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Director's Digest

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MEAT AND BONE MEAL: THE UNDERUTILIZED RAW MATERIAL

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In recent months, the use of animal products in animal feed has received considerable media attention. It is paradoxical that at a time when it is fashionable to seek recycling opportunities as a way of saving the natural resources of the planet, one of the most effective and valuable examples of recycling is projected in an unfavorable manner. Historically, the rendering industry has always been important. Whenever animals are slaughtered for human consumption, and the meat prepared and presented for sale, there is always a portion of the animal which is not desired by the human consumer. If these materials had no intrinsic value, disposing of them safely, and in an environmentally

acceptable manner, would represent a major on-cost to the human food industry.

The relative percentage of consumable products and byproducts from meat processing is summarized in Table 1. It is instructive to note that for every ton of meat prepared for human consumption in the U.K., 294 kg of inedible material is produced. Of this inedible material, 98 kg goes into pet food and the remaining 196 kg into the rendering industry. Much of this material ends up in a range of products which are recycled as animal feed.

Unfortunately, the large urban population in Europe now has little understanding of the way that its food is produced. Consequently, its opinions can be influenced easily by the media. In recent months the U.K. livestock industry has been seriously affected by bad press in the form of concern over salmonella in eggs and bovine spongiform encephalopathy (BSE) in cattle. Public concern over both of these issues has been directed against the use of animal byproducts in animal feeds. Yet, as this paper will demonstrate, with proper care animal byproducts are as safe to use in animal feeds as other ingredients and have an important role to play in animal feeding.

It would be inaccurate to give the impression that meat and bone meal is not widely used in pig diets. In the U.K. it has been extensively used not only in pig diets, but also in diets for poultry and ruminant animals. Good-quality meat and bone meals and meat meals are very price competitive.

Despite the considerable use of meat byproducts there are nutritionists and animal producers who are reluctant to use these products or who place strict limits on the quantity that they will include in diets.

The nutritionists and animal producers are reluctant to use greater quantities of animal byproducts in diets because they are concerned about microbiological quality, palatability, variability and consistency.

The following sections attempt to examine these concerns objectively.

Microbiological Quality

The willingness of nutritionists to use animal byproducts in feeds varies greatly from one country to another. A major factor involved in their attitude is the extent to which legislative instruments and control mechanisms are effective in ensuring the quality (safety) of the product. In parts of the world where rendering plants are small and inadequately controlled, they may be responsible not only for recycling valuable nutrients but also pathogenic organisms. Inadequate heat treatment and/or ineffective separation of incoming and outgoing material can result in recontamination of finished product. Where slaughterhousing facilities are small and geographically isolated and rendering capacity is restricted, the recycling of abattoir byproducts may be more safely achieved by using formic acid homogenization and feeding the material in a liquid or semi-liquid form. When properly controlled this is an effective means of maintaining microbial quality. However, in a number of countries, including the U.K., this approach would not be permitted as it contravenes waste foods legislation which requires that meat-based products must be heat sterilized before they may be fed to pigs.

In developed economies, the animal feed industry is based primarily on dry diets and the main requirement is for dried raw materials. Therefore, historically, abattoir byproducts have been rendered and heat sterilized producing dried friable products for use in the animal feed industry. Increasingly these processes are undertaken by large, efficient operations with high standards of quality control. A high degree of committed management control is needed in any plant to ensure the effective separation of incoming, and potentially contaminated materials, from outgoing sterilized products. Where such control is exercised the risk of animals being contaminated through being fed animal byproducts is no greater and is probably less than the risk of them being contaminated by other feed materials. The data in Table 2 shows the result of U.K. testing for salmonella. It is important to note that samples of fish meal and full-fat soybean meal were much more frequently contaminated with salmonella than meat and bone meal. There is a general misconception that only products of animal origin may be contaminated with salmonella. However, this is not true. Birds and rodents (rats and mice) frequently carry salmonella. Therefore, unless all dietary ingredients and finished products can be completely protected from birds and rodents throughout production, processing and subsequent storage they have the opportunity to become contaminated.

Cleansing Qualities

This problem is exacerbated in large livestock units which rely upon bulk handling and storage and mechanized feeding. The problem is further increased when pigs are fed *ad libitum* from open hoppers from which birds and vermin can also feed. Unfortunately routine hygiene on farms is generally poor. Few producers have an effective program of cleansing, disinfection, fumigation and vermin control. Consequently, many problems arise on farms from causes as diverse as salmonellosis and leptospirosis originating from rats to mycotoxicosis and grain mite sensitivity.

The risk factor associated with a particular raw material will depend upon:

* The percent incidence of contamination of that raw material, and
* The percent of that raw material incorporated into a diet.

This concept is illustrated for the case of salmonella in Table 3. The raw materials in Table 3 and their percentage contribution to the diet would be typical of a home mixed diet for a finishing pig in the U.K. If the inclusion level for each ingredient in Table 3 is multiplied by the percentage incidence of salmonella contamination given in Table 2, it is possible to produce a risk factor value for each raw material. It can be seen that in this example the greatest risk of the diet being contaminated with salmonella comes from the soybean component and that the fish meal component (even when using the lower figures for contamination) presents a risk three times as great as the meat meal. The combination of a relatively low inclusion rate and a low contamination percentage makes the meat meal the least likely source of salmonella in the diet in this example.

One further point is worth noting. The data here refer to salmonella contamination without specifying the salmonella type. When screening for salmonella it is important to identify whether the type identified is particularly harmful. In the U.K., *Salmonella enteritidis,* which is the most important from a human health viewpoint, was only isolated in animal protein three times in tests made by the Ministry of Agriculture between 1982 and 1989.

Naturally it is the concern of all in the animal feed industry that the risk of microbial contamination should be minimal. This places an obligation on the animal feed manufacturer as well as the raw material supplier and the animal feeder. As pointed out previously, contamination by birds and rodents can occur at any time before, during or after feed manufacture. Many modern feed mills condition the feed ingredients using heat and steam as part of the manufacturing process. In addition, the pelleting process used frequently raises the temperature of the material to a level that will destroy bacteria.

Problems can occur much more easily when diets are produced on the farm. Here there is less awareness of the potential problems and the need to exclude birds and vermin. Furthermore, the more sophisticated manufacturing processes are not available. The material is generally cold processed. When cold processing is used, a considerable degree of protection can be given by using 0.9-1.0% formic acid in the diet (Wieringa and Viering, 1972, var der Wal, 1976).

Acidification of feeds for pigs is now a common practice, and has been shown to reduce digestive upsets and thereby improve productivity. There is little information on the effects of some of these acidification practices on the microbial quality of the diets. Further investigations of this particular approach could be of value to both the feed manufacturer and the pig producer in further reducing contamination risks.

The recent hysteria created by BSE is a different case. The media in the U.K. have deliberately chosen to inflame public opinion by dubbing the condition "mad cow" disease and creating irrational fears. While the significance of this condition in cattle must not be minimized, fears that a similar condition exists in pigs appears to be unfounded.

In recent years, pig producers have frequently found themselves the focus for media attention whether the issue be animal welfare or drug residues in meat. Therefore it is not surprising that they should be sensitive to consumer reaction on the subject of BSE. Nevertheless, an objective view of the evidence shows that the risk of pigs contracting some form of spongiform encephalopathy through the use of meat and bone meal is probably non-existent. It should be noted that: (1) animal byproduct meals have been used more extensively and at higher inclusion rates than in cattle without any ill effect, and (2) there is no record anywhere in the world of pigs having succumbed to a transmissible spongiform encephalopathy (Meldrum, K.C. pers. comm. 1989).

Furthermore, unsuccessful attempts have been made to infect pigs with the disease. Both in the U.S. and the U.K., pigs have been injected with, and fed heavily infected material in massive doses with no affect. While the industry must be sensitive to public concerns it would be wrong for it to be stampeded into denying iself a valuable protein source when there is no scientific evidence to support the necessity for such a move.

Palatability

The percentage inclusion of meat meal, meat and bone meal and blood meal is often restricted to quite low levels in animal diets (Table 4). However, there is little justification for these restrictions on palatability grounds. The materials are well accepted by pigs at much higher inclusion levels. For example, in studies at Seale-Hayne we have had excellent results from growing pigs fed diets containing up to 9% meat and bone meal. Generally speaking, palatability problems only occur when the byproduct material contains high levels of fat and has been inadequately treated with antioxidant. Under such circumstances oxidative rancidity occurs, the fat becomes rancid and this in turn makes the diet unpalatable.

Variability

As with any manufacturing process the end product is to some extent determined by the raw material available. Renderers obtain their supplies from a variety of sources ranging from abattoirs to retail butchers shops. Consequently, the composition of the raw material varies considerably and this in turn affects the dcomposition of the meat meal or meat and bone meal produced (Tables 5 and 6). For this reason, meat and bone meal as a product is seen as more variable than many other raw materials (Table 7). However, this is not really a fair interpretation of the situation. If a particular rendering plant obtains its raw materials from a regular list of suppliers, in similar proportions it is possible for it to produce a uniform product (Table 8).

Amino Acid Availability

Meat meals and meat and bone meals differ greatly in crude protein and amino acid content. The biological availability of the amino acids found in these meals also differs.

In a series of studies it was found that the availability of lysine varied from as little as 48% to as much as 88% in samples of Australian meat and meat and bone meal (Batterham et al. 1986). Intense drying under condition of high temperature and pressure can have a damaging effect on proteins. This has long been established in the case of fish meals but applies also to animal byproducts. Both the temperature and pressure used in dry-rendering processing can affect lysine availability (Table 9). The implications of the above are that:

* The renderer wishing to produce a consistent product must control both raw material composition and processing conditions, and

* The customer wishing to use meat and bone meal should use a single source and check analysis regularly to determine consistency.

The image of meat and bone meal as an inconsistent product is not a fair one. Some renderers have produced consistent products over long periods of time. Unfortunately others have been less concerned to produce a consistent product and have taken less trouble to control the processing and hence the nutritional value of their product. These operators have disappointed customers and done little to increase the enthusiasm of the customer for their product. Sadly they have also done other operators in the sector a disservice as the customer has not always been able to discriminate between good and bad products.

It is worth noting that in the U.K. certain companies outside the rendering industry have done a great deal to improve the situation by producing protein supplements with a trade name. These branded products often contain both meat and bone meals and fish meals, sometimes with the addition of synthetic amino acids. By using a variety of raw material sources and by rigorous quality control these companies have produced consistent, quality-controlled products and by doing so have been able to secure and more importantly retain customers.

Diets with High Inclusion of Meat Meal

A review of literature shows surprisingly few studies in which meat meal or meat and bone meal has been included in diets at levels more than 3-4%. Furthermore such studies as have been reported generally relate to meat meals of much poorer specification than those available in Europe and North America and have been conducted on pigs which do not possess the lean growth potential of modern European white hybrids. Therefore at Polytechnic South West we have initiated a program on behalf of the European Renderers Assn. to look at the effect of high meat meal inclusions in the diets of modern genotypes (Table 9).

The meat meal used in the initial study was a 55% protein, 12% oil material (see Table 10). Initial formulation was aimed at producing a high meat meal diet using commonly used feed ingredients (barley, wheat and soybean meal). The diet was constrained to provide a minimum of 13.1 MJ of digestible energy (DE) and 1.1% lysine with the other essential amino acids provided in the ratio proposed by Agricultural Research Council (ARC) (1981). The maximum level of meat meal which could be included within the constraints set was found to be 9%. The actual formulated values for energy (13.4 MJ/kg), oil (2.28%) and phosphorous (0.16%) were added as constraints and a second diet formulated eliminating meat meal and offering Chilean fish meal. In order to meet the nutrient constraints imposed on this formulation it was necessary to offer a commercial fat product on high fiber carrier.

The formulated and analyzed nutrient values for these diets is given in Table 11 and their raw material composition in Table 12. Two intermediate (3-6% meal) diets were prepared by taking, respectively, one-third and two-thirds of the initial diets. Four entire male and four female Large White x (Large White x Landrace) pigs were fed each diet from approximately 28 kg live weight. The pigs were fed to a scale which allowed 85% of the anticipated voluntary feed intake derived from the asymptotic curve proposed by ARC (1981).

For a 30 kg pig the feed allowance was 1.7 kg per day and increased to 3.1 kg. at 85 kg. The pigs were wet fed twice daily with a water to feed ratio of 2.5:1. Further water was available *ad libitum* from drinkers. In the high temperature conditions that prevailed during the trial (Summer 1989) the allowances proved to be excessive for the smaller pigs and some feed refusals were encountered on all treatments. There were no indications that the inclusion of up to 9% meatmeal in the diet reduced palatability. The performance of the pigs is summarized in Table 13.

Treatment had no significant effect on daily gain or the feed conversion rate (FCR). The inconsistent but statistically significant effect on killing out percentage suggests that the extent of gut fill at the final weighing may have had a distorting effect on the calculated daily gains and FCRs. Indeed when the values were recalculated on a dead weight basis the difference in mean growth rate between the treatments was found to be less than 10 g per day.

Conclusions

As indicated, meat and bone meal is not a single product, but a variety of different products. Therefore it is important to attribute the correct nutrient values to it.

When using meat and bone meal in diets it is sensible to include a minimum tryptophan constraint in the formulation as this amino acid can become limiting to growth performance (Batterham and Watson, 1985).

Studies conducted at Seale-Hayne have shown that when the correct nutrient values are attributed to meat meal it can substitute for fish meal in diets without loss of growth performance or palatability. We shouldn't be surprised at this. The pig is interested in the amount of nutrients it receives, not what raw materials they are derived from. Where poor performance has been achieved in the past from animal byproducts it has generally resulted either from inappropriate nutrient values being ascribed to the product or from the formulation being inadequately constrained.

With the application of appropriate quality controls there is no reason why meat meals and meat and bone meals should not continue to provide a valuable and cost-effective source of protein in pig diets. Furthermore, there is clearly opportunity to increase the inclusion rate of these materials in diets well beyond the levels currently set by many nutritionists.

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TABLE

1. Relative proportions (%) of products from meat processing (after Foxcroft, 1984)

Meat products	63.5
Edible offals	3.1
Edible fats	1.2
Hides/wool	4.1
Blood	3 7
Feathers	1.7
Inedible byproducts into pet foods	6.2
Inedible byproducts into rendering plants	16.5
Total	100.0

TABLE

2. Salmonella contamination of feed materials is not confined to materials of animal origin (Wilson, S., pers. comm. 1989)

Ingredient	Samples tested	Percent salmonella positive	Data source
Cereals	1,026	0.9	a
Sunflower meal	496	6.4	a
Full fat soybean	339	19.8	a
Soybean (ext.)	1,167	2.7	a
South American fish meal	151	13.2	a
South American fish meal	1,215	23.4	b
Meat and bone meal	120	3.0	c

a. Data compiled from six major U.K. feed companies during 1984-1987.
b. Ministry of Agriculture, Fisheries & Food 1982-1985.
c. Data from daily test conducted during 1988 by U.K.'s largest producer of meat and bone meal (representing approximately 50% of U.K. production).

3. Relative risk of salmonella contamination from commonly used materials

	Inclusion level	% incidence of salmonella contamination	Risk factor
Cereals	66.9	0.9	0.602
Soybean	24.9	2.7	0.672
Fish meal	2.2	13 .2	0.290
Meat meal	3.0	3.0	0.090
Fat	0.8	—	—
Minerals and vitamins	2.2	—	—

4. Typical maximum inclusion rates of abattoir byproducts in compounded animal feeds (%) (from Hall [1978], quoted by Cook and Pugh [1980])

Animal	Meat and bone meal	Blood meal	Hydrolyzed feather meal	Poultry offal meal	Fat
Young calves, young pigs, chicks	2.5	Nil	Nil	1.0	1.0
Adult animals:					
Cattle	5	2	2	2.5	2
Sheep	5	2	2	2.5	1
Pigs	7.5	2	1	2.5	2.5
Poultry	7.5	2	1	2.5	1

5. Variability of chemical composition of meat and bone meals (dry matter basis) (Batterham et al., 1980)

Crude protein (g/kg)	438-567
Ether extract (g/kg)	78-139
Ash (g/kg)	224-345
Gross energy (MJ/kg)	14.18-18.22
Digestible energy (MK/kg)	9.44-13.21
Crude protein digestibility (%)	73.1-91.0

6. Digestible crude protein, lysine, methionine, calcium and phosporous in abattoir byproducts (from Hall [1978], quoted by Cook and Pugh [1980])

	Meat and bone meal	Blood meal	Hydrolyzed feather meal	Poultry offal meal
Digestible crude protein (%)	70-85	80	65-80	60
Available lysine (%)	2-2.4	5.5	1.5	2
Methionine (%)	0.64-0.82	0.9	0.26	0.7
Calcium (%)	9-14.5	0.35	0.5	15
Phosphorus (%)	4-6.5	0.3	0.4	0.6

7. Variability in protein content of several raw materials (Raine, 1988)

Raw materials	Protein (%)	S.D.
Wheat	12.5	±1.0
Wheat feed	15.8	±0.7
Ex. rice bran	13.9	±0.7
Maize gluten	19.2	±1.4
Distillers grains	25.0	±1.8
Ex. rapeseed	34.8	±1.1
Ex. sunflower	29.5	±2.0
Brazilian	46.0	±1.7
Herring	71.0	±1.5
Chilean fish	68.0	±2.0
Meat and bone	50.6	±3.6

8. Summary of meat and bone analysis from five production plants over a 13-week period (400 samples per plant) (Wilson, 1989)

Plant	A	B	C	D	E
Protein, %	47.06	49.4	48.2	45.5	44.9
S.E.M.	0.19	0.24	0.22	0.13	0.30
Avg. sample S.D.	1.07	1.05	1.01	1.76	1.56
Oil, %	14.26	13.9	12.3	13.9	16.3
S.E.M.	0.15	0.23	0.21	0.26	0.23
Avg. sample S.D.	0.85	1.0	0.92	1.48	1.21
Ash %	27.18	32.3	29.4	28.3	26.9
S.E.M.	0.16	0.20	0.36	0.27	0.37
Avg. sample S.D.	0.94	1.04	1.6	1.3t	1.56

All analysis on an as-received basis.

9. Effect of processing on lysine availability in meat and bone meal (after Batterham et al. 1986)

	Lysine availability %
1. Control wet-rendered	97
2. Atmospheric pressure max. temp. 125°C	84
3. Atmospheric pressure max. temp. 150°C	38
4. High pressure at early stage of process max. temp. 141°C	74
5. High pressure at late stage of process max. temp. 141°C	46

10. Analysis of materials used in experimental diets

	Meat meal	Chilean fish	Commercial fat product
Dry matter	94	90	95
Crude protein	55	65.9	2.63
Oil	12	10	49
Crude fiber	2	0.5	16.96
Ash	22	15	11.63
Lysine	2.8	5.0	—
Methionine	0.53	2.01	—
M+C	1.20	2.48	—
Tryptophan	0.45	0.61	—
Threonine	1.97	2.94	—
Calcium	7.3	3.6	0.08
Phosphorus	3.5	2.3	0.10
Magnesium	0.2	0.2	—
Sodium	0.85	0.9	—
Salt	1.30	2.3	—
Potassium	0.53	0.8	—

11. Formulated and analyzed nutrient levels in 0% and 9% meat meal diets

	0% meat meal		9% meat meal	
	Formulated	Analyzed	Formulated	Analyzed
Crude Protein, %	18.0	20.1	21.4	21.1
Crude fiber, %	5.3	5.2	5.5	4.5
Oil, %	2.3	3.3	2.3	3.3
Ash, %	—	6.2	—	5.8
Ca, %	0.85	0.80	0.85	1.00
P, %	0.61	0.62	0.61	0.72
DE, MJ/kg	13.4	13.4	13.4	13.9

TABLES

12. Composition of experimental diets by weight (kg)

Meat meal %	0	3	6	9
Meat meal	0.0	30.0	60.0	90.0
Fish meal	33.2	22.1	11.0	0.0
Soybean	254.3	249.0	243.0	238.0
Wheat	542.5	464.7	386.8	309.0
Barley	130.0	205.0	280.0	354.7
Commercial fat	12.3	8.3	4.1	0.0
Limestone	6.7	5.1	3.5	1.8
Salt	3.1	2.9	2.7	2.5
Dical	13.9	9.3	4.9	0.0
Minerals/vitamin supplement[a]	4.0	4.0	4.0	4.0

[a]Supplement provides/kg:

	Vitamin A	8,000 IU
	Vitamin D3	1,300 IU
	Vitamin E	28 IU
	$CuSO_4$	116 ppm
	Se	0.1 ppm
	Ca	0.64 g
	P	0.09 g
	Na	0.39 g
	Tylosin sulphate	20 mg

13. Effect of meat in diet on performance of growing/finishing pigs (Brooks, James, Russell and Morgan, 1990 unpublished)

	Percent meat meal in diet				
	0	3	6	9	SE_D
Initial wt. (kg)	28.5	28.2	28.3	28.3	1.07
Final wt. (kg)	87.5	87.1	87.8	87.7	0.92
Daily gain (g)	858	844	869	836	31
FCR	2.52	2.53	2.51	2.54	0.1
Dead wt. (kg)	63.2	64.0	63.1	64.6	0.84
KO %	71.2	73.4	71.9	73.6	0.55
Backfat P2 (mm)	11.9	12.0	13.0	11.1	0.83