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"The ban of by-products from terrestrial animals in livestock feeding: consequences for feeding, plant production, and alternative disposal ways"

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The ban of by-products from terrestrial animals in livestock feeding: consequences for feeding, plant production, and alternative disposal ways

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Preliminary report of the working group of the Society of Nutrition Physiology (GfE) on feedstuff resources

Content

1. Introduction

Products which originate from terrestrial animals are not approved as feedstuffs for ruminants in Germany since March 1994. In consequence of the first BSE-event in Germany (Nov. 24th, 2000) these products as well as fish meal were generally banned as animal feedstuffs (Dec. 2nd, 2000). Since the ban of fish meal was stopped in April 2001 (BMVEL 2001) and feeding to non-ruminants was allowed again it will not be considered in the following chapters.

These changes were the basis for the Society of Nutrition Physiology (GfE) to establish the working group on feed resources at the annual meeting in 2001. It is the major aim of this group to investigate and to evaluate the consequences of the feed ban with special emphasis on availability and economic aspects of alternative feed components. The present paper has to be regarded as the first preliminary report of this group.

Among the products derived from terrestrial animals, animal meal (**AM**) and bone meal (**BM**, both together in the following abbreviated as meat and bone meal **MBM)**, together with animal fat were the most important in terms of quantities. They contributed to the supply of pigs and poultry with amino acids, minerals and energy to a different extent. In this paper it is quantified to what extent MBM could potentially be used in pig and poultry feeding. The paper also deals with the alternatives and the consequences of the ban. In particular it focuses (i.) on the amounts of alternatives that are needed, (ii.) how the nutrient and energy cycles are affected and (iii.) the consequences of alternative use for burning on gaseous emissions.

2. Production and chemical composition

In recent years, roughly 420,000 t of AM and 210 000 t of BM were annually produced in Germany (Table 1). The production of animal fat was approximately 300,000 t/year. Other by-products such as blood meal, feather meal or poultry meal exist as well, but are quantitatively less important. In the EU-15, about 3 Mio. t MBM and 1.5 Mio. t animal fat were produced (EURA 1999). In Switzerland, approximately 55,000 t MBM and 22,000 t animal fat are annually produced (TMF 2001).

Table 1: Annual production in Germany (thousand t) (VERBAND FLEISCHMEHLINDUSTRIE 2001)

	1998	1999	2000
Animal meal	398	447	397
Bone meal	211	215	206
Blood meal	22	21	23
Feather meal	9	9	8
Poultry meal	9	9	14
Animal fat	279	310	330

The chemical composition of MBMs is rather variable (Table 2) and largely depends on raw materials. Feed value tables distinguish MBMs being rich in protein or rich in fat. Ash content of MBMs and, consequently, mineral content may also vary considerably depending on raw material. For most of the subsequent calculations, average values had to be used. Average composition data that are based on a large number of samples are given in Table 3.

3. Amount of MBM used in recent years

In recent years, the production of AM and BM in the EU, particularly in Germany, exceeded the amount that was used for feed compounding. The eastern European countries were the main export countries for AM from Germany, while the BM was almost completely used for internal purposes (EFPRA 2001). Thus, a total of ~300,000 t and ~2.3 Mio t of MBM were used in Germany and in the EU-15 in 1999, respectively.

In 1999, 11.3 and 79.7 Mio t of compound feed for pigs and poultry were industrially produced in Germany and the EU-15, respectively (DVT 2001). Assuming that the use of AM+BM was restricted to this industrially produced part of the feed (see chapter 4.3), the dietary proportion of AM+BM in these feedstuffs averaged 2.7% (Germany) and 2.9% (EU). In case that the total amount of feed was considered (including the on-farm mixing) this proportion would be considerably lower.

Table 2: Composition of meat and bone meal taken from the literature (g/kg; ~90% DM)

Reference	Crude protein	Ether extract	Organic rest	Crude ash
DLG (1991)	480	126	46	248
	519	113	56	212
	515	77	58	250
	562	113	50	175
	562	76	59	203
	614	128	26	132
	613	64	44	179
KLEINHANNS et al. (2000)	560	120	-	220
NEHRING et al. (1970)	518	113	49	220
	560	61	62	217
	630	46	67	157
NOTTRODT et al. (2001):				
-MBM, type 55	550	120	-	210
-MBM	405	100	-	395

Table 3: Overall averages (g/kg, if not otherwise stated) (VERBAND FLEISCHMEHLINDUSTRIE 2001)

	Animal meal	Bone meal
Crude ash	210	395
Crude protein	550	450
Ether extract	120	100
Gross energy[1)] (MJ/kg)	18.5	12.6
Phosphorus	31	61
Calcium	60	120
Lysine	31.0	22.4
Methionine	7.4	5.2
Threonine	20.0	12.8
Tryptophan	5.0	2.0

[1)] WENK (1995)

4. The potential for the use of MBM in feeding pigs and poultry

It is estimated in this chapter which amount of MBM could be maximally used in the feeding of pigs and poultry. This estimate is based on

- statistical data for pig and poultry production (ZMP 2001a, 2001b; Schweineproduktion 2000)
- the total amount of feed specific for each production system, which will be calculated herein
- recommendations regarding the inclusion level of MBM from the literature (MILLER and DE BOER 1988) and from feed compounding experiences.

Based on this estimate and irrespective of the amount that had been used in recent years, the amount of protein that potentially needs replacement by other sources will be calculated.

4.1. Presumptions for the production systems

4.1.1. Poultry

With regard to poultry meat production, broiler (>60%) and turkeys (>30%) are the major contributors. Species such as ducks and geese are important in certain regions. Their overall proportion in the market, however, is low, and they will not be considered in the subsequent calculations.

Broiler

The breeders are raised until the week 21. During the subsequent 41-week laying period, an average of 159 eggs (55% laying performance) and 132 chicks (83% hatching rate) are produced. Four and two types of feed, different in crude protein content, are used during the raising and the laying period, respectively. The flock comprises 8% males. Mortality is 5%.

Two types of broiler meat production are considered with a fattening period of either 35 or 56 days and 2 and 3 types of feed, respectively. Meat originates to 75 and 25% from broilers with 35 and 56 days of age, respectively. Mortality is 5%.

Turkeys

The breeders are raised until they are 29 weeks old. The laying period is from week 30 to 54, and 65 to 70 hatchlings can be obtained from each breeding hen (JAHRBUCH GEFLÜGELWIRTSCHAFT 2001). The types and the composition of feeds is according to what is used in the 5 phases for the fattening females.

The meat production with turkeys is sex-separated. Females are fed in 5 phases for a total of 17 weeks until they reach approximately 10 kg BW. Males are fed in 6 phases for a total of 22 weeks and approach a final BW of approximately 20 kg (TÜLLER 1998). Dressing percentage is 84% for males and 80% for females (PINGEL et al. 1998). Mortality is assumed 5% for both breeder and production flocks.

Laying hens

Breeder hens are used with 1.8 kg BW. They were raised for 20 weeks, and the laying period is from week 21 to 66. The proportion of males in the flock is 9%, and the laying performance is 70%. Assuming a fertility rate of 90%, a hatching rate of 82% and a proportion of 50% females in the hatch, 83 female chicks can be assumed per breeder hen.

For egg production, hens are raised as the breeder hens are. During the raising period and the laying period, 4 and 2, respectively, types of feed with different crude protein content are used. The laying performance is 80%, equivalent to 305 eggs or 19.5 kg egg mass per hen. A mortality of 5% is considered.

4.1.2. Pigs

The first farrowing of sows is with 11 months of age, and each sow has, on average, 3.5 litters and 2.2 litters per year. According to survey data (SCHWEINPRODUKTION 2000), 18.8 piglets were weaned per sow on average under practical conditions of the years between 1996 and 2000. The suckling period is 4 weeks.

During fattening, 2.8 kg feed are needed per kg BW gain. An average weight after slaughter of 90 and 140 kg is assumed for fattening pigs and sows, respectively.

4.2. Size of production and total feed needed

4.2.1. Poultry

Broiler

The gross production of meat from broilers in Germany accounted for 523,600 t in 2000 (ZMP 2001a). Taking values for the dressing percentage and the final BW of 74% and 1584 g (35 days) or 73% and 2803 g (56 days) (PINGEL et al. 1998) accounts for 335 Mio and 64 Mio animals that are fed annually in the two different production systems.

For each finished broiler, 368 g feed are needed for the breeder part and 3024 g (35 days) or 6649 g (56 days) for the broiler itself. The total amount of feed that can be derived from theses presumptions is summarised in Table 4.

Turkeys
The gross production of turkey meat in Germany and in the EU (for year 2000, ZMP 2001a) is given in Table 4. It is presumed that 60% of the meat comes from males (2.1 birds/place and year) and 40% from females (2.7 birds/place and year). For each turkey chick, 2 kg of feed were considered as the respective proportion for the breeders. From the total feed that is needed for turkeys, approximately 5%, 39% and 56% are used for breeders, fattened females and fattened males, respectively (Table 4).

Laying hens
Data on egg production (ZMP 2001a) and the related amount of feed are shown in Table 4. For each layer, 560 g feed are considered as the proportion for the breeders. The amount of feed needed per pullet and per laying hen is 7.8 and 45.4 kg, respectively. Approximately 1% of the total feed for egg production is needed for the breeders. For pullet and laying period, the proportion is 15% and 84%.

Table 4: Gross production of poultry meat and eggs and the corresponding amounts of feed that are needed (thousand t per year)

	Germany	EU-15
Broiler		
Meat production	524	6215
Feed for:		
- Breeders	147	1743
- Fattening until d 35	1013	12025
- Fattening until d 56	425	5047
Total feed broilers	1585	18815
Turkeys		
Meat production	294	1745
Feed for:		
- Breeders	53	314
- Females	417	2474
- Males	602	3572
Total feed turkeys	1071	6359
Laying hens		
Egg mass	900	5502
Feed for:		
- Breeders	30	185
- Pullets	378	2311
- Laying	2200	13450
Total feed laying hens	2608	15946

4.2.2. Pigs

In 2000, roughly 42.3 Mio pigs were slaughtered in Germany. The import and export accounted for approximately 1% and 4% of the inland gross production and will, therefore, be neglected. Approximately 42.3 Mio piglets were weaned from 2.25 Mio productive sows. From these, 1.1 Mio were needed for reproduction and 41.2 Mio. were fattened.

The German inland production of pork was 3.86 Mio t in 2000 (ZMP 2001b), to which fattening pigs and sows contributed to 96% and 4%, respectively. Data on the corresponding amount of feed this needed are given in Table 5 for Germany and the EU-15.

Table 5: Gross production of pork and the corresponding amounts of feed that are needed (thousand t per year)

	Germany	EU-15
Meat production	3,864	18,623
Feed for:		
- Piglets	1,961	9,449
- Sows until first conception	336	1,619
- Pregnant sows	1,530	7,371
- Lactating sows	1,020	4,914
- Fattening pigs	10,179	49,052
Total feed pigs	15,026	72,405

4.3. Potential for the inclusion of MBM

The following levels of MBM were regarded acceptable for the different species and production systems based on the literature (MILLER and DE BOER 1988) and on feed compounding experiences (% of compound diet):

- Broiler: 1.5 to 3 for both AM and BM
- Turkeys: 3 to 4 for BM in all phases, 2 to 3 for AM from week 10 onwards
- Laying hens: 1 for pullets, and up to 3 in the laying period for both AM and BM
- Pigs: 2.5 for both AM and BM, irrespective of BW and production system.

Based on these upper levels and on the total amount of feed as given in Table 4 and Table 5, the potential for the use of either AM and BM is shown in Table 6. It can be assumed that MBM was fed to animals only via industrially produced compound feed. The German production of industrially produced pig feed was 7 Mio t in 1999 (DVT 2001), which accounts for 47% of the feed that was used for pigs in total. Therefore, the potential amount of MBM that can be used for pigs is related to the industrially produced amount of feed only.

These model calculations are based on uniform production systems and do not fully reflect the heterogeneity of the poultry and pig industry under practical conditions. Thus, the values estimated for the total amount of feed that is needed and for the potential use of MBM are approximations.

However, it can be concluded that the potential for the use of approximately 0.65 Mio t and 4.04 Mio t of AM+BM is given in Germany and the EU-15, respectively. The proportion of this which would be used in pig feeding is about 55%, the one in poultry feeding is 45%.

This potential for the inclusion of MBM is higher than the amount which was used in Germany in 1999 (by approximately the factor 2.2, see chapter 3). Similarly, the production within the EU-15 (3 Mio t/y) is lower than the potential for the inclusion in pig and poultry diets is. Thus, all the MBM produced in the EU could be completely recycled in the feed industry.

5. Alternative supply of protein and amino acids

5.1. Poultry

Protein from MBM has to be replaced by plant protein sources under consideration of the differences in the content of both crude protein and essential amino acids. Table 7 shows important analytical data from both MBM and common plant proteins for poultry.

On a mass basis, only soybean meal has the potential to replace protein from MBM. A mix of BM and AM (1/3 to 2/3) is equivalent to soybean meal in crude protein. The replacement value for a 1:1 mix of AM and BM ranges between 1:1.05 (soybean meal) and 1:2.08 (peas).

A replacement based on crude protein equivalents would reduce the content of crude ash and improve ME content in the complete diet in most cases. With soybean meal as the alternative, the supply of the first-limiting amino acids lysine, methionine+cystine, threonine and tryptophan to the growing animal would be improved. Similarly, protein from rapeseed meal would supply comparable amounts of lysine and higher amounts of other amino acids. In this case, however, a compensation for the lower ME content is necessary. With protein-equivalent inclusion of legume seeds, the well-known deficit in S-containing amino acids needs to be accounted for.

Table 6: Maximum amount of bone meal (BM) and animal meal (AM) that could be used in the feeding of poultry and pigs (thousand t per year)

	Germany		EU-15	
	BM	AM	BM	AM
Broiler				
- Breeders	4.4	4.4	52.1	52.1
- Fattening until d 35	28.5	28.5	338.0	338.0
- Fattening until d 56	12.4	12.4	147.3	147.3
Subtotal broilers	*45.3*	*45.3*	*537.4*	*537.4*
Turkeys				
- Breeders	1.8	1.3	10.5	7.7
- Females	14.7	5.8	87.1	34.6
- Males	21.1	12.1	125.3	71.9
Subtotal turkeys	*37.6*	*19.2*	*222.9*	*114.2*
Laying hens				
- Breeders	0.7	0.7	4.0	4.0
- Pullets	9.2	9.2	56.0	56.0
- Laying	66.0	66.0	403.5	403.5
Subtotal laying hens	*75.8*	*75.8*	*463.5*	*463.5*
Pigs				
- Piglets	49.0	49.0	236.2	236.2
- Sows until first conception	8.4	8.4	40.5	40.5
- Pregnant sows	38.2	38.2	184.3	184.3
- Lactating sows	25.5	25.5	122.9	122.9
- Fattening pigs	254.5	254.5	1226.3	1226.3
Subtotal pigs	*375.6*	*375.6*	*1810.2*	*1810.2*
Total1)	**335**	**317**	**2075**	**1966**

1) from the “subtotal pigs”, only 47% were considered because this is the proportion of pig feed in Germany that is industrially produced (assumed for EU-15 as well)

Table 7: Nutrients (g/kg) and ME (MJ/kg) in selected raw materials for poultry diets

	DM	Crude ash	Crude protein	Lys	Met	Met +Cys	Thr	Trp	AME
Animal meal (AM)	950	264	543	29.5	7.9	14.7	19.9	4.2	11.23
Bone meal (BM)	940	433	404	20.4	5.5	9.6	13.0	2.1	8.56
AM/BM 1/1	945	348	474	25.0	6.7	12.2	16.5	3.2	9.90
AM/BM 0.34/0.66	943	376	451	23.5	6.3	11.3	15.3	2.8	9.47
Beans	880	34	263	16.5	2.1	5.3	9.5	2.3	12.66
Peas	880	33	228	16.3	2.3	5.6	8.6	2.1	13.63
Lupines, yellow	880	45	386	17.7	3.0	8.8	13.7	2.9	12.88
Rapeseed meal	890	70	361	19.2	7.3	17.1	16.1	4.9	9.90
Soybean meal	880	59	451	28.2	6.5	13.3	18.0	5.9	13.04

(DLG, 1991; Degussa 1996)

5.2. Pigs

In addition to the analytical data given in Table 7, the content of ileal digestible amino acids and ME for pigs is given for some raw materials in Table 8. With the inclusion of soybean meal instead of MBM, the crude protein content of the diet could be reduced and the ME content improved without negatively affecting the supply of ileal digestible amino acids. A protein-equivalent replacement with rapeseed meal alone would cause a reduced content of ileal digestible lysine. The replacement with legume seeds again needs the consideration of S-containing amino acids, particularly methionine.

Table 8: Content of ileal digestible amino acids (g/kg) and ME (MJ/kg) in selected raw materials for pig diets

	Lys	Met	Met+Cys	Thr	Trp	ME_{BFS}
Animal meal (AM)	24.7	6.8	11.6	16.3	3.4	10.81
Bone meal (BM)	17.1	4.7	7.6	10.6	1.7	8.55
AM/BM 1/1	21.6	5.8	9.6	13.4	2.5	9.68
AM/BM 0.34/0.66	20.9	5.4	9.0	12.5	2.2	9.3
Beans	14.6	1.7	4.2	7.8	1.9	12.66
Peas	13.5	1.8	4.2	6.5	1.5	13.63
Lupines, yellow	15.2	2.5	7.3	11.1		12.88
Rapeseed meal	14.5	6.4	14.3	12.0	3.9	9.89
Soybean meal	25.8	6.0	12.1	15.8	5.4	13.04

(AFZ, 2000)

5.3. Need for alternative feedstuffs with regard to protein

Based on crude protein concentrations as given in Table 7, the amount of alternative feedstuffs that is needed for replacement can be calculated. The mix of AM and BM (0.34:0.66) is considered. If all the MBM should be replaced that has been fed (0.3 Mio t in Germany and 2.3 Mio t in EU-15), an additional amount would be needed per year of about 0.30 Mio t of soybean meal or 0.60 Mio t peas or 0.51 Mio t beans or 0.36 Mio t lupines (additional free amino acids not considered). Possible consequences for crop production are outlined in chapter 8. The respective amounts for the EU-15 would be 2.30 Mio t soybean meal or 4.60 Mio t peas or 3.91 Mio t beans or 2.76 Mio t lupines. Under the more realistic assumption that MBM is replaced by a mix of soybean meal, peas and beans (in this example 0.54:0.30:0.10), an additional amount of 0.21 Mio t soybean meal and 0.12 Mio t peas and 0.04 Mio t beans is needed for Germany. For the EU-15, this would sum up to 1.61 Mio t soybean meal and 0.90 Mio to peas and 0.30 Mio t beans per year.

In case that the potential use of MBM is taken as a baseline (chapter 4.3) rather than the amount that has been used inland, the amounts of the respective alternative feedstuffs would be by the factor 2.2 higher for Germany and by the factor 1.8 higher for the EU-15.

However, all these calculations are based on protein and amino acid concentrations in the diet that are usual under the current conditions in practise. They assume a real must for replacement. If MBM would be included up to the above mentioned amount, it would contribute to about 10 to 15% of the protein requirement of the animals. The consequent application of feeding strategies which are aiming at an increased efficiency of utilisation and reduced N excretion (e.g. phase feeding, inclusion of free amino acids) would allow for a reduction in the overall use of protein that would be higher than the amount which MBM contributed.

From this point of view, therefore, the ban of MBM from feeding is not a real problem with regard to quantitative protein supply. Nevertheless, more effort should be put into promoting the utilisation of home-grown proteins in order to improve sustainability of food production with animals. Apart from this point of view, however, destroying approximately 1.4 Mio t of most valuable protein each year in the EU-15 is a big waste of resources.

6. Alternative supply of phosphorus

6.1. Phosphorus provided by MBM

Depending on the raw materials (mainly the proportion of bones) and on the details of the production process the content of crude ash and P in AM and BM varied considerably (see Table 2). This variation cannot be considered in the subsequent calculations. This chapter will deal with average concentrations and they are **31** and **61** g P/kg for AM and BM, respectively (Table 3). Considering the amounts or AM and BM that were annually used in feed compounding (0.3 and 2.3 Mio t for Germany and EU-15 (see chapter 3), this sums up to **15,500** (D) and **119,000** (EU) t of P from AM+BM that were annually provided as a P source for pigs and poultry (Table 9).

Table 9: Use of phosphorus (P) from animal meal (AM) and bone meal (BM) in the feeding of pigs and poultry

	Germany	EU15
Average P content, g/kg		
in AM	31	31
in BM	61	61
Use of AM, thousand t/year	94	721[1)]
Use of BM, thousand t/year	206	1,579
P use, thousand t/year		
from AM	2.9	22.4
from BM	12.6	96.6
total	**15.5**	**119.0**

[1)] Based on the assumption, that the distribution of CM+BM is the same in the EU as it is known for Germany

6.2. Phosphorus provided by alternative protein sources

Similar as for the amino acids, alternative P sources have to be considered now to ensure that the animal's P requirement is met. Sufficient P supply to growing pigs and poultry, particularly in the first half of the fattening period, is hardly possible with feedstuffs of plant origin alone. This is exemplarily shown for pigs in Figure 1. For reasons of simplicity, it is assumed herein that similar values for digestibility can be assumed for pigs and poultry.

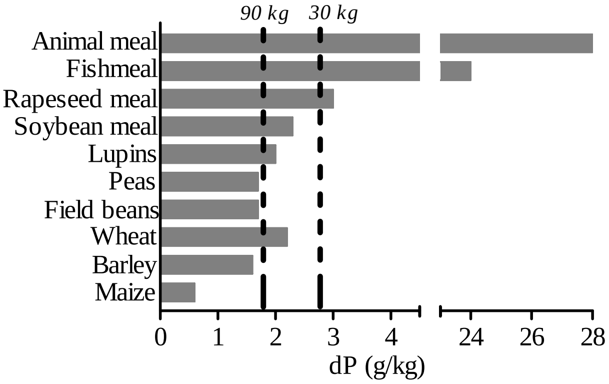

Figure 1: Comparison of the concentration of digestible P (dP) in different ingredients with the dP requirement of growing pigs (RODEHUTSCORD 2001)

Feedstuffs of plant origin that are rich in protein have a much lower concentration of P than AM or BM. Furthermore, the digestibility of P is lower (RODEHUTSCORD et al. 1997). In pigs the digestibility of P from AM and BM is 80%, from solvent extracted meals of soybeans and rapeseed it is roughly 30% and for legume grains it is no higher that 50% (DLG 1999). Therefore, the potential alternative protein sources show a concentration of digestible phosphorus (dP) of only 5 to 10%, relative to AM (Figure 2). In relation to BM this would be even lower (2 to 5%).

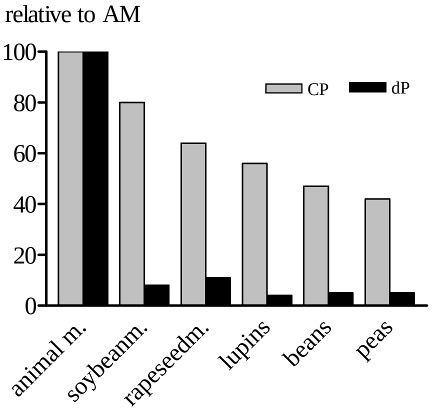

Figure 2: Comparison of the concentrations of crude protein (CP) and digestible phosphorus (dP) in animal meal and some alternative vegetable raw materials

6.3. The need for additional inorganic P

The first criterion when it comes to replacing MBM by plant ingredients in feed compounding is the adequate amino acid supply to the animal (see chapter 5). Different plant feedstuffs and free amino acids can be considered. Calculations show that, depending on the ingredient, a replacement on mass-basis roughly in the range of 1:1 to 2.1:1 is needed (chapter 5.1 and Figure 2). When P is considered as the next nutrient that needs to be optimised and replaced, consequently a large deficit occurs. If the supply of dP to the animal should stay on the same level as it was with AM+BM, a corresponding supplementation of inorganic phosphates is needed. Table 10 shows the dP content of some vegetable feedstuffs without and with supplementation of microbial phytase.

Table 10: Average concentrations of total P and digestible P (dP) (g/kg)

	Total-P	dP	
		without suppl. phytase	with suppl. phytase
Animal meal	35.0	28	28
Bone meal	65.0	52	52
Soybean meal, solvent extr.	6.5	2.3	4.2
Rapessed meal, solvent extr.	10.5	3.2	6.8
Peas	4.2	1.9	2.7
Field beans	4.2	1.5	2.7
Lupines	4.5	2.2	2.9

Based on these values it is calculated in Table 11, which deficit still needs to be covered by the supplementation of inorganic P sources when MBM is replaced. Different steps were considered in this calculation. The first step assumes that only one vegetable feedstuff is used to replace AM and BM, based on equivalent crude protein supply. It can be assumed that under current conditions most of the protein replacement is done by soybean meal, but a mix of soybean meal, peas and beans is assumed in the second step. The calculation however shows that this is less relevant with regard to the amount of inorganic P that remains to be supplemented. The differences that occur depending on the protein source can be considered as negligibly low in face of the accuracy of the procedure that was chosen here. This is why in the last row only average values are given. For Germany and the EU-15, an additional demand for P from mineral sources of **14,000** and **110,000** tonnes, respectively, is given in the case that no microbial phytase is considered.

Table 11: Calculations on the demand for inorganic P under considerations of different alternatives for AM and BM (thousand t)

		without phytase		with phytase	
		Germany	EU-15	Germany	EU-15
Digestible P (dP) from AM+BM[1]		12.4	95.2	12.4	95.2
dP from alternative ingredients Replacement ratio (MBM=1)[2]					
1.0	Soybean meal, solvent extr.	0.7	5.3	1.3	9.7
2.0	Peas	1.1	8.7	1.6	12.4
1.7	Field beans	0.8	5.9	1.4	10.6
1.2	Lupines	0.8	6.1	1.0	8.0
1.3	Soy:Peas:Beans (0.54:0.30:0.10)	0.8	6.1	1.4	10.5
Additional demand for dP		11.3-11.7	86.5-89.9	10.8-11.4	82.8-87.2
Additional dP from cereals due to phytase		–	–	11	64
Additional demand for inorganic P[4]		14	110	–	26

[1] Total P see Table 9, digestibility of P ~80% (RODEHUTSCORD et al. 1997)

[2] Ratio based on crude protein equivalent (see Table 7, mix of AM:BM=0.34:0.66)

[3] Assuming 70% of total feed (according to Table 4 and Table 5) is from cereals, and dP in cereals is 1.4 g/kg without phytase and 2.2 g/kg with phytase

[4] Based on digestibility of 80% for inorganic P sources (RODEHUTSCORD et al. 1994)

Supplementary microbial phytase, however, was repeatedly shown to increase the digestibility of P from vegetable ingredients (e.g. reviewed by DÜNGELHOEF and RODEHUTSCORD 1995). In this calculation it needs to be considered, that if phytase is supplemented, it does not only increase the digestibility of P from MBM alternatives, but also from the other plant ingredients that are contained in the diet. Under this scenario it becomes obvious that no additional inorganic phosphates were needed in Germany in the case that all diets for pigs and poultry were supplemented with microbial phytase.

6.4. The potential of MBM to save inorganic feed phosphates

No statistics on the use of mineral phosphates are available at present, which makes it difficult to calculate how these values range in face of the amount that has already been used before the ban of MBM.

With some assumptions, however, it can be estimated how much inorganic feed phosphates are required for supplying pigs and poultry according to the respective requirement. Results of this calculation are shown in Table 12. It is assumed that the animals are fed plant-based diets with varying proportions of protein-rich ingredients depending on amino acid requirement. No phytase is considered. Based on the production and feed data for Germany (Table 4 and Table 5), an annual need of approximately 27,000 t of P from feed phosphates is given.

Based on the data from Table 9, 57% of this could be replaced (15,500 t/y) by MBM if the amount of MBM used in recent years is assumed. If MBM would be used according to the potential derived in chapter 4.3, the need for supplemental P in the feeding of pigs and poultry could be completely covered by MBM.

Table 12: Calculation of the minimum amount of inorganic P which is annually needed for supplementation of plant-based diets for poultry and pigs in Germany

System	Total feed[1)] 1000 t/y	Recommen-dation for NPP or dP[2)] g/kg	NPP or dP from ingredients[3)] g/kg	NPP or dP to be supple-mented g/kg	Required supplem. of P[4)] t/year
Broilers					
- Breeders	147	3.2	1.4	1.8	266
- Fattening until d 35	1013	6.0	1.6	4.4	4483
- Fattening until d 56	425	5.0	1.5	3.5	1497
Turkeys					
- Breeders	53	3.2	1.4	1.8	96
- Females	417	4.0	1.6	2.4	1010
- Males	602	3.7	1.6	2.1	1279
Laying hens					
- Breeders	26	3.2	1.4	1.8	47
- Pullets	378	5.0	1.4	3.6	1366
- Laying	2200	3.2	1.4	1.8	3993
Pigs					
- Piglets	1961	3.5	1.7	1.8	4411
- Sows until 1st conc.	336	2.7	1.7	1.0	420
- Pregnant sows	1530	2.0	1.7	0.3	574
- Lactating sows	1020	3.3	1.7	1.6	2039
- Fattening pigs					
30-60 kg BW	2443	2.7	1.7	1.0	3054
60-90 kg BW	3155	2.2	1.7	0.5	1972
90-120 kg BW	4581	1.7	1.7	0	0
Total					**26,507**

1) from Table 4 and Table 5

2) Non-phytate P (NPP) for poultry (GfE 1999, NRC 1994, and own assumptions) and digestible P (dP) for pigs (DLG 1999)

3) Based on assumed diets with common ingredients, values for NPP in ingredients taken from ECKHOUT & DE PAPE (1994)

4) considering a digestibility of inorganic P for pigs of 80%

In face of the limited world-wide phosphate stores (MENGEL 1997) it offers the chance for a considerable save in restricted resources when the phosphates that were accumulated by the animals during growth can remain within the nutrient cycle. On the other hand it is of crucial importance for the overall P balance, whether or not the minerals that are contained in the residues can be applied as fertilisers in the case that MBM is burned.

7. Considerations on energy cycles

Energy cycles within the context of the ban of meat meal and other slaughter by-products in animal nutrition have to be considered in two different ways. First we can describe the energy flux from feed to the products with all losses in the form of excreta, gases, heat and offal.

7.1. Energetic cycles in farm animals

Figure 3 shows, for pigs, the medium energy turnover from the feed with a normal composition and nutrient digestibility to the products meat and adipose tissues. External energy input during fattening and slaughter are not included. Since the utilisation of energy depends on many different factors like the digestibility of nutrients or level and composition of performance the values in Figure 3 have to be considered as rough estimates. Furthermore, the cycles of reproduction and lactating animals or laying hens, which aren't included here, are also essential.

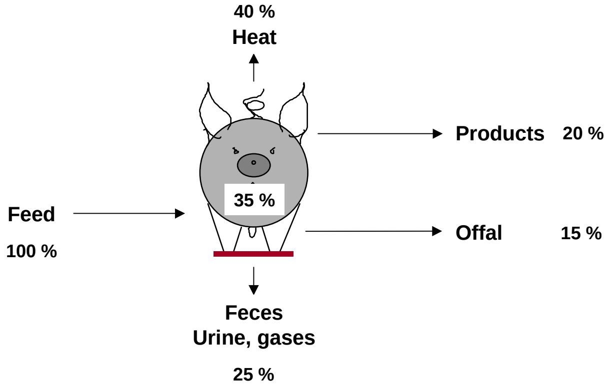

Figure 3: Energy flow in a growing pig (% of feed energy)

From energy input as feed a significant amount is excreted in the form of feces, urine and gases (mainly as methane). In growing pigs about 1/3 and in cattle 1/4 of the ingested energy is retained mainly in the form of protein and fat. That energy can only partly be utilized for human consumption. The edible part for human and pet consumption amounts only to about 20% for pigs and 12% for cattle of total energy intake. Offal represents an important energy loss in the range of 10 to 15%. In the rendering industry offal was transformed into by-products that could be re-utilized as valuable feed sources in the food chain. Animal meal has an energy content of 11.2 and 10.8 MJ ME/kg for poultry and pigs, respectively (Table 7 and Table 8). Extraction fat was used as energy source.

7.2. Energetic aspects of the removal of slaughter by-products after their ban as feed sources

In Figure 4 the main options for the removal of offal from slaughter animals and cadavers are presented. Law prescribes in Switzerland the sterilization for the production of meat meal and the fermentation. Furthermore slaughter offal should be burnt preferably in cement furnaces after the production of meat meal and extraction fat due to reducing the uncertainties with regard to NOx formation (see chapter 9.2). A high P-content of meat meal is not accepted in the cement industry, because a detrimental effect on cement quality is limiting. Only in the new technology of the "rotation furnace" (Wirbelschichtofen) slaughter offal can be used directly as energy source. The main energy forms for further utilization are heat, electricity, steam or motor power. The fermentation of meat meal is technically possible but the costs of nitrification of N-compounds in the water outflow in the sewage work are so high that this process is not practical in most cases.

The energetic aspects of the removal of slaughter by-products and cadavers from the food chain have been studied by the Swiss Federal Office of Energy (BFE) as well as the renderer and cement industry in 1997. The basic results are given in Table 13. Not taken into consideration in this review were the different forms of energy output in the form of heat, power, steam or electricity. Therefore the efficiency of energy utilization depends on the technical possibility how heat can be used for other purposes. In the study of BFE (1997) the possibility of the utilization of extracted fat as motor fuel, today regularly applied in Switzerland, was not taken into consideration.

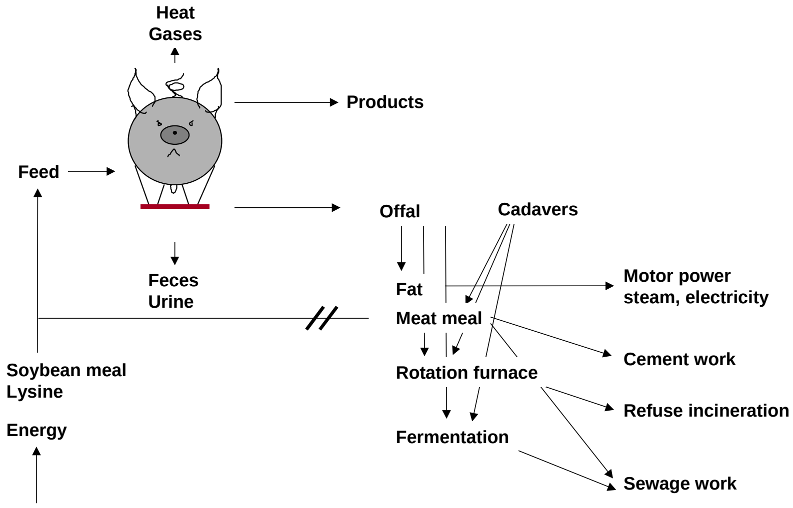

Figure 4: Energy flow from slaughter offal and cadavers to technical energy sources

Table 13: Energetic aspects of the removal of slaughter by-products from the food chain (BFE report 18704, 1997)

	Energy per 1000 kg offal (7750 MJ)		efficiency
	input (MJ)	output (MJ)	%
Offal and cadavers: Direct incineration in the rotation furnace	490	5760	68
Meat meal and extracted fat: Incineration in cement work	2880	7610	61
Meat meal and extracted fat: Fermentation	2080	2640	7

The incineration of offal and cadavers in a ground form in a rotation furnace is today technically possible and energetically efficient (efficiency about 2/3) if heat can be directly used. It represents a realistic technical solution for cadavers and high risk material.

As discussed earlier the refuse incineration cannot be applied for the combustion of offal and cadavers because of environmental concerns. Furthermore, for hygienic arguments the utilisation of offal for fermentation as well as the production of meat meal and extracted fat requires the sterilization at 133°C, 3 bar and 20 min. Compared to incineration, the fermentation is energetically inefficient. The energy input for outflow purification in the sewage work and removal of the residues in a refuse furnace is very high compared to the energy output in the fermentation unit. The energy utilization of meat meal and extracted fat in the cement work is technically simple and the efficiency in the range of 60%.

In conclusion, the efficiency of energy utilization of offal and cadavers by incineration or fermentation depends on the technique used. In the rotation furnace 2/3 of the energy of offal can be used if heat is directly required. The transformation of offal to meat meal and extracted fat and then incineration in a cement work gives a value of 60%. The energetic efficiency of fermentation is far lower. Finally it can be concluded that the energetic utilization of meat meal and slaughter fat is technically possible and rather efficient in the cement work or rotation furnace if heat is the main energy required.

8. Possible consequences for plant production

8.1. Crop area and harvest

Germany has an agricultural area of 19.3 million hectares (1997) which corresponds to more than half (54%) of the total area of 35.7 million hectares (ha). More than two third of the area actually used agriculturally (17.3 Mio ha) are arable land (11.8 Mio ha), and almost one third represents permanent grassland (5.3 Mio ha). The horticulture area and vineyards amount to less than 1% of the total agricultural land, now. The majority of arable land is used for cereal production (7.0 Mio ha, 59%) incl. corn and corn-cob mix (Table 14). Regarding the cultivation area other plants are of comparatively minor importance: Besides forage crops (1.8 Mio ha, ca. 15%), industrial plants like hops and special oil crops cover an acreage of 1.1 Mio ha (approx. 10%, 1997).

Table 14: Area harvested and total production of major agricultural crops in Germany (BML 2000)

Crops/Species	Acreage[1)]		Production[2)]	
	1997	1999	1997	1999
Cereals	**7,014**	**6,635**	**45,486**	**44,452**
Wheat	2,720	2,601	19,827	19,616
Barley	2,274	2,210	13,399	13,301
Rye	843	748	4,580	4,329
Oats	312	268	1,599	1,339
Corn & CCM	369	371	3,188	3,257
Oil crops	**948**	**1,231**	**2,952**	**4,369**
Oilseed rape	914	1,198	2,867	4,285
Sunflower	34	33	85	84
Grain legumes	**184**	**212**	**492**	**706**
Field peas	119	164	400	610
Field beans etc	65	48	92	96
Root crops	**825**	**809**	**39,088**	**40,177**
Potato	304	309	11,659	11,568
Sugar beet	504	489	25,769	27,569
Forage beet	17	11	1,660	1,040
Forage plants & pasture				
Silage corn[3)]	1,294	1,203	56,844	52,434
Clover & lucerne[4)]	264	233	2,340	2,125
Field gras[4)]	234	225	1,990	1,967
Pasture[4)]	4,140	5,114	32,896	33,738

[1)] in 1,000 ha [2)] in 1,000 t [3)] fresh weight basis [4)] as hay equivalent (BML 2000)

The acreage and harvest of the most important agricultural crops is presented in detail in Table 14, where the dominant position of cereals - and wheat in particular - becomes obvious. In relation to the total agricultural area only wheat has a share of 16% and its proportion of the arable land is as much as 23% so that almost every 4th field in Germany is grown with wheat (BML 2000). Therefore, it is assumed that the wheat acreage can hardly be increased further, without the risk of serious consequences for soil fertility and plant health. Recent increases of the area of wheat and other cereals (e.g. triticale) were primarily at the expense of traditional crops, like e.g. potatoes and forage plants (forage beets, clover, lucerne, etc.). In recent times, even cereals (like barley) have been partially replaced by wheat with a strong tendency of extending winter crops at the expense of spring crops (barley, oats) which traditionally were highly important in relation to animal husbandry, particularly in sub-alpine mountainous areas. Such spring cereals just like spring-grown grain legumes (peas, field beans) are not competitive with winter crops due to their lower yield potential and often lacking yield stability. Therefore, cultivation of grain legumes is quite limited with exceptions of particular years and special areas. On the contrary, oilseed rape sown in fall has reached an outstanding importance, not only in comparison to other oil and protein crops but even to cereals (Table 14). Corresponding to the rapeseed acreage of more than 1 Mio ha and the production of more than 4 Mio t (1999), substantial amounts of solvent extracted rapeseed meal, expeller and cakes are available for animal feeding purposes, now.

The traditional cultivation of forage crops has been declining since long, as exemplified for potatoes, forage beets and clover/lucerne in Table 15. This development is highly problematic, not only from an agronomical point of view, since it successively leads to a narrowing of rotations: Nowadays, oilseed rape is found as an almost unique leaf-crop in many regions where for example sugar beets are not applicable. Consequently, the risk of specific diseases and pests increases: adapted pathogens find ideal conditions for multiplication and spread, and even diseases of so far limited relevance gain importance. An impressive example of such processes is the spreading of Fusarium pathogens as major causal agents of foot and head diseases of cereals and maize: Fusarium toxins in animal feed can cause major health problems and reduced vigour of the animals.

The observed changes in crop relations during recent decades are somehow related to the yield increases which have been particularly impressive in cereals (Table 15). The augmentation of grain yield of major cereals which amounts to more than 50% during the last 30 years has been a result of intensive breeding activities initiated by the increasing acceptance of cereals as an animal feed (high energy density) and as industrial raw materials. As a consequence, cereals – in particular winter types – are nowadays outyielding spring grain crops like field beans and peas (Figure 5). In addition, grain legumes are characterized by an insufficient yield stability due to stronger reactions to adverse environments, e.g. drought (field beans) or wetness (peas). Because of these reasons grain legume cultivation can only be economic if their insufficient yield stability and harvest is compensated by sufficiently high product prices.

Table 15: Area harvested and grain yield of major crop plants today and 30 years earlier (BML 2000)

	1968		1998		Relative (1968=100)	
	Area (1000 ha)	Yield (dt/ha)	Area (1000 ha)	Yield (dt/ha)	Area	Yield
Wheat	1,464	42.3	2,787	72.0	190	170
Barley	1,330	37.4	2,176	57.4	163	153
Rye	962	33.1	931	50.9	97	154
Triticale	-	-	467	60.1	-	-
Oats	821	35.2	263	48.5	32	138
Corn & CCM	58	49.2	343	80.6	591	164
Silage corn	-	-	1,235	438.4 1)	-	-
Rape & Turnip	63	26.8	1,004	32.0	1,594	119
Sunflower	-	-	34	28.2	-	-
Grain legumes 2)	39	28.9	194	35.2	497	122
Potato	659	291.1	295	388.6	45	133
Forage beet	337	678.7	14	971.6	42	143
Sugar beet	290	470.0	503	532.2	173	113

1) Greenstuffs (fresh weight) 2) Field beans (*Vicia faba*) & peas (*Pisum sativum*).

A different situation is seen for root crops which used to have a great importance in the past. In addition to expensive mechanisation of root crop production, low energy density (e.g. forage beets) are not adequate for modern animal husbandry and production systems. On the contrary, cereals have obvious economic advantages because of advanced mechanisation throughout the whole vegetation, harvest and storage. This has to be seen as the major cause for the reduction of root and forage crops cultivation. The growing of clovers and lucerne has declined by 10% and 20%, respectively, in the 1990’s, when corresponding forage production figures even dropped by more than 40%. In the same period the production of root crops for forage even declined by 80% (Table 16). Consequently, the production of green forages on farm went down for quite a long time and has been continuously replaced by other feedstuffs mainly on the basis of cereals where wheat and barley play a dominant role (Table 15 and Table 16).

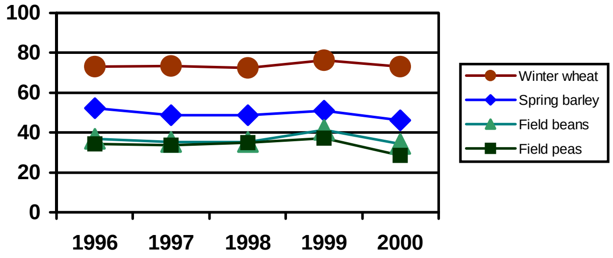

Figure 5: Average grain yield of selected field crops in Germany, expressed in dt/ha; years 1996-2000 (adapted from BML 2000).

Table 16: Available feed from domestic production and imports[1)] (mod. after BML 2000)

	1990/91[2)]	1994/95	1996/97	1998/99
Marketable primary feedstuff				
Cereals	20,285	21,305	22,324	23,893
Grain legumes	1,024	806	650	808
Processed vegetable feedstuffs				
Brans	1,251	1,134	1,174	1,174
Oil meals & cakes	5,973	5,725	5,072	5,928
Vegetable oils & fats	135	128	123	90
Forage crops & by-products				
Clover & lucerne	2,255	1,494	1,402	1,327
Meadows & pastures	19,315	19,064	18,142	19,161
Silage maize	9,934	8,585	10,378	9,779
Other forage plants (main crops)	1,712	232	220	274
Sugar beet leaves	796	629	678	697
Forage root crops	848	306	260	188
Potatoes	889	193	336	237
Total	73,579	66,923	67,737	69,949
thereof: Cereals	20,285	21,305	22,324	23,893
Concentrates	15,314	13,601	12,519	13,025
Root crops	2,719	1,190	1,326	1,157
Greenstuffs & roughage	34,280	30,040	30,799	31,159
Milk & milk products	981	787	769	712

[1)] in 1,000 t grain equivalents [2)] restricted comparability of 1990/91 with subsequent years.

8.2. Feeding value of different feedstuffs

The caryopses of cereals are characterized by high starch and comparatively low protein content; the crude protein content varies between 9 and 14%, depending on genotype and environmental conditions during grain filling. Cereal protein is additionally characterised by a deficit of certain essential amino acids, particularly lysine, methionine, threonine, and tryptophan which indicates comparatively low biological value of the protein. Cereal feedstuffs therefore deserve complementation by other ingredients with corresponding amino acid concentrations (see chapter 5).

For orientation, a comparison of different feedstuffs and raw materials is provided in Table 7 and Table 8. Hereof, the particular and great importance of soy meal in animal feeding becomes obvious: Soybean meal is characterised by a high lysine content and comes closest to MBM in amino acid content.

With regard to amino acid content, rapeseed meal can be positively estimated as well, since it has essential amino acids, particularly methionine, threonine and tryptophan at higher concentrations than feedstuffs based on grain legumes like field bean meal. On the other hand, rapeseed meal is less competitive regarding metabolisable energy where field beans are superior (Table 8). However, field bean meal is also characterised by an unbalanced amino acid composition with particular deficits in sulphurous amino acids (see chapter 5). Domestic grain legume production is therefore only partially suited for the compensation of MBM and soybean meal in feedstuffs. In this context, it has to be additionally considered that vegetable materials are clearly inferior to animal feedstuffs with regard to their mineral contents; this is particularly the case for phosphorus (PALLAUF, J., pers. communication; also see chapter 6.2).

8.3. Consequences for crop production

Since the situation in crop production is currently characterised by high acreages of cereal crops, in particular wheat and barley, some kind of diversification of plant cultivation would be highly wishful. For example, an extension of the area devoted to the cultivation of grain legumes (i.e. field peas and beans) would be expected to have beneficial effects on soil fertility and plant health. In addition, subsequent crops would benefit from the preceding crop value, i.e. residual nitrogen (N) due to N fixation of the legume. Actual crop rotations like Oilseed rape – Winter wheat – Winter barley can easily be extended by adding a grain legume as a crop rotation component, e.g.: Field peas – Oilseed rape – Winter wheat – Winter barley. Consequently, the share of leaf crops in the rotation would be increased from 33% to 50%, leading to various expected positive effects regarding soil fertility, plant health and crop stability. However, such an increase of the grain legume area would certainly require respective incentives due to the currently insufficient yield stability and competitiveness of peas and beans. Anyhow, the doubling of the grain legume acreage would lead to an increase of available protein-rich feedstuff by about 700,000 t, which is slightly more than the additional amount of peas needed in case that they should replace MBM (see chapter 5.3). Admittedly this would be at the expense of other grain crops in particular spring cereals like barley and oats.

Another alternative would be the extension of oilcrop cultivation. For example, the growing of sunflower could again be intensified in favourable regions where it has been extensively grown in the early 1990’s, e.g. grape wine growing areas. Oilseed rape (winter rape) could certainly be extended in areas where it is not grown extensively so far. The actual rapeseed acreage represents only less than 10% of the arable land, and it should be extendable to 15% at least. This would correspond to an area extension of approx. 700,000 ha, and it would lead to the production of ca. 1 Mio t of rapeseed meal and cakes as valuable feedstuffs.

8.4. Perspectives of crop breeding

The competitiveness of oilseed rape is not only determined by the oil extracted from the seed, but also by the expeller, meal or cakes as by-products of oil processing. In this context, the contents of low-value substances like crude fibre, tannins (polyphenolics), phytate and sinapine play a major role. The reduction of these contents could substantially improve the feeding value of rapeseed meal. Corresponding breeding activities have been initiated (Table 17). Finally, with its high protein content of 36-40% and due to its favourable amino acid composition rapeseed meal could represent a valuable feedstuff for diets rich in cereals. Currently, the use of rapeseed meal as a feedstuff is mainly restricted to ruminants.

Major components of rapeseed meal determining feed value relative to soybean meal are crude fibre and protein: high crude fibre (ca. 12% vs. 7%) and low protein (36 vs. 47%) contents actually limit the relative value of rapeseed meal and its use in feeding monogastric animals due to an inferior content of metabolisable energy. On the other hand, rapeseed meal is richer than soybean in essential amino acids like methionine and cysteine and in valuable minerals and vitamins. Further increases of protein content should substantially improve the competitiveness of rapeseed meal, therefore.

Along these lines, the use of yellow or light-seeded types of oilseed rape is seen as a promising route for a substantial improvement of rape meal quality in competition with soybean meal. In breeding programmes light-seeded lines have been identified repeatedly. However, the stability of the trait has been described as insufficient. This seems to be caused by the fact that seed colour of rape is a genetically complex trait: at least three genes act together and true-breeding yellow seediness would only be expected in case of a homozygous-recessive situation at all three loci. Furthermore, specific environmental conditions (i.e. stresses like temperature, light, or pathogen attack) can obviously modify the expression of the trait.

In a breeding programme run at our institute light-seeded oilseed rape materials with improved meal quality are being developed on the basis of various genetic sources for the yellow seed trait. An accelerated development of homozygous lines (doubled haploids) is carried out via microspore culture (Lühs et al. 2000). The trait expression in the breeding materials is characterised by digital picture analysis and NIRS as well as visually (Lühs et al. 2000). In addition, molecular markers are being developed for indirect “marker assisted” selection in the future. On this basis, stringent selection for the quality trait in addition to major agronomic traits will be feasible.

Above the reduction of crude fibre content and a simultaneous increase of protein content, further ameliorations of rapeseed meal quality are possible and are considered in respective breeding projects (Frauen et al. 2001, Friedt & Lühs 1999, 2001). For example, the reduction of sinapic esters (sinapine), of tannins and other polyphenolics is followed by biotechnology-aided breeding activities. Finally, these projects aim at a substantial improvement of the feeding value of rapeseed meals and cakes as a whole (Leckband & Voss 2001).

Table 17: Optimisation of meal quality of 00 rapeseed (canola)

Substance(s)	Negative effect(s)	Content, % DM	Measure(s)
Phenolic acids and derivatives Esters of sinapic acid (sinapine); free and bound phenolic acids	Bitter taste, astringent, dark meal colour, „fishy“ taste of eggs (sinapine)	0.5-3.0 0.1-0.3	Selection of low sinapin types; suppression of enzymes in the phenylpropanoid-pathway (mutagenesis, genetic engineering)
Tannins (Polyphenolics) • condensed tannins in the seed coat (ca. 1/3) • soluble tannins in the embryo (ca. 2/3)	Restricted feed intake and energy exchange, reduced digestibility of proteins due to complex formation, dark meal colour	1.5-4.0	Selection of low tannin types, e.g. yellow-seeded rape seed; suppression of enzymes in the phenylpropanoid-pathway (mutagenesis, genetic engineering)
Phytic acid and derivatives	Poorly available phosphorus (monogastric animals), restricted resorption of minor nutrient elements, complex formation with amino acids	2.0-5.0	Supplementation by phytase; induction of phytase activity (genetic engineering); selection of low-phytate materials (mutagenesis, genetic engineering)

8.5. Conclusive remarks on possible consequences for plant production

A compensation of the loss of MBM for livestock feeding would be partially feasible by a corresponding extension of oil and protein crop cultivation. However, a major problem is still seen in the provision of qualitatively comparable feedstuffs, which seems to be rather impossible with plant products alone. As demonstrated above, plant feeding materials are inferior to animal feedstuffs with regard to various components. This holds particularly true for the digestibility of organic matter, protein content, amino acid composition and mineral contents. Plant meals are additionally characterised by „anti-nutritive“ substances which can negatively affect feed intake and/or nutrient availability. Current breeding activities aim at an improvement of feeding value of plant meals as a whole. A significant example is the breeding activities focussing on the entire seed quality of oilseed rape: Further ameliorations of oil and meal quality are expected to enhance the competitiveness of rapeseed not only as an oil-source but also as a high-quality feedstuff.

9. Alternative disposal ways: pollution gas emissions of incineration and co-incineration

Immediately after the ban, scientists, food and disposal industry looked for alternatives to use or to eliminate animal by-products (KLEINHANSS et al. 2000). At present the most important and promising way for the disposal of MBM is the combustion process in incineration or co-incineration plants (e.g. cement plants, power plants). The German government also considers combustion to be the only measure for the complete destruction or denaturation of BSE pathogens of possibly infected materials. Ecological aspects of both burning and replacing MBM as protein source in animal nutrition will be considered in this chapter.

9.1. Elemental composition of animal meat and bone meal

From Table 2 it is obvious that the composition of MBM is highly variable. To simplify further calculations, an average MBM with 560 g protein, 120 g fat and 220 g crude ash per kg material (~90% DM) is assumed on the basis of data shown in Table 2. Considering the elementary composition of proteins (averages: 53% C, 22% O_2, 16% N_2, 7% H_2, 1% S, GEBHARDT 1981) and fats (77% C, 12% H_2, 11% O_2), elements coming from organic matter of MBMs were calculated (39% C, 13.5% O_2, 9% N, 5.5% H_2 and 0.6% S). But these values may vary in the practice (NOTTRODT et al. 2001). MBM contains other elements such as calcium, chlorine (as sodium chloride) and phosphorus, which can cause problems during the combustion process. Considerable amounts of calcium and phosphorus in MBM may change ash melting point and phosphorus may affect the process in cement plants.

Animal fat consists only of fatty acids and glycerol. C_{16}- and C_{18}-fatty acids are dominating. The heating values for MBM and fat (about 15-18 MJ/kg and 39 MJ/kg, NOTTRODT et al. 2001) are comparable to those for lignite and for crude oil respectively. Therefore combustion of both cannot be regarded for removal purposes only, but may also be of interest for heat and power generation. Thus fossil fuels and related emissions may be replaced.

9.2. Gas emissions from burning of animal by-products

At present MBMs are burnt by various technologies especially by licensed incineration plants for wastes (grate fire, rotary kiln) and sewage sludge (fluidised bed), cement plants and power plants by co-firing with fuels as coal, lignite, wastes and others. The most favourable techniques seem to be the fluidised bed combustion and the drum-type kiln. There are limits for different components of the flue gas output for such combustion systems regulated by the 17th BImSchV (1999). Therefore, complex and effective systems for the flue gas treatment are necessary.

All by-products are dried adequate to the previous feedstuff production. Therefore drying cannot be considered as an additional environmental problem. Combustion of 1 kg MBM causes about 1.4 kg CO_2 (not climate-relevant because it is derived from biomass) and some further trace gases (NO_x, N_2O, SO_2; Table 18) and CO, from which N_2O (nitrous oxide) is the most dangerous because its global warming potential accounts for 310 times that of CO_2 (IPCC 1995) and because of its ozone depleting potential in the stratosphere. But CO_2 dominates climate-relevant gas emissions from waste incineration, more than 100 times that of other gases as for example N_2O, calculated as CO_2 equivalent (JOHNKE 2000). Real emission data of N_2O from plants, co-incinerating MBM, are not known.

CO emissions from waste incineration plants should be on a very low level (50 mg/m^3, daily average limit value).

Table 18: Gas production during burning of animal by-products with the average composition mentioned above

Animal by-products	Gas (kg per kg)	
MBM	CO_2	1.43
	NOx	0.19
	SO_2	0.01
Animal fat	CO_2	2.83

NO_x is not regarded to be a directly acting greenhouse gas (a warming potential of 8 is imputed, Johnke 2000). It affects widely atmospheric chemistry as a catalyst and is responsible for ozone forming and destruction. During the combustion process, NO (which can be easily oxidised to NO_2) may be formed by oxidising air nitrogen as well as the nitrogen from the burning material. The amount of NO formed should, therefore, increase with the N-content of the MBM. This is known from the incineration of sewage sludge, but the N-content of MBM may be about two or three times that of sewage sludge.

NO_x-forming can be controlled by influencing the combustion process by different means. There are also further techniques available (as example SCR: selective catalytic reduction, and SNCR: selective non-catalytic reduction, using ammonia or/and urea) for reducing the NO_x-content of the flue gas, because the emissions of NO_x by a combustion plant is limited in Germany according to the 17th BImSchV to 200 mg/m^3 (daily average) flue gas for heating plants, waste incineration plants and power plants. The problem with NOx emission may be different in countries where other standards for flue gas are applied. Because a lot of the nitrogen of the burning material (meal) is bound as amino acids (reduced N-compounds such as NH_2-radicals), this may cause a NO_x-reduction during incineration (Nottrodt et al. 2001). The part of the MBM which can be added during co-firing (possibly a few per cent) depends on the capacity of the equipment for the gas cleaning as for NO_x-removal of the plant and on some other factors. At the moment there is not enough knowledge about the influence of the meal N-content on the energy consumption for the flue gas cleaning.

Although SO_2 is not considered to be a greenhouse gas, there is an influence on climate: due to its potential of forming aerosols in the atmosphere together with other molecules, it may contribute to atmospheric cooling.

SO_2 emissions from combustion are also limited by the 17th BImSchV to 50 mg/m^3 (daily average) of flue gas. Examples for techniques available to remove SO_2 from the flue gas may be the addition of lime to the combustion process or the SO_2-absorption in solutions of $Ca(OH)_2$ or NaOH by formation of gypsum. The sulphur content of the MBM doesn't cause difficulties.

Carbon monoxide (CO) – a greenhouse gas (with short life time) – may be controlled by measures of the combustion process itself.

In spite of considerable amounts of chlorine (from sodium chloride) of MBM or other animal products, there should not derive problems such as wall corrosion of the plants or forming of compounds such as dioxins, furans, PCBs and others. Temperatures of 850 °C (minimum) and residence times of at least 2 seconds are needed for waste incineration plants, whilst cement plants and power plants are operated at temperatures a few hundred degree higher. If MBM is co-incinerated in plants (e.g. coal firing) and if the SO_2 content in the flue gas is much higher as the hydrochloric acid (HCl) content, the de-novo-synthesis of dioxins and furans is prevented.

Thus the problem of dangerous gas emissions is solved in the incineration plant and doesn't affect the environment inadmissibly.

In spite of this, there is some doubt in the public, that all prions are destructed completely by the combustion process, because quality of combustion may be influenced by a lot of factors such as construction principle of the combustion plant, storage of the meal, operating conditions, control of the combustion process and others. For testing different residues such as slag, ash, dust, flue gas, and others with regard to prions a fast method is missing until now. Therefore, for most of the plants which co-incinerate MBM, the protein content of their residues is determined.

In the case of fat burning, only CO_2 is emitted into the environment (Table 18).

If most of the MBM is burnt in special, licensed waste incineration plants, cement plants or power plants (not only for removal of the waste), heat as well as electrical power are produced and therefore fossil fuels as coal and lignite are replaced by the MBM or fat. Thus, corresponding CO_2 emissions from fossil fuels can be saved. From this point of view the combustion of MBM can scarcely be considered to generate environment pollution by CO_2. In contrast to this, there seem to be positive effects for the environment.

The CO_2 output can be simply calculated from the amount of MBM burnt and from the specific CO_2 emission. If all MBM (~650 000 t) would be burnt, the corresponding CO_2 emission would amount to 930 000 t annually in Germany. Animal fat has a higher pollution potential (2.8 kg CO_2 per kg, the energetic value of fat is also at least twice that of the meal), but more alternatives are available (industrial and technical purposes) to avoid burning of fat.

9.3. Gas emissions related to the production of alternative proteins

Based on an average crude protein content of 56% in the 650 000 t of MBM about 365 000 t protein including important essential amino acids have been destroyed by burning. Feeds of plant origin, sometimes supplemented with free amino acids, may replace proteins of MBM as outlined in chapter 5.3.

Apart from combustion of MBM, the production of feeds to replace MBM as protein source in animal nutrition causes also pollution gas emissions and requires arable land. Recently BOCKISCH et al. (2000) evaluated various systems of agricultural production in relation to primary energy input and certain gas emissions. Based on CO_2 equivalent values and replacement values per kg MBM that can be calculated from Table 7, Table 19 shows CO_2 emissions to replace protein of 1 kg MBM. This varies between 0.3 and 1.3 kg. This estimate does not account for the emissions related to the production of free amino acids. Furthermore, the increased production of feed phosphates due to the increased demand is not yet considered in this calculation.

Table 19: Trace gases from plant production on the basis of CO_2 equivalent values (by BOCKISCH et al. 2000) and CO_2-emission to replace 1 kg MBM

Feedstuff	CO_2 equivalent values (kg CO_2 equivalents per kg feed)[1)]	CO_2 emission to replace 1 kg MBM (kg CO_2 per kg MBM)
Rape seed	0.81	1.30
Beans	0.21	0.46
Peas	0.21	0.55
Lupines, yellow	0.21	0.30

[1)] conventional production

10. Economic considerations

An estimation of the economic consequences of the ban of MBM as feed component has to consider two main aspects:

1. The substitution of MBM by feedstuffs of vegetable origin has direct economic consequences for those farmers who were using commercial feedstuffs as input factor. In economic terms price relations and price differences between alternative ingredients are concerned as well as the overall development of farm input and production costs. These considerations focus on a micro-economic evaluation.
2. Restrictions on the on-farm use of MBM have also consequences for the off-farm disposal of the feedstuff component. Alternative ways of disposal like the combustion process of incineration or co-incineration must be evaluated compared to livestock feeding.

Both aspects are difficult to quantify due to rather limited availability of relevant data. We start our analysis by measuring the effects restrictions of MBM feeding have on farm feeding decisions.

10.1. On-farm level

On the farm level the costs of pork and poultry production are basically influenced by the feedstuff price. The price for the components depends heavily on the nutritional value of the main ingredients and its substitutability. MBM has close substitutes in form of soybean meal, rapeseed meal and combinations of grain with free amino acids. The close substitutability between these mixed feed components explains the nearly similar price movements between the feedstuffs. Soybean meal is to be seen as the leading feedstuff component. The positive deviation of MBM from soybean meal can be explained by its favourable nutritional value caused by its higher protein content. From 1994 up to 1997 the price difference between both components remained nearly the same with a slightly higher price for MBM (Table 20). Since the last two years (1998 - 1999) the price difference was getting tighter and since 1999 MBM prices were reduced to a level below the soybean meal price which is mainly an effect of the image losses of MBM compared to feed from plant origin.

Table 20: Supply prices of different feedstuff components (€/kg)

	1994	1995	1996	1997	1998	1999
Lysine	2.19	1.84	1.93	2.69	1.61	1.15
Soybean Meal	0.15	0.18	0.25	0.24	0.15	0.19
Rapeseed Meal	0.10	0.12	0.16	0.14	0.10	0.12
MBM	0.20	0.22	0.26	0.30	0.15	0.18

Source: COMEXT-Database, Eurostat, several issues; ZMP (2001c) (and back issues); own calculations

A price comparison on the level of the main ingredients regarded as an equivalent to the price of the nutritional value of the main feed components, shows a slight deviation from the aforementioned results (Table 21).

Table 21: Price comparison of different feeding stuffs (average prices of the years 1999/2000)

	Crude protein	Lysine	Price of feedstuff	Protein price	Lysine price
	g/kg	g/kg	€/kg	€/kg	€/kg
Soybean meal	451	30.8	0.19	0.42	6.17
MBM 1/1[1]	474	26.0	0.18	0.38	6.92
Lysine	940	780	1.15	1.22	1.47

Source: own calculations [1] see Table 7

The price based on the content of natural protein and free lysine demonstrates that MBM has some advantages in terms of the price per protein- or lysine-content over substitutional products. A price quality relation can be calculated by a comparison of different feedstuffs and their protein content. Price differentiation based on the protein content comes up with a somewhat different price relation between the assigned feedstuffs. The price for protein inherent in MBM is more favourable compared to the protein price of soybean meal. The protein equivalent price of lysine as the alternative source of protein is more than three times higher than that of MBM. Measured by the main feeding ingredients MBM has from the point of view of a single farmer a relative competitiveness over alternative feeding stuff components.

The results demonstrate that MBM is on the one hand a relative low price ingredient measured by its protein value (see Table 21) but on the other hand price differences measured by product prices are not very significant (see Table 20).

Commercial feedstuffs are a major input factor in pig and poultry production. Feedstuffs count for roughly 60% of production costs in animal feeding. Consequently, price variations have important consequences on farm input costs. But as far as certain feed components are subject to price changes their contribution to the overall production costs must be estimated. In quantitative terms MBM participates with only 2.7 % (in Germany) and 2.9 % (in EU-15) to feedstuff dietaries (see chapter 3).

Expressed in economic terms KLEINHANS et al. 2000 estimated MBM´s contribution to the feeding stuff price with 4.4 % in pig feed, 4.2 % in feedstuffs for laying hens, and 3.6 % in broiler feeding stuffs. From the economic point of view the contribution of MBM to the input cost of fattening is to be seen as a minor factor. Additionally, their calculations of the likely price effects of a ban of MBM results in only slightly price increases between 0.7 % (broiler) and 1.5 % (laying hens) per unit mixed feed. These are the results for the scenario that only the direct effects on farm input prices of a MBM ban are calculated. Indirect effects, like inefficiencies in fattening processes due to an inappropriate composition of protein and/or phosphorus were not considered herein.

But what is the magnitude of the ban of MBM as an feed ingredient? Since the decision to ban MBM from feedstuffs in December 2000 we can see that the input price development of different feedstuffs for pork and poultry before and after the ban of MBM is not very significant (see Table 22).

Table 22: Input price development of different feedstuffs for pigs and poultry (September 2000 until August 2001; in €)

Month	Pigs	Laying hens	Broilers
Sept. 00	17.33	19.89	21.53
Oct. 00	17.64	19.89	22.14
Nov. 00	17.69	19.84	22.19
Dec. 00	18.25	21.12	23.26
Jan. 01	18.76	21.22	23.72
Febr. 01	18.66	21.27	23.72
Mar. 01	18.56	21.07	21.58
Apr. 01	18.57	21.01	23.52
May 01	18.65	21.01	23.42
Jun. 01	18.72	20.96	23.11
Jul. 01	18.71	21.17	23.16
Aug. 01	18.71	21.01	23.37
Annual price increase:			
Aug. 01/Sep. 00	+ 6.2 %	+ 4.6 %	+ 7.3 %
Aug. 00/Sep. 99	+ 7.8 %	+ 6.0 %	+ 6.4%
Aug. 99/Sep. 98	- 2.7 %	- 3.9 %	- 1.7%

Source: ZMP (2001c), own calculations

Compared to former years the effects of a MBM ban on the price for feedstuffs is not very significant. Obviously, substitution possibilities between different feed ingredients helped to exchange MBM from feed dietaries without large price distortions. The price increase for the year September 00 to August 01 is basically the result of changes of the currency rate between US-$ and European currencies (KRAFTFUTTER, various issues).

10.2. Macro-economic level

On a macro-economic level, the overall effects of a MBM ban can be calculated as well. It is to consider that a total ban will also have limiting consequences on the export possibilites of MBM in the long run. Estimation of economic effects have to be based on the total volume of MBM that has been produced in Germany. According to Table 1, total volume sums up to an three-years (1998-2000) average of about 625,000 t. This quantity has to be alternatively used. The disposal of MBM through combustion processes in incineration or co-incineration plants (cement industry, waste incineration or fertiliser processing) are seen as appropriate alternatives (see chapters 7 and 9). The cost that occur in case of using these assigned alternatives are calculated as follows.

To get an idea of the magnitude of the gains and/or losses that are to be expected with the use of these inferior distribution alternatives can give first insights into the likely effects. For these estimation the annual production of MBM will be used in three different alternatives (waste incineration, cement industry, fertiliser production). It is to be expected that a two stage procedure of disposal will still remain existent. From a hygienic point of view a direct incineration of offal and cadavers in its basic form in a rotation furnace will not be allowed. MBM will be first processed in specialised incineration plants and thereafter distributed to the assigned alternatives of use. We expect that the fees that have to be paid for delivering offals from slaughter animals and cadavers to the incineration plant for wastes and in a second step from incineration plant to co-incineration plants express the costs of alternative usage. The fee is to be seen as the result of cost and revenue calculations by the plants and it reflects the price of the use of the specific alternative distribution channel for a first estimation. According to different sources we calculate with a high and low fee in order to demonstrate the range of the overall costs that might occur. Table 23 demonstrates that in case of a ban of MBM for Germany the total costs of the alternative use of 625,000 t MBM varies between 199 and 324 Mio €.

Table 23: Costs calculations of alternative use of MBM

		Waste Incineration	Cement Industry	Fertilizer Production
MBM average annual production 1998-2000		625,000 t	625,000 t	625,000 t
Disposal fee 1st stage		180 €/t	180 €/t	180 €/t
Disposal fee 2nd stage:				
	upper limit	230 €/t	123 €/t	105 €/t
	lower limit	87 €/t	51 €/t	51 €/t
Total fee for alternatives				
	upper limit	323.8 €/t	256.9 €/t	245.6 €/t
	lower limit	198.2 €/t	211.9 €/t	211.9 €/t

Source: HILGER (2000), KLEINHANS (2000), KÜHL & HILGER (1997), and own calculations.

On average, every kg MBM not used as a feedstuff is charged with costs of about 0.32 €. This is nearly as twice the supply price of MBM in 1999 (see Table 20). Or expressed differently, with every kg MBM not used in pork or poultry feeding economic losses of about 0.14 € have to be carried by the society.

11. Summary and conclusions

MBM or extracted fat from slaughter offal represent highly valuable nutrients that can be used in the nutrition of non-ruminant farm animals and fish. For this application the appropriate sterilization treatment is an unalterable requirement. MBM contains essential amino acids, phosphorus and other nutrients that can efficiently be utilised by the animal. It was shown that up to 0.65 Mio of MBM could potentially be used annually in Germany (4.04 Mio t in the EU-15), which is about twice as high as the amount that was used in recent years and which is more than the amount of MBM that is produced.

- The ban of MBM from feeding caused a need for alternative protein sources. If all the amount of protein from MBM is to be replaced, about 0.30 Mio t of soybean meal or 0.60 Mio t peas or 0.51 Mio t beans or 0.36 Mio t lupines would be needed in Germany (additional free amino acids not considered).
- Plant feeding materials are inferior to animal feeds with regard to various components. Plant meals are additionally characterised by „anti-nutritive“ substances which can negatively affect feed intake and/or nutrient availability. Current breeding activities aim at an improvement of feeding value of plant meals as a whole.
- A wider application of phase feeding with adjusted dietary amino acid concentrations, however, would allow for saving protein to an extent which is similar to the amount of protein that was contributed by MBM. Thus, the ban is a minor problem in terms of ensuring amino acid supply. However, alternative disposal destroys protein that is of very high biological value. Using protein from MBM would allow for saving protein from plant raw materials (e.g. soybeans).

- Alternative plant ingredients cannot compensate for the gap in P supply that is caused by the ban. An additional demand for inorganic feed phosphates of about 14,000 t/y is given in Germany. At present, this gap is filled almost completely by increased mining of rock phosphates. Alternatively, a general application of microbial phytase to all diets would fill this gap. Until the ban, MBM contributed to 57% to the supplementation of P that was needed for pigs and poultry. The ban of MBM makes large amounts of P disappearing from the food chain.
- Energy from slaughter offal and cadavers can be utilized in different technologies, in the coarse of which the efficiency of energy utilization depends on the technology applied. It is efficient in the cement work or rotation furnace if heat is the main energy required. In contrast, the energetic efficiency of fermentation is low.
- Incineration or co-incineration of MBM and other by-products causes pollution gas emissions amounting to about 1.4 kg CO_2 and 0.2 kg NOx per kg. The CO_2 production as such is hardly disadvantageous, because heat and electrical energy can be generated by the combustion process and therefore fossil fuels and CO_2 emissions from burning fossil fuels may be substituted. But due to the loss of nutrients, feed must be produced to replace protein, amino acids, and other nutrients from MBM in animal nutrition. Depending on feedstuffs, CO_2 emission to replace protein from 1 kg MBM varies between 0.30 and 1.30 kg. It would be higher, if amino acids and other nutrients would be adequately replaced.
- Compared to former years, the effects of a MBM ban on the price for compound feed is not very significant. Obviously, substitution possibilities between different feed ingredients helped to exchange MBM without large price distortions. However, with each kg MBM not used in pork or poultry feeding economic losses of about 0.14 € have to be carried by the society.

If safety is given from the hygienic point of view, MBM could considerably contribute to the goal of keeping limited nutrients within the nutrient cycle. There are conditions for the technological treatment of slaughter by-products, at which they can be considered for hygienic and toxicological aspects as safe (133 °C, 3 bar and 20 min.). SSC (1998) arguments for more rigorous conditions of safety of hydrolyzed proteins produced from bovine hides for sterilization of 140°C, 3.6 bar and 30 min to ensure safe products which could be reintroduced into the food chain.

This paper does not account for the problems that arise in countries which had a net import of MBM and that are not as easily able to substitute nutrients and energy by other sources.

It is demanded by the consumer not to use slaughter by-products from the same species, e.g. that meat meal from pigs and ruminants should only be utilized in diets for poultry. The complete separation of slaughter by-products from different species is only possible in very big slaughter units. Furthermore there is no scientifically relevant argument not to feed meat meal or other slaughter by-products within the same species, as long as it is properly treated.

The by far highest proportion of raw materials for MBM was from by-products of the slaughter process. MBM and animal fat coming from this way and processed according to the standards can be regarded as valuable sources of amino acids, minerals and energy in feeding pigs and poultry. Using them as feedstuffs would contribute to a sustainable food production through a responsible management of limited resources.

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