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FAO ANIMAL PRODUCTION AND HEALTH

proceedings

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# Content

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# Foreword

Livestock production is growing rapidly as a result of the increasing demand for animal products. FAO projections suggest that global meat production and consumption will rise from 233 million tonnes (2000) to 300 million t (2020), and milk from 568 to 700 million t over the same period. Egg production will also increase by 30 percent. This forecast shows a massive increase in animal protein demand, needed to satisfy the growth in the human population. Asia is experiencing the world's highest growth rates in production and consumption of livestock products (meat, milk and eggs). The issues to be addressed are the environmental and feed supply problems arising from the concentration of livestock production.

The big increase in animal protein demand over the last few decades has been largely met by the world wide growth in intensive livestock production, particularly poultry and pigs. This is expected to continue as real income grows in the emerging economies.

Feed grains are thought to compete directly, or in the use of land, with grains for human consumption and because there is inefficient use of feed and energy in some livestock systems, it is often blamed for this occurrence. However, if efficiency is seen over the entire production chain, and expressed as input of edible human food/output in human edible food, the view of animal production takes on a more positive outlook. Note that 233 million t meat, 568 million t milk and 55 million t eggs produced globally contain more than 65 million t of protein. So while input is higher than output, if improved protein quality on the output side is considered, a reasonable balance emerges.

A recent FAO study shows that the increasing use of feed grains has not had an adverse effect on the provision of cereals for human consumption. Indeed, many argue that the production of cereals for feed acts as a global buffer and therefore has a positive effect on global food security.

Over the last 30 years, FAO has worked in the field to develop technologies for integrated farming systems appropriate to small producers, particularly in the tropics. For ruminant livestock, urea treatment of straw and the use of multi-nutrient blocks have been shown to greatly improve nutrition of animals fed on low quality roughage diets. Legumes and tree forages have also provided needed protein inputs into cattle, sheep and goat production systems, while benefiting the environment through nitrogen fixation and organic matter.

These technologies have been combined into integrated farming systems for the small producer. Such improved systems are biologically sustainable and achieve high levels of production, with minimal environmental problems as the manure is recycled or used for biogas production.

Undoubtedly, the technologies have contributed to the improvement of income and lifestyle of small farmers and represent an effective approach to sustainable development and poverty alleviation. But the approach has been divorced from the parallel growth of intensive livestock production systems throughout the world, which can be seen as providing the bulk of supply to meet the demand.

The challenge is to enable small producers (who are usually the ones applying the more sustainable technologies and integration of farming activities) to have access to a wider market - termed Ruralizing the Livestock Revolution. There is also a need and demand for low cost and simple technologies for livestock and product processing.

In recent years and in many countries, public concern about the safety of foods of animal origin has heightened due to problems that have arisen with bovine spongiform encephalopathy (BSE), dioxin contamination, outbreaks of food borne bacterial infections, as well as growing concern about veterinary drug residues and microbial resistance to antibiotics. These problems have drawn attention to feeding practices within the livestock industry and have prompted health professionals and the feed industry to closely scrutinise feed quality and safety problems that can arise in foods of animal origin as a result of animal feeding systems.

Given the direct links between feed safety and safety of foods of animal origin, it is essential that feed production and manufacture be considered as an integral part of the food production chain. Feed production must therefore be subject, in the same way as food production, to quality assurance including feed safety systems.

The industry is ultimately responsible for the quality and safety of the food and feed that it produces. National authorities should provide guidance to industry and this includes codes of practice and standards that the industry must respect. International organizations also have an important role to play in providing information and training which could be used at national level to improve the knowledge and skill of those involved in all areas of the feed industry, including primary producers of feed materials. By doing so, failures in food/feed safety systems can be prevented rather than doing damage.

Dialogue among producers of feed or feed ingredients, livestock and aquaculture industries and government should be encouraged as an essential part of the process of elaborating codes of practice for the feed industry. A close partnership between government and the producers will ensure the promulgation of regulations and guidelines acceptable to both parties.

In view of foregoing issues and production trends, the FAO Expert Consultation and Workshop on Protein Sources for the Animal Feed Industry was held in Bangkok, Thailand, from 29 April to 3 May 2002. This Consultation included talks by experts on the overview of world protein needs and supply; scientific aspects of protein nutrition of farm animals; local protein resources and supplementation for livestock production; the agricultural alternatives for the production of increased supplies of protein feeds from oilseeds, legumes and by-products; and innovative developments in the production and delivery of protein raw materials. It also included a discussion on the world market and sources of proteins for the animal feed industry: present and future trends, problems and perceptions of feed safety and developments in the feed industry.

It is hoped that the output of this meeting would reinforce the partnership not only between government and the producers but all those involved in the feed industry, so that, any farmer would always have a chance to compete in the global market.

Changchui He
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# Executive Summary

## BACKGROUND

Domestic animals continue to make important contributions to global food supply and, as a result, animal feeds have become an increasingly critical component of the integrated food chain. Livestock products account for about 30 percent of the global value of agriculture and 19 percent of the value of food production, and provide 34 percent of protein and 16 percent of the energy consumed in human diets. Meeting consumer demand for more meat, milk, eggs and other livestock products is dependent to a major extent on the availability of regular supplies of appropriate, cost-effective and safe animal feeds. Few issues have generated as much public concern in recent times, however, as the protein supply in feeds for livestock production.

Not only is the demand for livestock products increasing markedly due to population growth, particularly in the developing world, but feed suppliers also have to cope with increasing safety concerns, epitomized by the bovine spongiform encephalopathy (BSE) or mad cow disease crisis, associated with the feeding of meat and bone meal (MBM). There is also anxiety about the use of genetically modified crops such as soybean and maize and concern about incidents involving chemical contamination (e.g., dioxin) of feeds. The considerable and increasing demand for animal protein is focusing attention on the sources of feed protein and their suitability, quality and safety for future supply. Consumers in the market are increasingly demanding assurances about food safety and production methods throughout the integrated food chain.

Responding to these issues and related prospects for future livestock production, the Food and Agriculture Organization of the United Nations (FAO), with the support of the International Feed Industry Federation (IFIF), organized an Expert Consultation in Bangkok from April 29 to May 3 2002 to consider ‘Alternative Strategies and Sources of Protein for the Animal Feed Industry’. The consultation and following workshop were attended by 70 participants from 26 countries, representing developed, developing and transition countries.

This Executive Summary highlights some of the key issues raised. These are developed in greater detail in the following papers from contributors, and pose some important questions that still need to be addressed.

## A 'Livestock Revolution'

Several contributors referred to the strongly demand-led 'livestock revolution' that is taking place, as a result of the rapidly growing world population, income growth, increasing urbanization, changes in lifestyles and food preferences. In addition, global drivers for change in certain livestock sectors (such as poultry) include increasing consumer health concerns, the continuing growth of fast food chains and increasing consumption of convenience and processed foods.

Further justification, if required, for the FAO meeting is emphasized in some of the following statements from different presenters which highlight pressures on the animal feed industry. These are based on predictions from the International Food Policy Research Institute (IFPRI) IMPACT (International Model for Policy Analysis of Commodities and Trade) studies on the 'Livestock Revolution'.

Global demand for meat products will increase by 58 percent between 1995 and 2020. Consumption of meat will rise from 233 million t in 2000 to a possible 300 million t by 2020; milk consumption will increase from 568 to 700 million t by 2020, and there will be an estimated 30 percent increase in egg production.

Consumption of meat grew three times faster in developing countries than in the developed world between the 1970s and 1990s, much of this is being explained by consumption in Asia.

Between 1995 and 2020, about 97.5 percent of the global population increase will be in developing countries, by which time 84 percent of the world's people (an estimated 6.3 billion) will be living in developing nations.

Meat demand in the developing world will double by 2020. Between the mid-1970s and 1995, meat consumption in the developing world rose from 11 kg to 23 kg per person. Two major contributors to this demand were China and Brazil. With China and Brazil excluded, the increase per person was from 11 kg to 15 kg per caput.

Global demand for poultry meat will increase by up to 85 percent, beef by 80 percent and pig meat by 45 percent by 2020 (from 1995).

The growth of meat and milk consumption in the developing world is predicted to be 2.8 percent and 3.3 percent annually from 1990 to 2020, in marked contrast to 0.6 percent and 0.2 percent in developed countries.

Much of the predicted increase in consumption in the developing world will be of poultry and pig meat, as well as milk. The world meat economy has been driven both by the pig sector in China and rapid growth in the global poultry industry. During the last 30 years, the poultry share of total meat consumed has increased from 13 to 28 percent, with the USA, Brazil and Thailand being major contributors to production. Future increases in this sector are also likely to be boosted by considerable annual increases in both egg and broiler production in India.

Consumption in the developing world is determined by purchasing power, and greater consumption of meat and milk will be stimulated by economic growth and more disposable income in the growing, more prosperous middle class.

## Livestock Systems

Dependency on and the need for external supplies of formulated feed will be influenced by various factors including the nature of the livestock enterprise, local feed alternatives, land and labour availability, the farming system and economics. Chadd and colleagues identified major differences between grazing systems based on indigenous forage, mixed farming utilising crop residues with grazing, and limited imported feeds when required, compared with ‘landless’ (so-called ‘industrial’) systems with a high degree of dependency on purchased feeds.

Population and land use pressures in some developing countries are encouraging intensification and the expansion of ‘landless’ systems that result in increasing demands on natural resources and the local environment . Landless systems are exploited particularly for monogastrics, and are most common in developed countries. Such systems are also utilized on occasion for ruminants in both developed countries (e.g., the USA) and developing nations (e.g. West Asia).

Intensive, landless, enterprises might have a high degree of dependency on imported feed, requiring continuous supply of large quantities of known consistent quality. Local supplies of home-produced protein, in particular, are often less able to provide such a reliable supply of quality feed. Few detailed comparative studies are undertaken, however, between local and purchased external nutrient sources. There is an increasing trend with large pig and poultry producers to produce and utilize their own feedstuffs in vertically integrated systems.

The tendency in Western Europe, due to environmental pressures and animal welfare concerns, is to move away from very intensive production and there are often price premiums for livestock products from more extensive systems. Concerns about pollution from intensive units are focused particularly on water contamination from nitrogen and phosphorus.

## Feed Supply

Gilbert estimates that about 1000 million t of animal feed is produced globally every year, including 600 million t of compound feed. More than 80 percent of this feed is produced by 3800 feed mills, and 60 percent of the world total is from 10 countries. Feed for poultry is the greatest tonnage, followed by pig and cattle feeds. Although feed production for aquaculture is relatively low (at 14 million t) currently, there is an increasing demand for feed for farmed fish and crustaceans.

International trade of raw materials is the key to the global feed industry. Such feeds are formulated and milled locally. The availability of imported protein materials is often essential for local feed manufacture. Historically, the feed industry has also exploited price-supported inexpensive grain that is traded on the global market.

Considerable efforts are being made to utilize more diverse local sources of feed ingredients, in particular protein materials, in many developing countries (e.g., India). In some other countries (e.g. Thailand), for poultry enterprises, there is a heavy and increasing reliance on soybean meal and fishmeal.. Increasing concerns are being expressed in some developing countries about the costs of imported soybeans for animal feed formulation. Greater utilization of indigenous feed materials is being encouraged for resource-poor smallholder farmers for increasing ruminant production. For example, Wanapat reports considerable potential for cassava-based products in Thailand. Higher quality ‘protein and energy’ feeds are still encouraged, however, for higher performance and enterprises that are more intensive.

### Protein use

The value of gaining and then applying a much better understanding of protein nutrition for appropriate protein feed formulation for livestock was emphasized by Miller. The importance of an appropriate available energy supply in a balanced diet for efficient protein use by livestock was stressed, a high energy to protein ratio being needed to optimize the use of the protein. Different protein requirements for different species and the effects of age and growth stage of animals were noted. Examples included the greater need for protein in fish diets compared to feed for mammals, and the declining requirement for protein with age. Increased energy used by animals following, for example, exercise or exposure to ‘heat stress’, also reduces the protein requirement in the diet. The difference between ‘essential’, ‘semi-essential’ and ‘conditionally indispensable’ amino acids in relation to protein inclusion in the diet was highlighted. The significance of amino acid balance in feeds, of new amino acid synthesis and protein compensation in diets was explained. The significance of protein influences on the immune system, as antigenic factors and anti-nutrition agents, was also stressed, in addition to animal nutrition effects.

The amino acid strengths and weaknesses of different protein feed ingredients was described, such as the lysine limitation in maize, and methionine and cysteine limitations in soybean. These are key issues for appropriate protein use and feed formulation. However, amino acid composition revealed by chemical analysis may not correctly identify the availability of these amino acids at tissue level in the animal. The significance of 'ileal digestibility' of amino acids for diet formulation, rather than total amino acid content, was emphasized. The significance of microbial protein and its digestion in the small intestine of ruminants was stressed as a balanced and good nutritional supply of amino acids. A large part of the absorbed amino acids are derived from microbial activity in the rumen in ruminants. This supply may be limited, however, by the associated supply of fermented energy. The quantity of protein in a diet may substitute on occasion for protein quality, where perhaps only poorer quality, cheaper feed (e.g., a cereal-groundnut meal mix) is available. Protein use in such diets, however, is often more inefficient and can lead to excessive nitrogen excretion.

## Protein Sources

Sources of protein for animal feeds are many and varied, with considerable opportunities for further diversification and substitutions. More research is required on alternative sources before many of the opportunities can be exploited in practice.

## Plant Protein Sources

### *Soybean*

Soybean remains the most important and preferred source of high quality vegetable protein for animal feed manufacture. Soybean meal, which is the by-product of oil extraction, has a high crude protein content of 44 to 50 percent and a balanced amino acid composition, complementary to maize meal for feed formulation. A high level of inclusion (30-40 percent) is used in high performance monogastric diets.

A measure of success of this crop is the increase in production of 50 to 60 percent between 1985 and 2000, with most grown in the United States, Brazil and Argentina. Over half of the crop is now, however, genetically modified (GM) mainly for herbicide tolerance. The potential of soybeans for further nutritional quality enhancement was emphasized by Hard and there are prospects for considerable feed benefits, assuming acceptance of GM sources in the marketplace. Currently, Argentina and Brazil are reported to export 60 percent of their production and the USA about 16 percent. The market for non-GM soya seems to be growing and may be increasingly important in the future.

Comments by Hard and others emphasized the potential of soybeans for continuing improvement and possibly wider adaptation to different growing conditions. Chadd and colleagues mentioned the potential of forage soybeans in a European context, in locations where grain soybeans cannot (at present) be economically produced. Further development and exploitation of soybean genetics may prove the most appropriate strategy in some regions, rather than developing other alternative plant protein sources.

In the European Union soybean dominates the protein supply for animal feed and the ban on meat and bone meal has resulted in further imports, reportedly of up to 1.5 million t in 2001.

*Other oil meal crops*

There are many different potential oil crops in addition to soybean, each with strengths and weaknesses for protein meal supply. Local adaptation to growing conditions and local availability provide distinct advantages for feed production in many developing countries. A continuous supply of protein meal of known quality can be made available, as is the case with palm kernel cake, the by-product of oil palm production (e.g. in Malaysia and Indonesia).

According to Speedy, prospects continue to be good for future oil meal crop production. Global projections show increasing demands for vegetable oils of 2.1 percent per annum for the next 20 years, and a significant increase in demand for oil meals and cakes. Predictions of future land use suggest that the area of oil crops will increase substantially in some developing countries. Oil palm, sunflower and oilseed rape, in addition to soybeans, will dominate and provide much of the future increase. Currently, the major net exporters in the developing world are Malaysia, Indonesia, the Philippines, Brazil and Argentina, but more oil and protein meal may be retained in future years for their own domestic use.

Oilseed rape is grown extensively in temperate regions (e.g., in Canada and the European Union) and provides good protein meal. Although glucosinolates are present and the lysine content is lower than in soybean, it provides a much higher proportion of sulphur-containing amino acids (cysteine and methionine). Glucosinolates can be removed by breeding and GM types of oilseed rape have been developed. The crop is considered to have a lot of future potential, both for increasing oil content and modifying protein composition.

Chadd and colleagues also recommend more studies on the less well known and little grown oil crops such as niger and jojoba, which reportedly have a high crude protein in the extracted cake.

To what extent such crops as oil palm, coconut, sunflower, sesame, crambe or cotton (seed) can be utilized for meal inclusion in animal feeds depends to a large extent on what price the processor is able to obtain for the extracted oil. With the exception of soybean, the demand for these particular meals is markedly influenced by their vegetable oil price. This is important for the profitability of intensive livestock enterprises such as poultry production, working on low margins. Protein-rich meal inclusion from oilseed crops currently remains the key; however, to high quality feed supply for intensive enterprise performance.

*Legumes*

Legumes are a traditional source of plant proteins for animal feed and their production can provide a range of benefits both on farms and for feed manufacturers. The exploitation of soybean is a classic example of successful development and use. Peas, beans and lupins are exploited as grain crops in temperate farming systems and their production for home-grown protein supply is encouraged (and supported) in the European Union to reduce dependency on imported proteins. Each has strengths and weaknesses for quality protein provision. Lupins, for example, can yield high levels of crude protein but produce grain which is often low in lysine and sulphur-containing amino acids.

Chadd and colleagues described work in the tropics and sub-tropics on alternative, better adapted protein sources and reported the benefits of chickpea, cowpea and mungbean for incorporation in poultry diets. The successful exploitation of tropical tree legumes for successful ruminant feeding, in both warmer parts of Australia and sub-Saharan Africa, was also mentioned.

The considerable potential of a wide range of leguminous plants for forage use was highlighted for both temperate and tropical agriculture. The need for much more research, however, was emphasized to provide for more successful practical exploitation. The significance of lucerne, the most widely grown forage, and red clover has been highlighted.

The value of a wide range of tropical legumes was mentioned, in particular *Centrosema* spp., *Stylosanthes* spp. and *Leucaena* spp., and the potential of other tree legume sources is being recognized. *Leucaena leucocephala* has been most widely commercialized, and can be hedge-cropped both mechanically and manually, or grazed in situ. It is adapted to a wide range of soil and climatic conditions. The presence of mimosine, a toxic amino acid, however, limits its use in non-ruminant diets.

More research is required to determine the value of many of these legumes for the animal feed industry. More agronomic studies are also required to improve performance, combined with economic analyses of the unit costs of the resultant protein. Particular attention will need to be given to protein quality, in addition to protein yield.

Further studies will also need to be undertaken with many of these potential legume sources for anti-nutritional factors and toxins. These are dealt with during processing by such practices as de-hulling, heating or solvent extraction.

## Crop nutritional improvement

*Quality Protein Maize (QPM)*

Although cereals play a key role in world agriculture and the global economy, grain typically has low levels of poor quality (unbalanced) protein. However they provide 50 percent of the protein in human diets and, in developing countries, it is reported that 74 percent of dietary protein is obtained from cereals.

Rice has low crude protein (CP) (around 7 percent); maize, barley and sorghum have intermediate levels (9 to 10 percent CP); and wheat, oats and triticale have the highest levels (around 12 percent CP). Typically, a high protein content in cereal grain is inversely correlated with crop yield. For animal feed formulation and protein provision, all cereals are deficient in lysine with secondary deficiencies in threonine and trytophan. Classical breeding and selection has not significantly improved cereal protein status.

Vasal describes the exciting discovery in the 1960s of high lysine maize mutants (from ‘opaque-2’ and ‘floury-2’ changed alleles), with higher protein quality in the endosperm of grain. Mutants had double the levels of lysine and tryptophan, obtained by suppressing the zein (prolamin) protein fraction. However, the resultant grain was soft and the mutants also required agronomic improvement.

Considerable breeding efforts at the International Maize and Wheat Improvement Centre (CIMMYT) were required to subsequently achieve acceptable QPM hybrids with appropriate hard grain characteristics, involving the opaque-2 gene and identified genetic modifiers of the 02 locus. Vasal reported the release and production of QPM in 22 countries since 1998, including significant adoption in China, India and Vietnam.

Vasal also described the further improvement of QPM maize lines through hybrid development programmes, the transfer of the quality protein genes to elite cultivars of standard maize, and the creation of new so-called QPM synthetics (obtained by inter-crossing several inbred lines). Some of the new QPM hybrid lines contain up to 13.5 percent protein and 100 percent more lysine and tryptophan than normal maize.

Successful exploitation of improved QPM is described in China where it is being grown on 70,000 ha. The type ‘Zhang Dan 9409’ with 80 percent more lysine and tryptophan has up to 15 percent higher yield potential than other maize. Considerable improvements in live weight gain and better feed conversion are reported from poultry feeding trials, and as much as a 3.5 times faster growth rate in pigs fed on QPM.

### *Genetically Improved Crops*

Enhancing the value of major crops for animal feed use through genetic modification, utilizing both conventional breeding approaches and modern biotechnology, was advocated by Hard. He argued that genetic improvement can give not only better animal performance and health, but also lower feed costs and more affordable livestock protein products.

Hard predicts that the next commercial wave of genetically improved crops will focus on ‘output’ traits providing much better feeding values for livestock production. Improvement efforts will focus on protein quality (particularly amino acid balance), better digestibility (especially of fibre and starch) and greater metabolizable energy (from improved oil content), with less anti-nutritional factors (such as phytate).

Successful current examples of nutrient enrichment include pro-vitamin A enriched rice, high lysine maize, high oleic acid soybeans and low-phytate maize. Other targets, mentioned by Hard, include high methionine soybeans, high oil maize and low stachyose soybeans, all of which could provide significantly improved feed characteristics and animal performance.

An intriguing possibility was mentioned by Hard, that is the possible future development of antibody containing soybeans which, when fed before slaughter, could combat such pathogens as *E. coli* and *Salmonella* spp.

Hard emphasized the need for greater ‘identity preservation’ of such genetically improved crop feeds to achieve the desired objectives. To what extent these developments will be widely adopted in practice will depend on many factors, including economics and market acceptance.

### *Synthetic amino acids*

The use of industrially produced amino acids in animal feeds is not new. Synthetic amino acid incorporation in feed has at least a 40 year history. DL methionine was produced by chemical synthesis in the 1950s and 1960s for inclusion in poultry feeds. L-lysine production by fermentation began in the 1960s in Japan, followed by L-threonine and L-tryptophan in the late 1980s.

The adoption of modern biotechnology has revolutionized the synthesis process, and has significantly reduced the costs of amino acid production. The exploitation of genetically modified microbial strains has substantially improved competitiveness. The economics of production has dramatically changed, providing much greater opportunities for synthetic amino acid use. It is persuasively argued that improvements in protein use from animal feeds are required to meet the substantial growth in global demand for animal protein products. The increased substitution of synthetic amino acids for plant protein could provide greater efficiency and effectiveness of protein utilization, but the cost effectiveness of their use needs to be continually assessed.

It is suggested that the incorporation of one tonne of L-lysine hydrochloride could save the use of 33 t of soybean meal. Or, if 550,000 t of L-lysine hydrochloride is used globally, it could replace 18 million t of soybean meal, representing about half of the USA soybean meal production. There is potential for considerable impact on current protein supply channels and the types of protein which are now used.

It is also argued that greater synthetic amino acid use could reduce nitrogen pollution from animal wastes, as a result of better and more efficient nutrient utilization.

Future developments of synthetic amino acid production could apparently include synthetic isoleucine, valine and arginine, thus extending the range of amino acids available for use in feeds. The degree of use would be mainly determined by the economics.

*Food industry crop by-products*

Quality protein can be provided sometimes from various crop residues and by-products of food and drink manufacture, such as brewers' grain and maize gluten meal. These by-products are many and varied, and differ considerably in the value and significance for animal feed protein supply.

However, some of these by-products provide a valuable local source of protein which can be inexpensive, accessible and continuously available from the local food industry. Their use can also be regarded as a significant re-cycling opportunity, and more of a closed system for waste disposal. Many of these associations between local farmers and nearby food manufacturers have developed over a long period of time and still continue.

Food safety considerations may still dominate this protein supply route, with restrictions on certain by-product materials or their treatment before use in animal feed.

*Fishmeal*

The global significance and provision of fishmeal as a protein source is uncertain. Estimates suggest that it is still amongst the 'big three' sources of quality protein for feed manufacture. Gilbert quotes an annual figure of 316 million tonnes of oilseed protein, 14 million t from animal by-products and 7 million tonnes from fishmeal.

Unfortunately, it is reported that fishmeal produced by new processes cannot easily be distinguished from other animal proteins. It needs to be separately identifiable if it is to be excluded from bans on animal by-products such as that imposed by the European Union from 2001.

Fishmeal provides a good source of quality protein for monogastrics and an excellent source of by-pass protein for ruminants. Compared with other sources of plant protein and cereals, fishmeal can also provide a good nutritional source of calcium and phosphorus in animal diets. Meal from fish does not seem to have increased in production over the last 20 or so years and Speedy considered that it is unlikely to do so in present circumstances. Many seas, such as the North Sea, are being seriously over-fished, leading to increasing international restrictions on their exploitation to try to conserve and regenerate fish stocks. There are still underlying concerns about the contamination of fish stocks by pollutants dumped in the oceans, leading to fishmeal contamination for example by dioxin.

The fishing industry is not particularly well developed in many developing countries, and could perhaps make increased contributions to future fishmeal supply in some regions. The significance of increasing supplies of meal from farmed fish and aquaculture systems is possible and deserves evaluation. On a limited scale, in parts of some countries such as Vietnam and Cambodia, waste fishmeal is utilized for further fish pond production and incorporated into local livestock feeds.

### *Animal By-products*

Considerable public and political concern about the safety of foods of animal origin has developed in recent years as a result, in particular, of the bovine spongiform encephalopathy problem but also of food-borne bacterial infections, veterinary drug residues and chemical contamination.

There has been a total ban on the use of mammalian meat and bone meal protein in feed in the European Union since 2001, which may be lifted in due course for non-ruminant feeds. FAO also recommended a global ban (in 2001) on the feeding of MBM to cattle, sheep and goats. MBM is a protein-rich powder derived from the rendering of animal tissues which previously provided very useful and cost effective protein, complementary to grain for animal feed manufacture, whilst also providing a valuable means of animal by-products utilization. It was previously thought that the rendering processes, involving high temperatures to kill microbes, could provide a safe MBM product. This was challenged, however, after the first case of BSE was diagnosed in 1986 in the UK. By December 1997 ruminant MBM in animal feed was identified as the most likely means of BSE transmission.

A new class of infectious agents called prions, with novel modes of replication and transmission, has been discovered. The infection with the BSE agent, a prion, appears to be contracted by the ingestion of nervous or lymphatic tissues in contaminated meat and bone meal feed. Over 180,000 cases of BSE infection have been confirmed in the UK, and more than 1,800 reported from other countries. It is a very serious problem with considerable economic implications.

The BSE crisis has focused attention, in particular, on the rendering industry which processes about 60 million tonnes per year of animal by-products.

Up to 40 percent by weight of an animal is discarded at slaughter, according to Hamilton, and subsequently rendered into high quality fats and protein. Approximately 25 million tonnes of animal by-products are rendered in North America; 15 million tonnes in the European Union, and 10 million tonnes in South America and Australasia, to provide rendered products worth up to 8 billion US dollars annually.

In addition to MBM, rendering produces nutrient rich and easily digestible blood meal, feather meal and poultry by-products for animal feed. These are used in pet foods and aquaculture, in addition to agriculture.

Modern rendering processes can and do kill many pathogens but contamination can readily occur subsequently. Hamilton reported considerable advances in feed mill technology for heat treating feed and feed pasteurization is now possible. These developments would seem the way forward for continuing future utilization of rendered protein for feed manufacture and continuing access to these high quality and cost effective protein materials.

## Current concerns

Significant increases in global demand for livestock products will clearly require increasing amounts of feed protein supplies and sources and alternatives will need to be continually reviewed. There would seem to be strong justification for research and development investment into a number of very promising new sources. What is certain is that there will need to be considerable increases in feed manufacture, requiring a thriving, successful and modern feed industry.

Safety issues will remain paramount in the mind of consumers following recent food crises, and continuing investment is needed in quality assurance programmes to gain market access for animal products and to retain consumer confidence. There is a growing need for transparency in the animal food chain and continuing vigilance.

Greater efforts clearly need to be made to communicate the nature of animal production requirements to the consumer and to project both the animal and feed industry in a positive light.

It is clear that there is considerable potential for improving food security and supply by better protein feed provision to livestock, and these opportunities for improvement deserve to be further explored and supported. Insufficient funding support is provided for research and development. There are also insufficient data and shared information to improve supply chains. More investment in research, data accumulation and information sharing between public and private sectors would be particularly valuable. There is also a continuing need, as always, to provide more support to many developing countries to help appropriate future advances of animal production systems and their associated feeding requirement. Protein provision is a key to their future success globally, and deserves continuing attention.

## Conclusions

### *General Comments*

- It is clear that the feed industry and others must continue to look for alternative and enhanced sources of protein for animal feeds.
- Co-products produced during processing of crops for food (e.g. vegetable oil) and industrial uses (e.g. alcohol) will continue to increase and to be a major source of feed protein; co-products from new methods of processing should be fully exploited for animal feed.
- Nutritionally improved crops produced through genetic modification, by both classical breeding and modern biotechnology might hold tremendous potential to provide significant benefits for animal nutrition. Approval processes are needed, however, to assess genetically modified products for safety before they are introduced to the market.
- Nutritionally enhanced crops have the potential to benefit animal health, growth and performance, to reduce feed costs, to make animal protein more affordable, and to add essential protein to animal diets.
- Modern biotechnology is not the only answer to protein supply, but is one of several important ways or tools of securing sustainable protein production.
- While it is recognized that most of the additional supply of animal products may come from intensive poultry and pig production, cattle, sheep and goats are capable of production on feeds that are high in

complex carbohydrates and not usable in quantity by monogastrics. They offer considerable opportunities for meat and milk production in developing countries.

- With appropriate management, the abundant crop residues and other fibrous materials that are fed to ruminants can provide for reasonable production levels.
- Extension and veterinary services are considered essential to provide better technology transfer, small farmer support and to encourage further protein crop advances.
- Better technology transfer and small farmer support through improved extension and veterinary services are considered essential to promote integrated farming practices. These include intercropping of cereals, legumes, provision of food, feed, and cash crops, integrated use of locally produced co-products in animal production and, ultimately, increased feed protein supplies and their local utilization.
- More research is recommended in the short and medium term on agronomy and the further development of alternative and novel protein crops. More focused support for longer-term strategies of crop improvement, through both breeding advances and genetic manipulation, is urged.
- More meaningful and greater co-operation is advocated between policy-makers, the feed industry, farmers and researchers to better deliver the future protein supply potential.

*Safety issues*

- The increasing importance of both safety and quality aspects of protein products is stressed.
- Safety of animal feed is of paramount importance and codes of practice should be developed and increasingly adopted.
- Ideally, the adoption of voluntary codes of practice for the feed industry is preferable to legislation.
- Each stage of the animal feed manufacturing process should be subjected to Good Manufacturing Practices and/or Hazard Analysis and Critical Control Point (HACCP) principles.
- The feeding of ruminant meat meal to ruminants should be banned everywhere because of the BSE risk. If MBM is banned in domestic

animal feed then exports should also be banned. For countries that cannot enforce a ruminant feed ban, third party auditing is urgently needed.

- There should be full traceability of rendered products, the implementation of a Code of Practice for the rendering industry, as well as good manufacturing practices (GMP) and HACCP. Inspections and checking should be improved and material sources plants should be audited.
- Specialization of feed mills was identified as an important step to avoiding cross-contamination of feed materials, and this is supported by feed industry representatives.
- To ensure safe utilization of fishmeal, cross-contamination with mammalian proteins should be avoided and this should be proved by the development and widespread utilization of tests to differentiate sources of protein.

*Environmental issues*

- Correct protein nutrition is important not only for animal performance, but also to minimize nitrogen excretion and reduce pollution.
- There could be an increasingly serious disposal problem if animal by-products are not to be used for pigs and poultry, or for aquaculture production.
- The use of legume crops, both grain and forage, and their integration within farming systems should be encouraged to counteract soil erosion and loss of soil fertility.

*Information requirements*

- In national and international statistics, ‘Meat meal’ should be reclassified into more detailed categories and by species to provide a clearer picture of production, use and trade. The collection of adequate quantitative and qualitative information on supply and trade is required.
- More information is also required on alternative, locally available plants as sources of protein, to clearly identify the reasons for relatively low adoption. A much greater emphasis is recommended for improving plant protein supply in marginal growing environments.
- FAO should set up ‘country profiles’ of feed production by species and feed resources by countries.