the likely best prospect.

Unfortunately, the advent of BES in the United Kingdom has put paid, for the time being at least, to the possibilities for using ash fractions for cattle.

However, as can be seen in Section 5, the prospects for the use of ash fractions in chicken and pig rations are excellent.

N D Costa has reviewed the use of the ash fraction of meatmeal, and other considerations in Appendix 3. Aside from the potential for its use in tropical cattle production as a phosphorus supplement, there seems to be a limited application for its use in premium dog foods for large breeds of dogs during growth on account of its ideal balance of minerals. The requirement in cat foods to keep magnesium levels below 0.07% not only precludes bone from their diets, but meatmeal in general as well. There is no potential for it in aquaculture.

6.3. Gelatine & glue

The quoted price of $600 per tonne for separately processed bone that is clean and low in fat and destined for gelatine production is attractive and unlikely to be surpassed. It deserves high priority for further examination and investigation.

Clearly, if the gelatine is for photographic purposes, the question of colour, clarity, and the bloom characteristics, that can be achieved in gelatine produced from the bone fraction of dry rendered meatmeal are critical issues.

Nonetheless, even if a gelatine of photographic quality cannot be produced from the meatmeal fraction, it is possible that a high quality product suitable for other applications can be, and there is still the matter of the high grade phosphate by-product.

It is worth noting too, that the phosphorus in superphosphate (based on 9% P content) actually costs around $2,000 per tonne. This application appears to offer the best price prospects for significant quantities of ash fraction and warrants further investigation, notwithstanding that the market that uses it may by highly restricted in terms of competition.

6.4. Bone char, pigment feedstock and metallurgy

Notwithstanding the diminishing use of bone char for bleaching sugar, its characteristics seem to confer advantages on it in pack carburizing of steel where it allows for a higher level of control of the process than some alternative methods. In pigment production it imparts an attractive lustre to the inks where it tends to be used for special applications, however it is a low density pigment with weak covering properties.

These applications deal with small-scale quantities and cannot be regarded as significant in "whole of industry" terms.

6.5. Bone china

The stringent requirement about colour appears to rule out the use of bone recovered from dry rendered meatmeal in bone china production. While there may be good prospects for the use of separately processed bone in this application, it cannot be commended as a prospect for the bone fraction under discussion here.

Bone china production seems to be an ongoing, if not moderately growing business and it is probable that there are good opportunities for some individual plants to produce for it. There is no reason to believe that it is something significant in "whole of industry" terms.

6.6. General

Since the established industrial uses for bone are based on clean degreased bones as starting materials, the most obvious approach is to wet render bones separately from soft offal at low or intermediate temperatures and present them to end users in the forms that they are accustomed to.

Since most bone material enters the rendering industry from boning rooms or butcher shops that should not be a difficult thing to achieve.

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7. Recommendations on 'best prospect' applications for ash fractions

7.1. Fertilisers

Fertiliser represents the application with greatest potential for large scale use of ash fraction and perhaps the one easiest to realise.

Its production would fit in ideally with separation of the ash fraction from meatmeal as it is being produced now and not depend on separation out of bone prior to rendering.

To the extent that the ash fraction can align itself with "blood and bone" it is already recognised in the market place as a proven, high quality and effective product.

It is anticipated that the fertiliser trials in this project will provide hard data on the effectiveness of the ash fraction.

7.2. Feed supplements

Their appear to be excellent prospects in this direction for the use of ash fractions as phosphorus sources for chicken and pig production, and to a moderate extent in up-market pet foods. When the protein and fat contents of the ash fractions are taken into account, along with the phosphorus their potential values are most attractive as can be seen in Section 9.

7.3. Gelatine and char

Although funds in this project were insufficient, it would otherwise have been worthwhile to make fax contact with gelatine producers and photographic film producers to establish the extent and nature of the demand for bone for up-market gelatine production.

The feasibility of using high purity ash fraction of dry rendered meatmeal for high grade gelatine production should be evaluated by provision of samples to processors and by direct laboratory evaluation in Australia as well. Notwithstanding the outcome of this examination it seems logical however that producers in practice would process bone destined for these applications separately from the beginning anyhow.

The prospects of using fractionated material for char are worthy of examination in the same way as for gelatine. Like gelatine they are likely to be more significant to individual processors who choose to gear up for the purpose, rather than to the rendering industry as a whole.

7.4. Bone china

The prospects for bone china seem to be more promising than for char, although maybe not so bright as for gelatine.

In the same way as for gelatine, it seems probable that only separately processed bones would be suitable as feedstock. It may well be that up to the point of calcining the processes for both uses would be similar and could be done in the same plant.

Like gelatine and char, the prospects for production for bone china are likely to be more significant for individual processors who set up for it than for the rendering industry as a whole.

An early stage evaluation of the market prospects and requirements should not be too difficult or time consuming a task if done by fax, beginning with leading manufacturers of bone china. It is understood that all or most of the calcined bone ash used is supplied from England.

8. Demonstration and evaluation of ash fraction as a fertiliser

8.1. Commercial trials

Commercial trials were undertaken on organically produced:

Lettuces
Cabbages
Beans
Zucchinis
Carrots

Statistically significant yield increases to increasing rates of ash fraction utilisation were obtained with lettuces and zucchinis. Although the yield increases from extra applications were not significant for carrots, the farm's management observed that the quality of the crop was the best ever. The increase in zucchini production was in terms of yield and number of zucchinis.

The trials are reported on detail in Appendix 4.

8.2. Phosphate readily available

The outstanding significant finding from the trials was that the soil data and crop responses indicated that the nutrients in bone meal are readily soluble This dispels the image of bone meal and meatmeal as slow release fertilisers. It is significant besides because most of the "blood & bone" presently marketed is meatmeal with its phosphorus considerably boosted by the addition of rock phosphate, with exceedingly slow release phosphorus. It would be interesting to know if its notoriously slow release of its phosphorus is speeded up in the presence of the meatmeal.

8.3. Controlled release of phosphate

The ash fraction used in the trials was finely ground. This coupled with the rapid release of phosphorus observed raises the possibility of securing graduated phosphorus release by the use of fractions graded according to particle size.

9 Ash fractions as fertilisers

9.1. Prospects for the use of the ash fractions of meatmeal as a fertiliser

Table 1, previously shown in Section 3, shows typical results from the analyses of the ash fractions of meatmeals. *Sample A* is the material used in the fertiliser trials within this project and is produced by processing bone material separately from soft material in a low temperature rendering system. *Sample B* is ash fraction separated from a dry rendered meatmeal, it is material very free of soft meal and is probably near the ultimate of the ash fraction that can be separated out from meatmeal. *Samples C and D* are ash fractions crudely separated from two different meatmeals using very simple fractionation apparatus.

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Copper	6.8	6.8		
Zinc	30.0	32.6		
Total Phosphorus (P)	12.2	10.5	6.82	6.78
Water soluble P	0.02	0.085	0.19	0.30
Citrate insoluble P	10.7	9.2	5.0	4.4
Citrate soluble P	1.48	1.22	1.63	2.08
"Available" P (total - citrate insoluble)	1.5	1.3	1.82	2.38

It is notable that the phosphorus contents of *Samples A and B* are about 40% and 20% respectively higher than in superphosphate, while those of *Samples C and D* are about 75% of superphosphate.

Samples C and D are well within the specifications for blood and bone for minimum nitrogen and total phosphorus contents, although neither of them achieve the minimum level of 2.5% for citrate soluble phosphorus specified under the notoriously perverse Victorian Fertilizers Regulations.

A surprising finding of the field experiments (Milestone 3) was that at both rates of application of bone meal (1800 and 6075 kg/ha) the residual levels of phosphorus, nitrate and ammonia nitrogen, sulphur, organic carbon and reactive iron were less at the conclusion of the experiments than they had been at the beginning (4 months earlier). This contradicts the widely held belief that blood & bone or meatmeal are necessarily slow release forms of plant nutrients, at least under the liberally irrigated sandy soil conditions of the experiments.

It should be noted however, that the material used in the fertiliser trials was finely ground. The rate of release could be regulated widely by the degree of grinding and fractionation by sieving into appropriate particle sizes .

Hence, potential users of the meal can have phosphorus availability both ways. Firstly, when finely ground it is readily available. Secondly, its rate of release can be regulated by the fineness of its grinding. The ready availability of nutrients in meatmeal, especially the phosphorus, should be good news to most organic growers. Coarsely ground for slow release it has high prospects for use in situations where leaching from the soil could constitute an environmental threat.

9.2. The blood & bone market

A number of individuals interviewed expressed scepticism of the generally quoted figure of 1,000 tonnes of blood & bone produced per annum, considering it to be a massive understatement of the true amount. The indications in fact are that the annual production of "blood & bone" is 6,000 to 8,000 tonnes per annum.

However this production of "blood & bone" is mainly constituted of material in which the phosphorus content is boosted by the addition of rock phosphate, an extremely slowly available, but economical source of phosphorus. *Considering the findings in the fertiliser trials on the ready availability of the phosphorus in the ash fraction of meatmeal, the possibly very poor availability of this phosphorus should be a matter of grave concern to the rendering industry, since it could considerably reduce the effectiveness of a long standing industry product.*

The wholesale price of "blood & bone" is around $400 per tonne and the retail price around $600 per tonne. These are attractive, but as Table 2 shows, $400 per tonne values the product at $260 per tonne above the chemical value of its constituents. While the total quantity sold may not be spectacular, it is significant, the price is excellent and so its vulnerable position should therefore be defended and if possible, expanded.

The users of blood & bone are home gardeners, greenkeepers and organic growers to a limited extent.

The potential demand for "blood & bone" from organic growers could readily be over-estimated. The National Association of Sustainable Agriculture, Australia Pty Ltd (NASAA) and the Organic Vignerons Association of Australia Inc. approve of ongoing use of approved organic fertilisers, which could include approved "blood & bone". However, the Bio-Dynamic Agricultural Association of Australia does not accept the use of "blood & bone" at all, Biological Farmers of Australia will only agree to the application of 'approved' "blood & bone" as an interim measure, but not as an ongoing practice. It could be presumed that the larger non-certified body of "organic growers" growing produce for domestic use, would have no hesitation, other than consideration of cost, in using "blood and bone".

The suggested means to defend and expand the market share of "blood & bone" are to:

i. Make it more user friendly, for example by pelleting it, by deodorising it and by incorporating it into slow release products.

ii. Demonstrate and publicise its effectiveness.

iii. Promote its use among the most dedicated gardeners, especially the various plant and flower societies. Making samples available as raffle prizes and competition prizes at shows is a proven fertiliser promotion route.

9.3. Organic fertilisers

In practice organic growers make heavy use of waste materials such as feedlot and poultry waste, evidently freely available at $50 per tonne with a phosphorus content of around 1% and nitrogen around 2% and potassium around 0.2% i.e....... an ratio of 1:2:0.2.

The approximate prevailing prices for the leading brands of organic fertiliser are:

4:3:2	"Terra Firma" @	~$350 per tonne
~3:2:2	"Dynamic Lifter" @	~$300 per tonne
4:3:2	"Jomoco" @	$260 to $280 per tonne
3:3:3	"Neutral" @	~$300 per tonne

Considering that horticulturalists are primarily concerned to achieve higher nitrogen levels, the 5% to 7.4% nitrogen content of the ash fractions under consideration would have considerable appeal along with the phosphorus contents of 10.5% to 6.78%. The potassium contents are almost too low for consideration.

In 1988 the Western Australian market for Dynamic Lifter was approximately 4,000 tonnes per annum. Given that it was at that time the only product of its class available, one could surmise that it represented the total production of the class. Further, assuming that the Western Australian market represented 10% of the total national market it can be calculated that the total national market of the day was 40,000 tonnes. Given 10-15% per annum expansion of the market since that time, the present market size is likely to be of the order of 94,000 to 103,000 tonnes per annum.

NASAA's present 0.5% levy on the fertilisers that it certifies, earns $6,000 per annum, indicating total sales of $1.2m. equivalent to 4,000 tonnes @ $300 per tonne. Assuming that certified fertilisers represent one third of the total fertiliser used by NASAA's 270 certified growers, the total amount used by them would amount to around 12,000 tonnes per annum.

Hassall & Associates recently estimated the size of Organic food production at $80m. The annual value of production by NASAA accredited growers is $15m. or 19% of the $80m total. So fertiliser use by accredited growers on the same scale as NASAA members would put total usage by them at 64,000 tonnes per annum. However, deducting 50% for those organic growers not using fertilises at all, brings the figure back to 32,000 tonnes per annum.

On the other hand it is pointed out authoritatively that the AQIS system of certifying organisations and accredited growers is primarily targeted at production for export and for sale, and it is claimed that the true value of annual organic production is closer to $250m., around three times the Hasall's figure. *Pro rata* use of fertilisers on the 32,000 tonnes per annum scale would thus put their total fertiliser use at 100,000 tonnes per annum, a figure in line with that based on the Dynamic Lifter calculation.

The potential for ash fraction based fertilisers arises from the prospect of securing a share of the present 100,000 tonnes base plus a share in its growth:

i. One could reasonably predict them carving out a 15% share the present 100,000 tonne market or 15,000 tonnes per annum.

ii. A continuation of 10 to 15% per annum or 10,000 to 15,000 tonnes per annum expansion of organic growing from the current 100,000 tonnes per annum base would offer marketing opportunities for fertilisers based on the ash fractions of meatmeals. It would be realistic to suppose that ash fractions could initially secure 15% of these amounts, or 1,000 to 2,250 tonnes per annum growth.

This market would not develop passively. It would need to be actively developed and the products promoted. Since as with traditional "blood & bone" these products would to be pretty much generic there is good opportunity to reduce market development costs and improve its effectiveness by the rendering industry as a whole to a large extent.

Similar marketing and promotion opportunities to those referred to earlier for traditional "blood & bone" would apply to these products. However considering that these products would have much greater industrial application, it would be well worthwhile to place a heavy emphasis on commercial demonstrations and evaluations and displays such as at field days.

In this regard, attention is drawn to NASAA as an impressive accreditation body in the organic growing world, that it could prove beneficial and cost effective for everyone, including organic growers, to work with to their mutual advantages.

Mr Rod May of NASAA is an impressive person on account of his knowledge, attitude, approach and presumably his influence within NASAA. It can be anticipated that his influence could be leveraged through his NASAA association to the wider domestic "organic community". It is recommended that the prospects of the rendering industry working with Mr May to the greater benefit of NASAA, the domestic organic community and the rendering industry, through the improved marketing of ash fraction "blood & bone" be investigated.

9.4. Prices and value of blood & bone

The values of "blood & bone" based on using $943 per tonne for nitrogen, based on the prevailing urea price, $1835 per tonne for phosphorus based on the prevailing superphosphate price of $167 per tonne and $606 per tonne for potassium based on the current muriate of potash price of $297 per tonne are shown in Table 2 and are compared with its prevailing wholesale price of $400 per tonne. The figures show that "blood & bone" sells at a margin of $260 per tonne above the values of its main chemical content. The figures in Table 3 make the same comparisons of the four products: "Terra Firma", "Dynamic Lifter", "Jomoco" and "Neutral". They show a margin of $165 to $245 per tonne and the average margin is $208 per tonne.

Table 4 shows the values for meal fractions A, B, C and D calculated on their mineral content alone ranging from $193 to $268; on the mineral content plus the mean margin of $208 from the four proprietary fertilisers ranging from $401 to $476; and the mineral content plus the $266 margin "that blood & bone" secures in the market place ranging from $459 to $534.

While prices of $401+ per tonne for an ash fraction of meatmeal are attractive, particularly given that the low ash fraction would be sold into aquaculture for considerably more, it must be borne in mind that the figure represents a $100 per tonne increase in the prevailing prices for the established organic fertilisers already in the market place. The ash fraction "blood & bone" meals would therefore need to be marketed skilfully.

An issue for consideration is that modern farm machinery requires fertiliser materials to be free flowing. Modern fertilisers are generally pelleted or in prill form to ensure that they are acceptable. This includes organic fertilisers such as "Dynamic Lifter". A notable exception to this is superphosphate. However, while it is conceivable that they could need to be pelleted, which is a significant expense, a feature of all four of the meals was that they were free flowing, and this characteristic could improve even further if the fractions were graded according to size to better control the rates of release of nutrients.

It can be seen from Tables 2 to 4 that on the organic fertiliser market where the margin over the value calculated on the mineral content is $208 per tonne, the blood & bone ash fractions have values ranging from $401 per tonne to $476 per tonne. On the "blood & bone market" using a calculated margin of $266 per tonne, the corresponding values would range from $459 to $534 per tonne.

Table 3: The value of "blood & bone" based on using a value of $943 per tonne for nitrogen based on the prevailing urea price of $434 per tonne, of $1835 per tonne for phosphorus based on the prevailing superphosphate price of $167 per tonne and of $606 per tonne for potassium based on prevailing muriate of potash price of $297 per tonne.

	Nitrogen	Phosphorus	Potassium	Value calculated on mineral content	Actual price	Margin of actual price over calculated value
Urea	46%	0	0			
	@ $434			$434	$434	
Superphosphate	0	9.1%	0			
		@ $167		$167	$167	
Muriate of potash	0	0	49%			
			@ $297	$297	$297	
Blood & bone	4.5%	5.0%	-			
(Victorian standard)	@ $42.4	@ $91.8		$134.2	$400	$266

Table 4: Comparing the actual prices of "Terra Firma", "Dynamic Lifter", "Jomoco" and "Neutral" with the prices calculated for them on the basis of the mineral contents. The mean margin is $208 per tonne.

	Nitrogen	Phosphorus	Potassium	Value calculated on mineral content	Actual price	Margin of actual price over calculated value
"Terra Firma"	4%	3%	2%			
	@ $37.7	@ $55.1	@ $12.1	$104.9	$350	$245
"Dynamic Lifter"	3%	2%	2%			
	@ $28.3	@ $36.7	@ $12.1	$77.1	$300	$223
"Jomoco"	4%	3%	2%			
	@ $37.7	@ $55.1	@ $12.1	$104.9	$260-280	$165
"Neutral"	3%	3%	3%			
	@ $28.3	@ $55.1	@ $18.2	$101.6	$300	$198

Table 5: Showing the values calculated for the meals A, B, C and D on the basis of the mineral contents, those obtained by adding the mean of the margins for "Terra Firma", "Dynamic Lifter", "Jomoco" and "Neutral" of $208 per tonne to the calculated value, and those obtained by adding the $266 per tonne margin on blood & bone @ $400 per tonne calculated in Table 2.

	Nitrogen	Phosphorus	Potassium	Value calculated on mineral content	Calculated value + $208	Calculated value + $266
Blood & bone	4.7%	12.2%	0.04%			
sample A	@ $44.3	@ $223.9	@ $0.2	$268.4	$476	$534
Blood & bone	5%	10.5%	0.06%			
sample B	@ $47.2	@ $192.7	@ $0.4	$240.3	$448	$506
Blood & bone	7.2%	6.8%	-			
sample C	@ $67.9	@ $124.8		$192.7	$401	$459
Blood & bone	7.4%	6.8%	-			
sample D	@ $69.8	@ $124.8		$194.6	$403	$461

10. Ash fractions for animal feeds

It has previously been pointed out that the outbreak of BSE in the United Kingdom rules out the use of meatmeal fractions as ruminant supplements for at least the time being.

10.1 Phosphorus and protein

The animal feed industries use meatmeal almost as much on account of its phosphorus content as its protein content. Hence the main value of a phosphorus enriched meal would be based on its phosphorus content at a price of $2730 per tonne based on that of di-calcic phosphate of ~22% P at around $600 per tonne. To that at present would be added around $50 to $60 per tonne for its protein content of 31.2%.

It could be necessary or desirable for the meal to be further ground or graded to address this market most effectively.

On that basis the approximate values of the four 'ash fractions" are shown in Table 5.

Table 6: Showing approximate present day values of meals on the basis of Samples A, B, C, D on the equivalent of phosphorus at 22% of di-calcic phosphate @ $600 per tonne and an allowance of $50-$60 per tonne at 31.2% of protein in the meal.

Parameter	Sample A	Sample B	Sample C	Sample D
Nitrogen	4.7	5.0	7.2	7.4
Protein (Nx6.25)	29.4	31.2	45	46.2
Total Phosphorus (P)	12.2	10.5	6.82	6.78
Approximate present day value	$380-390	$336 - $346	$258-$268	$259-$269

10.2. Component values of ash fractions

An anomaly becomes apparent when the above figures are considered. Firstly, meatmeals with protein contents of 50% are generally priced at $400 per tonne or less. Secondly, solvent extracted soybean of only meal 44% protein, with negligible levels of phosphorus sells at $500 per tonne, equivalent to $1136 per tonne for its protein (on the assumption that protein is 100% of the value of soybean meal, or $966 per tonne on the assumption that the protein of meatmeal has only 85% the value of soybean protein). It compares even less favourably with the value of the protein in $1100 per tonne fishmeal of 67% protein, at $1695 per tonne on the same assumption. In the calculation in Table 5 the protein in meatmeal has a value of only $160 to $190 per tonne! Table 6 illustrates the point by showing the values of the four ash fractions when the value of $1136 per tonne for soybean meal protein is attributed to the protein in them.

Note that Table 6 does not take into account the value of around 10% tallow in the meatmeal, on the assumption that its energy value at around 2.5 times that of digestible carbohydrate is roughly equivalent to that of the carbohydrate in soybean meal.

Table 7: Showing approximate values per tonne of meals in stockfeeds on the basis of Samples A, B, C, D on the equivalent of phosphorus at 22% of di-calcic phosphate @ $600 per tonne and valuing the protein content as equal to that of soybean meal, namely $1136 per tonne and assuming that it has 85% the value of soybean protein.

Parameter	Sample A	Sample B	Sample C	Sample D
Nitrogen	4.7	5.0	7.2	7.4
Protein (Nx6.25)	29.4	31.2	45	46.2
Total Phosphorus (P)	12.2	10.5	6.82	6.78
Approximate value assuming protein = soybean protein	$667	$641	$708	$727
Approximate value assuming protein = 85% of soybean protein	$617	$588	$631	$648

10.3. Component value of meatmeal

The theoretical value of 50% protein, 6% phosphorus meatmeal based on soybean meal protein and di-calcic phosphate phosphorus values is calculated to be:

	Protein	= 50/100 x 1 x 1136	= $568 =	($482.80 at 85% of soybean protein value)
+	Phosphorus	= 6/100 x 1 x 2730	= $163.80 =	$163.80
	Total theoretical value		= $731.80 =	($646.60 at 85% of soybean protein value)

10.4. Market size

It is not possible to put an accurate figure on the size of the potential market for the high ash meatmeals because feed millers compound their rations on least cost formulations based on the costs prevailing on the day. Those costs vary. However, based on the chicken meat industry alone having a potential annual import replacement demand of 10,000 - 20,000 tonnes for the ash fraction, the overall total could be around 60% greater again for pigs, pet food and poultry that at 16,000 to 32,000 tonnes per annum. There would be additional demand to the extent that the phosphorus content of meatmeal is presently taken into account when it is included in rations. That is presumably equal in equivalents to the present annual usage of meatmeal in Australian feedstuffs of around 300,000 tonnes. Since di-calcic phosphate is an internationally traded commodity there is presumably a larger potential market available in overseas chicken and pig feeds.

Beyond that is the issue of correcting the marketing of meatmeal itself so that full credit is given to its phosphorus and fat as well as its protein contents.

There no doubt are some valid reasons for the gross differences between the value of meatmeal calculated from the value of its individual constituents. Apart from the rendering industry not making its clients fully aware of the constituents some of the reasons would be poor physical quality of meals, variations in quality and constituents and in particular the quality and variations in quality of the protein. However, to a considerable extent the low prices for the product must arise from its mix of constituents being unsuitable for some applications, of which aquaculture is one instance and poultry production would be another.

The production of high ash meatmeal fractions would go a significant way towards overcoming the latter restrictions.

The ideal means of fractionating meatmeal of course would be by greater segregation of the raw materials in the first place.

11. Recommendations on marketing of ash fractions

11.1. Animal feeds first priority

It is recommended that the animal feeds industry be the greatest priority target for market development on account of the prospects for price increases and the market size considering that:

i. There is an established market of 10,000 to 20,000 tonnes per annum in the animal feeds industry and likely to be 16,000 to 32,000 tonnes, for the ash fraction at around $2727 per tonne of phosphorus, or $286 per tonne for meal of 10.5% phosphorus;

ii. In addition there is a proportion of the existing 300,000 tonne domestic meatmeal market that would be open to use of the ash fraction in conjunction with another source of protein;

iii. The calculated values of the ash fraction (and indeed of normal meatmeal itself) taking into account its phosphorus, protein and fat contents are $230 to $450 per tonne above present prices and therefore constitute an impressive opportunity to increase profitability;

11.2. Industry marketing plan for feeds and fertiliser

It is recommended that the rendering industry pursue the opportunities for ash fractions commercially with an industry marketing plan in which marketing and promotional costs are shared, and in conjunction with research and demonstration to promote use of the fertilisers and to justify the premium prices sought for them considering that:

i. The existing market prices for "blood & bone" and proprietary organic fertilisers are $206 to $260 per tonne above the chemical value of their constituents, translating to attractive prices for the ash fractions examined of $401 to $534 per tonne;

ii. The make-up of the ash fractions would be attractive to horticulturalists on account of their relatively high nitrogen contents;

iii. The indicated market opportunity for such fertilisers of 15,000 tonnes per annum with annual growth of 1,000 to 2,250 tonnes;

iv. The $206 to $260 per tonne margin of price over chemical value of organic fertilisers constitutes a threat as well as an opportunity;

v. From a fertiliser point of view the chemical quality of protein is of no consequence, for example hair and hoof protein have the same value of that of lean meat;

11.3. Blood & bone development and marketing

It is recommended that promotion of traditional "blood & bone" be undertaken as a diversification step, to improve its price, to maintain its competitive position with respect to products such as "Dynamic Lifter". The present market for blood & bone is mainly separate from that for commercial organic fertilisers, but at $400 per tonne wholesale, which is competitive with the present stockfeed price, it is a position well worth defending by the rendering industry. This would ideally involve the rendering industry as a whole in conjunction with brand promotion.

11.4. Marketing to organic growers

Promotion to commercial organic growers can be simplified by cooperating with NASAA. In the first place NASAA certifies fertilisers that meet its criteria for a fee of $400 to $550 and a 0.5% royalty on sales. Secondly, it can provide a list of its members. Thirdly, the products can be promoted through its newsletters, preferably by arranging editorial space in conjunction with advertising. It would probably be feasible to arrange for field trials to be conducted under NASAA auspices as well. Presumably NASAA newsletters or other journals could then be used as vehicles to authoritatively publicise the outcomes of the trials.

11.5. Field days

An additional route for promotion is through the various field days held annually around Australia.

12. Conclusions

12.1. Animal feeds

There are large existing markets for the ash fraction of meatmeal in the animal feeds industry at prices that are not only acceptable at present rates, but which offer the potential for price increases approaching $230 to $400 per tonne.

12.2. Fertilisers

There is an unexploited opportunity to market high ash fractions of meatmeal as proprietary organic fertilisers to the extent of around 15,000 tonnes per annum with annual growth around 1,000 to 2,250 tonnes at prices of around $400 per tonne.

12.3. Traditional blood & bone

The existing market for traditional "blood & bone" should be defended and expanded as opportunities allow.

12.4. Joint industry action

There is considerable scope for the rendering industry as a whole to act together in the exploitation of these opportunities.

Appendix 1

Bonemeal from "Commercial Fertilizers"
by G H Gollings

Chapter Eight

Sources and Uses of Bone Phosphate and Basic Slag

Bones are known to have been employed as fertilizer in England as early as 1653. In fact, their value as a fertilizer material appears to have been recognized in England much earlier than in any other country.

Bone fertilizers have always been held in higher esteem than phosphate rock. This might be explained in part by the fact that fertilizer materials of plant or animal source have, for a long time, been considered to be superior to those of an inorganic source.

Sources of Bone

During the latter part of the nineteenth century deposits of bone were sought, particularly by the English, and collected from all parts of the world for use as fertilizer. Justus von Liebig has stated that even such battlefields as Leipzig, Waterloo, and the Crimea, as well as the catacombs of Sicily, served for a time as sources of supply. In the early days in this country large quantities of buffalo bones were collected from the western plains for fertilizer purposes. At present the principal source of supply of bones is the abattoirs, although small amounts of waste bone are secured from the manufacture of bone buttons, knife handles, and similar articles.

In the past, considerable quantities of bones have been shipped to Europe from Argentina and India. Recently, however, the government of India placed an embargo on the export of bones. As virulent anthrax organisms have sometimes been discovered on old bones, there was formerly a certain amount of prejudice in some sections against the use of raw bonemeal. Many countries require a certificate of sterilization before cargoes of bone may be imported.

Chemical Composition of Bone

Bone is made up largely of calcium phosphate scattered through an organic matrix. The formula generally ascribed to the phosphate found in bone is $Ca_3(PO_4)_2$. This phosphate is commonly referred to in the ferti-

lizer trade as *B. P. L.*, or bone phosphate of lime. Hendricks and Hill (1942), however, have presented evidence that seems to indicate that the phosphate found in bones may be a hydrated tricalcium phosphate type of compound containing sodium, magnesium, and carbonate as essential constituents. Apparently it is an apatite whose fluorine has been replaced by carbonate and whose calcium has been partially replaced by magnesium and sodium. Klemet (1938) showed that while the apatitelike unit structure of tricalcium phosphate hydrate is $(Ca_9)(PO_4)_6(H_2O)_2$ that of human bones is $(Ca_{8.50}Mg_{0.25}Na_{0.15})[(PO_4)_{5.07}(CO_3)_{1.24}](H_2O)_{2.0}$. Nevertheless, many investigators hold that the phosphate compound in bone is a carbonatoapatite $[Ca_3(PO_4)_2]_3 \cdot CaCO_3$. The organic matrix of bone is made up largely of fatty substances, but it also contains small amounts of nitrogenous compounds. The amount of phosphorus and nitrogen contained in bone fertilizers depends upon the kind and age of the bone. As a general rule, young bones contain less phosphorus and more nitrogen than older bones. Fluorine may also be present in bone as the fluorapatite, and may be present in large amounts if the animal ingested large quantities of fluorine. The percentage of fluorine in older bones is considerably higher than in younger bones.

Raw Bonemeal

Green bones are ground and sold under the name of raw bonemeal. The fatty materials found in raw bonemeal tend to delay the decomposition of the material when it is added to the soil. Raw bonemeal of good grade contains about 2 to 4 per cent of nitrogen, and from 22 to 25 per cent of phosphoric acid (9.6 per cent P).

Steamed Bonemeal

Most of the bonemeal that is found upon the fertilizer market is steamed bonemeal. That is, the meal is made from green bones that have been boiled or steamed at high pressure for the purpose of removing the fats, or from which the fat has been extracted with naphtha or other solvents. As fat does not contain nitrogen, phosphorus, or potassium, and as it has a commercial value, it should be removed, especially since its presence hinders the ready decay of the bonemeal after it is incorporated in the soil. During the boiling or steaming process a large amount of the fatty materials is separated from the bone, and the gelatinous materials are then removed by subjecting the bone to high steam pressure. The gelatinous material is used in the manufacture of gelatin and glue, and for other purposes. Its removal brings about a small loss in the nitrogen content of the resulting bonemeal, but an increase in the percentage of phosphorus.

FIG. 58. Sugar cane in Louisiana. (*Left*) Unfertilized. (*Right*) Fertilized. (Courtesy, United States Department of Agriculture.)

The steaming of bones changes their physical composition so that they may be ground more easily and may be put into a finer physical state for distribution in the soil. Bonemeal is sometimes sold under the name of bone dust. The name may indicate a degree of fineness, but the name is not always associated with the degree of fineness. Steamed bonemeal generally is ground more finely than raw bonemeal. The process of steaming also greatly increases the ammonium citrate solubility of the phosphate. Steamed bonemeal contains 1 to 2 per cent of nitrogen, and about 22 to 30 per cent of phosphoric acid (10 to 13 per cent P).

Steamed bonemeal may be so light in weight per volume that if it must be broadcast during windy weather, it should be mixed with fine damp soil or sawdust. It is superior to the mineral phosphates in its immediate crop-producing powers. This superiority may be due to its physical characteristics and to its organic origin. Bonemeal rates well as a source of phosphorus. The availability of its phosphorus appears to be slightly lower than that of basic slag. The effectiveness of bonemeal is increased by its nitrogen content and also by its content of secondary and rarer essential elements. Best results are secured when it is applied to acid soils containing an ample supply of organic matter. Parker and Tidmore (1926) have reported that liming the soil has a depressing influence on the solubility of phosphorus in steamed bonemeal, and Schreiner, Merz, and Brown (1938) have reported that the availability of the phosphorus in raw bonemeal is increased by the acid decomposition products of its organic matrix.

Precipitated Bone

Precipitated bone is a by-product produced in the manufacture of glue stock from bones. It contains 40 per cent of phosphoric acid (17 per cent P), largely in the form of dicalcium phosphate. It is obtained by neutralizing the hydrochloric acid solution of processed bone with calcium hydroxide.

Bone Ash

Bone ash has been imported to some extent into this country from South America. It is made by burning bones for the purpose of reducing their bulk for shipment. During the burning process most of the nitrogen is driven off. The material analyzes 30 to 40 per cent of phosphoric acid (13 to 17 per cent P), and contains a small amount of magnesium and fluorine. It is not extensively produced for, or used in, the fertilizer industry.

Bone-black or Bone Char

Bones are sometimes heated in a closed retort in a manner similar to that followed in the coking of coal. The residual charcoal is known as bone-black. Sugar refineries use considerable quantities of high-grade bone-black for the purpose of clarifying sugar. After it has served this purpose, it may be used as a fertilizer. It contains about 30 to 35 per cent of phosphoric acid (13 to 15 per cent P), 1 to 2 per cent of nitrogen, and 10 per cent of carbon. When used in mixed goods, its carbon content may act as a conditioner.

Dissolved Bone

Dissolved bone or *bone superphosphate,* or what is in Europe sometimes called *vitriolated bone,* is made by treating bonemeal with sulfuric acid. This process was first demonstrated by Liebig. An English farmer by the name of Fleming followed Liebig's suggestion and manufactured and sold the product as *German compost.* The action of sulfuric acid on bonemeal is similar to that which takes place in the manufacture of the superphosphates when sulfuric acid is added to the phosphate rock. The phosphorus in dissolved bone is generally conceded to have the same crop-producing value as superphosphate. It is today rarely encountered in the fertilizer trade.

Value of Bonemeals

The bonemeals, raw and steamed, appear to act more quickly when applied to well-aerated soils. They are generally slower in their action when applied to heavy silts and clays. For many years previous to the present popularity of superphosphate, bonemeal, because of its supposed superior lasting qualities, or residual effect, was held in very high esteem by farmers. It was long a favorite fertilizing material to be used before planting land to grass and for other crops having a long growing season. Because of its lime content the use of bonemeal tends to reduce the acidity of the soil. Contrary to expectation, growers prefer the coarse grades of bone to the more finely divided or flour grade.

Appendix 2

Bonemeal as fertiliser

by J Y Langdon

Bone Meal as a Fertiliser

Literature Review of Bone Meal and Relevant Phosphate Fertilisers

Meat Research Corporation Contract

Contract Officer

J Y Langdon
372 Stirling Highway
Claremont
Western Australia

Summary and Conclusions

The effectiveness of bone meal as a fertiliser has not been extensively investigated under Australian conditions in recent years. However, phosphate rock, a mineral with many similar chemical properties when applied as a fertiliser, has been investigated comprehensively in Australia and New Zealand. These experimental programmes have delineated the soils and conditions required for phosphate rock to be effective.

The conditions required for phosphate rock utilisation are likely to be similar to those needed for bone meal to be effective as a fertiliser, and the review of the literature is based upon this hypothesis.

It is apparent that bone meal would not be effective or economical if used as a P fertiliser for general and widespread use in Australia. However, there are significant areas where soils and conditions appear to be conducive for slow release fertilisers. In these situations, bone meal may have potential as a slow release P or even N fertiliser.

The conditions and areas where P has the greatest potential as a fertiliser are detailed in the review.

It is not possible to estimate the potential demand or use for bone meal, as these are subject to costs, the analytical composition of bone meal and its relative effectiveness which may be determined by experimental programmes and field use.

1 0 The Significance of Phosphorus in Plant Nutrition

Phosphates play a fundamental role in a very large number of enzymic reactions in plants and accordingly phosphorus is one of the major elements required for plant growth. (Russell, 1952)

Phosphate deficiency in soils is very widespread throughout the world and in many countries, particularly Australia, crop production over enormous areas is limited by the level of available phosphate in the soil. The level of phosphate may be below the requirements for crops initially when the land is cleared or after one or two crops have been removed.

Consequently, phosphate fertilisers have been the most important in the development of Australian agriculture and are required for nearly all soils that are cultivated, cropped or used for introduced pasture species.

Cereal and other crops take up phosphates rapidly when the plant is small and the rate of uptake declines as the plant matures. For these types of plants it is essential that adequate supplies of P are present in the soil and accessible to the plant in its early stages of growth.

Plants take up P almost exclusively as the inorganic phosphate ions, probably only as $H_2PO_4^-$ ions. Other phosphates besides orthophosphate act as phosphate fertilisers, as, for example, meta- and pyro-phosphates, and it is probable that these anions are hydrolised to orthophosphate before being absorbed. Plants are, however, relatively inefficient users of phosphates in the field, for rarely more than 20 to 30 per cent of the amount supplied as fertiliser is taken up. (Russell, 1952)

2.0 P in the Soil

Four groups of P compounds exist in the soil, in all of which the P is present as PO_4:

1. Inorganic minerals containing phosphates as an integral part of their structure. Apatites and fluor-apatites, in which fluoride replaces the hydroxyl group, are the most widespread, but iron phosphates also occur under some conditions.

2. Insoluble calcium phosphates - produced when soluble phosphates are added to the soil.

3. Phosphate held on the surface of hydrated iron and possibly aluminium oxides. Phosphates may also be held on the surface of clay particles by mechanisms other than these hydrated oxides.

4. Organic phosphates, such as phytin and other inositol phosphates, nucleic acid and its derivatives, the other compounds that make up the humic material, the

partially decomposed plant and animal tissues and the tissues of the living plant roots and soil population. Typically, the organic phosphorus content of a soil varies from 2 to 0.5 per cent of the organic carbon.

The hypothesis that $H_2PO_4^-$ ions are normally the sole source of phosphate for the plant has several consequences.

Firstly, the proportion of the $H_2PO_4^-$ in solution per 100 Mols of dissolved phosphate declines significantly as the pH increases above 6. However, in the field, the effective pH in the neighbourhood of the root is a significant factor affecting the availability of P to the plant.

Secondly, the ability of calcium phosphates to supply phosphate ions would be expected to increase with increasing acidity. When water soluble mono-calcium phosphate is added to soil containing exchangeable calcium ions, it becomes converted to the insoluble dicalcium phosphate which may be formed on the surface of the clay particles. But this phosphate is sufficiently soluble to allow an adequate proportion of $H_2PO_4^-$ ions, particularly in acid soils, for plant growth. (Russell, 1952)

Acid soils contain reactive forms of aluminium and iron which combine with the $H_2PO_4^-$ ions in solution to form aluminium and iron phosphates, some of which are so insoluble that added phosphate is effectively "fixed" in the soil. This particular form of reversion occurs most rapidly in hot tropical climates having a pronounced dry season and applies to many Australian soils.

The efficiency of P fertilisers on such soils may be improved by placing the fertiliser in bands near to the plant roots, preferably in a granular form and possibly as a water insoluble fertiliser such as dicalcium phosphate.

The use of ground phosphate rock, and hence bone meal, may be appropriate in some conditions on these soils, which will be examined further later in the report.

3.0 Sources of P Fertilisers

Following the commencement of cropping in Australia, cereal yields declined steadily during the latter part of the last century, largely due to the exhaustion of the available soil phosphate.

A variety of P fertilisers and manures were used in experiments conducted in all states to determine the most suitable and economical source of P. The materials used in these experiments included guano and rock phosphate from various sources, basic slag, Thomas' phosphate, bone ash, bone meal or bone dust, dried blood, offal, fish manures, night soil and superphosphate.

In Western Australia, P G Wicken (1905) reported that the fertiliser trade was increasing every year and, compared to the quantity used a few years previously, was now assuming fair proportions. Bone dust remained a high figure with the demand in the Eastern States being almost equal to the supply so that very little was available for export to W A except at a high price. He added that the bulk of the trade was in superphosphate.

Bone dust was recommended for several crops, particularly at sowing. (Wicken 1905)

The increasing availability and reduction in price of superphosphate ensured that it became the predominant P fertiliser.

Australia's main sources of phosphate for the manufacture of superphosphate have been the guano and phosphate rock deposits on Nauru, Ocean and Christmas Islands. As these were exhausted, other sources have been utilised.

Although world reserves of high quality apatites are large, the big demand for P fertilisers means that these reserves will become increasingly scarce and expensive. However, Australia has very large deposits of apatite phosphate rock in north-western Queensland. Some of these can be used directly, after grinding, for the manufacture of superphosphate and other deposits have to be upgraded. These deposits are capable of supplying Australia's phosphate requirements for the foreseeable future,

While superphosphate is still the predominate P fertiliser used in Australia, other fertilisers containing P are utilised. Also, as the level of P in the soil has increased, through the accumulated effects of repeated applications of superphosphate, conditions in many soils have changed significantly. Other forms of P fertiliser may now be more economic or acceptable for reasons apart from price than superphosphate on some soils and conditions.

Bone meal may find a place as a fertiliser in some of these situations.

As bone meal itself has not been used as a fertiliser nor included in experimental programmes, it has been necessary to review the literature pertaining to the use of various phosphate rocks to determine the possible effects of bone meal applied to the soil and the conditions in which bone meal would be most beneficial, economical or otherwise acceptable.

4.0 Reversion of P Fertilisers in the Soil

Phosphatic fertilisers differ from nitrogenous and potassic fertilisers in that only a small proportion of the applied P is taken up by the crop.

However, the effect of an application of a P fertiliser may be seen for several successive crops, even though no further P is applied.

When soluble phosphate is applied to the soil, chemical reactions occur which rapidly convert the phosphate to insoluble forms. The reactions are complex and have two major effects:

- The availability of the soluble phosphate to plants is greatly reduced, so that only part of the added P is used by the crop.

- The fertiliser usually remains close to the point of initial contact with the soil. Except in very sandy soils, it is not easily leached.

As a consequence, with repeated applications of fertiliser P, the level of residual P generally increases in the soil. It remains available to plants, but at a considerably reduced level compared to that when it was just applied.

Inorganic phosphate is more readily available to plants at high levels of saturation than at low levels. Accordingly, under permanent pasture onto which fertiliser is broadcast the level of P available to plants may be relatively high due to the concentration of P at the soil surface.

The achieve the same effect in cultivated soils used for cropping, P fertilisers are usually applied as a concentrated band within the soil as close to the plant as possible without affecting the growing plant.

5.0 Residual Value

Crops grown on soils that have received considerable amounts of superphosphate may require less or even no further P to achieve maximum yields. The residual value of the previous applications depends upon the type of soil, the total amount and the period over which the fertiliser has been applied, whether it has been drilled into the soil or broadcast, and other factors.

It was possible, using the results of experimental trails, to make general conclusions regarding the effectiveness of the soil P "bank". One such conclusion was that Australian soils have an appreciable residual effectiveness when about 2000 kg per ha of superphosphate had been applied. (Costin and Williams, 1981)

"Decide" is a method, developed by the CSIRO and the WA Department of Agriculture, for calibrating the most economical rate of superphosphate to use in different situations, taking into account the residual value of previous P applications. Similar computer models have been developed in the other states.

As more fertiliser is applied over the years, the residual value of the latest increment becomes greater and accordingly losses through soil reaction become reduced.

On soils with high residual P, crop response to applied P fertiliser is no longer expected. As the rate of dissolution of the applied P is not important, sources of lower solubility could be considered to maintain soil P levels. The main consideration would be that the source used should eventually react with the soil to supply phosphate for plants. Exceptions include potatoes and other short season vegetable crops which may respond to water soluble phosphate even on soils considered to have a high P status. (Engelstad and Terman, 1980)

Accordingly, it may be concluded that on soils with a sufficiently high residual P level, yields may be maintained by the annual applications of a P fertiliser with less available P than superphosphate, such as phosphate rock or bone meal.

In many Australian situations, it may be necessary to apply other elements, particularly sulphur, if the rate of superphosphate application is reduced or eliminated.

6.0 Experiments using Phosphate Rock

In the absence of trial data using bone meal as a fertiliser, it is necessary to review experiments in which phosphate rock has been used as a relatively insoluble P fertiliser.

MDA Bolland and RJ Gilkes (1990) reviewed the previous 100 years of research in which different types of phosphate rock were compared to superphosphate in several long term field experiments on a variety of non-leaching soils in south western Australia. The experiments have consistently shown that all types of phosphate rock are between 5 to 33 per cent as effective as superphosphate in the year of application and in subsequent years.

The primary reason given for the low effectiveness is the limited dissolution of these fertilisers in WA soils. As the soils are only moderately acid and generally have low pH buffering capacities, they cannot contribute a large supply of protons to promote extensive dissolution of the phosphate rock. The soils have low capacities to adsorb the P and Ca ions released during dissolution. Their water-holding capacity is low so that the soil surface rapidly dries between rains in the prevailing Mediterranean climate.

However the very sandy acid soils developed on podsolic, aeolian dune sands near the west and south coasts have extremely low capacities to retain P and have an average rainfall exceeding 800mm per year. These soils were the only exceptions to the above findings. The implications of these exceptions will be considered later.

These findings were confirmed by incubating 228 soil samples from the main agricultural areas of WA with North Carolina phosphate rock. In only 29 samples was more than 40% of the added phosphate rock dissolved. The 29 exceptions were humic podsols and peaty sands from areas with average rainfall above 800mm per year. They appear to have the best potential for phosphate rock retention. (Hughes and Gilkes, 1994)

However, in contrast to the generally negative results of the effectiveness of phosphate rock relative to water-soluble P fertilisers in Australian trials, with the exception of the podsolic and peaty sands of southern and south western Australia, phosphate rock and particularly the reactive phosphate rocks have been found to be as equally as effective as superphosphate or triple superphosphate as maintenance fertilisers for pastures in New Zealand. (Bolan, White and Hedley, 1990)

They indicated that, in 1990, between 5 to 10 per cent of the total P fertiliser applied in New Zealand consists of reactive phosphate rock.

7.0 Factors Affecting the Effectiveness of Phosphate Rock Fertilisers

7.1 Chemical nature of phosphate rocks

Phosphate rocks differ widely in their mineral constituents and in the composition of their most important mineral, apatite. Much of the Australian research on phosphate rock has used chemically unreactive hard rocks such as Christmas Island (A and C grade), Nauru, Duchess (Qld) and Mt Weld (WA).

NZ research was focused on the chemically more reactive "soft" rocks such as Gafsa, Chatham Rise, Sechura and North Carolina phosphate rocks. However, when North Carolina phosphate rock was used in trials in WA, its effectiveness was low.

The NZ trials show that the most reactive rocks have a relative effectiveness (that is, compared to superphosphate or triple superphosphate) generally approaching 100 per cent. By contrast, the Australian experiments show that the relative effectiveness is generally below 30 per cent, irrespective of rock reactivity, except in situations where leaching of soluble P fertiliser can occur.

7.2 Physical form of phosphate rock

It is generally advocated that phosphate rock should be ground to a fine powder to increase the area in contact with the soil and be more agronomically effective. However, as such powders are difficult to spread by land or from the air, attempts have been made to pelletise or granulate ground phosphate rock. In field trials in NZ, due to biological mixing of the soil, by earthworms, and stock treading, the pellets have been broken down and the phosphate rock particles have been distributed throughout the soil.

7.3 Soil factors

The dissolution of apatite or phosphate rock in the soil requires protons (H^+) and the removal of Ca^{++}, $H_2PO_4^-$ and F^- from the reaction site. Ca^{++} and F^- react to form CaF_2. The rate of dissolution depends upon the lowering of the Ca^{++} and the $H_2PO_4^-$ ion activities through diffusion, surface cation exchange and adsorption reactions, and the supply of soil acid.

The poor performance of phosphate rocks in many WA field experiments may be explained by the limited cation exchange/adsorption capacity of many WA lateritic soils. The consumption of H^+ ions by dissolution of phosphate rock will raise the pH in the vicinity of the particle, thereby suppressing the dissolution reaction.

In such circumstances, the effectiveness of any phosphate rock fertiliser may be expected to decrease as increasing amounts are applied. MDA Bolland and NJ Barrow (1988) confirmed these effects experimentally in a soil with very low buffering capacities for pH and phosphate with P levels greater than 100 kg P per ha.

7.4 Type of crop or pasture grown

Generally reactive phosphate rocks (RPRs) have proved to be much more effective in supplying P to permanent, white clover pastures in NZ than RPRs or Calciphos have been for cereal crops or pastures based on the annual legume Trifolium subterranean in Australia. The higher root density in the top 10 cm of soil of the permanent pasture can have a significant effect upon the dissolution of RPR. This is particularly so for leguminous roots, due to legume rhizosphere acidification.

In general, plants taking up NH_4^+-N with alkaline uptake patterns (an excess of cations over anions adsorbed) such as buckwheat and brassicas, and the N_2-fixing legumes, should use RPRs more effectively than non-legumes which do not take up NH_4^+-N or plants that do not have an alkaline uptake pattern.

Plants with high root densities and those adapted to low P concentrations in the soil solution should perform well when fertilised with RPRs. Perennial and established plants have a much lower daily requirement for P than cereals and other crops in the early stages of growth and so have a much lower requirement for P in the soil solution.

7.5 Climatic factors

The dissolution of phosphate rock requires adequate soil moisture, which affects the rate of diffusion of Ca^{++} and $H_2PO_4^-$ away from, and soil acids to, the reaction surface. Soil moisture also affects the rate of P uptake by plants. (Dolan, White and Hedley, 1990)

8.0 Potential for the Use of Reactive Phosphate Rock (RPR) in Australia and NZ

In NZ, the relative agronomic efficiency of RPRs, partially acidulated phosphate rocks (PAPRs) and superphosphate-RPR mixtures were evaluated following successive annual fertiliser applications at P rates intended to maintain near maximum yields. Sinclair and Dyson (1988) concluded from 12 trials in NZ that after 4 years of "maintenance" P applied to pastures on soils with a pH from 5 to 6, Sechura phosphate rock (a RPR) was as effective as triple superphosphate on a per kg P basis.

In Australia, reactive and other water insoluble P fertilisers have usually been compared with superphosphate on the basis of the initial and residual effects of a single application of each fertiliser. However unpublished data from MDA Bolland indicates that the relative effectiveness of successive applications of phosphate rocks is not additive under WA field conditions.

Based on the results to date from field trials in NZ and Australia, the major factors limiting the use of RPRs as direct application P fertilisers are -

i. poor soil H^+ ion supply; and

ii. low soil moisture. (Bolan, White and Hedley, 1990)

In NZ, it is not recommended for RPRs to be used on annual crops or pastures, or permanent pastures in the establishment phase in which the rate of P supply needed to ensure non-limited growth is higher than can be sustained by a dissolving RPR.

As a first approximation, they consider the upper limit of soil pH for effective use of RPRs on permanent pastures might be 6.0 (in water) and a minimum mean annual rainfall in NZ of 800mm. These two variables will interact so that as the pH falls to 5.5 or less, the rainfall limit may become less critical.

On this basis, there appears to be many soil groups and potentially large areas of soils in Australia and NZ with a pH less than 6.0 which might be suitable for RPR use.

In Australia, the seasonality of rainfall in much of the tropical, sub-tropical and Mediterranean climatic regions may render these soils unsuited to the direct application of RPRs for pastures, even though the soils have a pH less than 6.0 and a mean annual rainfall exceeding 800mm.

The bulk of the potentially suitable soils are therefore likely to be in coastal NSW, Victoria and north-eastern Tasmania, amounting to about 13 million ha most of which are used for agriculture (excluding forestry).

In NZ, the areas where soil and rainfall appear satisfactory for RPR use, seasonality of rainfall is not a major problem. Thus, of the total agricultural land area in NZ, about 8 million ha are potentially suitable for direct application of RPRs to pastures.

8.1 Conclusions and recommendations: (Bolan, White and Hedley, 1990)

1. Unreactive phosphate rocks, such as Nauru, Christmas Island A grade Duchess and Mt Weld, and the calcined products of unreactive phosphate rocks, such as Christmas Island C grade, are much less effective than superphosphate or triple superphosphate. These materials are not suitable alternatives to water-soluble P fertilisers in Australia or New Zealand.

2. Where RPRs, such as North Carolina PR, have been tested in Australia, they have been as effective as superphosphate only on highly leached acid sands. In WA these constitute about 40 000 ha with an annual rainfall exceeding 800mm.

More research is needed on a wider range of soil types in more favoured climates, particularly in eastern Australia, where soil pH's and per cent base saturation of the cation exchange complexes have been decreasing under improved pasture.

3. The major limitation for RPR use in Australia is the climate. The area of suitable land is estimated to be about 13 million ha in coastal NSW, Gippsland and a portion of north eastern Tasmania.

If the potentially suitable land in northern and south western Australia is included, the total area would be about 38 million ha: but use in these regions would depend upon soil moisture availability throughout the year and whether improved pasture species, particularly legumes, are grown.

In NZ the area of land potentially suitable for RPR use is 8 million ha and forms a large part of the agricultural land.

4. The most effective use of RPRs is on permanent pastures, where root density and biological activity are generally higher than on cropped land.

5. In Australia, much of the agricultural production depends upon seasonal rainfall, with rapid periods of plant growth and high, short-term demand for P. The P supplying power of partially acidulated phosphate rocks (PAPR) may better match plant requirements than RPRs.

PAPRs contain "fast" (water soluble) and "slow" (water insoluble) P release components and in NZ they have been shown to be as effective as superphosphate or triple superphosphate in supplying P for pasture growth.

PAPRs, made from RPRS, may be as effective as triple superphosphate for annual crops in suitable soils.

These products ought to be field tested in Australia because to date only fertilisers made by partial acidulation of unreactive phosphate rocks have been evaluated. Such products (fortified with sulphur) have been found to be as effective as superphosphate in some soils in wet areas when sulphate leaching occurs but inferior to superphosphate in dry seasons.

9.0 Characteristics and Chemical Assessment of Phosphate Rocks

As indicated previously, phosphate rocks vary appreciably in their chemical reactivity, a term often used to describe the solubility of a phosphate rock in certain chemical extractants and its potential agronomic effectiveness.

Variations in chemical reactivity have been attributed primarily to differences in the degree of saturation of carbonate for phosphate (P) in the apatite structure. The agronomic evaluation of a phosphate rock is generally based upon the degree of carbonate substitution, the concentration of the major elements and the solubility in certain extractants.

Syers, Mackay, Brown and Currie, (1986) compared several chemical and physical properties of 10 phosphate rock materials, which include the major sources of reactive phosphate rocks in the world. (Table 1)

The solubility of a phosphate rock which contains significant amounts of calcite cannot be assessed accurately by a single chemical extraction procedure. When solubility in a particular reagent forms the basis for establishing chemical reactivity, the true chemical reactivity of the phosphate rock is underestimated.

Phosphate Rock		2% Formic Acid	2% Citric Acid Cumulative Extraction			NAC
			1st	2nd	3rd	
Sechura PR	R	68	41	79	95	18
Gafsa PR	R	59	38	64	85	16
Chatham Rise PR	R	36	23	58	89	8
Arad PR		51	33	62	85	14
Nth Carolina PR	R	58	31	60	83	17
Jordanian PR		47	28	51	75	11
Mexican PR		39	25	48	72	9
Makatea Island PR		26	18	45	88	5
Nauru Island PR	NR	23	23	42	48	9
Nth Florida PR		21	23	40	48	13

R Reactive PR NR NonReactive PR

Table 1: P solubility, as a % of total P, of phosphate rocks in 2% formic acid, 2% citric acid and neutral ammonium citrate (NAC). (Syers, Mackay, Brown and Currie, 1986)

Sechura, North Carolina, Gafsa and Chatham Rise phosphate rocks been classified as reactive and about as effective as superphosphate in NZ trials. Nauru Island phosphate rock is classed as nonreactive and is less than half as effective as superphosphate in NZ. (Bolan, White, and Hedley, 1990)

The other phosphate rocks have not been tested in sufficient field experiments in NZ or Australia to be properly classified.

In addition, there is a need for information on the concentration of such elements as arsenic, cadmium and uranium, particularly for those phosphate rocks with potential as direct application P fertilisers. Cadmium and uranium can accumulate in biological systems and continued exposure to even low concentrations of these elements may ultimately present health hazards.

Syers et al, (1986) determined the chemical composition of the above phosphate rocks. (Table 2)

In addition, Syers et al found that these phosphate rocks contained from 127 to 156 grams of P per kg, with the exception of Chatham Rise, which is a phosphorite and which contained 39 grams of P per kg. Potassium and sulphur contents were more variable.

Phosphate Rock	Element (mg/kg)			
	Zn	Cd	As	U
Nauru Island PR	1010	100	3	64
Nth Carolina PR	400	48	23	69
Jordanian PR	235	4	12	72
Gafsa PR	393	38	4	88
Nth Florida PR	57	3	7	143
Sechura PR	178	11	5	72
Mexican PR	90	8	3	118
Arad PR	560	12	7	153
Makatea Island Pr	220	10	2	64
Chatham Rise PR	95	2	N D	101

Table 2: The zinc, cadmium, arsenic and uranium composition of phosphate rocks. (Syers, Mackay, Brown and Currie, 1986)

Although North Carolina phosphate rock is a reactive material, the higher levels of arsenic and cadmium might reduce its value as a long term direct application P fertilizer.

Before bone meal could be considered as a long-term fertiliser, comparable analyses would have to be performed on representative samples. These would determine the relative reactivity of bone meal compared to the assessed phosphate rocks and hence its agronomic and economic potentials could be established.

Baker, Trimm and Sikora, (1989) examined 2 commercially available bone meal products, primarily to determine the reason for lack of precision among laboratories when determining the availability of P in fertilisers. They found that the extractability of P by neutral ammonium citrate is directly proportional to the fineness of grinding. (Table 3)

They concluded that consistent grinding of the material to pass through a 40 mesh sieve would increase the precision among laboratories and more closely correlate with actual agronomic availability as indicated by greenhouse studies.

Analysis determined	Ground to pass mesh size		
	20	40	100
% Total Phosphate	17.2	17.4	16.9
% NAC-I Phosphate *	9.2	6.7	0.75
% NAC Soluble (Available)	8	10.7	16.2
Available as % of total	47	61	96

* Neutral Ammonium citrate-insoluble phosphoric acid

Table 3: Analysis of bone meal (0-12-0) ground to pass through successively smaller screens. (Baker, Trimm and Sikora, 1989)

Comparing these results with those of Syers et al, (1986) reported above, bone meal ground to pass through a 20 mesh sieve would be classed as unreactive, whereas if ground to pass through a 100 mesh sieve, it would be considered to be reactive.

10.0 Experimental Programmes in Australia Where Phosphate Rocks are likely to be Agronomically Effective

From the results discussed above, the most promising areas in Australia for the utilisation of phosphate rocks as a fertiliser are on acidic soils in the south eastern and south western regains with a mean annual rainfall exceeding 800mm. Apart from a trial in Tasmania (Paton and Loneragan, 1960), no other relevant trials appear to have been conducted in the eastern states, indicating that experimental programmes using phosphate rocks on these soils have not occurred.

However, an extensive experimental programme has been undertaken on the acidic sandy soils in the higher rainfall areas in south western Australia due largely to the effect that phosphate leached from the soils is having upon the environment of the rivers and estuaries in the region.

Water soluble P from superphosphate applied to such sandy soils rapidly moves out of the moist soil and is leached down the profile, accumulating in the drainage systems and contributing significantly to the algal pollution problems in estuaries. About 90% of the P exported to one estuarine system in WA came from only 20% of the catchment area as a result of increased superphosphate applications to the predominantly very sandy soils. (Birch, 1982)

As indicated previously, (Bolland and Gilkes, 1990 and Hughes and Gilkes, 1994) these soils have extremely low capacities to retain P and the slow release characteristics of phosphate rocks (and presumably bone meal) may be beneficial in overcoming both the agronomic and environmental problems.

One fertiliser developed for and successfully used on these soils was a granulated mixture of superphosphate, phosphate rock and elemental sulphur. Losses of P due to leaching were reduced to about 25% of those with superphosphate. (Yeates, Deeley, Clarke and Allen, 1984; Yeates, Deeley, Cockerton and Clarke, 1986; Bolland, 1984)

Yeates and Clarke (1992), in reporting on a research programme examining P and S nutrition of pastures on deep sandy soils, indicated that fertiliser sources, including finely ground phosphate rocks and calcined Christmas Island ores and granulated fertilisers derived from these ores can be more agronomically effective than normal superphosphate on soils where significant P leaching losses occur.

The granulated ores are of particular interest, as they contain a high proportion of P as slow release, water-insoluble P and can be formulated with a range of elemental sulphur contents to suit specific nutritional requirements. The use of granulated fertilisers containing a slow release sulphur source is of critical importance for pastures on the sandy soils in the higher rainfall areas of south western Australia.

The present form of fertiliser manufactured especially for these conditions, Coastal Superphosphate, has two components:

- a partially acidulated phosphate rock made by adding half the amount of sulphuric acid required to make normal superphosphate to apatite phosphate rock; and
- a by-product of fertiliser manufacture in WA known as sulphur residues, which contains 50% each of elemental sulphur and gypsum. The sulphur residues are added to the treated phosphate rock before granulation.

This form of coastal superphosphate performed 154% more effectively than normal superphosphate on the first crop grown on an acid peaty sand collected near Karridale 260 kms south of Perth, WA. In the second and third crops, with no additional fertiliser, it was slightly better and 65% as effective, respectively, as superphosphate. (Bolland, 1994)

Coastal superphosphate and normal superphosphate were both significantly more effective than Ecophos (made by adding acid to Christmas Island C grade ore) and North Carolina reactive phosphate rock. However, North Carolina PR was much more effective on the Karridale soil than on other soils studied previously. It was 75, 65 and 30% as effective as normal superphosphate in the first, second and third crops respectively.

The analysis of the fertiliser used was as follows:

Analysis	Normal super	Coastal super	Ecophos	Nth Carolina Phosphate rock
Total P	9.1	5.6	9.8	12.9
Water soluble P	7.3	2.5	2.5	0.1
Citrate soluble P	1.3	2	2.9	2.8
Acid soluble P	0.5	1.1	4.4	10
Sulphur	10.5	30	5.5	1.2

The acid peaty sands are normally very wet throughout most of winter, with water moving slowly through the soil. The findings of Hanafi and Syers (1993) are relevant to, but not part of, this experimental programme. They evaluated the solubility of Christmas Island A grade PR, Gafsa PR, and triple superphosphate in four soils in columns leached with distilled water to simulate field conditions in which the Ca^{++} and $H_2PO_4^-$ ions are continuously removed by plant uptake or by leaching. (Table 4)

Soil type	pH in Water	Dissolution per cent		
		Christmas Is. PR	Gafsa PR	Triple Superphosphate
Sedu silty clay	3	N. D.	81.3	88.6
Segamat clay	4.9	88.2	56.2	94.5
Bungor sandy clay loam	4.9	94.6	91.4	103
Kundor clay	4.9	N. D.	50.3	106

Table 4 Dissolution of Christmas Island Phosphate Rock, Gafsa Phosphate Rock and Triple superphosphate added at 500mg P per kg of soil in an open leaching system. (Hanafi and Syers, 1993)

It has been shown that the dissolution of PR was substantially greater in an open leaching system than in a closed incubation system. (Hanafi, Syers and Bolan, 1992)

The fertilisers used by Hanafi and Syers (1993) had the following analyses:

Fertiliser	Total per cent		Extraction per cent P		% of Total P
	P	Ca	Water	2% Formic acid	
Christmas Is. PR	15.4	36.8	<0.01	4.6	29.9
Gafsa PR	12.9	36.6	<0.01	8.1	62.8
Triple superphosphate	21.3	15.3	16.5	17.7	83.1

The dissolution rate of Christmas Island PR was 88.2 and 94.6 per cent of the total P added to the two soils in which this rock was tested. The dissolution rate of the Gafsa PR ranged from 56.2 to 91.4 per cent and with triple superphosphate, the range was from 88.2 to 106 per cent in 4 soils.

It was concluded that the combination of a soil with a low P-retention capacity, a low Ca-exchange capacity and a high permeability with a leaching regime would have removed the dissolution products, Ca^{++} and $H_2PO_4^-$, continuously from the site of the reaction, thus maintaining sinks for Ca^{++} and $H_2PO_4^-$.

These results and conclusion indicate that a low solubility product, such as bone meal, may be useful as a maintenance fertiliser on those areas of the acidic peaty sands that are low lying, relatively poorly drained and wet for most of the winter months. In WA, at least, such areas are used predominantly for permanent pastures, mostly of annual species.

11.0 Relevance to the Potential of Bone Meal as a Fertiliser

The above research indicates that phosphate rock has considerable potential as a maintenance fertiliser in certain conditions in southern Australia.

Environmental conditions in the surface layers of highly weathered soils in the humid tropics are generally conducive for the attainment of satisfactory rates of PR dissolution, especially as the reactivity of PR increases. (Sale and Mokwunye, 1993) There may well be areas within the northern areas of Australia where conditions of soil, climate and plant species are suitable for the use of PR, but these have not been as clearly identified as in the southern regions.

While there has been very little recent research examining the effectiveness of bone meal as a fertiliser or into determining the conditions in which it would be economic, the conclusions from phosphate rock research could provide useful starting points. Both are relatively insoluble in water but contain a high proportion of P which could be utilised by plants in certain conditions.

The potential for bone meal as a fertiliser may be indicated by comparing the chemical analysis and properties of bone meal with those of the various phosphate rocks for which the agronomic effectiveness has been determined. It should be possible to determine from such comparisons which soils, conditions and plants would be most conducive to the economic use of bone meal.

Experimental programmes would be necessary to confirm such conclusions in the field. As permanent pastures constitute the plant system most likely to have the widest potential, with the exception of special crops and conditions, such experimental programmes need to be conducted over several seasons.

Such long term programmes are outside the scope of this investigation.

As fineness of grinding has a significant effect upon the agronomic effectiveness of bone meal, (Baker, Trimm and Sikora, 1989), fine grinding followed by granulation would be essential for practical use of bone meal in the field. Other elements, such as sulphur, potash and trace elements, could be incorporated into the granules where necessary.

12.0 Other Factors Impacting Upon the Potential for Bone Meal as a Fertiliser

12.1 Nitrogen content

Bone meal contains approximately 5% nitrogen and, in some circumstances, it may be useful as a relatively slow release nitrogenous fertiliser.

Williams and Nelson (1992) mixed unsteamed bone meal (5.55% N) as a slow release N fertiliser in a trial comparing organic sources of N in a root substrate growing chrysanthemums (Dendranthema x grandiflora). Coarse bone meal applied at the rate of 1.82g N per litre, resulted in growth almost equivalent to the control, which received weekly liquid applications of a N solution, to give commercially acceptable growth. Coarse and regular particle sized bone meal, applied at 1.21 and 1.23g N per litre respectively, resulted in similar growth, but less than that of coarse bone meal at 1.82g N per litre.

In unsteamed bone meal, nitrogen is contained in the porous bone marrow in the form of the protein collagen. Particle size had little effect upon N availability, because the marrow was easily assessed by the soil solution.

12.2 Organic agriculture

Organic agricultural systems exclude or severely restrict the use of man-made fertilisers. Only minerals from crushed rocks and various natural preparations may be used as fertilisers on an organic farm so that it may retain its certification status.

Bone meal, unless contaminated by certain elements that may lead to the accumulation of undesirable residues in the soil, is acceptable for use by organic growers and farmers. This may provide a major opportunity for its utilisation. It may be applied directly to the soil or included in organically acceptable fertilisers or manures.

12.3 Increasing concern regarding the environment

Environmental authorities are becoming increasingly concerned with pollution and eutrophication of waterways and estuaries. One of the principal causes for such effects is the increasing levels of P entering the drainage systems due to the use of water-soluble P fertilisers on susceptible soils.

Many horticulturalists, particularly vegetable growers, use heavy amounts of poultry and other manures as relatively cheap sources of fertilises. They have been available virtually at disposal prices.

Local governments and other authorities are concerned that these practices are affecting the environment in areas that are becoming more urbanised. It is claimed that the use of heavy rates of such manures causes odour, insect and pollution problems in the neighbouring community.

The authorities are likely to impose more restrictions upon the use of any manure that may cause such problems.

13.0 Discussion on the Use of Bone Meal as a Fertiliser

This section summarises the above findings. The use of bone meal in any situation is dependent upon its chemical composition, determined by analysis, and properties being appropriate for the conditions. For economic and practical reasons, bone meal would have to be ground and granulated before use.

The following are possible reasons for the use of bone meal within Australia.

13.1 As a P source for pastures and crops

The results with PR indicate that on some acid soils in southern Australia with rainfall exceeding 800mm, bone meal could be effective when applied as a maintenance fertiliser to permanent, clover based pastures. It is possible that bone meal may be effective for leguminous crops in suitable soils and conditions.

Based on the results with PR, bone meal would not be effective for cereals or for pastures on newly developed soil which does not have sufficient reserves of P.

It is estimated that about 13 million ha are potentially suitable in coastal NSW, Gippslnd, north eastern Tasmania and south coastal areas of Western Australia.

Irrigated clover pastures on soils with pH less than 6 satisfy the conditions found to be necessary for the effective use of PR in Australia and NZ. Therefore, bone meal may be effective as a slow release P fertiliser for such pastures and for well-irrigated lawns, parks and ovals on acid soils in areas with less than 800mm annual rainfall.

The parameters for the effective use of PR have not been clearly established for soils and conditions in northern Australia, particularly where the soils are moist for most of the year. Accordingly it is not been possible to estimate the potential for bone meal as a fertiliser in this region.

13.2 In Environmentally Sensitive Situations

Bone meal could be used as a slow release P fertiliser on pastures and certain crops in situations where P, applied to the soil in a water soluble form, is leached through the soil into waterways and estuaries causing pollution, eutrophication and other problems. Such areas include the acid peaty sands of south western Australia, many vegetable gardens and other situations where the soil does not have the capacity to retain all the applied P.

Bone meal could be used to substitute for some or all of the organic manures that are regarded as offensive to the local community because of unpleasant odours, insects or other undesirable effects. These situations are likely to increase as urban development intrudes into rural and high-input agricultural areas.

13.3 As an Acceptable Fertiliser for Organic Farming Systems

Fertilisers that are man-made or chemically treated are excluded from use on farms that are certified by one of the organic certifying organisations. However, as bone meal is acceptable, it could be used as the main source of P fertiliser on such farms, provided that the soil and other conditions are suitable for the effective dissolution of the bone meal.

It has been reported that some organic farmers in Victoria, who have not applied P fertilisers for some years, have depleted their soil P reserves to such an extent that yields are being seriously affected.

On the other hand, organic vegetable growers and market gardeners, who use large amounts of manures instead of artificial fertilisers, are having restrictions applied to such continuing use for economic or environmental reasons or because the manures are no longer so readily available in the amounts required.

It has not been possible to estimate the effect that these possible changes will have on the demand for suitable alternatives to manures, such as bone meal.

13.4 In other horticultural and related activities

Bone meal could have three major attributes which could make it a very useful fertiliser for some significant and growing sections of the horticultural industry.

When applied to or mixed with soil, bone meal supplies P and N slowly over an extended period and so does not increase the osmotic pressure of the soil solution to the same extent as the more water soluble fertilisers.

Bone meal should be effective as a slow release P and N fertiliser when used as an ingredient in the various and special soils and mixes used in nurseries for growing seedlings, pot plants and trees, and sold commercially.

Similarly, it could be used as an ingredient in the special fertilisers developed for use by home gardeners, vegetable growers and horticulturalists generally.

Many native and some imported plants are very sensitive to even moderate levels of P in the soil. As these plants are in strong demand for export markets, home gardens and commercial cut flower production, they constitute an important section of the horticultural industry. If it is established that bone meal is capable of supplying the small amount of P required safely, without deleterious effects, this use could provide a significant potential use for the fertiliser.

Other areas where bone meal may be an effective supplier of P is in growing seedling shrubs and trees for subsequent planting in saline and salt affected land. In such circumstances, the reduced effect of the bone meal on the soil solution osmotic pressure may be a critical, or at least a significant advantage for the young plant while it is becoming established. However, due to the normally high pH of saline and salt affected soils, it is very unlikely that bone meal would be effective as a fertiliser applied directly to such soils.

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Appendix 3

Utilisation of the Ash Component of Meatmeal in Animal Feeds

by N D Costa

Utilisation of the Ash Component of Meatmeal in Animal Feeds

Meat Research Corporation Contract

Contract Officer
Dr Nick Costa
Senior Lecturer
Biochemistry & Nutrition

Address
School of Veterinary Studies
Murdoch University
Murdoch WA 6150

Summary and Recommendations

- In 1993, the MRC commissioned a study of the meatmeal and tallow industries and their markets (MRC Report M.258). The study concluded that meatmeal was under some threat from alternative protein sources, particularly from the oilseed and grain legume industries. As a result, meatmeal was losing market share in the intensive livestock industries, the major current end-user. If the current decline continued, the net loss to the meat industry would be $120 million over the next five years.
- MRC Reports M.258 and M.561 concluded that separation of the ash component of meatmeal would lead to higher quality meal of better specifications.
- Utilisation of the ash residues is crucial to the economics of producing a higher quality meatmeal for markets such as diets for aquaculture.
- Meatmeal is used extensively in the production of dry feeds for pets. In fact, the petfeed industry already prefers to use meatmeal in the generic lines of dog feed. Meatmeal holds an advantage over oilseed and grain legume meals because of its palatability and high mineral and trace mineral content. Removal of the ash fraction will not have any marked effect on the use of meatmeal in generic lines of dog food.
- Removal of the ash component will increase the use of meatmeal in premium dog feeds. The mineral content, particularly the calcium and phosphorus and ash in total is more accurately specified in these types of dog feed.
- Removal of magnesium from meatmeal is an essential prerequisite for higher inclusions of meatmeal in dry diets for cats.
- The ash component of meatmeal could be used as a high grade mineral supplement in premium dog foods. It should be marketed on the appropriate mix of minerals of high availability for bone development in pets.
- Bone meal should be promoted as an excellent supplementary source of phosphorus for cattle in Australia and in near neighbours, such as Indonesia. The demand for live cattle exports to Indonesia, Malaysia and the Philippines will expand the need for effective P sources in the wet season to maintain cattle fertility.

- The aquaculture industry is rapidly expanding and represents an important opportunity for use of meatmeal. Removal of ash is an essential prerequisite for substitution of diminishing and expensive fishmeal supplies with meatmeal. Manufacture of aquaculture feeds based on substantial inclusions of meatmeal will substantially increase the cost-competitiveness of Australian aquaculture feeds in the Asian markets.

- The ash fraction would not be of great use in diets for aquaculture. The form of tricalcium phosphate present in bone is not readily available as a phosphorus source for fish. Fish can extract their calcium and magnesium requirements from the water.

- The pig industry is under some pressure from imports. Removal of ash may not increase the use of meatmeal because this industry is price sensitive at the moment. The protein meals are competing on price, rather than specification.

- The vertical integration of the broiler industry, coupled with a preference for poultrymeal in starter and developer rations, may continue the decline in the use of meatmeal by this industry.

- Removal of the ash fraction would not enhance the use of meatmeal in egg production. Here the calcium content of the ash fraction is a desirable extra in the current specification of meatmeal.

- The bone fraction of meatmeal should be treated as mineral resource, and "mined" as such. Meatmeal could be treated with acid (such as hydrochloric acid) to solubilise most of the ash fraction, while simultaneously precipitating the protein. Straight away this increases the protein specification by approximately 25% (the average of the amount of ash in meatmeal) to an average of about 65% or more. The minerals could then be run-off and subsequently precipitated with sodium hydroxide.

1.0 Background: Meat and Bone Meal

The meat and livestock processing industries are major contributors to the income from the Australian primary industry. While the objective of the livestock industry is prime meat production, by-products from the slaughter of livestock such as tallow and meat and bone meal generate an important component of the financial return that production.

Meat and bone meal production constitutes a large volume of the output from the overall meat-processing operation. Approximately 30 - 40% of the animal is processed via rendering plants for meat and bone meal (Fernando 1992). Yields of raw materials and products from the rendering process depends on stock, season and type of rendering system (Fernando 1992). Most rendering plants are operated as a waste disposal process, and the efficiency of operation affects the rendered product yield significantly. Typical rendering yield for New Zealand are shown in the table 1.1.

Table 1.1 Typical Rendering Yields for New Zealand

Type	Raw material (kg)	Tallow (%)	Meat & Bone Meal (%)
Beef boned	140-200	18-24	25-30
Cattle bone-in	80-90	12-18	12-23
Cattle boned	120-180	18-23	22-27
Lamb bone-in	2.0-6.0	13-16	18-22
Lamb boned	1.5-3.0	12-15	18-25
Sheep bone-in	6-12	13-18	19-23
Sheep boned	8-15	18-25	20-30

Under Australian conditions, meat and bone meal represents about 10% of the output from livestock production but only 3% of the total value in $ terms (AAS Report 1993). Obviously the production of tallow and meat and bone meal are linked to total animals slaughtered and to each other but the close association of these two by-products may not be so closely linked in the future. In fact an increase in meat and bone meal production relative to tallow has been predicted (AAS Report 1993). Australian meat meal production has risen over the last 10-12 years to about 18% of total red meat production.

The markets for meat and bone meal list in the AAS Report (1993) are primarily:

- Stockfeed industry
- Pet food industry
- Fertilizer
- Export

The market for meat and bone in the aquaculture industry is being defined at present (Allan 1994).

Each of these markets for end-use of meat and bone is fragile. Feedmills servicing the intensive livestock industry, manufacturers of pet food, and feedmills involved in the production of aquaculture feeds have a wide choice of raw materials in Australia. In particular, the production of meals from grain legumes and vegetable meals such as canola meal which are by-products of oil-seeds are real competitors for meatmeal in all of the these markets. The production of canola meal represents a real threat to meatmeal in the intensive and extensive livestock industries, and possibly in the pet food industries as well.

The sources, rendering system that generates meat and bone meal and markets for meat and bone meal as sourced from AAS (1993) are represented in figure 1.1.

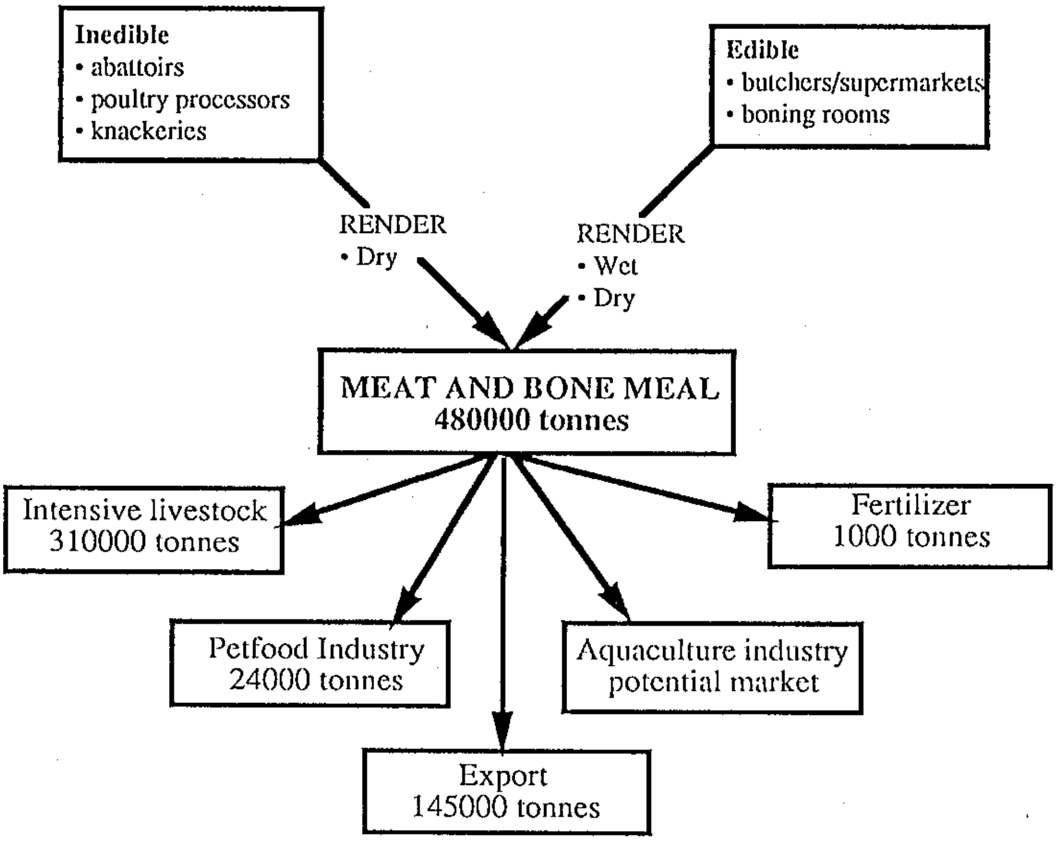


Figure 1.1 SOURCES, PRODUCTION and MARKETS for MEAT and BONE MEAL

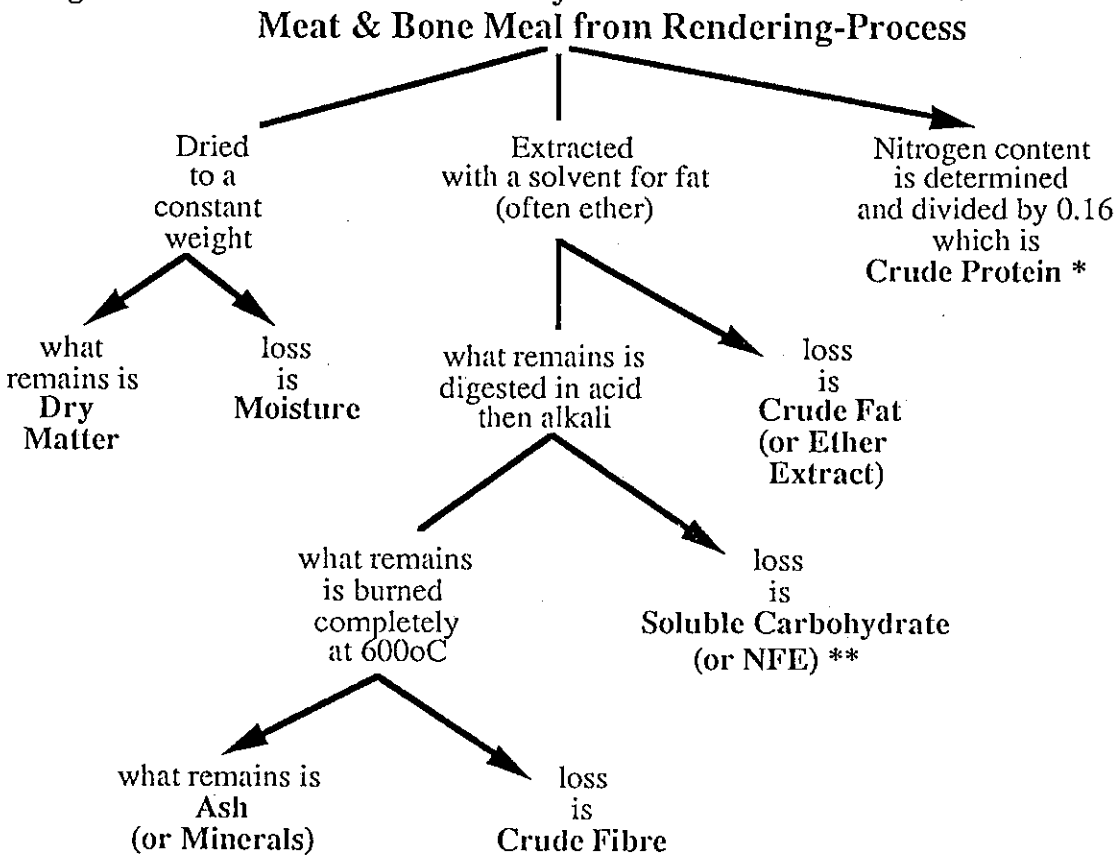
There are two types of renderers: abattoir renderers (122 in 1993) and service renderers (13 in 1993). Importantly service renderers supply about 27% of meat and bone meal production notwithstanding the fact that they represent about 10.7% of the total number of renderers. Most of the renderers in Australia use the "traditional" dry render process, mainly because of the pollution problems associated with stick-water in the "ideal" low-temperature rendering system. However this "traditional" method runs the risk of overheating the meal, thereby decreasing lysine availability. The other "problem" is the degree of contamination with blood and water, both of which can decrease the quality and value and tallow and meatmeal.

Generally meat and bone meals are sold on the basis of crude protein. Typically buyers' specification are: crude protein - 50% minimum; fat - 15% maximum, and moisture - 8% maximum. If the protein content falls below 50%, the prices are reduced accordingly. Notwithstanding this, the quality of meat and bone meal is extremely variable. End-users, particularly the petfood industry complain frequently about the variable quality which diminishes the quality of their products, and interrupts manufacture.

2.0 Definitions of Ash and Analysis in Australian Meatmeals

The component of meatmeal that has the greatest influence on market expansion is the ash component. The ash component of an ingredient of feed such as meat and bone meal is determined from the proximate analysis which is set out in figure 2.1. Ash is defined as the inorganic component of meatmeal; which is the fraction of meatmeal left after firing a sample at 600°C to volatilise organic material.

Figure 2.1 **Proximate Analysis of Meat and Bone Meal**



* proteins contain 16 ± 2% nitrogen, hence crude protein = N x 6.25 or N ÷ 0.16

** NFE is determined by difference i.e

100% - % moisture - % crude protein - % crude fat - % crude fibre - % ash

The proximate analysis of the 3 grades of meatmeal in Australia is reported from information taken from the Australian Feeds Information Centre (table 2.1).

Table 2.1 Average Analysis of Australian Meatmeals (AFIC)

Chemical Component	45% CProt MM	50% CProt MM	55% CProt MM
Moisture	9.28	9.27	9.40
	% DM	% DM	% DM
Ash	36.61	34.07	27.70
Crude Protein	47.02	51.00	54.96
Crude Fat	13.37	12.37	14.72
NFE	NA	6.68	11.38
Crude Fibre	0.84	2.41	3.8

In four samples of meatmeal of sufficient quality for inclusion in aquaculture diets for silver perch, Allan (1994) reported the following ash values:

Table 2.2 Ash Fraction of Meatmeal Sources Used for Silver Perch Diets

Meatmeal Source	Supplier	Ash
Beef meal	Beef City	36.0%
Lamb meal	Fletcher International	34.5%
Mixed meal	Midcoast Meat Company	12.1%
Provine®	Aspen Technology	3.0%

Obviously the protein quality of meatmeal is inversely related to the percentage of ash. The ash fraction represents bone (particularly bone chips), and possibly other material such eartags and intraruminal bullets, all of which make this fraction so variable.

In fact, the two major programs reporting on meat and bone meal, AAS Report 1993 and Allan 1994, have both stressed the need to evaluate the ash fraction of meat and bone meal for the following reasons:

- ash is the single most variable component of meat and bone meal
- ash limits the usefulness of meat and bone meal as a replacement for fishmeal in aquaculture diets.

Two other factors not listed in these reports are:

- ash limits the extensive use of meat and bone meal in the petfood industry
- ash represents an opportunity for value adding of meat and bone meal.

Not all of the news about ash is bad. In the intensive livestock industries such as pig, broiler chicken, and layer hen, the ash fraction makes an important contribution to the mineral nutrition and specification of the ration.

3.0 Minerals in Ash Component of Meatmeal

3.1 Mineral Analysis of Meatmeal

The mineral components of the ash fraction, by and large, are useful nutrients for animals and plants. Thus any discussion of the value-adding of the ash fraction should list the nutrients in some detail, and describe their role in nutrition. The average analysis of Australian meatmeals is presented in table 3.1 (data from the Australian Feeds Information Centre).

Table 3.1 Minerals Present in the Ash Fraction of Meatmeal

Mineral	45% CProt MM	50% CProt MM	55% CProt MM
	% DM	% DM	% DM
Calcium	13.2	12.7	10.61
Phosphorus	6.67	6.18	5.08
Magnesium	0.28	0.22	0.21
Sodium	0.58	0.61	0.79
Potassium	0.34	0.94	0.47
	ppm DM	ppm DM	ppm DM
Iron	127.0	3993	867
Copper	11.8	12.5	13.5
Zinc	91.0	85.9	83.6
Manganese	26.1	25.7	20.1
Lead	-	-	2.71
Cadmium	-	-	2.45
Mercury	-	0.03	-

Source (AFIC)

3.2 Minerals in the Bone Fraction of Meatmeal

The major source of most of the minerals in meatmeal is really associated with the bone and bone fragments. The composition of the bone fraction of meatmeal is shown in the table 3.2. As can be seen from the table, bone contains relatively high concentrations of the trace minerals, zinc, copper, iron and manganese. Each is present at concentrations that meet the nutritional requirements of most species. The iron content is relatively high but not all of the iron may be available for absorption. However the availability of these minerals has not been clarified for most species. It is safe to assume that these minerals are readily absorbed in species like the dog and cat, that are carnivorous and are known to eat the bones of their prey. The position in other species such as fish, and herbivores such as sheep, cattle and horses is not as clear. In omnivores such as pigs the minerals in the bone fraction are absorbed. The general evidence points to a relatively high availability of minerals from bone material for most livestock. There is a primary need to establish the veracity and efficacy of bone as a mineral supplement.

Table 3.2 Minerals in Bone from Three Sources

Mineral	**Bone (AFIC)**	**Bone Source A 60% Ash**	**Bone Source B 58.9% Ash**
	% DM	%DM	%DM
Calcium	29.5	31	31
Phosphorus	12.5	11	11
Magnesium	0.6	0.39	0.40
Sodium	0.5		
Potassium	0.01		
	ppm DM	ppm DM	ppm DM
Iron	382	18.3	26.2
Copper	16.5	6.8	6.8
Zinc	158	30.0	32.6
Manganese	9.3		

3.3 Variability of Mineral Concentrations in the Ash Fraction

The bone fraction of meat and bone meal contains most of minerals, particularly the calcium, phosphorus and magnesium. It is the variability in the amount of bone processed and efficiency of its extraction that is the major factor in variability of the quality and specifications of meatmeal. Calcium concentrations can range from 1.2% to 16.4% with a mean of 12.3% in meatmeal with a 50% crude protein specification. The variability in the specification of the trace minerals; iron, zinc, copper and manganese can be large. For instance range of iron concentrations over 489 samples was 21.9 to 66080 with a mean of 3993 for meat and bone meal with a 50% crude protein specification. From discussions with feedmillers, the variation in the iron is probably due to metal filings being abraded from machinery during rendering and thus being included in the final product sold to feedmills and petfood manufacturers. Elemental iron, such as that present in the filings, would not be available for absorption by animals but would constitute a risk as an oxidant of fats in the meal. Magnets can extract this type of impurity and should be part of high quality rendering process. Interestingly, some heavy metal contaminants such as cadmium and mercury have been found in meatmeals. The reason is for this contamination is not clear but one possibility is the inclusion of contaminated offal such as liver and kidney in the final mix for rendering.

3.4 Nutrients in the Ash Fraction of Meatmeal

The calcium, phosphorus, magnesium, sodium, potassium, and the trace elements iron, copper, zinc, manganese are all essential nutrients for animals. By far the largest proportion of these nutrient is associated with the bone fraction of meatmeal. Indeed 99% of the calcium and 80% of the phosphorus is in bone, whereas 30% of the magnesium is present in non-bone component of the ash. The percentage of magnesium is the least variable of the major minerals and this is probably a reflection of its dual distribution between bone and non-bone fractions in the source material before rendering (table 3.1). The calcium and phosphorus in meatmeal are present in the highest concentrations (table 3.1) and represent both the greatest benefit for the intensive livestock industries, and greatest problem for the emerging markets of petfood and aquaculture.

3.5 Cost of Minerals Used in Supplements

Bone meal could have a cost advantage over mineral mixes formulated from individual mineral salts. Some representative prices for the commonly used salts of minerals in Western Australia are shown in table 3.3. Bone meal should be competitive as a combined source of the minerals, particularly if the cost of the mineral components of bone meal are marketed on their concentration costs vis-a-vis the cost of the active ingredients of mineral salts (Table 3.3). Moreover, bonemeal can be marketed as a "natural source" of these minerals for the petfood sector in particular.

Table 3.3 Costs of Salts Used for Mineral Supplements

Mineral Salt	Cost $/tonne	Cost $ per active component
NaCl	242	242
KCl	750	2142
$CaCO_3$ (Coarse Grade)	220	550
DiCaP	640	640
MgO	820	1366
$CuSO_4$	1480	3700
$FeSO_4$	610	1658
ZnO	1650	2062
MnO_2	800	1266

Source: Advanced Feeds Pty Ltd

3.6 Comparison of Trace Minerals in Meatmeal with Those in Plant Protein Sources

The trace elements particularly iron and zinc are present in quite high concentration relative to their abundance in plant material in particular. This natural abundance is highlighted by comparison with the grain legume meals (Table 3.3). However, canolameal, a potential major competitor with meatmeal in a number of markets, has reasonable concentrations of the trace minerals. Nevertheless, meatmeal and particularly the ash fraction has an advantage in the concentration of zinc present.

3.3 Trace Minerals in Meatmeal, Lupinmeal and Canolameal

MEAL	iron	copper	zinc	manganese
meatmeal 50% protein [a]	837	7.82	85.4	25.4
lupinmeal [b]	50	7.7	46.6	20.8
canolameal [c]	159.0	10.4	71.4	53.9

a: analysis
b: AFIC
c: Davison Canola Meal

4.0 Use of Meatmeals in Petfoods

Meatmeal is commonly is used in the petfood market, particularly in dry dog food. The current estimates from the AAS report (1993) are 24,000 tonnes. It is likely that this will expand as the dry dog food segment of the market is undergoing more rapid growth than the wet dog food (which is totally dominated by UBA).

4.1 Use in Generic Brands of Dog Food

Generic lines of dog feed are both an opportunity to expand the use meatmeal in the short term because this section of the market is growing rapidly. There are a number of companies in each state that are competing in this area of the market. Price is the key factor here, and both in perception and price, meatmeal is the preferred protein meal. The grain-legume meals are not popular for dog feeds because of their oligosaccharide content which causes wind in dogs. Canola meal suffers from an image of poor palatability amongst dog owners and most manufacturers. Whether this palatability problem for canolameal can be masked through flavouring remains an open question. Nevertheless, a typical generic line of dog feed contains at least 20% crude protein and 8% crude fat and the main source of protein is usually meatmeal which can account for 40-50% of the total crude protein and 25% of the crude fat. Fifty percent or more of the remaining fat is derived from tallow. It is these two components which determine the palatability of generic lines of dog feed.

As stated the only problem is the high ash and the high calcium resulting from these rates of inclusion. Generic dog foods are always on the borderline of producing a zinc-responsive problem of coat condition because of their high calcium and high wheat (often 35% or more) content. Word-of-mouth travels quickly in the dog world and any problem with coat condition would run the risk of a consumer backlash against the high calcium content, and hence decrease use by the manufacturer.

4.2 Use of Meatmeals in Premium Brand Dog Food

The premium veterinary-only diets are close behind generic dog feeds in their expansion in the market. These dog and cat feeds are sold only through veterinary clinics, and are marketed on the quality of their ingredients. Central to this philosophy is close and accurate nutrient specification and high long-term palatability. The two main companies in this market are Iams/Eukanuba of the USA and Uncle Ben's of Australia (UBA). UBA are by far the largest manufacturer of quality dog and cat feeds in Australia. Precise market share is very difficult to determine with any accuracy in Australia, but UBA dominates all markets for both wet and dry petfeeds. To grow the market UBA have emphasised the quality of their ingredient selection. While high quality meatmeal can compete here, reduction of the ash fraction by fine screening of the bone fraction is essential. Poultrymeal and fishmeal are preferred for dry feeds for dogs and cats respectively in this section of the market. However, the palatability and fat stability of high quality meatmeal should be a selling point. Both fishmeal and poultry meal need to stabilised with antioxidants to prevent rancidity of their fat component. This is much less of a problem in meatmeal. Removal of the ash fraction will increase the palatability of the meatmeal.

Palatability is a key factor in formulation of these feeds. Premium petfeeds are marketed on their having passed quite stringent feeding protocols specified and overseen by the AAFCO. In addition, premium petfood are formulated to minimise faecal quantity. This depends on two factors i) an accurate specification of all nutrients and ii) high digestibility. Removal of the ash fraction will enhance both of these factors in meatmeal and enable it to compete at the premium end of the petfood market. Moreover, removal of ash, particularly bone chip will ensure a product that can be processed to very fine particle size, an essential prerequisite for large volume extrusion.

4.3 Use of Meatmeal in Cat Food

Cats fed on diets containing excessive magnesium can develop lower urinary tract diseases. More than sixty percent of the uroliths that developed were composed of compounds containing magnesium. As a preventative measure, the upper limit of magnesium in dry catfeeds is 0.07%. The magnesium content of meatmeals precludes their use for catfeeds because it is almost impossible to include more than about 3-5% meatmeal in catfood without exceeding this magnesium specification.

The market for dry feeds for cats is growing at a pace that even exceeds that for dogs. Generic cat feeds contain high amounts of wheat. Cats are obligate carnivores and can be sensitive to carbohydrate intakes of more than 16g per day. When wheat is used, this carbohydrate intake is frequently exceeded. Therefore meatmeal would otherwise be an excellent choice to enhance palatability of cat food if the magnesium content could be reduced.

As stated earlier, 70% of the magnesium in contained in bone, so removal of bone would reduce the magnesium from 0.22% in 50% crude protein meatmeal to 0.066% or less in a deboned product. Generic cat food is less sensitive to price than generic dog food, and competes on specification and price basis.

4.4 Specification of Mineral Nutrients in Dog Food

The importance of zinc as a micronutrient in petfood diets, particularly dog food cannot be overemphasised. Zinc is required by both cats and dogs, but the requirement is readily affected by other components of the diet. Most importantly, a high calcium content or a vegetable-protein-based diet can dramatically increase the zinc requirement. Phytic acid present in cereal plants such as wheat used in dog diets can also reduce zinc availability. In fact zinc deficiency signs have been seen in dogs receiving cereal-based diets containing higher than minimum recommended amounts of zinc.

Although all nutrients must be supplied to requirement, the link between zinc and coat condition makes this trace element crucial to the performance of a dog feed. Any sub-optimal amount of zinc in the diet detracts from the appearance of the dog. Some breeds of dog that are popular in Australia such as Alaskan Malamutes and Siberian Huskies have much higher requirements for zinc. The requirement specified by the Association of American Feed Control Officials (AAFCO), now accepted as the premier authority for recommendations on petfood diets, is 120 ppm (Table 4.1). No plant material normally used in petfeeds contains this concentration of zinc. In fact only the ash fraction of meatmeal comes close to at 85.4 ppm (Table 4.1).

Table 4.1 AAFCO Minimum Nutrient Profiles for Dog Foods (1994)

Nutrient	Units	Growth & Reproduction	Adult
Protein	%	22.0	18.0
Fat	%	8.0	5.0
Linoleic acid	%	1.0	1.0
Calcium	%	1.0	0.6
Phosphorus	%	0.8	0.5
Potassium	%	0.6	0.6
Sodium	%	0.3	0.06
Chloride	%	0.45	0.09
Magnesium	%	0.04	0.04
Iron	mg/kg	80	80
Copper	mg/kg	7.3	7.3
Iodine	mg/kg	1.5	1.5
Zinc	mg/kg	120	120
Manganese	mg/kg	5.0	5.0
Selenium	mg/kg	0.11	0.11

In contrast to zinc, the calcium concentration of the ash fraction of meatmeal is so high that use of meatmeal in dog diets, quickly exceeds the maximum of 2.5% calcium recommended under the Association of American Feed Control Officials (AAFCO) [Table 4.1]. This can occur when manufacturers use high rates of inclusion of meatmeal that has been poorly screened for bone fragments. High calcium's are endemic in the generic lines of dog food where there is no margin to pay for the cost of screening.

Nevertheless, the ash fraction of meatmeal has an ideal composition of macro- and trace minerals for marketing as a mineral supplement for bone development in large and giant breeds of dogs. A basic premise of nutrition is that the dietary constituent should resemble the target protein or growth factor in the animal. On this basis, the minerals derived from bone ash must be of ideal composition for supporting bone growth in dogs and cats.

5.0 Utilisation the Ash Fraction in Mineral Supplements for Cattle

5.1 Demand for Cattle to Year 2000

The cattle industry is undergoing spectacular growth through demand for the live export of feeder steers to the near-Asian market (Table 5.1).

Table 5.1 Australian Feeder Steers Exports (number of head) AMLC Sydney

Country	90/91	92/93	93/94
Malaysia	21000	26000	26000
Philippines	17000	64000	114000
Indonesia	7000	31000	86000
TOTAL	45000	121000	226000

The future demand for live steers is also predicted to increase at a spectacular rate (Peggs 1994) but this demand is very sensitive to the exchange rate and may be variable (Table 5.2).

Table 5.2 Future Demand for Feeder Steers (No of head)

	1998	2003
Malaysia	30000	35000
Philippines	100000	150000
Indonesia	150000	300000
TOTAL	280000	485000

Source: Peggs 1994

Expansion of this magnitude will put pressure on breeding both the numbers and specification. Most of this potential demand will have to be met through expansion of cattle production in the tropical regions of Australia.

5.2 Nutrients in Ash Fraction of Meatmeal for Cattle

Phosphorus is the most common mineral deficiency in extensive animal production in the tropics and northern regions of Australia (McDowell, Conrad and Glen Hembry, 1993). Phosphorus supplementation increased fertility and liveweight gain of cattle during the wet season in the Kimberleys (Petty 1994). In fact supplementation of P can be the most effective means of improving animal production in the tropics (Minson 1990; McDowell, Conrad and Glen Hembry, 1993). Most of the original work to diagnose and confirm P deficiency in cattle was carried out in South Africa and the supplement of choice from this work was bone meal (Theiler et al 1924).

Bone ash was the most effective source of phosphate in supplementary trials. Bone ash contains about 180 g P/kg DM (Minson 1990) predominantly as carbonatoapatite $[Ca_3(PO_4)_2]_3.CaCO_3$, and must be protected from the wind and rain. However, superphosphate (74 g P/kg DM of soluble P as monocalcium phosphate CaH_2PO_4) and triple superphosphate with 190 g P/kg DM are now the preferred source of P in northern Australia. The monocalcium phosphate is separated by mixing superphosphate with 2-4 times its weight in water and siphoning off the water. Both superphosphate and bone ash present some labour and equipment difficulties in supplementation of P. Bone ash has an environmental advantage over superphosphate because it can be dispersed and not concentrated at watering points, as well as an advantage of actually getting to the cow or steers who may not come to drink at the watering points during the wet season when P deficiency is prevalent.

Thus the ash fraction of meat and bone meal could be utilised as a P supplement for cattle production in northern Australia, and the near tropical neighbours such as Indonesia.

6.0 Use of Meatmeal and Ash Fractions in Aquaculture Diets

6.1 The Need to Replace Fishmeal as Source of Protein

The need to replace fishmeal in aquaculture diets is a major international research priority. The aquaculture operations consume marine protein sources at about 8% of the world fishmeal production in the mid-80s, and consumption has been rising to a predicted 15-17% by the year 2000 (Wikkstrom and New 1989). The International Fish Meal Manufacturers Association estimates that world fish meal production will fall by about 5% during the 1990s. Alternative sources of protein must be exploited in Australian aquaculture.

Meatmeal can be effective as a replacement for fishmeal. Allan (1994) has shown that beef-based meatmeal [49.2% crude protein; 9.2% crude fat and 36.0% ash] and lamb-based meatmeal [54.3% crude protein; 7.2% crude fat and 34.5% ash] have high dry matter digestibilities in diets for silver perch (48.1 ± 9.8 for beefmeal at 30% inclusion, and 53.3 ± 1.5 for lambmeal at 30% inclusion). These findings are consistent with findings for rainbow trout as well. The digestible energy values for beefmeal and lambmeal were comparable between silver perch, rainbow trout and channel catfish (Allan 1994). As the quality of the meat-based meal improved to products such as Provine ®, so did the digestibilities for dry matter and energy (Allan 1994). Protein digestibilities for these meatmeals were also comparable between silver perch and rainbow trout.

Allan points out that meatmeal has fewer anti-nutritional factors than grain-legume and oilseed meals, provided that bone fragments are removed. Thus removal of bone (or ash) must be a priority for meatmeal to compete effectively in this market. Premium grades of fishmeal such as Danish fishmeal are an expensive (>$1100 per tonne) and limiting ingredient (New 1991).

6.2 The Asian Market for Australian Aquaculture Diets

The Asian aquaculture production had been expanding at a mean of 7% per annum during the 1980s (Hood 1990). Given that Asia is far and away the largest region for aquaculture, then Australia has an opportunity to market aquaculture feeds manufactured in Australia from our ingredients. The current estimation of the Asian market for aquaculture feeds is 2.6 million tonnes per annum. If high quality meatmeal can be included at 25% in aquaculture diets, then this market would require the total Australian meatmeal tonnage of 470,000 per year! Of course this projection is facetious to some extent, but these figures do demonstrate the potential for the use of meatmeal in aquaculture diets in the Asian market.

6.3 Biological Availability of the Minerals in the Ash Fraction of Meatmeal in Aquaculture

The use of the ash fraction in the market for aquaculture feeds is problematical. Mineral components such as calcium, phosphorus and magnesium are essential nutrients for bone development in fish. However, the calcium and magnesium requirement for fish is met largely through absorption of these nutrients from the water (NRC 1993). The dietary phosphorus supply is more critical than that of calcium (NRC 1993). Feedstuffs based on oilseed meals or grain-legume meals contain phosphorus that is not readily available to fish because of their stomach structure. Phosphate from mono- and dicalcium phosphate, but not tricalcium phosphate, is readily available (Ogino et al 1979). Moreover, phosphorus digestibility was inconsistent in studies on prawns (*Penaeus monodon*) by Smith (1995). Meat and bone meal from Beef City and Fletcher's performed well in promoting growth and could replace possibly 50% of the fishmeal in these diets, if the phosphorus digestibility could be improved by removing bone fragments. The P availability of powdered bone meal should be investigated as a prerequisite for using the ash fraction in aquaculture applications.

Zinc is an essential nutrient for all fish, and its availability is decreased by the presence of phytates in plant protein meals. However, tricalcium phosphate present in the bone fraction complexes zinc. The availability of zinc is inversely proportional to the tricalcium phosphate content (Satoh et al 1987). Thus diets using combinations of wheat or barley plus meatmeal will have double lowering effect on zinc supply to fish (NRC 1993). This problem can be overcome by feeding zinc supplements but this somewhat defeats the purpose of using ash as a mineral supplement.

6.4 The Future for Use of Meatmeal in Aquaculture Diets

Meatmeal can replace fishmeal in a number of the circumstances investigated so far (silver perch, Allan 1994; prawn, Smith 1995). However, the efficacy of meatmeal as a fishmeal replacement increases with removal of bone fragments. This does not auger well for the effective use of the ash fraction as mineral supplement in aquaculture diets. On the balance of evidence, it would not be cost-effective to use the ash fraction of meatmeal in aquaculture.

In addition, the decade of the 1980s saw Australian attempts at developing aquaculture and mariculture industries littered with failure; mainly due to excessive diversity and low levels of capitalisation (Hood 1990). This situation has been turned around in the 1990s to some extent. Oysters and Atlantic Salmon/Sea Trout are now well established, and the 1990s has seen major developments with barramundi, yabbies and prawns. Nevertheless, most of the potential for growth in the use of meatmeal (with bone fragments removed) remains with production of feeds for export; feeds that have been fully assessed as productive by Australian expertise. Australia is competitive in the area of costs of raw materials, and in each State there is the infrastructure to conduct feed evaluation trials. We should promote these advantages and not undersell either our raw materials or our expertise. The trend in fishmeal prices vis-a-vis meatmeal, allied to fishmeal's decreasing availability can only enhance these advantages in the future.

7.0 Use of Meatmeal and Ash Fractions in Diets for Pigs

7.1 Diets for Pigs

The intensive livestock industry consumes the majority of the meatmeal produced in Australia (AAS 1993). However, dietary considerations and costing are in a state of flux in the Australian pig industry for two major reasons.

Firstly the impact of imported pork has driven down prices for pork and bacon on the Australian market. This in turn has placed a greater emphasis on price of the final ration. In this situation, livestock feed manufacturers have placed meatmeal as a priority feed, mainly on the basis of its cost competitiveness but also because of the significant contribution that the ash fraction of meatmeal makes to the mineral composition and availability of the diet.

The availability of phosphorus from the ash fraction is an important consideration in pig rations. By using meatmeal, feed formulation for pigs need less complex and costly mineral mixes. Moreover, in those sectors of the pig industry that are looking to reinvigorate extensive pig production, the phosphorus availability is a key consideration. Extensive pig production is in some measure a response to improve the animal welfare aspects of pig production by moving from an intensive, indoor system to an extensive, outdoor system. While this change can improve the welfare of the pigs, the extensive, outdoor system such as AusPork in WA is mindful of polluting the environment with N and P. As a result, N and P specifications have to be close to optimum, with little room for error leading to wastage.

Cereal P is bound to a significant extent in phytate phosphorus, so the remaining inorganic P in the ash fraction of meatmeal is a key source of phosphorus to the pig, and must be closely specified. Meatmeal allows the nitrogen and phosphorus content of the ration to move in parallel, thereby making it easier to match these two nutrients and decrease the possibility of any excess amount polluting water systems around the piggery. Again the consistency of the ash fraction in terms of overall amount and relative contribution of meat versus bone meal is paramount. If there is too much variability then one the major advantages of meatmeal disappears in the context of extensive, outdoor pig production.

Secondly, the genotype of used pig production has changed significantly over the last 20 years as can be shown in table 7.1.

The 'classic' sow research was performed in the 1960s and 1970s. Now research is aimed at learning how to feed the and manage the modern genotype.

Meatmeal is still an important ingredient in feeds for the modern genotype but it under competition from canolameal and to a lesser extent lupinmeal. Therefore, it is important that the MRC maintain a watching brief on the use of meatmeal in the pig industry.

Table 7.1 The Modern Sow/Gilt

	1975	**1995**
Age at Mating (wks)	36-38	28-30
Weight at Mating (kg)	130-140	120-130
Appetite	Good	Poor
Subcutaneous Fat [gilts at mating] (kg)	20-30	15
Weaning Age (wks)	8	3-5

7.3 Removal of the Ash Fraction from Meatmeal in Diets for Pigs

Both the intensive and extensive pig industries have increased the demand for high-quality ingredients. Removal of the ash fraction has no advantages in this sector of usage of meatmeal. The ash itself is an important consideration in the inclusion of meatmeal. Removal of ash would increase the price of meatmeal but the higher protein specifications are of no great importance because; i) lower grade protein can be improved through the use of amino acid supplements such as lysine, methionine, tryptophan and phenylalanine, and ii) the mineral nutrients would have be supplied through vitamin and mineral mixes.

8.0 Use of Meatmeal and the Ash Fraction of Meatmeal in Diets for Poultry

8.1 Poultry Production Trends

The poultry industry is dominated by broiler production which has grown at 37% over the eight years to 1993 (AAS 1993). However the broiler industry is dominated by only a few major companies, and these companies have been successful in vertically integrating their production structure. The competition between these companies means that the margin between success and failure is very fine. The trend to even fewer companies will probably continue for the foreseeable future.

Egg production on the other hand has quite diverse ownership but is under increasing pressure for consolidation of ownership. Egg consumption declined over the period 83-89 (AAS 1993). However this decline was associated with health perceptions that eggs contained excessive cholesterol and thereby constituted a major risk-factor for cardio-vascular disease (CVD). More recently, doctors and nutritionists are less inclined to place such emphasis on dietary cholesterol intake as the major risk-factor for CVD. Given this, eggs consumption will probably increase over the 1990s as the more positive aspects of their excellent protein composition and high digestibility, especially for children, again take prominence in marketing.

8.1 Use of Meatmeals in Diets for Poultry

Meatmeal is frequently and extensively used in both broiler and layer rations. Meatmeal's advantages are price and amino acid composition, and importantly the minerals in the ash fraction. However, with the vertical integration of the broiler industry, companies have ready a supply of poultrymeal which is the preferred animal protein base for broiler rations. Poultrymeal has a higher protein content than meatmeal as shown in the following table 8.1.

Table 8.1 Comparison of Analysis of Meatmeal and Poultrymeal

	Meatmeal [a]	Poultrymeal [b]
Moisture (%)	3.4	3.1
Protein (%)	55.4	67.6
Fat (%)	9.3	9.8
Ash (%)	28.9	13.9

a: Meatmeal from Tallowman Bushmead WA
b: Poultrymeal from Inghams Enterprises Pty Ltd (WA)

The price differential for poultrymeal is 1.95 x meatmeal ie generally 1.95 x $400-$450; adjusted quarterly. Thus meatmeal is good value on a $ per % protein basis, and should remain sufficiently competitive to hold a place in broiler rations.

The ash fraction of meatmeal is an essential component in layer rations. Layers need a higher calcium content in their diet, and the calcium content of ash in meatmeal is ideal for this purpose.

8.3 Removal of the Ash Fraction from Meatmeal in Diets for Poultry

Besides price, the other factor in the continued use of meatmeal in the broiler industry is consistency of amino acid analysis. Here the most important measure of quality is lysine availability. Removal of the ash fraction would lead to a more consistent product of higher amino acid specification. However, the vertical integration of the broiler industry may mitigate against increased use of meatmeal notwithstanding any increase in quality and consistency. It is doubtful that higher specifications of meatmeal would lead to higher use in the broiler industry.

Removal of the ash fraction has no advantages in usage of meatmeal for layer rations. The ash itself is an important consideration in the inclusion of meatmeal for egg production. In this sector of the poultry industry, the higher protein specifications are of no great importance because; i) lower grade protein will suffice for the most part and ii) calcium would have be supplied through a mineral mix.

9.0 Possible New Methods/Technology for Preparation and Fractionation of the Ash Fraction

This section of the report is highly speculative, but represents a new frontier for thinking about the ash fraction of meatmeal. Since the ash fraction represents the mineral component of meatmeal, then the minerals could be separated along the lines of mining for minerals. This could involve the techniques of simple solution chemistry to first solubilise and then separate the minerals.

The simplest method for this would be to acid-treat the meatmeal (preferably with concentrated hydrochloric acid or sulphuric acids). This would precipitate most of the protein content and solubilise most of the mineral fraction. The resultant protein could be used in catfeed un-neutralised since cats have a high tolerance, and even a preference for acidic food. Moreover acid-treated meatmeal would be stabilised against microbial attack. Some of the amino acids would be hydrolysed by acid treatment of the protein. This would increase the availability those amino acids, and possibly enhance the palatability of the meatmeal. The removal of the ash fraction would increase the protein from 50% in the normal meatmeal specification to approximately >65% in an ash-free meatmeal. Meatmeal with a 65% crude protein content is on a par with the protein content of poultrymeal and many fishmeals. If the lysine availability is not adversely affected, then ash-free meatmeal should be competitive on a quality with these other animal-protein meals.

Having solubilised the minerals, then sodium hydroxide (caustic soda) could be used to selectively precipitate minerals. This methodology could be developed select certain minerals such as magnesium which command high prices. Even the hydroxide of magnesium, milk of magnesia, generated under the methods outlined above has a higher cost use as an antacid. A combination of soluble and insoluble magnesium salts would also be a premium fertilizer for plants. If ash is about median 25% of all meatmeals, then 120,000 tonnes of pure mineral are available to the techniques of mining such as solution chemistry to dissolve and then extract particular minerals such as magnesium. This could supply up to 1300 tonnes of magnesium for instance.

The soluble and insoluble salts of trace elements would be very effective in controlled release systems for both plants and animals, particularly ruminants. Technology already exists for incorporating insoluble salts of trace elements into the matrix of controlled release delivery systems which can be placed in the rumen.

The technological adjustment for treatment of meatmeal with acid and alkali is not great. Certainly a pilot scale assessment of this approach could be undertaken quickly and the extraction of the minerals checked by atomic absorption spectroscopy quite readily.

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Appendix 4

Field experiments with Five Vegetable Crops Using Bone Meal as a Fertiliser

J Y Langdon

Field Experiments with Five Vegetable Crops Using Bone Meal as a Fertiliser

Meat Research Corporation Contract

Contract Officer

J Y Langdon
372 Stirling Highway
Claremont
Western Australia

Summary and Conclusions

The aim of the project was to determine the potential of the ash fraction of meatmeal (bone meal) for use as a slow release fertiliser in market gardens, including situations where serious pollution problems in waterways and estuaries may be caused by nutrients leaching from soils receiving high rates of readily soluble fertilisers.

The response of five organically grown vegetable crops, lettuce (*Lactuca sativa)*, cabbage (*Brassica oleracea var. capitata)*, carrots (*Daucos carota*), beans (*Phaseolus vulgaris)* and zucchinis (*Cucurbita pepo)* to applied bone meal were investigated on Karrakatta sand under irrigation 30 kms south of Perth, W A. A large proportion of the vegetables grown in W A are produced on this soil type.

The lettuce and cabbage plots received a basal dressing of 14.09 t/ha of composted poultry manure and from nil to 4556 kg/ha of bone meal; the beans, 7.04 t/ha of poultry manure and from nil to 6075 kg/ha of bone meal; the zucchinis, 7.04 t/ha of poultry manure and 2 applications of bone meal at rates up to 6075 kg/ha on each application and the carrots received bone meal only at rates from nil to 6075 kg/ha.

The yields of lettuce and both the yields and numbers of zucchinis gave significant responses to additional bone meal. The bean and carrot crops grew well and although yields were satisfactory, the effects were not significant. The carrots particularly were of very good quality and were better than previous crops grown on this farm under organic methods.

Although establishment and early growth of the cabbages were reasonable, the plants became severely nutrient deficient about 8 weeks after planting and growth was affected. Leaf tissue analysis showed that the plants were severely deficient in nitrogen. At maturity, the crop was very uneven and even the cabbages which had received the heaviest rates of bone meal were mainly small and of variable quality. These plots had received 405 and 228 kg/ha of nitrogen from the poultry manure and the bone meal respectively making a total of 633 kg/ha of N immediately prior to planting.

The soil to a depth of 600 mm was sampled and analysed after the carrots were harvested to determine the leaching of nutrients from the bone meal. This area did not receive poultry manure prior to the carrots being sown. The analytical data showed that the levels of P and N in the surface 150

mm of soil were significantly less after the experiment than before, even though bone meal at rates up to 6075 kg/ha had been applied.

While P was slightly higher in the top 300 mm of soil with the highest rate of bone meal, there were no differences between P and N levels in the 300 to 600 mm layer after bone meal rates of nil, 1800 and 6075 kg/ha respectively.

The soil data and crop responses indicated that the nutrients in bone meal are readily soluble and, in this particular soil, are quickly leached from the crop root zone.

The growth responses with significant effects were those with lettuce, a quick maturing crop, and zucchinis, which received a second application of bone meal during the growing period when showing signs of nutrient deficiency.

The carrot and bean crops, which took slightly longer to mature, grew satisfactorily in the main but the yield differences were not significant. Cabbages, the slowest maturing crop and with the highest nutritional requirements, developed severe nitrogen deficiency symptoms which were confirmed by leaf tissue analysis.

The chemical reactions of bone meal in soil were not investigated, but it is apparent that bone meal is not only much more soluble than rock phosphates and leaches readily so that there is little residual P in the soil subsequently.

In practical terms, bone meal may be of use as a P and N fertiliser for perennial or annual plants which have established, dense root systems. It may be beneficial composted with other organic materials so that the soluble nutrients are incorporated into the compost before addition to the soil.

It is concluded that bone meal reacts much more quickly than phosphate rocks in the soil and is not suitable as a slow release fertiliser under the conditions of the experiments. However, improved knowledge of the soil chemistry relative to bone meal should lead to the development of practical and economical uses for bone meal as a fertiliser where readily available P and N are required in an organic form.

1.0 Aim of the field experimental programme

The literature review of experiments with phosphate rocks indicated several potential uses for the "ash" fraction of meatmeal as a fertiliser. The potential use with the greatest economical and agronomic benefit was seen as a slow release P fertiliser which should be as effective as more water-soluble P fertilisers in certain soil, climatic and plant conditions.

In these circumstances the ash fraction would be used to maintain P after soil P levels had been increased by superphosphate applications.

Its effectiveness and potential as an acceptable fertiliser for organic farming is one area that may be evaluated reasonably quickly.

The specific task for this section of the report is to demonstrate and evaluate the "ash" fraction as a fertiliser on 5 vegetable crops grown under organic farming conditions. As there is very little information from field experiments regarding the effectiveness of the ash component of meatmeal, hereafter referred to as bone meal, for vegetable production, this overall task has been broken into four parts:

1. to determine if bone meal is suitable as a fertiliser on a range of vegetable crops under organic farming conditions;

2. to indicate the range over which individual crops will respond to various rates of application of bone meal for further, more precise, experimental investigations;

3. to measure the response of the crops to different levels of bone meal; and

4. to determine the leaching of P from soils following the application of bone meal as a fertiliser.

2.0 Introduction

Except on acidic sandy soils with relatively high rainfall, the level of P in soil tends to increase with successive applications of P fertilisers due to the reversion of soluble phosphates to insoluble forms of P. However, the availability of P to plants increases with the level of soil P through cation exchange and other soil processes.

As further applications of P fertilisers are made, the residual value of P becomes greater and losses through soil reaction are reduced. Responses by crops to additional P become less and eventually, as more P is applied, yields no longer increase.

Vegetable growers apply high rates of fertilisers and manures to ensure that yields are not limited by nutrient deficiency. Consequently, most soils used for market gardening for even a few years tend to have high residual P values, and slow release P fertilisers, such as phosphate rocks and possibly bone meal, may be capable of maintaining the soil P at an acceptable level to achieve similar yields.

Organic vegetable growers have a limited choice of fertilisers which they may use to retain accreditation as organic growers. Bone meal is acceptable whereas manufactured forms of fertilisers such as superphosphate are not.

Similarly, fertilisers leached from market gardens in some areas and on susceptible soils have been found to cause pollution, eutrophication and other environmental problems in waterways and estuaries. Slow release fertilisers may reduce the leaching of fertilisers in such conditions.

Because of these overlying factors, this project examined the effects of seven rates of bone meal upon yields and growth of five different vegetable crops in an established organic market garden. The results from these experiments would have considerable application directly to a significant number of market gardens and conditions.

In effect, these experiments are more concerned with determining the appropriate application rates of bone meal for maintenance purposes in soils with a high P level than in examining the responses by crops on soils with low P. In the latter, there may be significant responses to additional rates of P fertiliser, even in slow release form, but these would have little practical, long-term relevance to established market gardens.

The experiments also examine the effects of the nitrogen component of the bone meal upon the yield and growth of the crops.

3.0 Experimental Details and Methods

3.1 Site

The experimental site was selected on yellow Karrakatta sand (Karrakatta association, Karrakatta series as defined by McArthur and Bettenay (1960) or Uc 4.22 (Northcote classification: Northcote 1979) at Wellard, 30 km south of Perth WA on the Swan coastal plain.

This soil has low fertility in its natural state with relatively low ability to retain P and with a low water-holding capacity. These soils are extensively used for vegetable production for the Perth and export markets with high rates of fertiliser being applied. They require irrigating at least once daily throughout most of the year through permanent overhead sprinklers.

This particular area had been used as a market garden for approximately the last seven years, during which successive crops have received heavy rates of manures, mainly composted poultry litter and other organically accepted fertilisers. Immediately before the experimental period, the whole area had been planted with vetches as a green manure crop which was rotary hoed into the soil about one month before the experiments commenced. Subsequently the area was cultivated in the normal manner to control weeds and prepare the soil for planting.

Because the farm is an accredited organic farm, chemical weedicides and insecticides are not permitted. Accordingly and in contrast to the practice on non-organic farms, no weedicides were applied prior to or after the crops were planted. Weeds were controlled manually. All fertilisers used in the experiments are acceptable to organic farming principles and requirements.

3.2 Experimental Design

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The five vegetables used in the programme were

- lettuce (*Lactuca sativa*),
- cabbage (*Brassica oleracea var. capita*),
- beans (*Phaseolus vulgaris*),
- zucchinis (*Cucurbita pepo)*, and
- carrots (*Daucos carota*).

For the benefit of the investigation, other crops, such as potatoes and tomatoes in particular, could have been included but these are susceptible to disease in these conditions. The Western Australian Department of Agriculture has been investigating the relationship between the level of residual P in the soil and the responses to various rates of superphosphate of potatoes on Karrakatta and related soils. These sandy soils, when used with heavy rates of P fertilisers for market gardening, are responsible for a significant amount of the eutrophication of waterways on the Swan coastal plain and the fertiliser practices have been under close study in recent years.

Each crop was treated as a separate experiment with certain common factors. Each experiment had a block design with seven rates of bone meal by three replications, with the exception of zucchinis which had four replications. The rates of bone meal applied varied with the crop grown.

Each plot was 3.2 m long with the width varying between experiments.

3.3 Initial soil analysis

Soil samples to a depth of 150 mm from the entire experimental area were analysed to determine the level of nutrients in the soil prior to the commencement of the trials. The analytical data determined the site for each individual experiment and the rate of composted poultry manure applied as a general dressing prior to planting each crop.

The samples were analysed by the CSBP Soil Analysis Laboratory, Bassandean and the full analytical results are shown in Table 1.

In addition the soil conductivity was determined with the results showing that the salt content was very low in all samples. Samples from an additional site were analysed but this area was disregarded for further consideration on the basis of the results and the poor, uneven growth of vetches grown previously on that area.

In general the results indicated that the levels of nitrogen and potassium in the soil were low, but the P content was adequate for maximum yields of carrots and cabbages on all sites except site C. (McPharlin, Jeffery and Weissburg, 1994 and McPharlin, Robertson, Jeffery and Weissburg, 1995)

SITE	A	B	C	D	E
ANALYSIS					
NITROGEN					
NITRATE mg/kg	7	8	6	7	7
AMMONIA mg/kg	10	10	9	11	11
PHOSPHORUS mg/kg	71	76	50	97	106
POTASSIUM mg/kg	43	32	31	32	31
SULPHUR mg/kg	6	7	6	9	9
ORGANIC CARBON %	1.32	1.12	0.92	1.17	1.12
REACTIVE IRON mg/kg	208	222	190	261	290
pH 1:5 CaCl2	7	7.1	7.1	7.1	7.1
CROP GROWN	Beans	Zucchinis	Carrots	Lettuce	Cabbage

Table 1: Laboratory analysis of the initial soil samples from the experimental sites.

Accordingly, the crops were grown on the sites as indicated in Table 1. Site C was selected for growing carrots because it had the lowest soil P level and carrots do not normally receive additional manures immediately prior to being sown. This combination of low initial soil P with no other added P fertiliser was the most likely to give a significant response to various rates of bone meal.

As all sites were deficient in soil nitrogen, which would be relatively common for vegetable crops, the main emphasis of the experiments was to determine the effectiveness of bone meal as a slow release N and P fertiliser. The rates of composted poultry manure applied as a general dressing to each site, with the exception of that for carrots, were calculated to supply part of the nitrogen required for maximum yields with the remainder being derived from the applied bone meal.

3.4 Fertilisers

Acceptable rates of bone meal alone would not supply adequate nitrogen to meet the nutrient requirements of the selected crops, with the exception of carrots. Normally composted poultry manure is used on organic market gardens to supply the main requirements for phosphorus and nitrogen.

Rates of bone meal and composted poultry manure were calculated so that the higher rates of bone meal would provide adequate levels of these nutrients in each of the experiments.

The analyses of the bone meal and composted poultry manure used are as follows:

<u>Analysis of bone meal:</u>

	%
Total P	12.2
Water soluble P	0.02
Citrate insoluble P	10.7
Citrate soluble P	1.48
Total Nitrogen	5.0

<u>Analysis of composted poultry manure:</u>

	g/100g
Dry matter	76.9
Phosphorus	0.96
Total Kjeldahl Nitrogen	2.9
Ammonia Nitrogen	0.6
Nitrate Nitrogen	0.001

Partially composted poultry manure was applied at the following rates to the site of each experiment on September 1st, 1995 and cultivated into the surface of the soil. (Table 2)

Crop	Poultry manure applied	P applied	N applied
	t/ha	kg/ha	kg/ha
Lettuce	14.088	133.8	405.7
Cabbage	14.088	133.8	405.7
Beans	7.044	66.9	202.9
Zucchnins	7.044	66.9	202.9
Carrots	Nil	Nil	Nil

Table 2: Rates of composted poultry manure, phosphorus and total nitrogen applied to each crop site prior to planting.

The bone meal application rates for each experiment are shown in Table 3. The application of bone meal to the zucchinis was repeated as a side dressing during the experiment on 22nd November, 1995. The rates shown on Table 3 are those for each application.

Treatment	Beans	Zucchinis *	Carrots	Lettuce	Cabbages
1	0	0	0	0	0
2	800	800	800	600	600
3	1200	1200	1200	900	900
4	1800	1800	1800	1350	1350
5	2700	2700	2700	2025	2025
6	4050	4050	4050	3037	3037
7	6075	6075	6075	4556	4556

* Two applications at these rates were applied to zucchinis.

Table 3. The rates of bone meal applied in each experiment. (kg/ha)

Before use the bone meal was crushed to increase the surface area in contact with the soil, thereby increasing its reactivity. The particle sizes were determined by measuring the percentage of material retained by three sieves of varying sizes, as below:

Sieve size	% Retained
2.00 mm	5.4
1.70 mm	9.6
850 µm	46.5

In practical terms. bone meal of this particle size would require granulation before it could be used commercially.

The bone meal was applied to and worked into the soil surface a few days before each crop was planted. The second application of bone meal to the zucchinis was spread on the surface close to the plants but not mixed into the soil.

Each week from planting until the individual crops were harvested, potassium and magnesium sulphates were applied to all plots as follows:

Experimental crop	Sulphate of Potash	Magnesium Sulphate
Cabbage, lettuce	125 kg/ha	20 kg/ha
Beans, carrots, zucchinis	60 kg/ha	10 kg/ha

In addition, 5 l/ha of Sea Organix seaweed solution were applied to all plots fortnightly and 2.5 l/ha of Agro Best micronutrient solution were applied on 1 October, 1995 to maintain the level of trace elements and micronutrients in the crops.

The analysis of the Agro Best solution was given as:

	w/v
Sulphur as Sulphates	2.2%
Boron as Boric acid	0.3%
Copper as copper lignosulphonate	0.2%
Iron as ferric lignosulphonate	1.5%
Manganese as manganese lignosulphonate	0.4%
Zinc as zinc lignosulphonate	1.6%
Molybdenum as sodium molybdate	0.04%
Water added	63.9%

3.5 Crop Management

3.5.1 Lettuce (*Lactuca sativa*, ssp *longifolia and* ssp *capitata*)

Two of the three replications of lettuce were planted to Cos lettuce (ssp *longifolia)* seedlings on 14 September and the third to Brown Mignonette (ssp *capitata*) seedlings on 12 October, 1995.

The seedlings were planted in plots 140 cm wide with 5 rows per plot making 35 cm between rows, and 35 cm between plants in the rows.

At harvest, the eight centre lettuces in the three middle rows of each plot, making 24 from each plot, were cut and each lettuce was individually weighed. The lettuce were harvested when most were of market standard which for the Cos lettuce was on the 21st and 23rd of October and the Brown Mignonette on 13th November.

One plot of Brown Mignonette was disregarded because the plants had suffered severe damage from geese.

3.5.2 Cabbage *(Brassica oleracea var. capitata)*

Green Coronet cabbage seedlings were planted on 14 September, 1995 in plots 150 cm wide with 4 rows per plot. The seedlings were 45 cm apart along the rows which were 50 cm apart from each other.

The 6 cabbages from the middle of each of the two central rows in each plot were cut, individually weighed and the weights recorded. The cabbages in the two outside rows and at the ends of each middle row were disregarded for experimental purposes.

The cabbages grew at a satisfactory rate early in the trial but it became apparent that many plants had symptoms of severe nitrogen deficiency. Nitrogen deficiency was confirmed by leaf analysis. The symptoms were most acute in the centre of the experimental area and not consistent with the rate of added bone meal treatments.

Some plants on the outer edge of the experimental area had much better growth rates than the others. These were influenced by piles of manure which had been placed in the vicinity during a previous cropping cycle and were not obvious when the current crop was planted. These plants were not used in the experiment.

A partial explanation for the nitrogen deficiency found in the cabbages was that the poultry manure was incompletely composted when used for the cabbage experiment. The poultry manure came from deep litter sources and contained a considerable proportion of sawdust. It was possible that the bacteria breaking down the organic material was still utilising the total nitrogen content of the compost, so that the only nitrogen available for plants was the initial soil N and that in the bone meal as it became available.

Be that as it may, the total amount of nitrogen that was estimated to be available from the manure and bone meal was inadequate for cabbages or was leached from the soil before it could be absorbed by the plants. On non-organic farms, applications of nitrogenous fertilisers are repeated four or five times during the growing period to overcome the leaching problem.

Because the growth of the cabbages was uneven, some in each plot reached a marketable standard while others were still immature. Accordingly, four cabbages were cut from all plots on each of three days, the 8th, 11th and 18th of December, to allow less developed cabbages to grow for a slightly longer period.

3.5.3 Carrots *(Daucus carota)*

Seed of the carrot cultivar Amsterdam Forcing were sown by drill on 20 September, 1995 into plots 140 cm wide with 5 rows per plot or 35 cm between rows. Weeds were a serious problem but were kept under reasonable control by mechanical and hand weeding.

As it is claimed that this particular cultivar does not require thinning in commercial practice, this was not done for the experiment

One of the three centre rows for the full length of the plots were pulled on each of three days, the 18th, 20th and 22nd of December, 1995. As the carrots were uniformly clean, they were weighed with tops on and before washing.

Samples were test weighed with tops on before washing and without tops after washing. It was found that the weight of the roots after washing was consistently just over 80 % of whole plants before washing. As a result, the weight of the whole carrots prior to washing was used for recording the yields.

If necessary, the carrots would have been graded with the total weight of carrots in each grade being measured and used for analysis. However the carrots were very uniform and of such consistently good quality that this was not required.

3.5.4 Beans *(Phaseolus vulgaris)*

Seeds of the dwarf bean cultivar Labrador were sown by hand in plots 1 m wide with 3 rows 50 cm apart per row on 20 September, 1995. The seeds were sown in pairs which were 15 cm apart down the rows.

Because the branches of neighbouring plants became intermingled, the beans from all plants in each plot were harvested and weighed to determine its total yield. Harvesting commenced by hand on the 27 November and continued on three days per week until the final pick on 6 December. All beans of marketable size were picked at each harvest.

The weight of beans from each plot at each harvest was measured and the total yield from all harvests calculated for analytical purposes

3.5.5 Zucchini (*Cucurbita pepo*)

Seeds of zucchini, cultivar Blackjack, were planted in pairs, with each pair of seeds 50 cm from the next pair, in the centre of beds 120 cm wide on 20 September, 1995.

Because the zucchini plants were not growing as vigorously as they had previously and they appeared to be slightly nitrogen deficient, the application of bone meal was repeated on 22 November.

The harvesting of zucchini commenced on 20 November and continued, with three pickings per week, until the final harvest on 22 December, 1995. In the initial harvests, zucchini from the six pairs of plants closest to the centre of each plot were picked when they exceeded about 20 cm in length. In the final two harvests, on 20 and 22 December, all zucchini over 10 cm were picked.

The zucchini from each plot and harvest were counted and the yield from the plot obtained by weighing. The total number and weight of zucchini harvested from each plot was obtained by adding the daily totals.

3.6 Analysis of Data

Analyses of variance were carried out on the yields from all experiments and the number of zucchini harvested.

3.7 Soil P Levels

The leaching of nutrients on sandy soils that are cropped and irrigated is of serious concern from a number of issues. This factor has serious implications for market gardens on the Swan coastal plain, where heavy applications of fertilisers are used in such conditions to achieve near maximum yields.

Plots on which nil, 1800 and 6075 kg/ha of bone meal (nil, 219.6 and 741.15 P kg/ha respectively) had been applied at the commencement of the trial, were sampled to determine whether P and other nutrients from the applied bone meal had leached down the soil profile..

The levels of P and other elements in the soil were determined at depths of 0 to 150 mm, 150 to 300 mm, 300 to 450 mm and 450 to 600 mm on the carrot experimental site after the carrots were harvested. This site did not receive poultry manure before the crop was sown.

The samples were analysed by the CSBP Soil Analysis Service, Bassandean and the results are presented in Table 4.

Rate of bone meal (kg/ha)	0	1800	6075
(Rate of P kg/ha)	0	219.6	741.15
Lab. Analysis of soil samples			
Phosphorus (mg/kg)			
0-150mm	29	27	48
150 - 300 mm	35	24	34
300 - 450 mm	23	19	22
450 - 600 mm	24	26	20
Nitrate (mg.kg)			
0-150mm	4	4	7
150 - 300 mm	3	3	5
300 - 450 mm	1	2	2
450 - 600 mm	2	2	2
Ammonium (mg/kg)			
0-150mm	3	2	3
150 - 300 mm	2	2	3
300 - 450 mm	2	2	2
450 - 600 mm	2	2	2
Potassium (mg/kg)			
0-150mm	32	25	45
150 - 300 mm	30	49	33
300 - 450 mm	25	33	30
450 - 600 mm	21	33	17
Sulphur (mg/kg)			
0-150mm	4	4	6
150 - 300 mm	5	4	5
300 - 450 mm	3	3	5
450 - 600 mm	2	3	6
Organic carbon (mg/kg)			
0-150mm	0.68	0.67	0.61
150 - 300 mm	0.52	0.45	0.61
300 - 450 mm	0.28	0.25	0.27
450 - 600 mm	0.31	0.26	0.29
Reactive iron (mg/kg)			
0-150mm	164	189	178
150 - 300 mm	185	168	220
300 - 450 mm	168	157	194
450 - 600 mm	168	202	194

Table 4: Analysis of soil samples from 0 to 600 mm taken after carrots were harvested with different rates of bone meal.

4.0 Results

4.1 Growth

With the exception of the cabbages, which suffered nitrogen deficiency of increasing severity as the crop matured, the growth, appearance and quality of the crops compared reasonably with similar crops grown previously on the farm.

The Brown Mignonette lettuces, particularly, were very even and of good quality. They matured quickly and were of marketable standard and harvested 32 days after the seedlings were planted. The Cos lettuce were less even but overall the quality and growth were acceptable for organic conditions. Growth differences in the Cos lettuces were detectable visually on 20 October, 1995 which were maintained until they were harvested. Similarly, the Brown Mignonette lettuces responded to increasing rates of bone meal application.

The early growth and appearance of the cabbages were good with little differences noticeable between treatments. However, 2 months after the seedlings were planted, symptoms of nitrogen deficiency were apparent, particularly in the plots in the middle of the experimental area. Tissue samples of leaves taken on 4 December, 1995 confirmed that very low nitrogen levels were present and responsible for poor and uneven growth.

The carrots resulted in a very even, high quality crop with very few reject or abnormal carrots. It was stated that this was the best quality crop produced on the farm. Differential visual responses to treatments during the growing period were very small and inconclusive.

Although the growth of the beans was even with only small differences between treatments, growth rates and the density of the crop were less than normally experienced on the farm. However the crop was satisfactory.

The growth of the zucchinis was reasonable but as the plants were showing symptoms of nitrogen deficiency by the end of November, a second application of bone meal at the same rates as before was made on 22 November and not cultivated into the soil.

Visual growth and colour responses to the second application of bone meal to the zucchini were apparent on 15 December, 1995 but was of very short duration. When the experiment terminated a week later, all except those plots receiving the heavier rates of bone meal had began to display the initial signs of nutrient deficiency.

4.2 Yields and Analysis of Variance.

4.2.1 Lettuce.

The lettuce crop gave a significant ($P<0.05$) yield response to the rate of applied bone meal.

Applied Bone meal (kg/ha)	Lettuce Total yield (t/ha)
Nil	37.79
600	42.01
900	39.59
1350	41.44
2025	40.15
3037	47.30
4556	47.51
Mean yield	42.26
5% LSD	6.93

The equation for estimated yield response for lettuce is:

$$y=38.49 + 0.2108 \text{ x rate } (R^2 = 77.5\%)$$

where yield and rate of bone meal applied are measured in tonnes per hectare.

4.2.2 Cabbage

The response by the cabbages to the applied bone meal was not significant.

Applied Bone meal (kg/ha)	Cabbage Total yield (t/ha)
nil	23.42
600	26.93
900	27.24
1350	29.22
2025	26.34
3037	26.36
4556	34.81
Mean yield	27.75

4.2.3 Carrots

Although the yields of carrots to increasing rates of applied bone meal were not significant, this crop was, apparently, the best grown on the farm and yields were satisfactory.

Applied Bone meal (kg/ha)	Carrots Total yield (t/ha)
Nil	61.14
800	56.14
1200	67.59
1800	59.92
2700	64.12
4050	64.65
6075	59.70
Mean yield	61.89

4.2.4 Beans

Although the yields were generally satisfactory and the quality of the crop was excellent, the yields to increasing rates of bone meal were not significant.

Applied Bone meal (kg/ha)	Beans Total yield (t/ha)
Nil	26.82
800	22.55
1200	24.76
1800	26.92
2700	23.20
4050	24.43
6075	22.41
Mean	24.43

4.2.5 Zucchinis

The zucchinis were harvested 3 times per week from 20 November to 22 December. As the weight of individual zucchinis increases rapidly until they are ready for picking, both the number of zucchinis and the total weight harvested from each plot were recorded for statistical purposes. Both the total yield and number of zucchinis harvested gave a significant ($P<0.05$) response to the rate of bone meal applied.

Bone meal Total applied in 2 app'ns (kg/ha)	Zucchinis Number (0000/ha)	Zucchinis Yield (t/ha)
Nil	19.06	53.60
1600	18.54	56.59
2400	19.09	57.32
3600	21.61	65.35
5400	20.05	55.08
8100	22.06	64.52
12150	22.66	69.23
Mean	20.44	60.24
5% LSD	2.74	9.91

The equations for the response by zucchini to added bone meal are

$$\text{Number of zucchini/ha} = 188\,250 + 3.396 \times \text{rate (kg/ha)};$$

$$\text{Yield of zucchini (kg/m}^2\text{)} = 5.478 + 0.0001149 \times \text{rate (kg/ha)};$$

or -

$$\text{Yield of zucchini (t/ha)} = 54.78 + 1.149 \times \text{rate (t/ha)}.$$

5.0 Discussion

Bone meal has a composition of 12.2% total P, of which 1.5% is available to plants, and 5% nitrogen. Accordingly, it should be useful as a fertiliser applied to vegetable crops on soils with high residual P levels.

In this situation, the P component would be sufficient to maintain soil P at levels that are satisfactory for most crops with the exception of those that have very high requirements Additionally. appropriate rates of bone meal should provide much of the nitrogen requirements for most crops.

Compared to fertilisers with high solubility and availability, bone meal was expected to have a slow release pattern which would make it suitable for use on leaching soils.

Contrary to expectations, the growth, yields and soil analysis data indicate that the benefits from bone meal, at least when applied to vegetable crops on a sandy soil, is of short duration. These results show that, of the five crops in the trials, only lettuce, which was harvested within six weeks of planting, and zucchini, which received two applications of bone meal, gave significant responses to bone meal.

McPharlin, Jeffery and Weissburg (1994) showed that the critical soil test levels required for 95% or 99% of maximum yield on the soil type used in these experiments were 45 and 60μgP/g. Their results indicated that the maximum predicted yields were 93 tonnes of carrots per hectare.

The area sown to carrots in these experiments had soil P and N levels of 50 and 15μg/g respectively prior to the application of bone meal. At these levels, a significant response to additional P would not be expected but the additional nitrogen could be expected to increase the yield of carrots.

Even though the rates of bone meal applied to the carrots varied from nil to 6075 kg/ha, the difference in rates applied had very little effect upon the growth and appearance of the carrots and there was no significant effect upon yields.

The relatively high mean yield of 61.9 t/ha suggests that the nitrogen released from the bone meal was not only highly soluble but entered the soil solution and may have been translocated between plots.

The low residual soil N levels after the carrots were harvested and the very low levels of nitrogen in the cabbages prior to harvest suggests that the nitrogen components of the bone meal rapidly became soluble in the soil solution so that the benefits from the nitrogen contents are of short duration on an irrigated sandy soil.

Similarly, the analyses of the soil samples taken to a depth of 600 mm after the completion of the carrot experiment showed that only the high rate of bone meal influenced the P content of the surface layer. Even then, the final level, after the application of 6075 kg/ha of bone meal, was less than when the bone meal was applied.

The consistently low amounts of P in the soil below 150 mm regardless of the rate of surface application suggests that P from bone meal is readily leached from such sandy soil. As the chemistry of the reaction of bone meal with soil was not investigated, it is not possible to determine how these effects took place in this soil nor the likely results in different soils.

The expected slow release of P did not occur, nor was there a high residual P value at the conclusion of the experiment. The residual P level with the highest rate of application was slightly higher in the surface 150 mm but not at deeper layers than with the other rates.

It is significant, however, that the soil P levels at each interval from the surface to a depth of 600 mm after the application of bone meal at the rate of 1800 kg/ha (220 kg of P/ha) was less than or equivalent to the soil P levels with no added bone meal.

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Appendix 5

Organic farm certification organisations and organic agriculture contacts within state and federal government departments.

Organic farm certification organisations

The following organisations operate, or plan to operate, national organic farm certification schemes. These and any other national organisations may apply for accreditation by AQIS in order to become recognised certification bodies. Such recognition is necessary if produce covered by a certification scheme is to be exported under an 'organic' label. The current status of any certification body may be confirmed with AQIS. AQIS itself may also assess and certify organic growers. These organisations may also be approached regarding the certification of food processing establishments and farm inputs.

Growers unsure of which certification scheme to join should speak with certified growers for advice or contact a number of the organisations listed here to judge for themselves.

Australian Quarantine and
Inspection Service
Food Standards Policy
GPO Box 858
Canberra, ACT 2600
Telephone: (06) 272 5112
Fax: (06) 272 3103

Bio-Dynamic Agricultural
Association of Australia
c/o PO
Powelltown, Vic. 3797
Telephone: (059) 66 7370
Fax: (059) 66 7339

Biological Farmers of Australia
PO Box 56
Marleston, SA 5033
Telephone: (08) 238 3477
Fax: (08) 238 3469

National Association for
Sustainable Agriculture,
Australia Pty Ltd
PO Box 768
Stirling, SA 5152
Telephone: (08) 370 8455
Fax: (08) 370 8381

Organic Herb Growers of Australia
PO Box 6171
South Lismore, NSW 2480
Telephone/Fax: (066) 29 1057

Organic Vignerons Association of Australia Inc.
PO Box 503
Nuriootpa, SA 5355
Telephone: (085) 62 2122
Fax: (085) 62 3034

Tasmanian Organic-Dynamic Producers Co-op. Ltd
GPO Box 351
Hobart, Tas. 7001
Telephone/Fax: (002) 97 1773

While not certifying organic farms, the following organisation is a useful source of information on organic agriculture and operates an organic advisory service and a certification scheme for organic retail outlets.

Organic Retailers and Growers Association of Australia Inc.
PO Box 12852
A'Beckett St Post Office
Melbourne, Vic. 3000
Telephone: (03) 9386 2999

Organic Advisory Service
Stringybark Farm
Tschampions Road
Macclesfield, Vic. 3782
Telephone: (059) 68 3040
after 8:30 p.m.

Organic agriculture contacts within state and federal government agriculture departments

Note: The officers listed below may not have specialised knowledge of organics, but are first-contact points within their department. Local field officers may also be able to help locate the information required.

Federal Government

OPAC – Organic Produce Advisory Committee

AQIS – Australian Quarantine and Inspection Service

Ms Ruth Lovisolo
Manager
Food Standards Policy
Australian Quarantine and Inspection Service
GPO Box 858
Canberra, ACT 2600
Telephone: (06) 272 5112
Fax: (06) 272 3103

New South Wales

Michael Burlace
Organic Farming Officer
NSW Agriculture
Locked Bag 21
Orange, NSW 2800
Telephone: (063) 91 3155
Fax: (063) 91 3206
Policy and general queries

Jenny Denison
Agricultural Enquiries Officer
NSW Agriculture
PO Box 530
Coffs Harbour, NSW 2450
Telephone: (066) 51 9040
Fax: (066) 51 2780
General queries

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