Anim. Prod. Aust. 2002 Vol. 24: 490-499

SUSTAINABLE ANIMAL PRODUCTION IN AUSTRALIA – PRESIDENT'S ADDRESS

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INTRODUCTION

The production of meat, milk, wool and wheat in the past 150 years of Australia's development has generated vast wealth and has fed and clothed millions of people worldwide. However this has been at the expense of this country's old and fragile natural ecosystems. The unsustainability of our past and some current agricultural practices is indisputable, and evident not only in biophysical deterioration such as the cancerous growth of soil salinity, soil acidity, soil sodicity, erosion, and declining water quality, but also in the deterioration of our rural communities. As we enter the new Millennium, economic "rationalism" is still the dominant paradigm, dictating as it does in many cases continued depletion of natural capital stocks. There is an on-going failure to apportion economic value to externalities, presumably because of the difficulties of valuing aesthetic 'commodities,' or activities divorced geographically or temporally from a production activity (eg pollution downstream or in 10 years time). It is conservatively estimated that at least $2bill of unallocated environmental costs are incurred per annum as a result of current agricultural practices (salinity $270 mill pa), soil sodicity ($200mill pa), soil acidity ($300 mill pa), soil erosion ($80 mill pa), water quality ($515 mill pa) in addition to the costs of degradation of aquatic, estuarine and coastal waterways. This economic irrationalism is perpetuated by an increasingly urbanised population that bears little ownership of its role in creating unsustainable agricultural practices. These problems are well recognised. Potential solutions however are rarely addressed. In this paper I make an attempt, albeit a necessarily superficial one, to highlight what I see as the key issues around sustainability of the major livestock industries. For the intensive pig and poultry industries the tremendous gains that have been made in biological efficiency must now be tempered by attention to more socially-acceptable practices, development of alternatives to antibiotic growth promotants, and efficient treatment and utilization of effluent and carcasses. The ruminant industries, likewise, must develop alternatives to practices likely to come under fire from consumers, including mulesing, castration and tail docking.. Reducing greenhouse gas emissions from our ruminants has become a high priority, as has the development of grazing systems that mimic natural ecosystems in terms of water flows, nutrient flows, and biodiversity. All animal production systems will need to reduce chemical usage and ensure that animal products are safe. Science, technology and education will go some way to addressing many of these issues, but without a shared vision for the ultimate nature of our landscapes and animal production systems, and the means of sharing the costs of achieving that vision, we will not achieve 'sustainability'.

Keywords: sustainable, animal, production, ecological, social, economic

WHAT DO WE MEAN BY SUSTAINABLE?

Definitions of sustainability vary but the triple-bottom line of ecological sustainability, social acceptability and economic viability (Conway 1985) suffice for the purpose of the current discussion. Using the definition that a sustainable system is one that fits all three criteria, no system that remains static can be sustainable given the consistent decline in the terms of trade facing producers. To remain financially viable an enterprise must increase productivity by approximately 2% per annum. Often the means by which this is achieved is via intensification and increased input of non-renewable resources and chemicals, factors that often mitigate against the other two criteria of sustainability.

THE COMPONENTS OF 'SUSTAINABILITY' AND FACTORS THAT WILL INFLUENCE THEM IN THE FUTURE

Social acceptability

The social acceptability of animal production practices in the future is impossible to predict, particularly as 'society' can be defined as domestic and overseas communities. An important demographic, however, is the urbanisation of Australians and their increasing remoteness from animal production systems. In 1911, 43% of the Australian population lived in rural and remote areas. In 1996 this figure was 14% and declining. That is, 86% of Australians live in urban areas and 70% live in the capital cities (ABS 2002). Between 1995 and 2000 73% of Australia's population growth occurred in the capital cities. The fastest growth rate (15% per annum) of any sector of Australian society was in the inner city populations, a group that has little or no association with animals, no understanding of animal production systems, and importantly, no basis on which to construct an *informed* empathic view of animals.

The growth of vegetarianism will obviously impact on the sustainability of meat production in the future. A recent study in the USA found that the strongest predictor of vegetarianism as a dietary choice was the belief that vegetarianism is beneficial to the environment (Kalof *et al.* 1999). These altruistic beliefs that vegetarianism is beneficial to human health, the environment, farm animals, and world hunger is most evident in children (especially teenagers), who are particularly sensitive to issues relating to animal welfare and the negative impacts of animals on the environment (Brooke 1990).

The impact of so-called 'organic' agriculture trends on animal production is difficult to predict. Organic agriculture is the fastest growing sector of agriculture reflecting consumer belief, largely unsubstantiated, that the use of synthetic chemicals and fertilizers is responsible for ill-health of the environment and humans. Alternatives to anthelminthics, insecticides, antibiotics, and growth promotants (discussed later) will be required if organic animal production systems are to be developed.

Vegetarianism, the animal rights movements, campaigns against native animal consumption, outbreaks of animal diseases, concerns over chemical residues in animal products and of the impact of animal practices on environmental outcomes, will all impact on the public acceptability of animal production practices in the future. Until there is widespread acceptance of the impact of the consumptive habits of all individuals on the environment (as expressed in the useful concept of 'ecological footprints' espoused originally by Wackernagel and Rees (1997)) and an economic structure that allocates the costs appropriately, there will continue to be disproportionate pressure on primary producers to bear the costs of ecological sustainability and increasingly, the social costs of animal production.

Economic viability

Animal enterprises will continue to be faced with a declining terms of trade of approx. 2% per annum. Increased production per unit input (of land, labour, fertiliser, feed, water, breeding animal) will depend on application of existing and new technologies in animal genetics and breeding, pasture management, pasture plant breeding, nutrition, reproduction, disease amelioration, parasite management, and housing. A trend away from bulk commodities to niche market opportunities (eg ultrafine wool, saltbush mutton, organic milk, organic beef, nutrient-enhanced eggs etc) will continue, as will increasing value-adding to animal products to capture more of the economic benefits up the value chain. Vertical integration as a means of quality assurance and ensuring economies of scale is likely to apply to more animal production systems than previously. Increased value-adding and vertical integration by more corporatised animal industries is likely to have animal welfare and environmental consequences which will have to be addressed.

Ecological sustainability

A strong factor mitigating against ecological sustainability that is common to most western agricultural producing nations, is the heavy involvement of the "input" sector which has little interest in promoting or developing processes or systems that are environmentally-benign. Another is that western agricultural science for the past 50 years or so has been dominated by 'scientism', with its reliance on reductionism and compartmentalisation, concepts that are distinctly anti-ecological.

An ecologically sustainable system can be described as one that has the properties of a natural system. The principles underlying the ability or inability of agricultural ecosystems to 'mimic' natural ecosystems are discussed in detail in a series of papers in Lefroy *et al.* (1999). The essentials of a sustainable system are: negligible erosion of the soil, balanced leakage of water and solutes (salt in = salt out; water in = water out), no persistent toxicity; and control of pests and weeds. These attributes result in resilience of the system (ie the ability to recover from disturbances). To achieve these ends the lessons from natural systems are:

- a need for persistent ground cover and minimal soil disturbance
- the presence of deep-rooted perennials which allows capture of water that has escaped the roots of annual plants when rainfall exceeds evaporation
- seasonal release of nutrients mediated by microbial activity that match the nutritional demands of plants thus promoting tighter cycling and minimal nutrient losses
- adequate biodiversity above and below the ground to ensure that turnover of nutrients in the soil are met; that biological control of pests and diseases is achieved; and that risk caused by extremes of weather are minimized
- a mosaic nature of land to ensure that patches of land are treated on the basis of their natural properties rather than on artificial survey basis.

(Passioura 1999).

The extent to which our current and future grazing systems meet these criteria needs examination. Simplistic assumptions for example that simple systems cannot meet these criteria, or that persistent and 'stable' perennial polycultures are inherently less productive than simpler systems, may not withstand close scrutiny.

It is perhaps not surprising that application of reductionist science within a framework of overly-simplistic economic analysis has resulted in unsustainable modern agricultural systems. *The real question is: have we learnt from the past and what technologies can we apply to ensure sustainable production in the future?* The following sections consider some selective examples of what I believe are likely to be key issues around sustainability of the major animal industries.

SOCIAL ACCEPTABILITY OF ANIMAL PRODUCTION PRACTICES

Much of the public concern about the acceptability or otherwise of animal production systems focuses on perceptions of overcrowding, overuse of medications, high technological input, lack of freedom to exhibit normal behaviour, pollution (both effluent and gases), and poor product safety. Potential solutions to at least some of these issues are now considered.

Animal welfare in intensive systems

Of all animal enterprises the farming of layer hens in battery systems and the intensive production of broilers are perhaps the least sustainable in social-acceptability terms, with community concerns about animal suffering, environmental pollution, perceptions that hormones are used in production, and implication in the transfer of antibiotic resistance to human pathogens. Ethical concerns in the layer industry relate to the inability of birds to display natural behaviours in a factory farm (battery cage) environment (Albrecht 2001).

During the past 75 years the application of technologies in the poultry industries has resulted in spectacular responses in both layers and broilers. Modern broilers grow 4 times faster and have an 8-fold increase in breast muscle growth (Havenstein *et al.* 1994) compared to "layer" and control lines. Layer hens now produce 3-times more eggs/bird/year (Burt 2002). These advances have been accompanied by serious ethical and welfare consequences. Problems include reduced immune function (Dunnington *et al.* 1987) and major musculo-skeletal (Thorp 1994) and metabolic disorders (Scheele 1997). Sandercock *et al.* (2001) has proposed that the rapid growth rate and muscle yield in modern broilers has detrimental effects on muscle function and membrane integrity and may be due to genetically-induced alterations in muscle fibre status. The most serious welfare problem in broiler production is the high incidence of skeletal disorders, particularly leg problems. More than 90% of commercial broilers have detectable gait abnormalities at market age and in about 30% of birds those abnormalities are high to severe, sufficient to compromise their welfare (Kestin *et al.* 1992). Birds with severe leg problems may weigh less because they have difficulty competing for food and water (Kestin *et al.* 1992). In layer-type hens there has been an increase in osteoporosis (Burt 2002). The egg and broiler sectors are therefore coming under community pressure to develop alternative, less intensive systems of production. These include the use of more fibrous diets and free range systems to allow freedom of movement and reduce physiological stress on birds resulting from rapid growth. Rapid growth of broilers is wrongly perceived by consumers as being the result of the use of growth-stimulating hormones. While this does not appear at present to translate to purchasing decisions it may well do so as the new crop of consumers with a greater consciousness of food-safety and animal ethics enter the market.

Technological solutions to these problems centre around increasing broiler activity in order to decrease skeletal problems, for example by increasing space between feeders and drinkers, manipulating lighting, providing additional space and perches (Mench *et al*. 2001). When broilers are fed a 'free range' type diet that has a lower energy density and higher fibre content than conventional broiler diets, the activity of the birds increases, offering a potential solution to leg weakness problems. Of course the cost will be reduced growth rates, lower feed conversion efficiencies and increased costs of production.

It is anticipated that in the next few years an international campaign will be mounted by organizations criticising the intensive broiler industry for the high level of welfare problems arising from rapid growth (Mike Appleby (CEO Humane Society USA with 8 mill. members) in a personal communication with Dr Phil Glatz, Pig and Poultry Production Institute). The challenge for the industry will be to meet the inevitable pressure from welfare groups, to develop alternative, less-intensive systems of broiler and layer production that are not only socially-acceptable but also economically-viable.

As broiler birds approach biological limits to growth rate and efficiency, further gains in productivity will presumably come from achieving these high efficiencies at reduced feed costs by using alternative, cheaper sources of protein and energy. Genetic resistance to pathogens will become an important goal

The trend in pig production is towards less-intensive systems that are perceived to be more 'animal-friendly'. Often, however the changing of an animal practice perceived to be unacceptable from an animal welfare viewpoint results in a plethora of new animal welfare or health problems. Group housing of dry sows, for example, results in an increase in aggressive behaviour and social stress. The increasing use of straw-based ecoshelters that allow the pigs to move freely and display many natural behaviours such as burrowing, may also result in an increase in respiratory problems. Farrowing crates that allow greater movement of the sow, with the option to turn around and to display 'nest building' activity have been developed (Weber 2000). No decline in reproductive performance is reported with these systems (Weber 2000), suggesting that the dual objectives of social acceptability and economic viability may be met.

Animal welfare in the sheep industries

A number of sheep production practices are coming under, or are likely to come under, increasing scrutiny from the public with regards animal welfare. These include mulesing, castration, tail docking, transport, and abattoir practices. Alternatives to mulesing have been sought for some time and have included attempts at permanently removing the wool from the breech using caustic preparations (Morley 1949), bombardment with high-energy electrons (Sorrel *et al.* 1990), phenol treatment (Pratt and Hopkins 1976) and application of cationic compounds (Chapman 1993). Unfortunately these treatments cause considerable damage to the skin, are unsafe for the operator, or are simply not practical for field application. Currently three different options are being tested; one is based on application of a light-sensitive amino acid mixture to the shorn skin on the breech followed by high intensity light treatment (Alan Brownlee pers. comm.) to destroy the follicles and thereby render the breech hairless. A second method aims to permanently remove the follicles from the skin (Phil Hynd and Natasha Penno unpubl.), again rendering the breech hairless. It remains to be seen whether these treatments reduce wrinkle or whether depilation alone is sufficient to prevent blowfly strike. Alternatives to mulesing must meet the following criteria: be safe to the operator, cheap, easy to administer, and equally effective to mulesing at preventing breech strike. It remains to be seen if either of these alternatives meets these criteria. A third possibility is to breed sheep that are naturally bare around the breech (Peter James, SARDI Livestock Systems, pers. comm.). The phenotypic variance and heritability of bare area, and the genetic association of bare area with other economically-important traits are being determined. Provided there are no adverse associations of bare area with other traits, selection and breeding of sheep which do not require mulesing is an attractive possibility. Similar research is being conducted in New Zealand (see paper by D. R. Scobie- this conference).

Development of an alternative to tail docking in merino sheep, namely the breeding of sheep that naturally have a short tail, would have significant advantages from the point of view of animal welfare concerns, and a reduction in infection caused by marking wounds (James *et al.* 1990). While such tailless sheep exist (James *et al.* 1990) there are reports that tailless-ness is associated with genetic disorders such as embryonic mortatility and 'rear end disorders'. The mode of inheritance of taillessness appears to be through a small number of genes of large effect but its genetic association with other production traits remains to be determined. As pressure mounts on practices such as lamb marking, further studies of the potential for developing a tailless strain of Merino may be warranted.

Animal welfare in the dairy industry

Dairy production systems in which the cows are housed continuously or for long periods of time will face the same challenges as the pig and poultry industries with regards housing. These include issues such as space required per animal, ventilation, design of and access to feeding and watering troughs, natural and artificial lighting, flooring materials, bedding, and safety for animals and farm workers (Dolezal 2000). Many of the issues that will confront the dairy industry are analogous to those of the chicken meat industry 10-20 years ago, namely increasing corporatisation, vertical integration (ownership of genetics, feed, cows), contract production, intensification, large scale of production, and high technical input. Whilst the economic sustainability of such corporatisation might be secure, some aspects of animal welfare, social acceptability, and environmental concerns are likely to come to the fore. For example what will be the public perception of a highly-corporatised dairy industry in which large corporations own say 5 or more herds of 1500 to 2000 cows per herd and farmers will own the land and provide labour. The dairy company will invest in the genetics, cows and feed and dictate management.

Public concerns regarding the safety of animal products

Fresh meat is often viewed as a vehicle for a significant proportion of human food-borne disease, and this perception has undoubtedly been reinforced by the outbreak of Bovine Spongiform Encephalopathy (BSE). Fresh meat is referred to as the food in which consumer confidence has decreased most in the past decade. The spectrum of meat-borne diseases related to public health changes with production and processing systems, but in general relates to *E. coli* 157:H7, *Salmonella spp., Campylobacter spp*. and *Yersinia enterolitica*. Primary production is a significant source of hazards associated with fresh meat and there will be an increasing demand for provision of information on animals intended for slaughter. This will require implementation of risk-based meat hygiene programmes.

ECOLOGICAL SUSTAINABILITY OF ANIMAL PRODUCTION SYSTEMS

Is sheep production an ecologically sustainable activity?

Sheep production in Australia has contributed significantly to the economy for almost 200 years and continues to produce export earnings of over $4bill. pa (ABARE 2001). However of all the animal industries, it is perhaps the sheep industry that is singled out for harshest criticism from environmental groups. Sheep, it is argued, are responsible for destruction of the rangelands as a consequence of their hard hooves causing soil erosion, camping behaviour causing nutrient redistribution, and selective grazing causing species removal and reduced biodiversity. A full analysis of the impact of grazing sheep on ecological sustainability of rangelands and cropping regions is beyond the scope of this paper. However, it can be argued that appropriately-stocked and managed sheep grazing systems fulfill many, if not all, of the criteria of replacers of the original large herbivores that were extant on Aboriginal arrival in this country (Flannery 1996). Sheep are well-adapted to many Australian climatic zones, and are extremely efficient at collecting and converting low-nutrient, high-fibre herbages into-high-protein, high-value products. If they can do so whilst at the same time achieving the requirements of ecological sustainability outlined above, they represent an ideal component of pastoral and cereal zone land use in Australia. While kangaroo farming/harvesting may superficially appear a better alternative to introduced species (Grigg 2002 this conference), our definition of sustainability precludes activities that are unprofitable, and at present the market for kangaroo products is small (and indeed may always be problematical because of emotive attitudes of global consumers to cute native animals). The safety of animal products harvested from the wild may also become an issue. Nevertheless a combination of opportunistic native animal harvesting with lower density ruminant production systems may be more sustainable than a single species system. Evidence that roos and sheep have a degree of complementarity of diet selection and quite possibly different parasite burdens, supports this notion.

Greenhouse gas emissions from ruminants

Ruminant livestock produce approx. 50% of the anthropogenic methane emissions in Australia, equivalent to 2.8mill. tonnes annually (Klieve and Hegarty 1999). Methane emissions per unit of GDP are higher for the livestock sector than for any other sector (Howden and Reyenga 1999). If taxes on carbon emissions are implemented and no new technologies to reduce methane production from livestock are introduced, the ruminant industries in Australia will be under threat. There are several potential technologies that might be used to reduce greenhouse gas emissions from ruminants. They include:

- manipulation of diet (McCrabb and Hunter 1999).
- encouragement of acetogenic microbes to outcompete and displace methanogens (Joblin 1999)
- vaccination of ruminants against their methanogenic bacteria (S. Baker pers. comm.)
- selection of animals that appear to produce less methane per unit of feed intake (Lassey *et al.* 1997)
- defaunation of the rumen (Hegarty 1999)

As for many aspects of sustainable agriculture the solution to problems is often found in application of systems approaches rather than technological ‘fixes’ based on chemical manipulation of specific pathways or microbes. Any practice that increases the efficiency of production per unit input allows a reduction in stocking rate with direct impact on gas production per hectare or per unit animal product. For example, changing from Autumn to Spring lambing in southern Australia results in an increase in returns per unit emission of 15 to 20% providing an opportunity to reduce stocking rate and gas emissions without financial penalty (Howden *et al.* 1996). Greater sustainability of animal production would arise both from increased efficiency of energy use (profitability and/or stocking rate reduction) as well as reduced gas emissions Alternatively the diet of ruminants might be manipulated given the wide ratios of methane output per unit of gross energy between forages and between grains versus forage (McCrabb and Hunter 1999). These authors reported a close negative relationship between liveweight gain and methane output suggesting that increased growth rates by grain feeding or better pastures would serve the dual role of increasing productivity and reduced methane production. The possibility of breeding pasture plants that contain compounds that inhibit rumen protozoa and thereby reduce the population of ciliate-associated methanogens is also worthy of investigation.

Interestingly the contribution of native herbivores to greenhouse gas emissions is not considered to be part of the anthropogenic gas emissions, despite the fact that native animal populations are manipulated by humans. Cynically one could see this as an opportunity to ‘meet Kyoto protocols’ by replacing sheep production with harvesting or farming of kangaroos, although one wonders how the climate distinguishes between greenhouse gases from native versus introduced animals.

Reduced chemical use in animal production

There are two reasons for urgent attention to developing alternatives to chemicals used to control endoparasites in sheep. The first relates to consumer concerns about chemical residues in animal products, and the second is the rapid development of worms that are resistant to the anthelminthics (Waller 1994). There are a number of alternatives to using synthetic chemicals to eliminate or reduce the impact of worms on sheep and cattle production. They include genetic selection for animals that are tolerant of parasites; development and release of pasture plants that suppress the activity/severity of parasitic infection; development of ‘plant-derived’ compounds with parasitocidal activity, and development of vaccines against parasites.

Large differences in the ability to resist parasitic infection between animal species, breeds, strains and individuals, raises the possibility of judicious use of resistant species, mixed grazing of two or more species, breed substitution, or within-breed selection. The latter is often the only practical and economic option, and breeding programs that increase the resistance of sheep to worms and reduce the number of chemical interventions, have been shown to be successful (Woolaston and Baker 1996).

The potential use of pasture plants that have anthelminthic activity is a relatively recent and interesting concept. Research in New Zealand has shown that condensed tannins found in certain pasture plants such as *Hedysarum coronarium* (sulla), *Lotus pedunculatis*, and *Lotus corniculatis* can have a dramatic effect on intestinal and abomasal parasite numbers (Niezen *et al.* 1995). Parasitised lambs grazing sulla for instance had 58% lower worm burdens than similar lambs grazing lucerne. That this effect is due to the condensed tannins and not some other component of the plant, was confirmed by simultaneous provision of polyethylene glycol which neutralizes the tannins (Molan *et al.* 2000). The effects of the tannins on nematodes may be direct or indirect. Direct effects include inhibition of motility (Molan *et al.* 2000), reduced enzyme activity (Fakae et al. 2000), reduced development and impaired reproduction (Konig *et al.* 1994; Mori *et al.* 2000). Indirect effects of the tannins such as increased protein supply to the intestines, or a change in the mucosal epithelium, may also play a role. Presumably worms will develop resistance to the direct anthelminthic effects of tannins and further research on incorporating pasture tannins into worm management programs is required.

Tannins are not the only plant-derived compounds with anthelminthic activity. Table 1 lists the range of phytogenic compounds found to inhibit nematode activity or viability. Most studies of the antinemic properties of plant extracts have concentrated on soil nematodes and few have investigated the effects on gastrointestinal nematodes.

Table 1. Some naturally-occurring plant-and fungal- derived compounds with anthelminthic activity

Class	Compounds	Typical sources
Polyphenolics	condensed tannins	*Lotus spp.*
	proanthocyanidins	*Hedysarum coronarium*
		Chenopods
Essential oils	terpenes	
	eugenol	*Ocimum spp.*
	terpenoids (ascaridole)	*Chenopodium ambrosoides*
	α-thujone	*various*
	sesquiterpene lactones	*various*
Peptides	cylcodepsipeptides	*Mycelia sterilia*
Pthalides	sedanolide	*Apium graveolens*
Glycosides	isoflavone glycoside	*Solanum spp*.
	vernoniosides	*Vernonia amygdalina*
	triterpenoid saponins	*Acacia spp.*

The fact that animals acquire immunity to helminth parasites raises the possibility of developing vaccines against parasitic antigens (Smith 1999). Several potential antigens are under investigation, including surface oncosphere proteins, excretory/secretory products and gut membrane proteins. The latter seem to be highly-effective against haematophagous parasites such as *Haemonchus. contortus*. Use of glutathione S-transferases as antigens also appears to hold promise against liver flukes (*Fasciola hepatica*). Vaccination against helminth parasites is likely to become a major step towards sustainable ruminant production.

Widespread chemical use in the sheep industry is coming under increasing scrutiny from domestic consumers and overseas markets with concerns centring on residues in food products, residues entering waterways following early stage wool processing, and a general increasing interest in what are perceived to be ‘environmentally-friendly’ practices. As for the anthelminthics, resistance to many of the ectoparasiticides is increasing at an alarming rate (Levot 2000) and alternatives may not be developed in time.

Integrated Pest Management programs aim to increase the genetic resistance of the host, improve the management systems, use biological or physical control methods, and use chemicals selectively and minimally. For each ectoparasite there appears to be opportunities for these IPM principles to be applied..

The high genetic correlation of flystrike with fleece rot incidence means that progress can be made towards development of flystrike resistant sheep provided climatic conditions conducive to fleece rot prevail. Molecular genetic markers for resistance would be an ideal means of selection. James *et al.* (1998) has demonstrated variation in resistance to the sheep body louse within and between breeds of American sheep and, more recently, Merinos. A favourable correlation between fecal egg count and louse susceptibility raises the possibility of simultaneous selection for louse and worm resistant sheep. Again, genetic markers associated with louse resistance would be an ideal means of selecting resistant sheep. Few biological or physical methods are extant for lice control. Trapping offers some opportunities for fly control, and 2 parasitoid wasps have been released in New Zealand to control blowfly numbers.

The successful development of a vaccine against the cattle tick (Frisch 1999) raises the prospect of development of vaccines against the sheep blowfly (Tellam and Bowles 1997) and also the sheep body louse (James 1999). Immunisation against ectoparasites would be an attractive component of an IPM program.

Alternatives to antibiotics in animal diets

Public concern over the use of antibiotics in livestock production is based on the likelihood of residues being present in edible animal products, and of antibiotic resistance passing to human pathogens. This has led to the banning of a number of antibiotics in the European Union which has placed increasing pressure on the development of alternative means of suppressing animal pathogens (14% of all antibiotic use in the EU) and for replacing feed additive antibiotics as growth promotants (36% of all antibiotic use in the EU).

Alternatives to antibiotics in livestock production include:

- adoption of stringent disease prevention measures such as batch production (eg all-in-all-out), age separation, biosecurity routes, optimal nutrition and temperature
- development of vaccines to prevent bacterial infection (eg vaccine against coliforms in piglets) has eliminated diarrhoea in piglets
- use of probiotics (one or more species of microbes that modify the intestinal milieu and thereby improve feed efficiency), prebiotics (indigestible carbohydrates that promote the growth of favourable microorganisms), organic acids (such as propionic acid, acetic acid, formic acid, citric acid and tartaric acid that promote lactic acid fermentation), enzymes to assist in the digestion of components of the ration.

Increasing evidence for instance suggests that the incidence of *Salmonella* infection depends on the carbohydrate type, feed structure and feed processing (Bach-Knudsen 2000). By feeding appropriate combinations of hemicelluloses and lactose, for example, the lactose reaches the small intestine encouraging proliferation in the small intestine so that pathogens such as *Salmonella,* cannot establish.

Tannins are important regulators of microflora in the digestive tract of ruminants and other herbivores, and act as natural antibiotics particularly against *E. coli* (Begovic 1978). Recent studies of a range of medicinal plants indicated that phenols, tannins and flavonoids were responsible for a significant broad-spectrum antimicrobial effect (Iqbal-Ahmed *et al.* 2001). Triterpenoids, extracted from *Heilotropium ellipticum*, were found to possess the widest spectrum and highest level of antimicrobial activity, often comparable with that of reference antibiotics (Jain *et al.* 2001). Beta-amyrin showed mostly antibacterial activity, while beta-amyrin acetate was more active agains fungi. Essential oils extracted from various plants also exhibit antimicrobial activity, even against those microbes that have developed resistance to therapeutic antibiotics. Plant-based antimicrobial agents can significantly increase growth performance in finishing pigs (Bae *et al.* 1999).

Disposal of pig carcases

Disposal of carcases in pig enterprises is an increasing challenge for the pig industry given environmental concerns regarding pollution of groundwater and air. A typical 5,000 sow farrow-to-finish farming system with mortalities of 7%, 10%, 5%, 1% and 1% in the sow, neonatal, nursery, growing and finishing herd respectively, produces more than 100,000kg of dead pigs per annum. Burying, incinerating or rendering are becoming less acceptable from an environmental viewpoint, and composting and fermentation are becoming increasingly attractive. Merging of industries such as farming of crocodiles near pig farms in some environments might allow carcases to be disposed of via another industry. The emphasis should not be on getting rid of dead pigs, but turning them into profit.

Sustainable grazing systems

Many of the ecological issues around animal production in high-rainfall zones in Australia are related to pasture persistence, water use efficiency, and nutrient capture. In contrast to the common perceptions that sustainable grazing systems require a high diversity of plant species in the sward, low fertiliser input and prescriptive grazing regimes, Scott *et al.* (2000) present the case that sustainable grazing systems require a soil/plant system that uses water efficiently (reducing run-off and nutrient loss), pastures dominated by nutrient responsive, deep-rooted perennial grass and legume, with high plant production per hectare, high stocking rate and high animal production per hectare. High water use efficiency in such enterprises is achieved by high pasture consumption per hectare, high stocking rates and high milk production per cow (Doyle *et al.* 2000). At least for these regions it appears that high financial return and some aspects of ecological sustainability (in this case water use efficiency) may be attained simultaneously.

CONCLUSIONS

Animal production in Australia in general has been based on systems that have achieved economic growth and prosperity through increasingly intensive, high-input systems of production of largely untransformed commodities. Our heavy reliance on non-renewable resource inputs, chemotherapeutic approaches to parasite and microbial control, and uniformity of the genetic base of most of our livestock species, is now showing unequivocal signs of inadequacy. Parasites have become resistant to most of our chemical arsenal against blowflies, lice, ticks and worms; microbes resistant to antibiotics added to animal feeds are thought to be conferring resistance to human pathogens; genetic diseases have been disseminated widely in several species; effluent outflows from intensive systems are polluting waterways; soil degradation from salinity, sodicity, acidity and erosion is increasing; and we are becoming aware of new threats to the environment and to climate, some of which are directly attributed to animal production. Simultaneously, domestic and international consumers are becoming increasingly concerned about the environmental consequences of animal production, the safety of animal products, the ethics of animal farming, and welfare aspects of some animal production systems. However, animal production systems that simultaneously achieve high levels of animal welfare, are acceptable to the public at large, and that are produced in an ecologically sustainable manner, are likely to be more expensive. If consumers continue to make purchasing decisions largely based on price, the global marketplace dictates that we will import animal products and transfer our ecological and animal welfare footprint elsewhere. (Wackernagel and Rees 1996). Animal producers in this country will become increasingly impoverished and their stewardship of the land unsustainable. If, on the other hand, Australians genuinely wish to contribute to creating landscapes that are “perennially-peopled and productive” (Passioura 1999) we need to adopt principles and practices that allow all sectors of society to share not only in the economic and non-economic benefits of animal production, but also in the costs.

REFERENCES

ABS (2001). www.abs.gov.au/websitedbs/D331

ALBRECHT, G. (2001). *Proc. Aust. Poult. Sci. Sym.* **13**, 43-50

BACH-KNUDSEN, K.E. (2000). *Proc. Nutr. Soc.* **60**, 291-9.

BAE, K.H., KO, T.G., KIM, J.H., CHO, W.T., HAN, Y.K., HAN, I. K. (1999). *Korean J. Anim. Sci.* **41**, 23-30

BEGOVIC, S. (1978). *Veterinaria Yugoslavia* 4: 433-43.

BROOK, R. (1990). *J. Royal Agric. Soc. England* **151**, 103-11.

BURT, D.W. (2002). *World Poultry Sci. J.* **58**, 5-13.

CHAPMAN, R.E. (1993). *Wool Tech. Sheep Breed*. **41**, 1-10.

CONWAY, G. (1985). *Agric. Administration* **20**, 31-55

DOLEZAL, O. (2000). *Mechanizace Zemedelstvi* 5, 50-4.

DOYLE, P.T., ARMSTRONG, D.P., KNEE, J.E., PRITCHARD, K.E. and GYLES, O.A. (2000). *Asian Aus. J. Anim. Sci.* **13**, 37-9.

DUNNINGTON, E.A., MARTIN, A. and SIEGEL, P.B. (1987). *Poult. Sci.* **66**, 2060-2.

FAKAE, B.B., CAMPBELL, A.M., BARRETT, J., SCOTT, I.M., TEESDALE-SPITTLE, P.H., LIEBAU, E. and BROPHY, P.M. (2000). *Phytotherapy Res.* **14**, 630-4.

FLANNERY, T. (1996). 'The Future Eaters: An Ecological History of the Australian Lands and People'. (Reed Books, Chatswood, NSW).

FRISCH, J.E. (1999). *Int. J. Parasitol.* **29**, 57-71.

GRIGG, G. (2002). *Anim. Prod. Aust.* (these proceedings)

HAVENSTEIN, G.B., FERKET, P.R., SCHEIDELER, S.E. and LARSON, B.T. (1994). *Poult. Sci.* **73**, 1785-94.

HEGARTY, R.S. (1999*). Aust. J. Agric. Res.* **50**, 1299-1305.

HOWDEN, S.M. and REYENGA, P.J. (1999). *Aust. J. Agric. Res.* **50**, 1285-91.

HOWDEN, S.M., WHITE, D.H. and BOWMAN, P.J. (1996). *Ecological Modelling* **86**, 201-6.

IQBAL-AHMED, BEG, A. Z. and AHMAD, I. (2001). *J. Ethnopharmacology* **74**, 113-23.

JAIN, S.C., SINGH, B. and JAIN, R. (2001). *Fitoterapia* **72**, 666-8.

JAMES, P.J. (1999). *Int. J. Parasitol.* **29**, 869-75.

JAMES, P.J., MOON, R.D., and RAGSDALE, D.W. (1998). *Med. Vet. Entomol.* **12**, 276-83.

JAMES, P.J., GARE, D.R., SINGH, A.W., CLARK, J.P., PONZONI, R.W. and ANCELL, P.M. (1990). *Wool Technol. and Sheep Breed*. Sept/Oct. 1990 & Dec 1990/Jan 1991. 106- 111.

JAMES, P.J., PONZONI, R.W., GARE, D.R. and CACKRUM, K.S. (1991). *Proc. Aust. Assoc. Anim. Breed. Genet.* **9**, 404-7.

JOBLIN, K.N. (1999). *Aust. J. Agric. Res.* **50**, 1307-13.

KALOF, L., DIETZ, T., STERN, P.C. and GUAGNANO, G.A. (1999). *Rural Sociology* **64**, 500-11.

KESTIN, S.C., KNOWLES, T.G., TINCH, A.E., AND GREGORY, N.G. (1992). *Vet. Rec.* **131**, 190-4.

KLIEVE, A.V. and HEGARTY, R.S. (1999). *Aust. J. Agric. Res.* **50**, 1315-19.

KONIG, M., SCHOLZ, E., HARTMANN, R., LEHMANN, W., and RIMPLER, H. (1994*). J. Natural Products* **57**,1411-5.

LASSEY, K.R., ULYATT, M.J., MARTIN, R.J., WALKER, C.F. and SHELTON, I.D. (1997). *Atmospheric Environment* **31**, 2905-14.

LEFROY, E.C., HOBBS, R.J., O'CONNOR, M.H. and PATE, J.S. (1999). *Agroforestry Systems* 45, 423-36.

LEVOT, G.W. (2000). *Int. J. Parasitol.* **30**, 291-7.

LEVOT, G.W. (1995). *Int.. J. Parasitol.* **25**, 1355-62.

MCCRABB, G.J. and HUNTER, R.A. (1999). *Aust. J. Agric. Res.* **50**, 1335-39.

MENCH, J.A., GARNER, J.P., and FALCONE, C. (2001). *In* 'Proc. 6th European. Symposium on Poultry Welfare' (eds H. Oester and C. Wyss) pp152-6.

MOLAN, A.L., ALEXANDER, R.A., BROOKES, I.M., MCNABB, W.C., and PETERSON, S.W. (2000). *Proc. NZ Soc. Anim. Prod.* **60**, 21-5.

MORLEY, F.H.W. (1949). *Agric. Gaz. N.S.W.* **60**, 543-8.

NIEZEN, J.H., WAGHORN, T.S., CHARLESTON, W.A.G., and WAGHORN, G.C. (1995). *J. Agric. Sci. (Camb.)* **125**, 281-9.

PASSIOURA, J.B. (1999). *Agroforestry Systems* **45**, 411-21.

PRATT, M.S. and HOPKINS, P.S. (1976). *Proc. Aust. Soc. Anim. Prod.* **11**, 189-92.

PRETTY, J. (1999). *In* 'Sustainable Agriculture and Environment' (Eds. A. K. Dragun and C. Tisdell). pp 79 (Edward Elgar Publ. Inc Mass. USA).

SANDERCOCK, D.A, HUNTER, R.R., MITCHELL, M.A. and HOCKING, P.M. (2001). *In* 'Proc. 6th European Symp. on Poultry Welfare' (Eds H. Oester and C. Wyss) pp118-123.

SCHEELE, C. W. (1997). *Vet. Quarterly* **19**, 127-30.

SCOTT, J.M., HUTCHINSON, K.J., BLAIR, G.J. and KING, K.L. (2000). *Asian Aus. J. Anim. Sci.* **13**, 8-12.

SMITH, W.D. (1999). *Int. J. Parasitol.* 29, 17-24.

SORREL, G.C., HYND, P.I., HOCKING, J.E., KUCHEL, T. and DESARAM, W. (1990). *Aust. Vet. J.* **67**, 51-5.

TELLAM, R.L. and BOWLES, V.M. (1997). *Int. J. Parasitol.* **27**, 261-73.

TISDELL, C. (1999). *In* 'Sustainable Agriculture and Environment' (Eds. A.K. Dragun and C. Tisdell). pp 37 (Edward Elgar Publ. Inc Mass. USA).

WACKERNAGEL, M. and REES, W.E. (1997). *Ecological Economics* **20**, 3-24.

WALLER, P.J. (1994). *Acta Tropica* 56, 233-43.

WEBER, R. (2000). 'Alternative housing systems for farrowing and lactating sows'. EAAP publication **102**, 109-15.

WENK, C. (2000). *Asian Aus. J. Anim. Sci.* **13 (Vol 1)**, 86 – 95.

WOOLASTON, R.R. and BAKER, R.L. (1996). *Int. J. Parasitol.* 26, 845-55.

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