Where in the world will we find the ingredients to feed our livestock by the year 2007?

D.J. Farrell

The Department of Agriculture, The University of Queensland, St Lucia Qld 4067 and
The Queensland Poultry Research and Development Centre, Alexandra Hills Qld 4161

Summary

This paper raises questions about the ability of the feed industry to meet the projected needs of the intensive livestock sector in the next 10 years. The expanding economies in most countries in Asia, coupled with increasing affluence, indicate an increasing demand for poultry meat at about 8% per annum, pig meat at 5% and eggs at 2.5%; a lower growth rate is anticipated for these products in developing countries. Information is taken from different sources and frequently there is some lack of agreement between them. China is the dominant nation and livestock developments there will have a major influence on world feed usage. Difficulties stem from the recognition that in many developing countries the majority of nonruminant livestock are not fed compounded feeds nor intensively housed; calculations made here assume that this situation will change in the future. Countries in Central and South America, particularly Mexico and Brazil, will have a major influence on feed supply and feed demand.

Sources of additional feed are identified, particularly of grain. The US will be the major exporter of feedstuffs in the next few years; this will be achieved through use of several million acres of arable land, which was until recently out of production. The likely increase in the export of maize between 1994 and 2004 is about 29 million tonnes (Mt). The US will also export about 6 Mt of soybean meal by the year 2002. Much of the increase in protein demand will come from oilseed meals, particularly canola, with some increase in grain legumes for feed purposes. Increased use of feed enzymes, free amino acids and diets formulated with reduced crude protein will make greater use of existing ingredients; selection for more livestock–friendly plant proteins, and perhaps greater use of agricultural byproducts will stave off the day when demand will exceed supply. This day will inevitably come on the basis of present predictions about the year 2007. Between 1996 and 2002 the calculated increase in demand for compounded feed will be 126 Mt/year of which grain will be 86 Mt. By the year 2007 total feed usage is estimated to be about 900 Mt/year, of which grain will be 630 Mt. It is difficult to forecast where this additional grain will come from.

Special attention is given to the feed situation in Australia and predictions of the small increase in feed over the next few years. All livestock sectors are expected to grow slowly with dairy cattle showing the highest demand for compounded feed between 1995 and 2000. Grain needs will still be only 10.3 Mt. With global animal industries emerging, and trade barriers being dismantled, it is predicted that the intensive animal industries in Australia will become less competitive and shrink. The demand for Australian feed ingredients, particularly from countries in the Asian region, will greatly increase the demand for these feeds and their cost.

Introduction

'It has been estimated that within 40 years Asia will represent the major share of the wealth of this world and will be richer than North America and Europe put together ... The food requirements will not include more rice or cassava, but products such as wheat, meat, dairy produce, fruit and vegetables as a result of increases in income.'
Professor Derek Tribe speaking at a symposium 'Future of Agriculture' in 1993.

Australia has on its doorstep Asia where there are the most rapidly-expanding economies on a global basis. With increasing affluence there is traditionally rapid demand for animal protein which in turn means an increased requirement for grain and protein ingredients to feed intensively-housed livestock. At this same Symposium series in 1977, Professor G.L. McClymont presented a paper 'Future grain supplies for the intensive animal industry' (McClymont, 1977), recognising that the future of the livestock industry in its present form depends on an adequate supply of grain and other raw materials. The purpose of this paper is to examine this

matter and to speculate about whether it will be possible to meet the projected global demand for eggs, chicken meat and pig meat over the next few years. The impact of this demand on Australia's intensive animal industry will also be examined.

The population of the world will increase by almost one billion during the next five years; the majority of this increase will occur in Asia. By the year 2040 agricultural output will need to triple to meet the demands of the expected 9 billion people (Avery, 1996). The consequence of this will be not only more mouths to feed but also less land to till. Almost all of the world's arable land is now cultivated and increased grain production must come from improved cultivars, irrigation and higher inputs of fertiliser, herbicides and pesticides. The long term sustainability of such a system must be questioned. Sustainability has been defined as 'the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations' (Devendra and Chantalakhana, 1992).

The intensive livestock industry can respond rapidly to demands for high-quality protein (eggs and meat), particularly the poultry industry. In these modern high-intensive industries, the technology is portable and needs to be modified only slightly to meet local needs. Expansion can be rapid provided the resources are available either in-country or, more commonly, from outside. With affluence comes also the demand for bakery products made largely from wheat flour. Thus for some grains, particularly wheat, there will be greater competition for this grain as a food and as a feed.

Although this paper aims to examine changes in feed supply and demand on a global basis, it is logical that greater focus is on Asia because of its proximity to Australia and its enormous human population, almost 60% of the total population of the world. The current world's population of about 5.8 billion is growing at an annual rate of almost 2%. The highest growth rate is in the developing countries, e.g. Africa 3%. A key factor in determining a country's capacity to increase demand for livestock products is its per capita gross national production (GNP). A country with a very low GNP will generally have a small demand for animal protein, while a country with a relatively large GNP will have a comparatively high demand. When GNP increases beyond a certain threshold (about $3,000 US), then the demand for animal products and other consumables starts to increase rapidly (see Table 1). Fischer (1995) cited workers who estimated that a GNP of $1,000 US/year is when consumers start to substitute other foods for rice. The countries which dominate the Asian region are China with a human population of > 1.2 billion and India with > 0.94 billion (Table 1).

In order to estimate current and future compounded feed requirements, particularly grain, it is necessary to examine annual livestock production and projected increases, and from these statistics calculate current and future feed usage. Depending on whose data are used, outcomes may vary considerably. In these calculations, no account is taken of compounded feed used in the beef feedlot and dairy industries. In the future this may be substantial. The projected demand for most animal products in Asia to the year 2020 is given in Table 2.

Livestock Products

Egg production

Of the estimated annual global egg production of 41 million tonnes (Mt) China accounted for 30% (12.3 Mt) followed by the USA with 11% (Anon., 1996a). More

Table 1   Gross national production (GNP), forecast change for 1996 and per capita annual consumption 1995.*

	Annual GNP ($) 1994	Forecast† GNP (%) change (1996)	Population (millions)	Population growth (1990–2000) (%)	Eggs (kg)	Poultry meat (kg)	Pig meat (kg)	Duck meat (g)
Bangladesh	230	5.3	120	2.2	0.6	0.75	—	14
Cambodia	—	6.8	10	2.7	10.0	1.6	7	470
China	530	8.9	1221	1.1	10	5.5	24	1250
India	310	6.5	935	1.8	1.5	0.43	0.5	—
Indonesia	880	6.8	197	1.5	2.1	2.8	1	61
Laos	320	—	5	2.9	7.2	5.9	2	100
Malaysia	3520	8.0	20	3.3	17.4	28.3	15	43
Pakistan	440	6.0	140	2.6	1.8	2.3	—	57
Philippines	960	5.5	68	1.7	3.9	4.9	12	307
Thailand	2210	8.0	59	0.8	7.2	12.7	2	1450
Vietnam	190	9.0	75	1.7	1.8	1.7	10	512

*World Bank and Watt Poultry Statistical Year Book 1996 (Anon., 1996a)
† Asia Development Bank

recent data from the National Statistical Bureau (Anon., 1996b) has put the figure at 15 Mt for China; of this, about 20% comes from waterfowl (Chuang and Quinghua, 1995). The predicted annual increase is 2.1%. In contrast, egg production and consumption in developed countries is showing little increase and in some cases a decline. Because of the change in attitude towards dietary cholesterol by some national health authorities, in the USA for example, there has been a 2% increase in egg consumption over the past two years (Smith, 1996). Grande *et al.* (1994) has forecast a decline over the long term in the USA, but recent data confirm an increase of 2.6% between 1996 and 1997 (Anon., 1997).

Poultry meat

The fastest growing livestock industry in 1997 is chicken meat (broilers and culled hens). World consumption of quality meat is close to 50 Mt (Anon., 1996a); turkey meat was 4.3 Mt. The fastest growing sector is duck meat at >25% in the past two years. This had increased to 2.23 Mt in 1995 (Anon., 1996a). Thus annual world poultry meat production from all avian species should exceed 58 Mt in 1997. The USA is the largest producer with almost 25% of world production, followed by China (15%); Brazil is the third largest producer (3.8 Mt) and, like the USA, exports a substantial part of its production. Almost 54% of all turkey is produced meat in the USA and almost 70% of all duck meat is consumed in China.

Pig meat

Of the world meat production of 200 Mt in 1995, pig meat accounted for 84 Mt, with beef and chicken each contributing about 54 Mt (Anon., 1996c). The world pig population is close to 950 million; almost half of the pigs are found in Asia, and of these >400 million are in China. Predominantly Muslin countries such as Malaysia (2.7 million) and Indonesia (7.0 million) have significant numbers. Estimated pig numbers in India, a predominantly vegetarian society, is about 10 million. Vietnam and Japan also have populations of >11 million

pigs. Recently the National Statistical Bureau of China gave a per capita consumption of pig meat as a remarkably large 26.7 kg/year (30 Mt) or 43% of the world pig meat produced (Anon., 1996c).

Forecasting feedingstuff requirements

The difficulty in attempting to estimate the quantity of feed ingredients now needed and make predictions for the future depends on how many animals are intensively-housed and how many are kept in extensive, traditional backyard systems. For example, in China, it is estimated that only 20% of pigs are in modern production systems and less than 50% of poultry, although this situation is changing rapidly. Native chicken products are generally more popular than those from improved breeds. Most of the ducks produced in Asia are in association with wet-land rice production and like other livestock are held out–of–doors; most receive only small amounts of additional feed. Faylon and Roxas (1995) reported that 72% of chickens, 82% of pigs and 91% of ducks were kept in the traditional backyard systems in the Philippines, as opposed to commercial conditions. In China, Chuang and Quinghua (1995) emphasised the strong consumer preference for meat of the native breeds and estimated that of the 3.3 8 billion layers there are one billion native chickens kept for meat and eggs although their annual egg production is only 3 kg/bird. Van der Sluis (1995) has categorised Indonesian poultry into intensive and backyard farming systems with the latter accounting for 30% of layers and 20% of broilers (Soejoedano, 1996). Over 95% of village (native) chickens are unmanaged. The accuracy of these data is uncertain but it is estimated that in Indonesia, scavenging native chickens number >200 million, and in 1994 native chickens contributed 20% to total egg production and ducks 2 1%. A major difficulty is to define village poultry production. There are small–scale rural poultry producers who use modern husbandry and genotypes, purchase compounded feed and make a substantial contribution to national meat and egg production in many developing countries.

Table 2 Projected per capita demand for livestock products in Asia (kg/year)*

Year	South Asia			South-East Asia			East Asia (excluding Japan)		
	1990	2010	2020	1990	2010	2020	1990	2010	2020
Products									
Beef	1.2	1.4	1.5	2.5	4.5	6.0	1.3	2.3	3.1
Pig	0.3	0.4	0.4	5.5	8.6	10.5	18.8	30.6	38.2
Sheep meat	1.0	1.1	1.2	0.3	0.5	0.7	0.7	1.0	1.2
Poultry meat	0.5	0.6	0.7	4.2	6.9	8.5	3.0	5.2	6.5
Eggs	1.3	1.6	1.8	3.3	5.5	7.0	6.8	10.9	13.6
Milk	63.4	84.9	95.3	3.2	3.8	3.5	7.7	9.3	10.2

*Rosegrant *et al.* (1995)

Pressure is often exerted by the large commercial chicken operations to squeeze out the small fanner, largely by reducing greatly the price of chicken meat in the market place (Soejoedono, 1996).

It is generally accepted that the bulk of the increase in demand for non-ruminant livestock products will come from developing countries. Although chicken meat consumption is increasing in developed countries, demand is slowing down and egg production is showing almost no growth. However, very recent figures (*Poultry World*, January 1997) for the European Union showed an increase in numbers of layers of 6.8% and of broilers of 3.5% between 1995 and 1996.

In order to project feed demand over the next 10 years it is assumed that the bulk of the increase will come from developing countries. Conservative annual increases are 8% for chicken meat, 5% for pig meat and 2.5% for eggs (see Table 3). Corresponding figures for developed countries are 2%, 1.5% and 0.25%. As has been shown in several developing countries, the lower the GNP the higher the rate of increase that can be expected. Countries such as India, currently with a per capita consumption of 0.4 kg of chicken meat/year, are likely to increase on a percent basis at a more rapid rate than Malaysia (28.3 kg) or Thailand (8 kg) for example. The former USSR has shown a sharp decline in intensive livestock production during the past five to six years and any marked upturn in the future will impact heavily on feed demand; this cannot be considered in present calculations. Between 1990 and 1993, compounded feed declined by 36 Mt/year in the former Soviet Union. Egg production continues to decline slowly (Anon., 1997).

If Japan, Korea and Taiwan are considered to be developed countries, there is an almost equal split for egg and chicken meat production between developed and developing countries. For turkey meat, the division is 95% for developed countries and for duck meat 45%.

This means that of the 58 Mt of poultry meat produced, 30 Mt will be in developed countries (52%) and 28 Mt in developing countries (Anon., 1996a). These divisions are in line with those of Chantalkhana (1996) for Asia and the Pacific region.

Calculations of Current and Future Feed Requirements

The simplest way, initially, to calculate feed demand is to take current production statistics using standard feed conversion data and where necessary adjust for meat yield of killed animals. Certain assumptions may be made about the maintenance cost of breeding stock; this can then be included in the feed efficiency figure for each species. The estimates made here are conservative and probably underestimate true feed demand. The grain component of the compounded feed has been assumed to be 70, 75 and 65% for pigs, broilers and layers and feed conversion ratios used are 2.7: 1, 2.0: 1 and 2.5: 1, respectively. On the basis of current information already discussed, it was possible to partition roughly the contribution of developing and developed countries to world total production for each livestock commodity. Projections over the next five years (1997-2002) are also conservative with predicted increases varying according to livestock species and whether the increase is occurring in developed or developing countries. Details and results are given in Table 4. The total projected increase is 126 Mt of which the grain component is 86 Mt by the year 2002; of this 64 Mt will be produced by developing countries.

If this rate of increase in demand for pig and poultry products continues at the same rate for a further five years, i.e. to the year 2007, feed demand will be grater by 261 Mt than in 1997; the grain component of this

Table 3 Human population and hen **egg** and chicken output between **1990** and 1994 in some Southeast Asian countries and expected increases to the year 2000.

Country	Human population (millions)		Annual growth	Egg output (millions)		Annual growth output	Chicken meat (tonnes)		Annual growth
	1990	2000	(%)	1990	1994	(%)	1990	1994	(%)
Cambodia	9	12	+ 2.7	220	266	+ 4.9	20	25	+ 5.7
Indonesia	183	213	+ 1.5	8115	9697	+ 3.5	473	576	+ 5.0
Laos	4	6	+ 2.9	753	821	+ 2.2	24	28	+ 3.9
Malaysia	18	22	+ 2.2	5029	6445	+ 6.4	304	606	+ 18.8
Myanmar	42	52	+ 2.1	728	825	+ 3.2	75	82	+ 2.3
Philippines	61	75	+ 2.0	5560	5501	+ 0.3	261	328	+ 5.9
Singapore	3	3	+ 0.9	365	311	- 4.0	66	60	- 2.4
Thailand	56	62	+ 1.1	8165	7330	- 2.7	530	740	+ 8.7
Vietnam	67	83	+ 2.1	1896	2352	+ 5.5	130	122	- 1.6
Total	443	528	+ 1.8	3116	33548	+ 1.8	1883	2567	+ 8.1

Source: FAO (1994)

shortfall will be will contribute 183 Mt. Using the same projections, total annual compounded feed usage will be almost 900 Mt by the year 2007 and of this 630 Mt will be grain. Cereal grains make the major contribution to compounded feed; a rule of thumb suggests that the split is 70% for pigs, 65% for layers and 75% for broilers (Table 4); while the balance is mainly protein-rich ingredients and agricultural byproducts. It should be emphasized that these calculations assume that all non–ruminant livestock are now, and will in the future be fed compounded diets.

Compounded Feed Production

One estimate of the current global production of compounded feed is about 528 Mt/year (Table 5). This figure is based on a report by Rabobank, The Netherlands (Anon. 1996c) but the data are about four years old. Tonnage was divided equally among pigs, poultry and cattle with 10% for other animals (pets, minor livestock species *etc.).* More recent estimates (Meyers Feed Grains Study Report, 1995) put the total figure at 600 Mt. In 1993 the largest single producers were the USA and the European Union each with 115 Mt; China produced 47.5 Mt. Feed International (November 1996) estimated 52 Mt for 1996 for China, with projections to reach 117 Mt by 20 10. In 1993 about 70% of all compounded feed was produced in developed countries. Production in South America is increasing at a rapid rate and is now close to 35 Mt/year with Brazil the dominant producer (>23 Mt).

Many countries with large intensive livestock industries such as Saudi Arabia, Taiwan, Japan, Korea, Malaysia and Mexico are consistently net importers of animal feed ingredients and are therefore vulnerable to price changes through supply and demand. Countries such as China and Thailand which were, until recently, net exporters of feed grains are now importers. Several countries that have variable crop production may sometimes have to import feed grain (e.g. Indonesia). Recently Australia imported grain sorghum because of greatly reduced grain production, and is a consistent importer of soybean meal (0.3 Mt/year).

There is clearly a discrepancy between reported compounded feed produced (Table 5) and that estimated (Table 4). Even if it is accepted that current production is 600 Mt/year (Meyers Feed Grains Study Report, 1995) which covers all livestock species there is still a shortfall

Table 5 World feed production (millions of metric tonnes) for 1994 (Rabobank, 1995 report on world compounded feed industry, Anon., 1996e).

European Union	115
Former European Free Trade Association	8
Central Europe	23
Former Soviet Union	60
USA	115
Canada	17
Mexico	12
Asia	50
China	48
Japan	26
Brazil	19
Latin America	15
Middle East and Africa	20

Table 4 Estimates of current (1997) pig and poultry production, feed and grain requirement forecasts after five years (1997 to 2002) for developed and developing countries.

World production	Poultry production				Feed requirement (Mt/year)			
	Developed		Developing		Developed		Developing	
	%	Mt	%	Mt	feed	grain	feed	grain
Pig meat now 97 Mt*	50.0	48.5	50.0	48.5	180	130	186	130
5 year annual increase	1.5	52.2	5.0	62.0	200	140	237	166
Poultry meat now 58 Mt†	52.0	30.0	48.0	28 .0	85	64	79	59
5 year annual increase	4.0	35.4	8.0	38.7	100	75	110	82
Layers eggs now‡ 41 Mt	50.0	20.5	50.0	20.5	51	33	51	33
5 year annual increase	0.25	20.7	2.5.0	23.2	53	34	58	38
1997 Total					316	277	316	222
2002 Total					353	249	405	286
Change over 5 years					37	22	89	64

*Pigs: FCR 2.7, killing out percent 71; grain 70% of feed
†Poultry: FCR 2.0, killing out percent 71; grain 75% of feed
‡Layers: FCR 2.5, grain 65% of feed

of about 30 Mt. The discrepancy appears to lie with the developing countries whose current production is estimated to be the same as that of developed countries (Table 4). Production in 1993 put the breakdown at 70% for developed countries and only 30% for developing countries (Rabobank Report, 1995). Since then the situation has changed considerably with China alone increasing production by 5 Mt in the past three years. The Meyers Feed Grains Study Report 1995 (p. 119) expected compound feed in China to reach >100 Mt by the year *2000.*

Of the total compounded feed produced only 60% was for pigs and poultry in 1993; this would reduce world production to not more than 360 Mt/year for these species. A major reason for the discrepancy between values in Table 5 and other estimates lies in the assumption that all pigs and poultry are raised intensively and fed on concentrate feed. As discussed previously, this is not the case in many developing countries, particularly in Asia and Africa. Nevertheless the estimated increase from 1997 of 126 Mt of feed to the year 2002 and 261 Mt by 2007 will be given almost exclusively to intensively-housed, modem genotypes. It is this sector that is growing most rapidly to meet consumer demand. It is also recognised that extensively-managed livestock and those held in confinement in backyard production systems are supplemented with grain and other ingredients.

Where will the Increased Feed Come From?

Grain production is forecast to grow at a much slower rate than demand. The cost of production will rise with further damage to the environment (Leng, 1995). Some of this additional grain will be used to feed the increase in population particularly through the demand for wheat flour by an expanding affluent middle class in developing countries. A considerable amount of grain is now used in the production of ethanol in some countries (e.g. China, Brazil). The Meyers Feed Grains Study Report 1995 (Table 9.2) estimated import requirements of key countries would increase by 20 Mt between 1993 and 2003. This has probably already been surpassed.

USA is the dominant provider of grain and protein concentrate and much of the world's poultry and pig production is dependent on a supply of maize and soybean meal. In the short term, this will come mainly through the use of tens of millions of acres of arable land that until recently has been held in a Conservation Reserve and out of production in the US through government policy (Avery, 1996). The continued thrust to produce more grain and other plant feed ingredients for livestock leads to the destabilisation of the agricultural ecosystem. Water pollution and atmospheric pollution are now serious problems and the clearing of forest land for arable farming is having undesirable consequences (Leng, 1995).

US Grains Council (1995) forecasts exports of maize to increase by 29 Mt from 33 Mt in 1993/94 to 62 Mt in 2003/4. This increase may account therefore for half of the predicted demand by the year 2002 and assumes average yields. Countries such as Argentina are expected to increase exports of maize by 2 Mt during the same period. This will be traded mainly within South America and quite clearly much of the increase must come from improved production technology and reduced wastage. The Meyers Feed Grains Study Report (1995, p. 192) estimates losses of as much as 25% of the grain crop in China with inefficiencies in several areas. Thus there is capacity through improved technology to increase grain production without any expansion in land usage or additional fertilisers or chemicals.

China is the dominant player in world grain demand. The Meyers Feed Grain Study Report (1995, p. 122) forecast that for feed grains, the need will be around 142 Mt/year by the year 2000. If the production of compounded feed estimated for 1996 is only about 52 Mt/year in China (Anon., 1996a) it is quite clear that less than one third of feed grains are used there in manufactured feed. If these figures are correct substantial amounts of grain are not included in compounded feed but given directly to pigs and poultry. China is already a net importer of grain and will depend increasingly on imports in the immediate future.

Although the European Union provides 26% of world grain supply, production is declining and exports are shrinking although forecast to be 4 Mt by the year 2002 (US Feed Grains Forecast Council 1995) or only 2 Mt in the Meyers Feed Grains Study Report (1995).

Soybean meal is the most commonly used source of protein in diets of pigs and poultry. Of the world's 115 Mt annual production, the major producers of soybeans are USA (50 Mt), Brazil (24.5 Mt), Argentina (12 Mt) and China (15 Mt). USA is the major exporter and is expected to export 60 Mt by the year 2002 (US Feed Grains Council, 1995). This is only a small increase over 1994-1995 and is not likely to contribute much to the predicted demand. Other oil seed meal production particularly canola and sunflower as well as some grain legumes will increase significantly. China and some other countries do not have access to low uric acid and low glucosinolate cultivars of canola seed but this situation is currently being examined and will change. As a consequence there will be a large increase in usage of 'canola' (rapeseed) in China.

There are several additional factors which may increase the demand for feedingstuffs. Most of the early forecasts of demand for pigs and poultry were too conservative. Changes in public perception and some unfortunate developments have contributed to this, e.g. the consequence of 'mad cow' disease, bovine *spongiform encephalopathy* (BSE) in the UK. New cultivars, improved cultivation technology, use of fertilizers, pesticides and herbicides have improved grain yield and these are likely to continue to do so in the short term. These all contribute to increased production costs.

The impact of BSE will have profound consequences in the short-term on demand for other livestock products. European demand for beef has decreased by about 15%. M. Sloyan of MLC (UK) forecast 24 percent increase in spending on chicken and turkey meats between 1996 and 1998; this will impact heavily on feed demand (Anon., 1996f). In the UK, MAFF's recent national survey saw a decline in beef and veal consumption of 25 percent; there was an increase in other livestock products, particularly sheep meat, to meet this decline. More importantly, because of a ban, there has been a 98% reduction in meat and bone meal in the UK, and this meal will no longer be acceptable in diets of poultry and pigs (Bedford, 1996). Not only is there an estimated production of 6 Mt of meat and bone meal/year in Europe and the US, but poultry offal meal is commonly used in poultry diets. These protein sources may well disappear in the future, putting more pressure on vegetable protein supplies. There has been an estimated increase in use of protein concentrates of 38 percent in the UK (Bedford, 1996). An increase in the price of soybeans of $70/t over the last 14 months has put up the cost of compounded feeds by $20/t in the UK despite a decline in cereal grain prices.

Duck production for eggs and meat is currently increasing, the latter by over 25 percent during the last two years putting a further strain on feed resources. Although numbers are still relatively small, the expansion is occurring mainly in Asia.

It seems that the capacity of the USA and other countries to meet projected grain demands, together with China's ability to increase grain yield and reduce wastage, may see the intensive livestock industries survive in their present form until the year 2002. Beyond this, it is difficult to see how supply can keep pace with demand for a further 135 Mt of compounded feed per year by 2007; of this 95 Mt will be grain.

Better Use of Existing Feed and Other Strategies

Additional steps that are likely to be taken initially to meet the increased demand for feedingstuffs will include wider use of feed enzymes to increase energy yield, mainly from cereal grains, and to enhance protein digestibility. About 20 percent of dry matter in poultry excreta and pig faeces is potentially useful but now unavailable mainly because of the inadequate digestive system of these species. Greater use of synthetic amino acids will allow dietary protein to be more efficiently utilised through better amino acid balance with a reduction in dietary protein and in nitrogen excretion. Feed phytase has been shown not only to release bound plant phosphorus but also some other nutrients. Reductions in nitrogen and phosphorus are seen as environmentally friendly but these initiatives will take time in developing countries. Reduction in

antinutritional factors through plant breeding and/or treatment will give the feed manufacturer a wider range of alternative feedingstuffs, in particular some grain legumes. Sweet lupins for example can be grown on very sandy marginal land in dry regions; they also provide valuable nitrogen to the soil but they are high in the oligosaccharides which can cause unacceptably wet excreta. Relaxing of nutritional constraints for livestock will allow a wider choice of feed ingredients at least cost in diet formulation; even though animal production may not be maximal it may well be economically optimal. According to Avery (1996), the U.S. Food and Drug Administration in the near future will approve pig growth hormone (slow release) giving 15% more carcass protein and less fat on 25% less feed. The public perception of such biotechnological developments is not always positive.

There will likely be attempts to bring useful marginal land into cultivation to produce high yielding starchy tubers such as cassava. These will provide alternative sources of energy and are already included in some diet formulations. Agricultural byproducts, particularly rice bran, now produced in large quantities (about 45 Mt/year) will be used widely and particularly for pigs and ducks. There is a need to improve its nutritional value as well as to slow down lipid oxidation causing rancidity. Much depends on the ability of the large feed mills to handle and incorporate these alternative feeds into compounded diets.

It is inevitable that conventional feed supplies will not meet projected demand much beyond the next five years (Table 4). Even though alternative ingredients and other strategies will be put into place to meet the needs of the highly intensive modem livestock industry, this will eventually be unsustainable. What will the consequences be? First, supply and demand factors with force ingredient continue to rise through resulting in higher grain and compounded feed prices. This will in turn mean that the price of eggs, poultry meat and pig meat will increase and demand will decline. As this demand falls, the high technology, high producing modem units maybe replaced by alternative production systems. In short, modem systems will start to become less sustainable beyond the year 2002 given the conservative forecasts for product demand over the next five years, simply because the traditional livestock feed resources will become limiting. Countries that will be hardest hit, initially, will be those that have only small reserves of foreign currency with large populations and small capacity to increase crop production such as India, Vietnam, Bangladesh and those importing large quantities of feedstuffs such as Malaysia, Korea, Japan.

The Australian Feed Industry

The production of the global grain industry fluctuates from year to year and nowhere does this occur more frequently than in Australia. The price of wheat

fluctuates with these changes. World wheat production for 1996 was about 560 Mt and coarse grain production was *876* Mt *(Australian Grain* 1995). A record harvest in Australia (about 30 Mt) in 1996-97 contrasts with some previous harvests producing as low as 15 Mt. Wheat production in Argentina has increased from 9 Mt in 1995 to 16 Mt in 1996. As a consequence the price of feed wheat has declined from about $260/t to $180/t ex–farm in early 1997. The predicted demand for feed grams for each of the major livestock sectors in Australia is shown in Table 6. (Meyers Feed Grains Report 1995).

This demand is forecast to increase from 8.4 Mt in 1995-96 to 10.3 Mt in 1999/00. Feed wheat is typically about 12% of wheat production but is likely to be only 6% in 1996-97. The cattle industries (beef and dairy) currently use 40% of the feed grain with pigs and poultry sharing 44% (Table 6). Recent figures from the Australian Bureau of Statistics showed that all livestock products declined over the past year by as much as 14% for mutton, 6% for pork and 3% for poultry meat during 1995-96. Thus the feed grain forecasts (Table 6) may already be too generous. The breakdown of the different feed grains and their contribution to feed usage in Australia and forecast to the year 2000 is given in Table 7. Interestingly barley is the most widely used feed grain. In 1995-96, of the three major grains wheat contributed 40% to the total (Table 7)

The uncertainty of the status of cooked chicken meat importation looms heavily over the industry. On a global basis, the Australian chicken meat industry is not competitive, in part due to scale of production. The General Agreement on Trade and Tariffs (GATT) will eventually create a level playing field such that importation of livestock products and export of feed ingredients will occur freely and without trade tariffs.

As discussed in previous sections of this paper, the enormous predicted demand for feed ingredients, particularly from Asia, will result in increased demand and higher prices for Australian feedstuffs. As a consequence of this prices will be higher for poultry products. The Australian pig and poultry industries are

not particularly efficient. There are several reasons for this. Economy of scale cannot be compared with much larger operations in Brazil, the US and Thailand for example. Labour in many of these countries is much cheaper than here. Importation of pig meat is already happening in Australia and chicken meat must inevitably follow. Importation of new strains of broiler breeders and laying stock has brought with it a number of problems; not least are some diseases and poor reproduction. The consequence has been high layer mortality, high costs of chicks at the hatchery, shortage of poultry products and increased prices. Furthermore the grain growers are usually some distance from the livestock production units. Transport will likely not get any cheaper and this will add to feed costs. In short, the intensive livestock industries will become less competitive into the next millennium. The long-term prognosis is that the industry in Australia will shrink considerably due to reduced demand and greater importation of these meat products. The layer industry will probably survive and perhaps show a small expansion as is occurring now in the US but this industry in Australia uses comparatively little feed, <1 Mt per year.

Already many of the recent predictions used in this paper are obsolete. Current projections (Anon., 1997) show the need to upgrade these. By the year 2010 per capita consumption of meat and eggs in China is expected to reach 50 kg and 15 kg respectively. Egg production is increasing in many countries at 4.5% per year.

On a global basis, the supply and demand for feedstuffs will be such that the projected expansion for livestock production, particularly for poultry and pigs, will not be sustainable, and forecasts will need to be downgraded. Avery (1996) concluded from his assessment of the future of the poultry industry: 'There will be continual competition in quality and efficiencies over the years. Those who achieve them will reap the rewards. Those who don't will disappear from the industry.'

Table 6   Predicted demand for feed grain in Australia by livestock type (Meyers Feed Grains Study Report, 1995).

	1995-96	**1996-97**	**1997-98**	**1998-99**	**1999/00**
Pigs (%)	20	19	19	18	18
Poultry (%)	24	24	23	22	22
Beef cattle (%)	24	25	25	26	26
Dairy cattle (%)	16	17	18	19	20
Sheep (%)	5	5	5	5	5
Others (%)	11	11	10	10	10
Total feed grain (Mt)	8.44	8.92	9.41	9.85	10.31

Table 7 Total feed usage in Australia by grain components (kt = 1 000 metric tonnes) (Meyers Feed Grains Study Report, 1995)

	1995/96	1996/97	1997/98	1998/99	1999/00
Wheat (kt)	1897	1965	2060	2140	2220
Barley (kt)	2095	2075	2219	2347	2485
Sorghum (kt)	886	1142	1214	1278	1347
Other coarse grains (kt)	1675	1756	1838	1915	1994
Bran/pollard/offals (kt)	507	540	573	602	633
Total cereals (kt)	7060	7479	7904	8282	8679
Percent growth	4	6	6	5	5
Lupins and other beans (kt)	510	534	559	581	605
Field and other peas (kt)	183	191	198	203	207
Total pulses (kt)	693	726	757	784	813
Percent growth	4	5	4	4	4
Soybean meal (kt)	230	254	263	282	300
Canola meal (kt)	133	139	145	150	154
Other grain meal (kt)	200	209	215	219	223
Total grain meals (kt)	563	602	624	651	677
Percent growth	6	7	4	4	4
Cotton seed (kt)	110	117	126	134	144
Total feedgrain (kt)	8426	8923	9411	9852	10312
Percent growth	4	6	5	5	5
Other protein meals (kt)	576	598	615	626	636
Roughage and additives (kt)	8783	8765	8753	8742	8720
Total feed (kt)	17785	18286	18779	19220	19668
Percent growth	2	3	3	2	2

References

Anonymous (1995a) *Poultry World* **11** (1 1), 25.

Anonymous (1995b). *Poultry International 3* (4), *32-36.*

Anonymous (1995d). *Feeding Times* **1** (4), 20–22.

Anonymous (1996a). Watt Poultry Statistical Yearbook 1996. Feed International November 1996 p. 50. *Poultry International 35,* (8), *4-55.*

Anonymous (1996b). *Poultry International 35,* (13), 20.

Anonymous (1996c) *Poultry International 35* (14), 10.

Anonymous (1996d). *Poultry International 35,* (5), *8.*

Anonymous (1996e) Feeding Times **1** (4), **20-22.**

Anonymous (1996f). *Poultry World*, October 1996, p. 17.

Anonymous (1997). *Poultry International 36* (1), p. 8.

(Australian Grain 1995, **6** [4], p. 30
Avery, D.T. (1996). Can the world afford poultry for 9 million people? *Proceedings Arkansas Nutrition Conference,* Arkansas, pp. 45-56.

Bedford, M. (1996). Making the most of meat and bone alternatives. *Poultry World,* October 1996 p. 19.

Chantalakhana, C. (1996). Unpublished paper presented to the Australian Society of Animal Production, Brisbane, July 8-12 1996.

Chuang, M. and *Quinghua,* Z. (1995). *World Poultry* **11** (1 1), 23-26.

Devendra, D. and Chantalakhana, C. (1992). Development of sustainable crop-animal systems in Asia. *Proceedings of the 6th AAAP Animal Science Congress,* Vol. 1, pp. 21-32. Animal Husbandry Association of Thailand, Bangkok.

Faylon, P.S. and Roscos, D.B. (1995). Proceedings of the Consultation for the South–East Asia Region, pp. 147-172. IRRI, Los Banos, The Philippines.

Fischer, K.S. (1995). *Proceedings of the Consultation for the South-East Asia Region,* pp. 91-104. IRRI, Los Banos, The Philippines.

Grande, J. Hoack, J.R. and Olson, K.D. (1994). Projected consumption of livestock products. Staff Paper, pp. *94-8, Department of Agricultural and Applied Economics,* University of Minnesota: St Paul.

Leng, R.A. (1995). In: *Recent Advances in Animal Nutrition in Australia 1995,* pp. 149-159 (Eds. J.B. Rowe and J. V. Nolan). Department of Animal Science, University of New England: Armidale.

McClymont, GL. (1977). In: *Recent Advances in Animal Nutrition in Australia 1977,* pp. 1–15 (Ed. D.J. Farrell), The University of New England: Armidale.

McMahon, M. (1995). Poultr-Where in the first century? *First Poultry Industry Seminar, Melbourne, June 30, 1995.*

Meyers Feed Grains Report 1995.

Rosegrant, M.W., Agcaoili, M. and Perez, N. (1995). In: *Proceedings Final Workshop on Regional Projections and Policy Implications and Long-term Rice Supply and Demand.* p. 70. Beijing, China.

Smith, R. (1996). *Feedstuffs* **8** (50), p. 26.

Soejoedano, R.R. (1996). *Poultry International 35* (13), 22.

van der Sluis, W. (1995). *World Poultry* **11 (8),** 10-14.