Biotechnology in Animal Feeds and Animal Feeding

Edited by
R. John Wallace and Andrew Chesson

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Preface

The problems faced by livestock producers and feed suppliers have probably never been greater. In most developed countries a static or falling demand for red meat coupled with downward pressure on prices exerted by the major retail buyers have meant that margins for the producer are ever smaller. In stark contrast, in many parts of the developing world the continuing shortage of feed of sufficient quality to allow even a modest production benefit means that animal products still contribute little to local food needs. Biotechnology offers hope for the amelioration of both of these extremes. In its more traditional guise of products from the fermentation industry, biotechnology already contributes much in the developed world to better diet formulation and to the provision of prophylactic agents that promote efficiency of feed conversion. This is set to continue and develop. Although the more traditional forms of biotechnology have had limited impact on livestock production in non-industrialised societies, recombinant DNA technology has the potential to extend the benefits of biotechnology and alleviate some of the many problems faced by livestock producers in these more deprived areas.

Biotechnology, and particularly genetic engineering, is viewed with concern by some. Public attitudes surveys still show that up to half of the national populations of countries of the European Union and the United States either are undecided about the merits of biotechnology or believe that biotechnology will adversely affect their lives. These concerns are reflected in legislation and, as a result, the statutes governing the introduction of products are more tightly drawn, more demanding in terms of proof of safety and more expensive to satisfy. The many vicissitudes surrounding the introduction of bovine and porcine somatotrophin well illustrates some of the present difficulties faced by manufacturers wishing to introduce engineered products. It is inevitable that public opinion will continue to influence the rate of development and introduction of new products. However public appreciation of biotechnology is not consistent. Applied to pollution control and bioremediation or to a reduction in the use of antibiotics, biotechnology is seen to offer solutions rather than problems. Consequently, products which have, or can be given a green image, or which do not directly impact on the human food supply are less likely to attract adverse attention. The registration of the enzyme phytase, one of the first products of genetic engineering introduced for use as a feed additive within the European Union, caused few problems. As a gene product it avoided the more stringent scrutiny applied to the release of genetically modified organisms and its intended use in reducing the need for added phosphorus in diets was seen by legislators to provide a solution to an acute environmental problem.

This book focuses on the application of biotechnology to animal feeds and feeding, deliberately avoiding the far more contentious issues surrounding the application of biotechnology to the animal itself. If this is a somewhat pragmatic stance, it reflects the editors views on which areas of current practice will develop and which areas of research are sufficiently well advanced to allow the early introduction of products. In this respect the book is intended to provide a guide to the possible and the practical in animal feeding. Despite this immediacy in the selection of

topics for inclusion in this book, new possibilities have emerged during the time taken for its preparation and production. Two subjects of current interest to ruminant nutritionists are protected dietary peptides for use both as signal molecules and as a potential means of directed nutrition of the mammary gland, and the application of biotechnology to "by-pass" starch. Of more general interest is the potential use of oligosaccharides, particularly those of microbial origin, as agents able to stimulate a local and systemic immune response and the provision of minerals in organic form as more readily absorbed "bioplexes".

It is a mark of the vitality of the animal feed and animal production industries that developments move so rapidly from laboratory to field to become incorporated into the mainstream of production knowledge.

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1 Biotechnology in animal feeds and animal feeding: an overview

Frederick George Perry

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INTRODUCTION

Malnutrition affects about half a billion people throughout the world and a further 1.5 billion are undernourished or do not eat a properly balanced diet. Food shortages will become an ever increasing problem unless agricultural output can keep pace with population growth (Fig. 1). Animal products are crucial in this regard. They provide foods of high nutritive value, including milk, meat and eggs. In the case of ruminants in particular these products are formed from feedstuffs, such as forages and industrial by-products, that are not suitable for human consumption. Although biotechnology has been a component of the animal feed industry for many years it is essential that maximum use is made of the recent advances, notably in genetic engineering, to provide the increased production of animals and their products that will meet the needs of the human population in the coming decades.

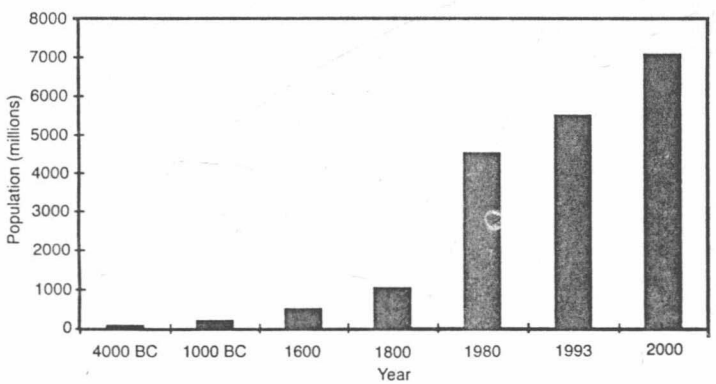

Figure 1. Growth of world population.

Improving the world supply of animal products generally means some form of intensification of animal production, although not all parts of the world are equally capable of adapting themselves to this challenge. There is no doubt that animal production in the Western World has improved over the last 30 years, in some cases quite dramatically (Table 1). Milk production per cow has improved in Europe by around 70%, most of this increase occurring in the last 10 years (Anon, 1992). Average milk yield per cow in Denmark and Netherlands, in 1991, was already in excess of 6200 kg per cow. Similar dramatic improvements have occurred in egg production. In pig meat production improvements have not been quite so dramatic, nonetheless increases approaching 50% have been achieved. Although the rate of improvement is showing signs of slowing down in the last decade, scope for improvement still exists in many countries. For example, in Greece, Spain and Portugal, milk yields are around

Table 1. Improvement in animal production over the last 30 years.

	Year			Improvement
	1960	1980	1990	
Milk production per cow (kg year^{-1})	3395	4400	6000	77%
Egg production per bird (year^{-1})	157	242	290	85%
Swine production				
Average daily weight gain (g)	450	600	630	40%
Feed efficiency (kg compound feed to yield 1 kg meat)	4.5	3.4	2.4	46%
Broilers				
Days to reach 2 kg liveweight	78	52	40	49%

3500 kg. While genetics and better management have contributed, improved nutrition of the cows, aided by the greater knowledge and understanding of the use of additives to the feed, many of which are produced by biotechnological processes, will have had a major role in achieving these results. Table 1 shows the effects of improvements in animal production under intensive conditions. It should be remembered, however, that large areas of the world have little or no choice other than to keep animals under extensive conditions. This usually means some form of roughage, often poor quality natural grasses, which are incapable of sustaining high levels of production. These feeds are never complete diets, lacking in trace elements, vitamins and major minerals such as phosphorus, as well as the animals being at some risk to a substantial parasitic burden. A well balanced, good quality feed is needed at all times for efficient production; a full stomach is simply not enough. For more detail of these issues, the reader is referred to Ørskov (1993), who describes the biotechnological constraints and possibilities in those nations desperately in need of better animal production.

FEED ADDITIVES

What are they?

Additives are now available in various forms ranging from direct-fed to slow release boluses which can substantially improve the efficiency of the diet, including low quality feeds, thereby improving animal production output for the local population. Biotechnology has been a significant contributor to the development of additives which help improve efficiency in both intensive and extensive forms of animal production. The range of additives used in the animal production industry is very broad, ranging from vitamins, trace minerals, growth promoters, disease preventing agents and auxiliary substances which, although not essential from the point of view of nutrition, have played a role in improving palatability, physical characteristics and preventing rancidity of the feed (Table 2).

Table 2. Classes of additives affecting efficiency of livestock production.

Supplements	Auxiliary substances	Disease preventing agents	Growth promoters
Vitamins	Antioxidants	Coccidiostats	Chemical
Trace elements	Flavours	Additives preventing	- ionophores
Amino acids	Emulsifiers	blackhead in	- antibiotics
Non-protein N	Free-flowing agents	turkeys	Biological
	Preservatives		- probiotics
	Pelleting additives		- enzymes
			- oligosaccharides

Consumer awareness

The addition of new additives to the list can take up to ten years or more, particularly with the exacting needs of toxicity testing and national and international registration requirements (Chapter 2). We can expect these regulations to increase, not only to protect the livestock and the farmer but also to impose safety standards which effectively ensure that food products from our animals are completely fit for human consumption. What the consumer wants from our end products will increasingly dictate our attitude to the way we feed our farm livestock.

Concern about the safety of the food we eat has increased, and will continue to increase, at least in the developed world. Food constitutes the inner environment of the human body and greater attention is now given to the involvement of our diet as a major factor in the development of a number of conditions affecting our health. This will undoubtedly lead to a call for animal products of different composition from those provided by the animal feed industry today. Biotechnological developments are beginning to address these issues. However, there will be problems of consumer acceptance. Some will say that such resultant products are far from natural, in much the same way some people distrust eggs from battery hens. We have yet to see the same distrust develop for stone ground flour from the modern genetically selected high yielding short straw varieties of wheat. This is a clear message to those involved in the biotechnological changes that affect the animal feed industry. Having satisfied the legislative, economic, toxicological and social requirements, they must ensure the consumer has confidence in the end product if they are to be successful in their mission.

At the present time we are used to seeing such headlines as "Biotech Comes of Age" and there is no doubt biotechnology already is having an impact on animal production, but it does bring its problems and dilemmas. For example, in Europe there are already substantial surpluses of some of the very products these biotechnology developments will assist with in greater production. Some, however, will result in lowered costs of production with no change in output and will thus become acceptable by making their contribution to better profitability of the industry.

THE DIET

Major feedstuffs

The majority of industrial animal feed formulations are composed of plant derived materials. Cereals and their by-products from various industries are the major components, followed by

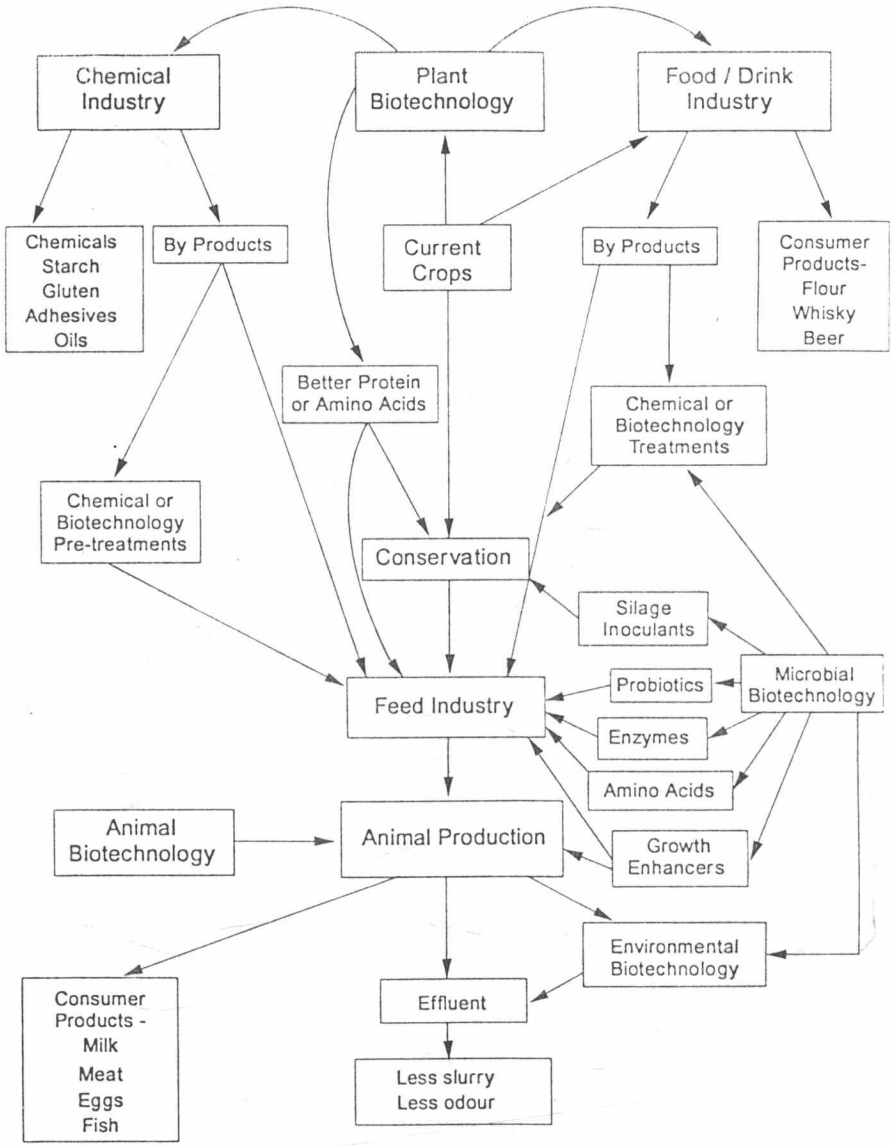

Figure 2. Contribution of biotechnology to animal production.

plant materials which are considered proteinaceous, such as legumes. Lesser components are animal by-products including meat and bone meal and fats such as tallow or lard. Additives such as vitamins, major and trace elements, synthetic amino acids, growth promoters and antibiotics generally complete the diet. More recently, enzymes and probiotics also feature as additives.

Depending on the animal production system, this formulated feed may be a complete diet as in the case of non-ruminants such as pigs and poultry and fish, or may be used as part of the diet to supplement locally grown and conserved forages for ruminating animals. This description forms the basis for a more detailed breakdown of the impact of biotechnology on the feed industry and animal production (Fig. 2).

By-products

Although this overview is concerned with the animal feed industry it has to be realised that many of its basic raw materials are by-products or waste products of other mature industries serving different consumer needs. Many of these by-products come from industries such as brewing, distilling and malting - starch conversion processes which in their own right have been subjected to developments in biotechnology and may be the carrier for that product into the feed industry. For example, by-products of the fermentation industry may contain within them the microbial residues upon which the process was based. These microbes themselves are likely to have been influenced by modern methods of biotechnology in order to improve the efficiency of the primary process.

Were it not for the use which the animal feed industry makes of by-products, they would create a major pollution problem. Fortunately, many of these raw materials lend themselves to upgrading either before the animal consumes them, or after consumption. Chemical and mechanical processes are often used before consumption, usually as part of the animal feed production process whereas biotechnological treatments, either as enzymes or microbes, are most often the choice after consumption.

Obviously all steps need to be taken to minimise pollution from the feed industry and farming community. Plant breeding techniques designed to produce better crops for livestock will have a major role to play. However, caution should be exercised in breeding plants for particular industrial uses. This must be a team effort, because these techniques will eventually lead to a by-product which will be targeted to the feed industry for its disposal. Plant breeders must ensure that there are no residual antinutritional components present, as well as keeping an eye on the volume produced: the industrialised feed industry can only cope with controlled volumes, otherwise the by-product of this effort will become a disposal problem.

Use of microorganisms

Microorganisms, long used for the preservation of food products, are playing an increasing role in the feed industry and gaining credibility both as inoculants for assisting in the preservation of forages such as grass or maize or as probiotics, where science is now bringing a better understanding to how these should be used in the animal.

Another interesting development has been the use of microbes to improve trace element supplementation. Some trace elements, such as selenium, have a narrow safety margin

between nutritional requirement and toxicity. Selenium deficiency is on the increase, including in humans, as changes are brought about in the modern diet. The switch in the UK from less dependence on Canadian wheat compared to home grown wheat is currently being blamed for a significant fall in the daily intake of selenium to well below recommended levels for the population. To rectify this situation, selenium enriched yeast products are now a common sight on chemist's shelves as well as being used in the feed industry in bulk quantities. As scientists gain more knowledge of the role of minor trace elements we can expect to see more such products. Chromium and vanadium enriched yeasts are already in the pipeline.

APPLICATIONS OF BIOTECHNOLOGY

Improving the amino acid content of cereal grains

For poultry, pigs and fish fed conventional feed formulations, the essential amino acids lysine, methionine and threonine are usually present in limiting amounts unless the diet is supplemented with the synthetic version of these nutrients. However, considerable effort is being put into plant breeding to enhance the natural amino acid profile of the seeds (see Chapter 14).

Some success has already been achieved with conventional mutagenesis programmes. Wheat, maize, sorghum, milo and barley together with rice are the main cereal grains used in animal feeds, especially for non-ruminant animals. Each of these cereals has a drawback in their nutritional profile. For example it might be the tannin content of sorghum or the low protein content of rice. The protein component of the feed is probably the most critical part of the specification. Obviously as the nutritionist increases his understanding of what would be the ideal protein for the animal, in terms of its amino acid composition, then better use can be made of raw materials and better guidance can be given to the plant breeder.

As long ago as 1970, Munck *et al.* surveyed the world barley collection and identified one line named Hiproly which was high in protein and lysine content. Doll (1984) screened a large number of mutant barleys and identified several with enhanced lysine content. Miflin *et al* (1985) described future work aimed at identifying factors important in increasing gene expression not only for improving lysine but also the methionine and threonine content of barley. Although increases were achieved in terms of the free pool of amino acids they were not considered sufficient to satisfy nutritional requirements. None of the cultivars arising from this work has reached commercial production, largely due to other factors such as small grains or grain yield or poor disease resistance. In the current climate of cereal surpluses perhaps more attention should be given to acceptance of lower yields but better nutritional quality provided other factors are compatible with industry requirements.

Oats as a broiler feed

One recent example, obtained through conventional plant selection techniques, has achieved a cereal of a composition which is almost a complete diet in itself for broiler chickens. Oats is a cereal almost unknown as an ingredient in broiler feeds. The husk of the oat grain constitutes about 25% of the weight of the grain. The low metabolizable energy of oats excludes it from broiler diets but the protein content has always been regarded as being of