

BREEDING LIVESTOCK FOR REDUCED RELIANCE ON CHEMICALS

R.R. Woolaston

CSIRO Division of Animal Production
Armidale, NSW Australia

SUMMARY

Chemicals are used extensively in animal industries, from production of the feed base through to processing of animal products. Concerns over chemical use arise from the possibility of residues in animal products, resistance of some organisms (most notably bacteria and parasites), environmental consequences and carcass damage. Many traits targeted by chemicals are heritable, so breeding can sometimes achieve similar ends. In many applications though, chemicals used for improved production will be augmented by, rather than replaced by genetic improvement. Breeding for disease resistance is an exception, as it should often be possible to reduce reliance on veterinary chemicals. The optimal emphasis to place on resistance in breeding programs depends on a number of factors, some of which are difficult to measure. Genetic correlations between disease resistance and productivity appear to be slightly unfavourable in a number of species, so that if resistance is ignored in breeding programs, reliance on other means of control, including chemical therapy, may increase. Public acceptance of transgenic animals that produce abnormal levels of chemical substances, even those naturally occurring, should not be taken for granted.

Keywords: Breeding, chemical residues, disease resistance

INTRODUCTION

Potential applications for chemicals in animal production are practically limitless. In any recent issue of an animal science journal, there are likely to be several articles reporting the potential of feed supplements, fungicides, pesticides, growth promotants, antibiotics or other chemicals to improve animal production. The task of reviewing the entire topic is obviously beyond the scope of this short review, so instead I have chosen to touch on the issues involved in using chemicals in livestock production and to identify some areas where breeding has the potential to alleviate problems.

CHEMICALS USED IN ANIMAL PRODUCTION

Chemical substances used to modify animal production fall into several categories:

- those used in the production of animal feeds (fertilisers, herbicides, pesticides)
- those designed to increase animal production (more product)
- those designed to improve product quality (better products)
- those intended to improve animal health (e.g. insecticides, anthelmintics, antibiotics, fungicides, vaccines)

- those with a specific physiological effect designed to aid management (e.g. reduce pain, regulate reproduction, perturb fibre production, reduce stress, induce moulting).

Many animal traits targeted by chemical applications are genetically influenced. Most quantitative production traits (e.g. growth, milk production, fibre production, reproduction, egg production) are heritable, as are many qualitative traits (leanness, marbling, milk composition, fibre properties). Resistance to many diseases is also heritable, evidence of which can be found readily in these proceedings and those of previous meetings. Thus animal breeding could often achieve similar ends to chemical therapy, albeit slowly. This does not mean though, that breeding can always substitute for chemicals. When chemical therapy can be shown to favourably influence livestock production, there is little evidence to suggest that the effect will be any less in genetically improved animals, except in the case of disease control, as will be detailed later. In most other circumstances, the two technologies (i.e. chemical therapy and genetic improvement) are more likely to be complementary than competing.

WHAT'S WRONG WITH CHEMICALS?

Not all, or even most of the chemicals used in livestock production are potentially harmful. However, some have the potential to cause problems and these fall into a number of categories:

Environmental. Problems can arise at various stages:

i) During production of feedstuffs. Fertilisers, herbicides and insecticides may have detrimental effects, mainly on soil and in waterways (Morse 1995; Atkinson and Watson 1996). In some situations, low input, chemical-free livestock systems using alternative genotypes may be an option. For example, goats are sometimes grazed strategically to control woody weeds, and in Australia, native marsupials are being considered as the basis for commercial livestock enterprises, as they are well adapted to fragile landscapes. It is also possible that more conventional species may be genetically modified to better utilise existing pastures.

ii) To enhance animal production or health. Anti-parasitic compounds can adversely affect non-target species such as soil microbiota (Madsen *et al.* 1990) and when applied externally to fibre-producing species, can cause pollution when released during fibre processing (Shaw 1997). Breeding livestock for resistance to parasites can reduce dependence on such chemicals.

iii) During processing of animal products. Wool processing, for example, requires the addition of chemicals for scouring, dyeing and enhancing the surface properties of the fibre, all of which create disposal problems. Although it may be possible to genetically modify animals with products requiring less of these substances, an expedient solution is more likely to be found through the development of improved processing techniques.

Residues. Chemical residues can be introduced through stock feed or direct application.

i) Through feedstuffs. A recent example is chlorfluazuron, a pesticide used in cotton production which led to residues in beef when cotton trash was fed to drought-affected cattle in Australia (Hill 1996). It may be possible to breed animals, using either conventional methods or

transgenesis, with the capacity to catabolise undesirable residues. A more cost-effective solution however, is likely to be found through improved information on residues in feedstuffs and changed management to reduce exposure to contaminated feedstuffs.

ii) *Administered directly.* DDT (dichlorodiphenyltrichloroethane) is a well-known example of a chemical that persists for many years in the field (Spencer *et al.* 1996). Recommended acceptable levels of veterinary drug residues are published by organisations such as the World Health Organisation (WHO 1991). Concerns over the effects of residues on human health will not abate, with the ever-increasing power of modern technology to detect residues in animal products and the implementation of trace-back systems for slaughter animals and animal products. Furthermore, detectable residues will continue to cause restrictions in trade of livestock products. Potentially contentious substances include antibiotics, insecticides, anthelmintics and growth promotants. Selective breeding will sometimes offer alternatives to pharmaceutical compounds, but most problems may be circumvented by a combination of good management, judicious choice of genotype and prudent use of exogenous chemicals. New technologies such as semen and embryo sexing and somatic cell cloning will provide producers with opportunities for tailoring the frequency of desired genotypes for any given system and perhaps reduce the need for compounds such as those used in chemical castration.

Product damage. Some chemicals adversely affect the quality of animal products because of their mode of administration. The most common source of concern is carcass damage caused by lesions at the site of injection of substances including vaccines, antibiotics and vitamins (George *et al.* 1995). In sheep, caseous lymphadenitis (Rizvi *et al.* 1997) can be caused by shearing cuts, with poor hygiene during off-shears dipping identified as a factor in spread of the disease (Nairn and Robertson 1974). Inappropriate implant sites may also cause problems. The simplest solutions to these problems will lie in improved methods of pharmaceutical delivery and good hygiene. Nevertheless, any breeding strategy to reduce the need for vaccination or injectable pharmaceutical compounds will also help.

Chemical resistance. When a pathogen is targeted by chemicals, whether it be a bacterium, fungus, virus, internal or external parasite, it is possible that a chemical-based control strategy may not be sustainable, as resistance can develop. This will be of obvious concern to producers who rely on pesticides for disease control, but of general concern to the community if it leads to the development of drug-resistant strains of bacteria affecting human health (Corpet 1996).

GENETIC ENGINEERING

By careful selection of existing genotypes, it is already possible to produce wool in a range of shades from black, brown and grey through to white. If it is possible to grow coloured cotton varieties, might not it also be possible to genetically engineer sheep to grow blue or red wool, for example? And on the subject of transgenic sheep, may not it also be possible to produce sheep that manufacture their own insecticide for controlling external parasites, that grow wool with surface properties modified for better processing performance, that produce greater

quantities of growth hormone, or are capable of synthesizing cysteine from dietary sulphur? Fanciful as it may seem, many of these goals are already the subject of active research projects.

In evaluating the feasibility of developing transgenic animals to reduce chemical usage, there are other matters to be considered. Are chemicals produced by animals in abnormal quantities any more contentious than exogenous applications of the same chemicals? If the safety of bovine somatotropin application is still controversial, might there still be need to question whether animals engineered (through transgenesis or selective breeding) to have enhanced somatotropin levels, are any more acceptable? If residues from chemicals used for controlling external parasites are a problem for consumers, what will be the reaction to products from animals that have been engineered to produce their own insecticide? In a discussion of the ethics of genetic engineering, Rollin (1996) pointed out that genetic engineering is perhaps the most powerful technology ever devised by humans and that "fast-track technologies" such as transgenesis do not have the enforced waiting period demanded by conventional breeding. Responsibility must rest with scientists to be particularly cautious and vigilant in testing for unforeseen consequences before the release of novel genotypes. Clearly the new biotechnologies will generate much public debate, posing questions which must be answered before the technology will be adopted.

CONVENTIONAL BREEDING PROGRAMS TO REDUCE CHEMICAL USE

Of all the potential applications of breeding to reduce reliance on chemicals, breeding for disease resistance appears to offer the most promise. Pesticide residues are potential problems in livestock products and in the environment, their long-term effectiveness is problematic and they can represent a significant direct cost to producers. In small ruminants, anthelmintic use is of particular concern. Resistance of gastro-intestinal roundworms to chemicals is prevalent in ruminants of many countries (Rolfe 1997; Waller 1997) and there is growing opinion that more sustainable control measures are needed. Wright (1997) found in a survey of Australian Merino breeders in medium and high rainfall zones, that more than 60% of respondents were very or extremely concerned about anthelmintic resistance. Considerable research in both Australia (Woolaston and Eady 1995) and New Zealand (Morris *et al.* 1995) has shown that breeding offers a genuine alternative. In a recent field trial for example, the effectiveness of genetically selected Merinos in reducing worm faecal egg counts (FEC) was compared with protein supplementation and a strategic drenching program (Woolaston *et al.* 1997). When grazed on contaminated pastures over a 224 day test period, FEC in undrenched selected sheep were lower than drenched unselected sheep. Using an epidemiological model, Eady *et al.* (1997a) calculated that on the northern tablelands of New South Wales, the number of anthelmintic treatments needed for Merino weaners could be reduced after nine years of selection. Chemical treatment could virtually be eliminated after 13-18 years. This simulation assumed single-character selection, but with modest selection intensities. The advent of new aids to selection and accelerated breeding techniques may make these rates of improvement in disease resistance feasible in multi-trait objectives.

Fear of total anthelmintic failure has stimulated workers in several other countries to evaluate sheep and goat breeds for their potential to resist internal parasites. This may result in widespread breed substitution and crossing to insure against anthelmintic failure. In livestock systems where breed substitution is not feasible, support networks have been established to assist breeders improve the resistance of their flocks through selective breeding. In Australia, the *Nemesis* worm control network (Eady *et al.* 1997b) has attracted widespread interest. A similar service, known as WormFEC™, operates in New Zealand (McEwan *et al.* 1995).

In Norwegian dairy cattle, including mastitis as a selection criteria is considered worthwhile as it is predicted to reduce mastitis frequency by 0.9% in a sire generation, compared with an increase of 1.3% if it is ignored (Solbu and Lie 1990). Another notable example of breeding livestock to reduce reliance on pesticides in extensive systems is in beef-producing areas of the sub-tropics, where there has been widespread infusion of *Bos indicus* breeds to reduce reliance on acaricides (Angus 1996). This has had dramatic effects on resistance of cattle to tick infestation. Resistance is moderately heritable (Mackinnon *et al.* 1991) and so it is possible to improve resistance through selection. The report by Utech and Wharton (1982) indicated that the progeny of *B. indicus* - *Bos taurus* crosses have similar levels of resistance to that achieved by selective breeding of *B. taurus* animals for 3-4 generations. If a putative major gene for resistance (Kerr *et al.* 1994) is confirmed and appropriate gene markers developed, this may accelerate genetic progress.

Resistance to external parasites of sheep, particularly the sheep blowfly (*Lucilia caprina*) and body louse (*Bovicola ovis*), represent other possible areas for genetic improvement. The effectiveness of preventative measures using chemical treatment is threatened by adaptation of the parasites and ineffective application techniques (Levot 1997). Moreover, chemical residues in wool effluent are a major threat to wool scouring operations in Europe (Shaw 1997). Research into genetic resistance to ectopathogens and to various other diseases of small ruminants has recently been reviewed by a number of authors (see Gray *et al.* 1995).

BREEDING FOR DISEASE RESISTANCE - WHAT IS THE DOWNSIDE?

When exotic genotypes can be identified that are at least as productive as existing breeds, but are more resistant to major diseases, then crossbreeding or breed substitution is feasible (eg. Romjali *et al.* 1997). If disease resistance is used for within-breed selection however, an obvious consequence is that its inclusion adds another trait to breeding objectives, so progress in improving each individual trait will be slower. This is not necessarily disadvantageous if disease resistance has an economic value and is heritable. It is sub-optimal to omit traits contributing to profitability in a breeding objective (Gjedrem 1972), even if some of the component traits are unfavourably correlated. Estimating economic weights for disease resistance brings special problems, some of which have been discussed by Ponzoni (1984), Woolaston and Baker (1996) and McEwan *et al.* (1997) with reference to parasites of sheep. When assessing economic weights for parasite resistance, there are three aspects to be considered. These are the cost of treatment (anthelmintics), production losses incurred when

anthelmintics do not completely eliminate parasites (which is the norm rather than the exception) and the cost if anthelmintics totally lose their effectiveness. Treatment costs are simple to calculate, but production loss functions are usually based on data collected on research flocks under circumstances which may not be generally applicable. In pointing out the scarcity of data on the cost of maintaining an immune response against parasites, Sykes (1994) speculated that this might, on average, amount to a loss in production of 15%. The cost due to total anthelmintic failure requires an assessment of productivity losses and mortalities under such circumstances, moderated by the perceived probability of this scenario eventuating. To circumvent these difficulties, the advice given to commercial breeders in Australia (Woolaston 1994) and New Zealand (McEwan *et al.* 1995) is to use a "desired gains" approach with respect to resistance. Although restricted indices are prone to criticism (Gibson and Kennedy 1990), this is seen as a reasonable compromise, because at least the gain in non-disease traits can be optimised according to their relative economic values (Brascamp 1984), and the breeder is aware of the selection pressure foregone.

When genetic relationships among traits are generally favourable, the penalty for using inappropriate economic weights is less than when relationships are unfavourable. With favourable correlations between traits under selection, often many of the same individuals are chosen regardless of the weightings given to the traits, but this is not so when the relationships are unfavourable. Unfortunately, the genetic relationships between productivity and disease resistance are often neutral to slightly unfavourable (broiler chickens - Dunnington 1990; dairy cattle - Shook 1989; Solbu and Lie 1990; Ronningen 1994; beef cattle - Mackinnon *et al.* 1991; turkeys - Bayyari *et al.* 1997; sheep - Morris *et al.* 1997). For most livestock species, more information is needed to ascertain whether selection for productivity will generally increase susceptibility to diseases and so increase reliance on chemotherapy for control.

In some circumstances, the physiological load of mounting an immune response may manifest itself as an adverse "genetic" relationship. Knowledge of gene associations and functions at a molecular level will help explain whether genetic relationships are due to pleiotropy or linkage and thus whether the associations can readily be broken. Breeding an animal with general disease resistance will not be a short term project, as resistance to different diseases appear to be essentially unrelated, at least in sheep (Raadsma *et al.* 1997) and dairy cattle (Lund *et al.* 1994). Identifying suitable selection criteria for disease resistance can also pose difficulties, particularly if selection candidates must be challenged with the causative agent. For parasites such as roundworms, which are ubiquitous in many breeding areas, acceptable criteria can usually be found - in this case, FEC. The level of challenge necessary to discriminate between genotypes does not necessarily jeopardise production (Kisielewicz *et al.* 1995). Resistance to other diseases, such as mastitis, can be assessed through traits such as somatic cell count (Philipson *et al.* 1995) and the genetic disorders caused by single loci can be detected by molecular markers (Montgomery and Kinghorn 1997). When the pedigree structure of a breeding population is known, the requirement to deliberately challenge selection candidates can be circumvented, using disease frequency in relatives as a guide to genotype. Clearly

genetic markers will be useful for identifying resistant genotypes (eg. Crawford *et al.* 1997), but it remains to be seen whether resistance to complex diseases such as nematodiasis are controlled by few, or many loci.

CONCLUSIONS

A number of circumstances have been identified where breeding may reduce the need for chemicals. Where chemicals pose threats to the environment or to human health, breeding can contribute to a solution. In each case, the desirability of using selection pressure for such ends must be considered on its merits. Conventional methods for determining economic weights are not always applicable and some innovative thinking is needed to quantify the benefits. If chemical failure is imminent, as seems to be the situation with some anthelmintics, there is an urgent need to consider breeding as an alternative, or at least as part of an integrated approach. There is a need to move past complete reliance on drugs to thinking in a different way about how to best handle disease in livestock. Host resistance is a powerful tool.

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