
VOLUME 62 2002

The pastoral animal industries in the 21st century

J. J. ROBINSON

Rowett Research Institute, Bucksburn, Aberdeen, AB2 9SB.

ABSTRACT

Masked by the short-term influences of under or over-production at national level, concerns about the quality and hygiene of animal products and fears regarding dietary influences on human health, long-term projections of what will be expected of the pastoral animal industries are difficult to make. Concerns about the welfare of animals in intensive systems coupled with the political changes taking place in Russia and Eastern Europe are likely to swing animal production more towards pastoral systems. The removal of large quantities of fat from the food chain is likely to become a permanent feature. So too is the trend for a more even flow of high-quality products on to the market. In meeting these goals the role of the current biotechnological revolution, both directly in primary animal production, and indirectly through its contribution to the animal- product and food-processing industries, will be essential. We can not afford intellectual scientific complacency in a world where famine could, however remotely, become a truly global phenomenon. It is against this background that those aspects of the pastoral animal industries that currently limit production are viewed and the opportunities for implementing new technologies outlined.

INTRODUCTION

To comment on the likely features of the pastoral animal industries in the 21st century is a daunting task. It is little more than a decade ago since alarm was being expressed in Britain on the rate at which highly productive agricultural land was disappearing under motorways and into extended urban development. *'How can the agricultural industry accommodate this loss, and feed a nation of 55 million people?'* was the question being asked by leading agriculturists. Yet to-day, in order to curb surpluses of agricultural produce we have in Britain, thousands of hectares taken out of production in a set-aside scheme and milk production being limited through the use of quotas. Additionally the general public is becoming more and more concerned about the welfare of farm animals, the quality and hygiene of animal products and the effects of dietary products of animal origin on human health. In short the agricultural and food industries have had to accommodate change and be fully accountable and beyond reproach.

Over the same period we have witnessed advances in biotechnology that could transform the animal production and food processing industries. Although the main aim of this paper is to provide a personal view on those aspects of the pastoral animal production industries that may benefit from new technology, it is interesting, in the first instance, to look briefly at how a change in attitude to animal products is altering demand.

THE IMPACT OF THE NACNE AND COMA REPORTS

Following the reports of the National Advisory Committee on Nutrition Education (NACNE, 1983) and the Committee on Medical Aspects of Food Policy (COMA, 1984) associating coronary heart disease with the excessive consumption of saturated fat, we have witnessed in the U.K. decreases in the consumption of whole milk and butter in the U.K. of 27 and 38% respectively (Figure 1). Over the same period there has been almost a two fold increase in the consumption of low-fat milk. Similarly, the decrease in butter consumption has been accompanied by an increase in 'low-fat' and 'dairy' spreads. The weight of red meat consumed has also declined but this may well reflect trends in deboning and fat trimming prior to sale. Television adverts ans slogans such as 'go to work on an egg' have been overtaken by concerns regarding cholesterol intake. The decline in egg consumption reflects this and is further accentuated of course by the recent 'salmonella' scare which reduced consumption in the first three months of 1989 by 20%, although by the end of the year the reduction was only 6%.

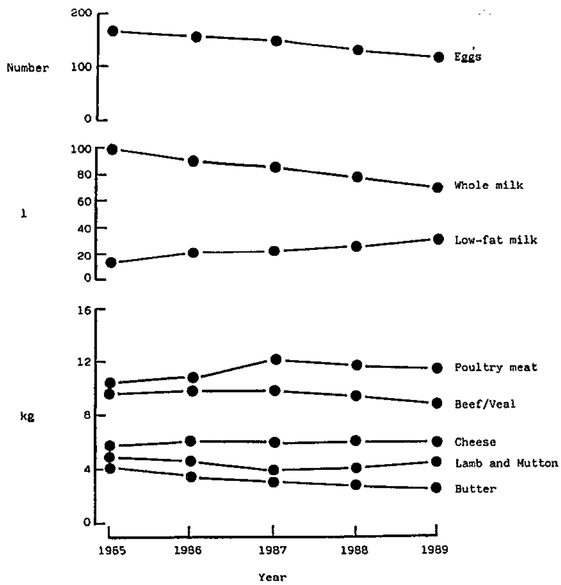

FIG 1 UK annual *per capita* household consumption of a selection of animal products following the NACNE and COMA reports. (Source: Ministry of Agriculture, Fisheries and Food, 1985-1989).

These relatively short-term changes in the consumption of animal products, some of which may well result in the establishment of permanent dietary eating habits that are very different to those of the past, clearly demonstrate the problem of predicting the demands that may be placed on the animal industries in the next century. Concern about possible risks does not negate the value of animal products for a healthy diet. These relate to their supply of vitamins and minerals (Figure 2). In a more extensive review each mineral and vitamin would warrant comment but in the context of the decline in the consumption of whole milk the large contribution (over 70%) that milk and milk products make to calcium intake is particularly noteworthy in that it reinforces the need to ensure that the downward trend for whole milk is balanced, during growth in children, by an increase in consumption of low-fat milk. With regard to the red meats, these are rich in vitamins, supplying in some cases, e.g. vitamin B12, half the total per capita intake (Figure 2). Meat also provides around 20% of the iron intake. Coming as it does from haemoglobin and myoglobin, 'this iron is much more readily absorbed than the nonhaem iron that is provided by the other components of the diet (James *et al.*, 1988); indeed it also enhances the absorption of iron from the nonhaem dietary sources. This is particularly relevant in that animal studies, and now studies in human infants, show that there can be an irreversible impairment of mental ability arising from iron deficiency in early life (Pollit *et al.*, 1989).

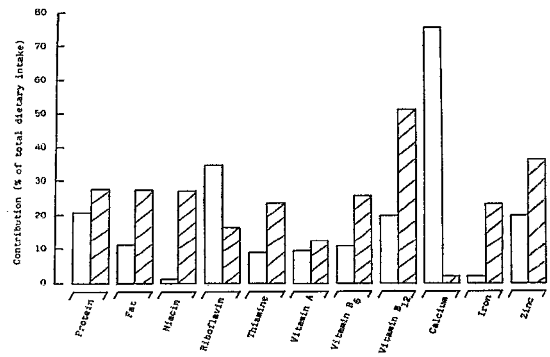

FIG 2 The contributions that milk and milk products ▭ and red meat ▨ make to the intake of a selection of nutrients. (NRC, 1988).

The preceding brief comments merely illustrate that as information on diet and human health accumulates, it is inevitable that there will be many short-term fluctuations and indeed in some instances a more permanent shift in the demand for specific animal products. Of course even greater shifts may occur. On a world basis the major surpluses of grain (wheat, rice and coarse grains) that occurred between 1983 and 1986 have been followed by even greater deficits in the subsequent three years. Many would argue that the dramatic political changes that we are now seeing in Russia and Eastern Europe will create a massive demand for grain, thereby swinging the animal production industries much more towards pastoral systems.

BIOTECHNOLOGY IN PERSPECTIVE

Superimposed on the recent trends in the consumption of animal products there have been enormous advances in biotechnology. To those at the forefront of the bioindustrial revolution, this advance of science is seen as a logical progression; after all our forefathers showed remarkable ingenuity in harnessing the essential ingredients of biotechnology in the making of bread, cheese and wine to mention only a few of its early products. To many of the lay public however, the application of current biotechnological innovations in agriculture in Britain and, I suspect elsewhere, has become, in their minds synonymous with bovine somatotropin (BST) and therefore regarded as unnecessary and unacceptable. It is an interesting thought, that had the discovery of how to produce wine and beer been made only a few years ago, it probably would have been banned on the grounds that it was the product of an unnecessary biotechnological revolution and a danger to public health.

For a moment therefore let us reflect on how our descendants may, with hindsight, view the 20th century. It may well be that we will be seen as the generation that played 'fast and loose' with the earth's fossil fuels and non-renewable resources, polluted the environment and then rejected the biotechnological advances that could have reversed these trends (Prentis, 1985). We may be also seen as the generation that produced 'knee-jerk' reactions to short- term changes in supply and demand, and made little attempt to cater for the possibility that in the 21st century famine may be a truly global phenomenon. Assuming an expansion of 15% in the land area for the production of food, a mixed diet of cereals, vegetables and animal products and equity of food supply, Blaxter (1987) calculated that the World Bank estimate of an equilibrium World population of 10,450 million by AD 2100 would require a 2.5 fold increase in output per unit area of land. Such predictions of world population, however uncertain, and the resources they would demand, make it difficult for agriculture to turn a 'blind-eye' to further scientific endeavour and to the application of advances in biotechnology. We are, as Blaxter (1986) so eloquently put it, *'in a monopoly situation as far as our children's children are concerned and it must be our purpose to provide the fabric of their future from the threads of understanding that rest in our hands'*. There is no doubt that biotechnology has much to offer. Equally its application will involve a strong element of public acceptability (Mepham, 1989). Therefore the suggestions made in the subsequent sections of this paper about pastoral animal production systems and biotechnology should be regarded as personal ones. As they are merely part of the open and on-going debate that is needed to ensure that modern biotechnology is applied sensibly and with success.

REPRODUCTION

'There is every reason to believe that a new era is dawning in cattle breeding and that in due course a majority of cows in a herd will be recipients carrying embryos of the breed type that the farmer wishes to produce' (Gordon, 1989).

This quotation from the conclusions of a paper describing the techniques developed by Professor Gordon and his colleagues at the University of Dublin for the large-scale production of cattle embryos by the *in vitro* culture and fertilization of immature follicular oocytes harvested from slaughtered beef heifers, coincided in timing with the birth of the first calves in commercial dairy herds in Ireland following the use of the technique. In these herds artificial insemination was replaced by the non-surgical transfer of embryos produced from *in vitro* culture in Professor Gordon's laboratory. The first of the on-farm results in which British Friesian cows were each implanted with beef embryos derived from *in vitro* fertilization were presented recently (Mayne and McCaughey, 1990); conception rate was 56% and of these 39% produced twins. Such developments suggest that there is a real possibility that embryo transfer could take over from artificial insemination, thereby enhancing the quality of beef from the dairy herd. At the same time the current technique for sexing embryos by amplifying the DNA sequences on the Y-chromosome to the point that they can be visualized (Handyside *et al.*, 1989) will no doubt be simplified for commercial application. Likewise the separation of X and Y chromosome-bearing sperm according to their DNA content by flow cytometry, while at the same time maintaining their fertilizing ability, would now appear to be a real possibility, provided the recent observations by Johnson *et al.* (1989) for the rabbit can be repeated for other farm species.

These advances in biotechnology can be regarded as a logical progression from artificial insemination (AI) and can be easily applied at farm level through the current structure of the AI service. In contrast the use of the technique to enhance twinning rates in cattle or indeed of any technique that attempts to enhance the prolificacy of farm livestock, involves important decisions regarding the extent to which improvements in reproductive rate can be tolerated by the animal in a pastoral environment. With this in mind it is important to consider which components of the reproductive process currently limit production and to what extent they can be altered within the context of what is an acceptable interpretation of peoples' dominion over animals.

Optimum ovulation rates

Looking back on almost half a century of research on attempts to improve the ovulation rate and litter size of sheep and indeed of the more recent attempts at twinning in cattle and red deer, it is surely time that we asked, 'are the targets that we are setting for the reproductive performance of our ruminant species reasonable'? Perhaps one of the most simple tests that we can apply in answering this question is to look at the extent to which increases in litter size result in deviations from the interspecies line relating birth weight to maternal size. These deviations, which are illustrated in Figure 3, may be used as indices of the physical stress that increases in litter size place on the various species.

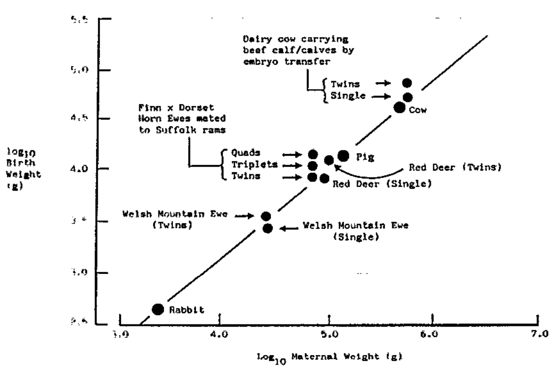

FIG 3 Total weight of newborn in relation to weight of dam. Dat for the cow, pig, Welsh Mountain ewe and rabbit in the interspecies line taken from Leitch et al 1959; Finn Dorset ewe from Robinson et al 1977; Red Deer (single) from Adam et al 1988; Red Deer (twins) from Adam 1984; Dairy cow with beef calf/calves from Mayne and McCaughey 1990.

The positions of the values in Figure 3 are of course eminently sensible with, in the case of the ewe, singleton and twin foetuses lying below and above the line respectively. The value for the red deer with a singleton foetus that lies slightly below the line and twins just above the line is also interesting in that it implies that deer may not be unduly physically stressed when carrying twins. In contrast the value for the singleton beef calf carried by the dairy cow lies slightly above the line. Twin beef calves, when carried by dairy cows, lie well above the line and occupy positions that are comparable, in relative terms, to the ewe with triplet foetuses. Thus all the evidence points to the fact that, through their apparent inability to set a 'reasonable' upper limit to total foetal weight, our domesticated ruminant species subject themselves to considerable physical stress in late pregnancy when foetal numbers are increased above the accepted norm. Of course when the only factor that is used to enhance the ovulation rate and litter size in the ewe is the naturally-occurring one of nutrition, the vast majority of our traditional breeds avoid the physical stress problem and merely straddle the interspecies line by having only singletons or twins.

The second test that we can apply to identify realistic targets in foetal numbers relates to the extent to which the ruminant gastrointestinal tract can, from the *ad libitum* consumption of the available forage, meet the nutrient needs of the gravid uterus. Here the triplet-bearing Booroola x Romney ewes studied by Barry and Manley (1985) within the context of the feed resources of the New Zealand pastoral system provide a good example. Their late- pregnancy nutrient requirements, in particular for amino acids, are well in excess of those supplied from high quality forage. The net result is poor colostrum production, reduced wool growth in the ewe and a substantial loss of maternal tissue protein, all of which are corrected by the infusion of casein into the abomasum (Figure 4). These results clearly demonstrate that triplet-bearing ewes have a demand for nutrients, in particular amino acids, that can not be met from high quality ryegrass/clover pasture (metabolizable energy 11.8 MJ and total nitrogen 45 g/kg dry matter). Taken in conjunction with the physical stress that high multiples place on the ewe, these data cast doubt on the desirability of increasing litter size beyond twins.

Of course to comment on the optimal foetal numbers for the other species would require similar observations on the extent to which grazed herbage meets their nutrient needs of late pregnancy. However, there is the suggestion that the nutrient requirements for twins in late pregnancy are more readily met from forage diets in the cow than in the ewe (Robinson, 1990a). For the red deer the timing of mating so that the high nutrient demands of twin-bearing hinds in late pregnancy correspond with their seasonal increase in appetite (Kay, 1985) will undoubtedly be important if twinning is to be successful in this species.

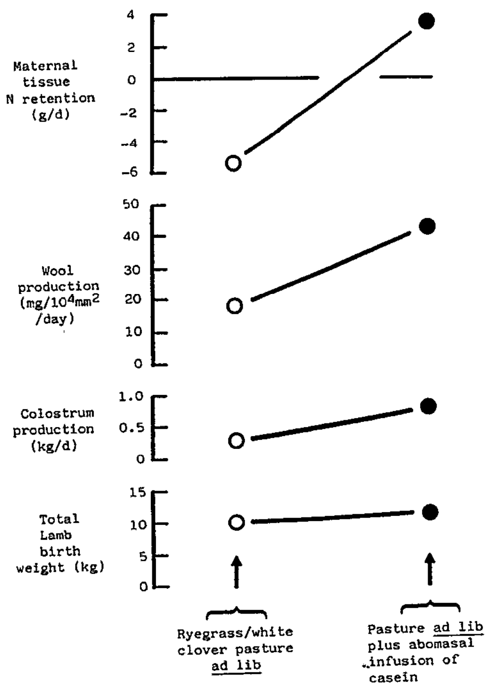

FIG 4 Production criteria and maternal tissue nitrogen (N) balance in triplet-bearing Booroola Romney ewes given fresh forage ad libitum or the forage plus an abomasal infusion of casein. (Barry and Manley 1985).

The preceding analysis implies that careful thought is necessary before embarking on major research programmes to improve the ovulation rate and prolificacy of ruminants. This should not however be interpreted as implying that there is no further need to develop procedures for enhancing ovulation rate. Successful superovulation is essential for genetic improvement programmes involving multiple ovulation and embryo transfer, yet current procedures for superovulation are based on empiricism in the administration of exogenous gonadotrophins and give highly variable and quite unsatisfactory results. There is thus a great need for fundamental studies on the control of folliculogenesis of the type being undertaken, here in New Zealand, by McNatty *et al.* (1989). In terms of more novel methods of superovulating ewes than the administration of gonadotrophins, the recent report of Mizumachi *et al.* (1990) that immunization of ewes against the human recombinant inhibin α-subunit resulted in a four fold increase in ovulation rate is of particular interest.

Enhancing embryo survival

Despite the enormous research effort that has gone into studying factors that affect embryo survival, hope that animals of the future would have enhanced embryo survival rates was fading fast. However, recent findings have altered the situation. Firstly, the view and indeed recommendation that a high plane of nutrition in early pregnancy is important in minimising embryo mortality has now been shown to have no scientific basis; in fact through its adverse effect on circulating progesterone concentrations, high-plane feeding reduces embryo survival (Robinson, 1990a). Secondly, at the more fundamental research level, new concepts on the importance to embryo survival in sheep and cattle of the biochemical dialogue between the developing embryo and the maternal endometrium may lead to new techniques for reducing embryo mortality. This biochemical dialogue involves specific trophoblastic proteins. These proteins are functionally-active interferons and the results of recent studies suggest that an intramuscular injection of a related recombinant bovine interferon (rbo $IFN_{\alpha 1}1$) in early pregnancy enhances pregnancy rate and litter size in ewes (Roberts *et al.*, 1990). In terms of its implementation, it is to be hoped that this new technology will eventually provide a means of improving the notoriously low conception rates that are an unacceptable feature of first inseminations in the dairy and beef cattle industries.

Removing seasonal anoestrus

In temperate latitudes the seasonal breeding pattern of sheep, goats and red deer places an unacceptable restriction on their production (see Smith *et al.*, 1989 for the seasonal pattern of ovarian activity in New Zealand sheep breeds). Within their restricted breeding season a further unacceptable feature, that is well documented for ewes, is the very short period (4 to 6 weeks) over which ovulation rates are at their maximum (Figure 5). Thus, any desire to advance or extend the breeding season leads to an unacceptable reduction of 25 to 30% in the potential lamb crop. That the maximum inherent reproductive potential of a species that has been farmed for centuries should be restricted to matings within a 4 to 6 week period each year is hard to comprehend. Even more so when one recognises that improvements in annual lamb production that are based on more frequent breeding and a litter size of 2 are much more compatible in their nutrient demands, with the corresponding nutrient supply from the digestion of a predominantly forage diet, than those relying on triplets and higher multiples in a once-per-year breeding system (see earlier section on ovulation rate).

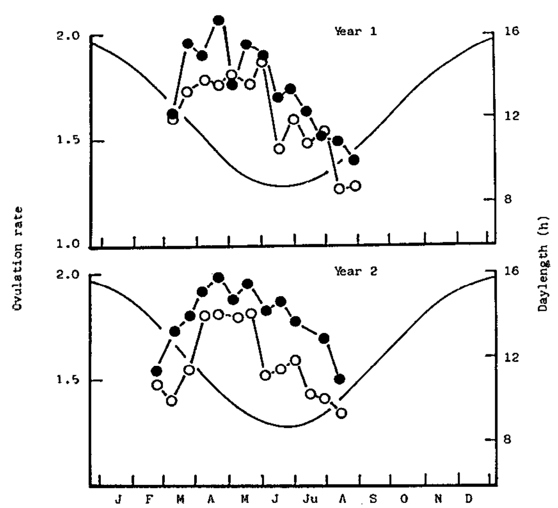

FIG 5 The seasonal pattern in the ovulation rate of Coopworth ewes in New Zealand maintained at body weights of approximately 50 kg (- o -) or 60 kg (- • -). (Montgomery *et al* 1988).

Recent advances in our understanding of the biochemistry involved in the control of seasonal breeding imply that it may eventually be possible for sheep, goats and red deer to be as non- seasonal in their reproduction as cattle. Following the recognition that the pineal indoleamine, melatonin, which is secreted during darkness, is the chemical signal that transmits information on the changing photoperiod, it was shown that exogenously-administered melatonin could not only advance but completely reverse the breeding season of highly-seasonal sheep breeds (Wigzell *et al.*, 1986a; Wallace *et al.*, 1988), and at the same time enhance ovulation rate at first behavioural oestrus (Wigzell *et al.*, 1986b). For red deer its continuous administration to cyclic hinds stimulates prolonged ovarian cyclicity (Adam *et al.*, 1989). Figure 6 provides a summary of how the timings of oestrous activity in sheep and red deer and their corresponding lambings and calvings have been altered in Scotland (latitude 57°N) by the judicious use of melatonin.

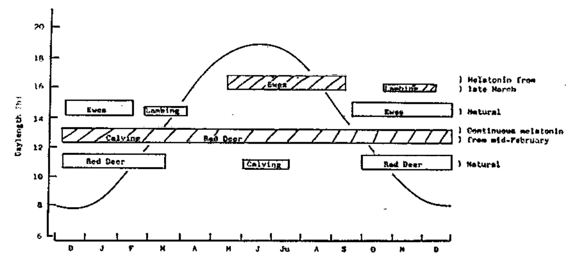

FIG 6 The natural periods of oestrus activity ▭ in Scottish Blackface ewes and red deer hinds in Scotland, their modification by melatonin, ▨ and the influence of meletonin on lambing and calving dates. (From: Adam *et al* 1989; Wigzell *et al* 1986a,b; Wallace *et al* 1988).

Of course these observations do not advance our knowledge of the mode of action of melatonin and as such are unlikely to lead to any novel way of removing seasonal anoestrus. In contrast the identification and characterisation of high-affinity melatonin receptors in the *pars tuberalis* of the sheep pituitary (Morgan *et al.*, 1989b) is a major step forward. So too are current findings on the nature of the receptor-mediated events in primary cultures of ovine *pars tuberalis* cells (Morgan *et al.*, 1989a). At the same time the *in vitro* culture techniques that are an integral part of this research, provide an extremely powerful and efficient laboratory assay for determining the biological activity of putative melatonin agonists and antagonists (Morgan *et al.*, 1989a).

Reducing the rebreeding interval

Removal of seasonal anoestrus would add a completely new dimension to the importance of the duration of the parturition to rebreeding interval in sheep, goats and red deer. For this reason, and in view of its additional relevance to the dairy and beef-cow industries, considerable research effort is now being directed into the factors controlling ovarian function and uterine involution in the early post partum period. From these studies it is clear that the ovaries are capable of shedding eggs well in advance of the ability of natural mating or cervical insemination to achieve successful fertilization. In our laboratory the use of laparoscopic intrauterine insemination to deposit semen at the tip of the uterine horn, thus by-passing the hostile environment of the early post-partum uterus of the ewe, has resulted in fertilization and development up to the morula stage as early as 22 days after lambing (Wallace *et al.*, 1989).

GROWTH

For the pastoral livestock industries of the world, efforts to improve lamb growth rates is always a priority. In the first 6 weeks, lamb growth rates reflect the level of milk production by the ewe and here, as in other dietary situations, there is ample evidence of milk yield responses to increases in the amounts of amino acid nitrogen reaching the abomasum (Figure 7).

These observations coupled with the finding that in the absence of a dietary protein supplement, ewes appear to use their body proteins (if not exhausted by the preceding pregnancy) to enhance the efficiency of milk synthesis (Geenty and Sykes, 1986), are strong indicators that high quality pasture does not provide the correct quantity and/or quality of amino acids for maximal milk production in the ewe (see later section on the possibilities for the genetic manipulation of forage plants and rumen bacteria). After 5 to 6 weeks the rapid decline in the ewe's lactation curve represents a withdrawal from the lamb of valuable truly rumen by-pass protein in the form of milk. Coming at a time when the growing lamb has to cope with the gastro-intestinal parasites and the additional energy and protein demands for the acquisition of immunity, this rapid decline in milk production restricts lamb growth. Selecting ewes for a more persistent lactation would seem a sensible alternative for achieving the enhanced lamb growth rates that have been shown by Poppi *et al.*, (1988) to be attainable when lambs at pasture are given a dietary supplement of undegraded protein in the form of fish meal (see Figure 8).

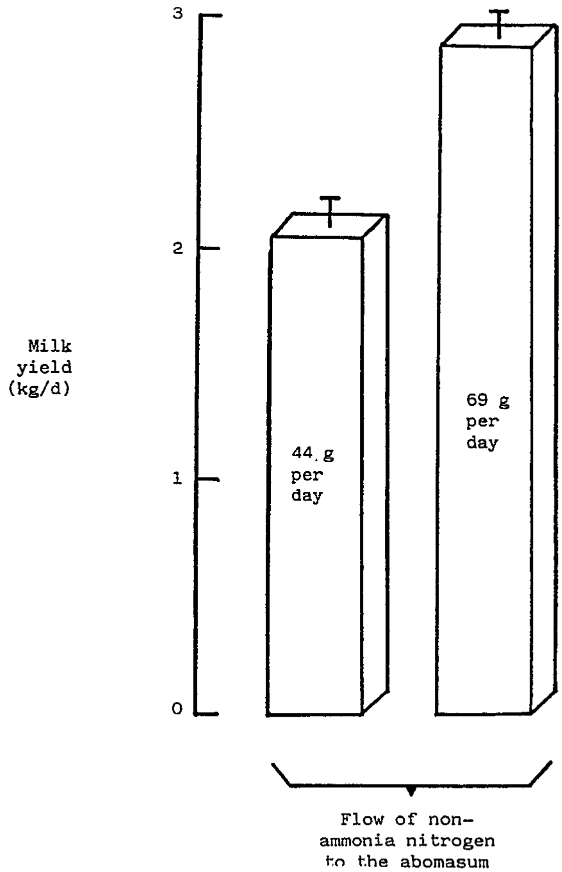

FIG 7 The effect of an increase in the flow of amino nitrogen to the abomasum on the milk yield of ewes grazing perennial ryegrass. (Dove *et al* 1985).

In terms of understanding the mechanisms involved in creating a more persistent lactation it is interesting to note that in the ewe, bovine growth hormone either alone (Sandles *et al.*, 1988) or, more intriguingly, when complexed with monoclonal antibody to enhance its activity (Forsyth *et al.*, 1989), creates a more persistent lactation.

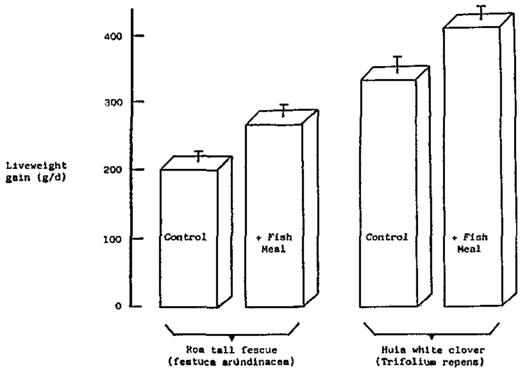

FIG 8 The effect of the dietary supplement of fishmeal on the growth rate of Dorset Down x Coopworth ram lambs grazing either tall fescue or white clover pastures. (Poppi *et al* 1988).

Of course, careful choice of pasture constituents may provide an alternative method of alleviating the mid-season decline in lamb growth rates. Recent work at the Edinburgh School of Agriculture and the Macaulay Land Use Research Institute (Vipond *et al.*, 1990) has shown that under intensive and continuous grazing by sheep, the small leaved clover (S184) is capable of producing twice as much dry matter as the larger-leaved varieties and, unlike the larger-leaved varieties, persists when grazed continuously. In combination with a suitable companion rye grass (e.g. the tetraploid variety, Condesa) that has the essential feature of an open sward structure that allows the clover to spread, it is sustaining remarkably high lamb growth rates (see Figure 9); the only major drawback is its lower stock- carrying capacity in the early grazing season. Nonetheless these observations imply that much has still to be learned, both by plant breeders and livestock researchers, in the development of pastures in such a way that the individual plant species can express their full potential. Of course complementarity is not limited solely to the plant species but can also involve integration of the stock classes so that overall production is increased. In this context the mixed grazing of sheep and cattle on New Zealand hill country (Rattray, 1989) and sheep and goats in what has traditionally been hill sheep grazing systems in Scotland (Russel *et al.*, 1983) are examples of how overall output can be enhanced by the mixed grazing of animal species.

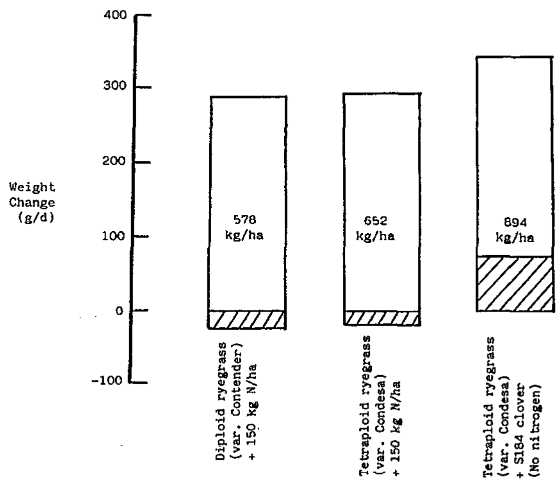

FIG 9 Comparison of the effects on the liveweight change of ewes ▨ and lambs ▭ of combining a small-leafed clover (S184) with an open sward tetraploid ryegrass species (Condesa) and no nitrogen (N) fertiliser with pure ryegrass swards given 150 kg N/ha. Data are for the second grazing season when the clover content had risen to 15-30% from its 5-10% level in the first season. (Vipond *et al* 1990).

CARCASS QUALITY

To meet the NACNE and COMA recommendations, 28 and 48% respectively of the total fat contained in animal products in Britain would have to be removed (Jones, 1985). Of course for meat, the easiest way to achieve this reduction during production is to slaughter animals at lighter weights thereby obviating the alternative of trimming fat from the carcass. This fat may enter the food chain in processed meat products. For sheep, slaughtering at lighter weights is an option that can be exercised with relatively little detrimental effect on overall efficiency of production, provided the number of lambs produced by the ewe per unit of time can be increased. Reducing slaughter weight does, of course, have its disadvantages both in terms of the higher slaughtering costs per unit of meat and the relative unattractiveness to the housewife of a small eye muscle area. For these reasons large lean carcasses have been gaining in popularity and in this respect New Zealand is no exception (Allison *et al.*, 1989).

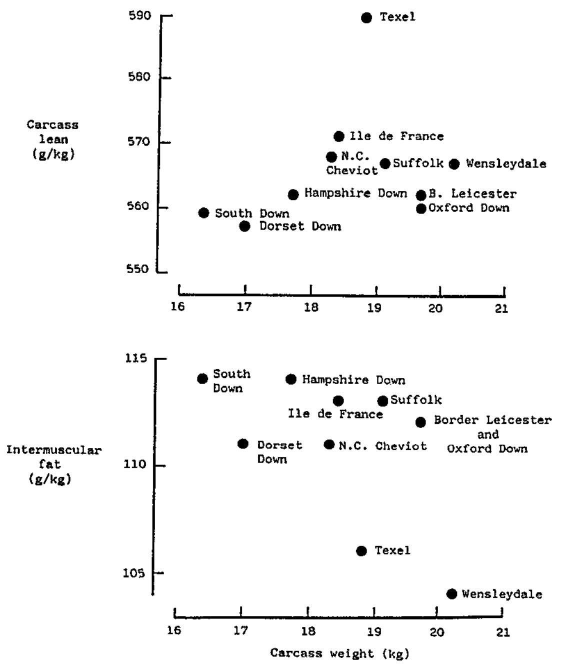

FIG 10 Carcass weights and their lean and intermuscular fat levels at the same level of subcutaneous fat in the crossbred lambs from 10 sire breeds. (From: Kempster *et al* 1987; Croston *et al* 1987).

Of the extensive range of terminal sire breeds tested in Britain the Texel although slower, by about 9%, in growth rate than, for example, the Suffolk, gives crossbred lamb carcasses that are considerably leaner at a given level of subcutaneous fat than those from any of the other terminal sires (Figure 10). It also has a relatively low content of intermuscular fat. Their above average killing-out percentage (Wolf *et al.*, 1980) may also be seen as a valuable attribute. It should however be judged in the broader context that it may reflect a reduced capacity to consume the large quantities of forage that are needed to meet the high nutrient demands of late pregnancy and early lactation.

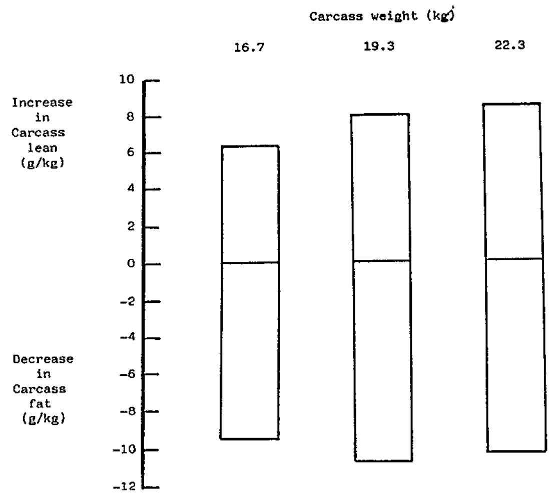

FIG 11 Increases in lean and decreases in fat in the crossbred progeny of ram lambs selected for reduced backfat and increased muscle depth. (Simm *et al* 1990).

There is, however, considerable within-breed variation in carcass lean and in eye muscle area which can now be detected in the live animal by ultrasonic scanning. Following four years of selection of pure bred Suffolk ram lambs for reduced backfat and increased muscle at the 13th rib and 3rd lumbar vertebra, Simm *et al.*, (1990) have recorded significant improvements in both measures and the improvements have also been reflected in crossbred progeny reared extensively at pasture (Figure 11). In an industry that can project a 'natural' image this approach is much more likely to be acceptable to the consumer than the injection of somatotropin or the oral administration of ß-agonists, two products that reduce the fat and increase the lean content of lamb (Butler-Hogg and Johnsson, 1987; Beermann *et al.*, 1986).

WOOL

Now that the textile industry has overcome the problems of shrinkage following washing, the demand for wool and other high quality animal fibres is increasing and is likely to continue to do so. After all the world

TABLE 1 Simplified techniques which allow repeated collections of embryos from ewes without resorting to laparotomy.

Methods	Proportion of ewes successfully flushed	Proportion of embryos collected	Reference
By laparoscope	1. 1.0 2. 1.0 3. 1.0	0.35 0.76 0.66	+McKelvey *et al* (1986)
Transcervical	0.33	0.79	Coonrod *et al* (1986)
By laparoscope	1.0	0.79	Legendre *et al* (1988)
Transcervical following PGE_2 and oestradiol to relax the cervix	1.0	0.65	Barry *et al* (1990)

+Ewes flushed for embryo collections on three occasions. Intervals between flushings were 27 and 34 days.

production of wool currently represents only about 5% of the total synthetic and natural fibres used to clothe the world's population (International Wool Textile Organisation, 1989) the large dependence of our apparel, upholstry and carpet industries on synthetic fibres is yet another component of our current irresponsible approach to the use of fossils fuels and non-renewable resources.

While genetic selection has played a major role in achieving the current high yields and fine quality of the top wool producing breeds, it is well recognised that the potential for wool growth is usually well in excess of what can be achieved from the supply of amino acids reaching the small intestine. This is seen in the data presented in Figure 4 where a dramatic response in wool production was achieved when pasture-fed ewes in late pregnancy were given an abomasal infusion of casein. With cysteine being the major limiting amino acid for wool growth, one of the current novel approaches to enhancing wool growth that could have considerable impact in the next century is the attempt to produce transgenic sheep which express, in their rumen epithelium, activity for the two key enzymes (serine acetyltransferase and O-acetylserine sulphydrylase) that are required for cysteine biosynthesis (Rogers, 1990). The ability of the sheep to enhance its available cysteine supply would not only have benefits to wool production but also to other physiological states, such as late pregnancy, where microbial protein fails to meet the cysteine needs for foetal growth (Robinson, 1990b).

DISEASE CONTROL

To New Zealand and Australia, countries that are free of Scrapie, an infectious degenerative disease of the central nervous system of sheep and goats, desirable attributes of foreign breeds, have in the past been largely of academic interest due to the restrictions placed on importations from countries where the disease occurs. Thanks to recent advances in molecular biology this no longer may be the case. Researchers at the Neuropathogenesis Unit in Edinburgh have developed a blood test which identifies those animals that are genetically resistant to the expression of the known field strains of Scrapie (Hunter *et al.*, 1989; Hope, 1989). This is the first objective test of genotype certification for resistance to Scrapie and should lead to much greater freedom in the International trading of sheep and goats.

In the pasture-based sheep industries, gastrointestinal parasites represent a major economic loss (equivalent to £20-30 million per year in the UK alone) with the effects not being restricted to growth but also to wool and milk production (see Parkins and Holmes, 1989, for a review of research data quantifying these effects). To date all attempts to produce an effective vaccine have failed. Nonetheless this important area of pastoral animal production is bound to benefit from the advances of modern biotechnology and in this respect Aitken (1990) has made some interesting projections. For the blood-sucking nematode *Haemonchus contortus* the production of genetically-engineered vaccines of nematode gut antigens is seen as a potential way forward; their formulation could involve adjuvant preparations for inoculation or as recombinant vaccines in a non- virulent bacterium within the gut (Aitken, 1990).

GENETIC SELECTION

The use of fibre optics for the deposition of semen directly into the uterine lumen has now opened up the way for the widespread dissemination of frozen semen from rams of superior genetic merit. To this technology, we can now add simplified techniques for the recovery and transfer of ovine embryos. These techniques, the essential features of which are given in Table 1, should enable the sheep industry to use multiple ovulation and embryo transfer (MOET) to:-

a) speed up the multiplication of exotic imports and Transgenics.
b) double the rate of progress in genetic selection programmes for improving the quality and quantity of wool, milk production, lean tissue growth rates and resistance to disease.

TRANSGENICS

Plants

Throughout this paper a recurring theme has been the failure of microbial protein yields for ewes grazing ryegrass/clover swards to provide adequate amino acids to meet the needs of the ewe in late pregnancy and early lactation and of the growing lamb in the post-weaning period. For wool growth and for foetal growth in late pregnancy cysteine appears to be the first-limiting amino acid (Robinson, 1990b) and for milk production it is probably methionine. To meet these needs, considerable progress is currently being made in the production of genetically-engineered dicotyledonous plants such as lucerne and these could eventually have a major impact on the production of pastoral animal systems. For example, the gene for a low-molecular-weight pea seed protein, PA1, which is high in rumen undegradable cysteine (Spencer *et al.*, 1988) has been isolated, sequenced and transferred to lucerne; so too has vicilin, another pea seed protein (Rogers, 1990). Both are expressed in the leaves of the lucerne plant, albeit still at too low a level to have a major impact on production.

Rumen bacteria

The major areas of rumen function that might benefit from the introduction of transgenic rumen bacteria have been reviewed by Armstrong and Gilbert (1985) and Forsberg *et al.*, (1986). These include enhanced cellulolytic activity, the capability to cleave ligno-hemicellulose complexes, reduced methane production, decreased proteolytic and/or deaminase activities, increased capability for N- fixation and increased microbial production of specific amino acids. In view of the inadequacies of the rumen microbial amino acid supply from pasture, the genetic manipulation of the rumen bacteria to enhance their available amino acid content is particularly relevant. In this regard the first successful transfer of foreign genes into rumen bacteria (*Bacteroides ruminicola*) has been achieved by Thomson and Flint (1989) at the Rowett Research Institute. Although this is still a long way from the production of genetically-engineered rumen bacteria that enhance the production of specific amino acids, it is a major step forward. Of course it is also recognised that populations of transgenic rumen bacteria may be difficult to establish alongside indigenous competitors and here the use of specific substrates to promote their establishment shows promise (Wallace, 1989).

Another important area where transgenic rumen microbes could play an important role is in the detoxification of plant poisons (Gregg, 1989). A precedent that such an approach is worthwhile already exists; a rumen bacterial inoculum obtained from goats in Hawaii was successfully introduced into the rumen of cattle in Australia to detoxify 3 hydroxy 4 (IH) pyridine (3,4DHP), a breakdown product of the non-protein amino acid mimosine that is present in *Leucaena* forage (Jones and Megarrity, 1986). Potential target toxins that may well benefit from such an approach in New Zealand would appear to be those that cause facial eczema, and ryegrass staggers (Smith, 1989).

Animals

The use of gene transfer to confer resistance to the major chronic and debilitating diseases that affect animals is far more likely to meet with public approval than any attempt to increase directly a specific production trait such as growth. Already the concept that compounds produced by transgenic animals could be used to combat human illness is now a reality. Fragments of the sheep ß- lactoglobulin gene fused to cDNA for the human blood clotting factor 1X and α-1 antitrypsin have enabled these products to be produced in the milk of transgenic mice and sheep at the AFRC Institute of Animal Physiology and Genetics in Edinburgh (Wilmut *et al.*, 1990; Clark, 1990). Experience with these techniques opens up the way for using gene transfer to alter other features of the milk proteins in line with processing needs and market demands. Of course the development of gene transfer technology requires a major research effort and for this reason the direction of its use to alter animal production requires careful thought and consultation right across the whole spectrum of expertise involved in the science and practice of animal production. To use this expensive new technology to alter the nature of an animal product on the basis of scant medical evidence that it could be beneficial to human health would be entirely irresponsible. Equally irresponsible would be to use it to enhance the level of production of animals without regard for their higher nutrient demands and long-term well being.

DIVERSIFICATION OF SPECIES AND PRODUCTS

New Zealand has been at the forefront in diversifying its pastoral animal species e.g. red deer for lean meat and antler velvet, goats for their high quality fibre, exotic sheep breeds such as the Gotland for its high-quality pelt and now the camelids for the reputed high value (£100/kg) of their fleece. For some species, notably goats, the new enterprises were built on city money with the initial exorbitant prices for breeding stock having nothing to do with commercial reality (Lyon, 1989). The inevitable slump in prices and the losses incurred by investors and farmers alike have delayed unnecessarily the steady developments that are needed to ensure that these new forms of animal production make a significant contribution. Of the novel industries that have been mooted in recent times it is perhaps no coincidence that their success appears to be inversely proportional to the hype surrounding their introduction! However when all the hype has gone there is every reason to believe that these alternative forms of production, joined perhaps by the nilgai antelope with its high content of lean meat and natural ability to produce twin calves (Kyle, 1990) will find their niche and make a significant contribution to the pastoral animal industries. Why a dairy-sheep industry does not join them is difficult to understand, particularly as the ability to alter by dietary means, the fatty acid content of ewe's milk to bring it more in line with consumer needs, would appear to be easier than for the cow (Robinson, 1990b).

With over half of New Zealand's export earnings coming from meat, wool and dairy products (Page, 1989) it is essential for the future of her pastoral industries that the latest technological advances in the processing, packaging and diversification of the product range for each commodity remains at the forefront. Those involved solely in the primary animal production industries may be over awed by recent advances in biotechnology and how they could affect animal production systems; if so they will be speechless when they appreciate the degree to which biotechnology is likely to transform the food processing industry (Agricultural and Food Research Council, 1989).

CONCLUSIONS

In this paper the opportunities for applying new technologies to the pastoral animal systems are seen against the background of those features that currently appear to be exercising unacceptable restrictions to production. Throughout, I have attempted to support these views by experimental observations made on grazing ruminants. Nonetheless many of the views that I have expressed e.g. those regarding the unacceptable nature to the animal of high prolificacy, the unnecessary restriction that seasonal breeding places on the production of some farmed species or the inability of fresh herbage to provide the amino acid needs during peak periods of production, arose from our studies on highly intensive in-door systems where the solutions to these problems are very different to those advocated here. Furthermore, by their very nature these intensive systems avoid many of the chronic gastro-intestinal parasite infestations that reduce production in the pastoral situation. In so doing they highlight the importance of ensuring that modern biotechnology provides novel approaches to disease control in the grassland animal production systems.

No doubt researchers from other scientific disciplines might take a very different view. Meteorologists would argue that global warming as a consequence of the greenhouse effect could have far more radical influences (Parry *et al.*, 1989; Rowntree *et al.*, 1989). Of course these influences are far less likely to come from the direct result of the greenhouse effect itself than from the global arrangements that will probably be brought into play to reduce its impact. It is anticipated that these will come into force within the next decade and will involve a reduction in fossil fuel burning, improved efficiency of energy use and a slowing down of the rate of deforestation (Parry *et al.*, 1989). Taking an optimistic view, the impact of such changes to the pastoral animal industries would be a increase in the cost of artificial fertilizers and I doubt if that would be a major cause for concern in New Zealand!

REFERENCES

Adam, C. L. 1984. *Personal communication.*

Adam, C. L., McDonald, I., Moir, C. E. and Pennie, K. 1988. Foetal development in red deer (*Cervus elaphus*). 1. Growth of the foetus and associated tissues. *Animal Production 46*: 131-138.

Adam, C. L., Moir, C. E. and Shiach, P. 1989. Melatonin can induce year-round ovarian cyclicity in red deer (*Cervus elaphus*). *Journal of Reproduction and Fertility 87*: 401-408.

Agricultural and Food Research Council 1989. Institute of Food Research, Annual Report, Shinfield, Reading.

Aitken, I. D. 1990. Sheep health: Research developments and emerging problems. In: *New Developments in Sheep Production.* Occasional Publication of the *British Society of Animal Production* (In Press).

Allison, A. J., Aspinall, J. M., Edwards, J. R., Lynch, P. R. and Vivanco, H. W. 1989. Sheep breeds exotic to New Zealand: their performance and application to industry. In: *Second International Congress for Sheep Veterinarians*, Massey University, Palmerston North, pp 204-214.

Armstrong, D. G. and Gilbert, H. J. 1985. Biotechnology and the rumen: a mini review. *Journal of Science Food and Agriculture 36*: 1039-1046.

Barry, T. N. and Manley, T. R. 1985. Glucose and protein metabolism during late pregnancy in triplet-bearing ewes given fresh forage *ad lib.* 1. Voluntary intake and birth weight. *British Journal of Nutrition 54*: 521-533.

Barry, D. M., van Niekerk, C. H., Rust, J. and van der Walt, T. 1990. Cervical embryo collection in sheep after ripening of the cervix with prostaglandin E_2 and estradiol. *Theriogenology 33*: 190.

Beermann, D. H., Hogue, D. E., Fishell, V. K., Dalrymple, R. H. and Ricks, C.A. 1986. Effects of cimaterol and fishmeal on performance, carcass characteristics and skeletal muscle growth in lambs. *Journal of Animal Science 62*: 370-380.

Blaxter, K. L. 1986. *People, food and resources. Cambridge University Press, London.*

Blaxter, K. L. 1987. Future hunger? *The Lancet 1*: 309-313.

Butler-Hogg, B. W. and Johnsson, I. D. 1987. Bovine growth hormone in lambs: effects on carcass composition and tissue distribution in crossbred females. *Animal Production 44*: 117-124.

Committee on Medical Aspects of Food Policy. 1984. *Diet and Cardiovascular Disease.* Report on Health and Social Subjects No.28. H. M. Stationery Office, London.

Coonrod, S. A., Coren, B. R., McBride, B. L., Bowen, M. J. and Kraemer, D. C. 1986. Successful non-surgical collection of ovine embryos. *Theriogenology 25*: 149.

Croston, D., Kempster, A. J., Guy, D. R. and Jones, D. W. 1987. Carcass composition of crossbred lambs by ten sire breeds compared at the same carcass subcutaneous fat proportion. *Animal Production 44*: 99-106.

Dove, H., Milne, J. A., Lamb, C. S., McCormack, H. A. and Spence, A. M. 1985. The effect of supplementation on non-ammonia nitrogen flows at the abomasum of lactating grazing ewes. *Proceedings of the Nutrition Society 44*: 63A.

Forsberg, C. W., Crosby, B. and Thomas, D. Y. 1986. Potential for manipulation of the rumen fermentation through the use of recombinant DNA techniques. *Journal of Animal Science 63*: 310-325.

Forsyth, I., Holder, A. and Pell, J. 1989. Increasing the bioactivity of growth hormone in sheep. In: *Bioscience in Animal Production.* Ed. J. Hardcastle. Agricultural and Food Research Council, Windon. pp 6-7.

Geenty, K. G. and Sykes, A. R. 1986. Effect of herbage allowance during pregnancy and lactation on feed intake, milk production, body composition and energy utilization of ewes at pasture. *Journal of Agricultural Science, Cambridge 106*: 351-367.

Gordon, I. 1989. Large-scale production of cattle embryos by *in vitro* culture methods. *AgBiotech News and Information 1*: No.3, pp 345-348.

Gregg, K. 1989. Enhancement of microbial detoxification by gene transfer. In: *VII International Symposium on Ruminant Physiology*, p 58. Japanese Society of Zootechnical Science.

Handyside, A. H., Penketh, R. J. A., Winston, R. M. L., Patterson, J.K., Delhanty, J. D. A. and Tuddenham, E. G. D. 1989. Biopsy of human preimplantation embryos and sexing by DNA amplification. *The Lancet 1*:(8633) 347-349.

Hope, J. 1989. Bioscience provides a blood test for scrapie resistance in sheep. In: *Bioscience in Animal Production.* Ed. J. Hardcastle. Agricultural and Food Research Council, Swindon, pp 26-27.

Hunter, N., Foster, J. D., Dickinson, A. G. and Hope, J. 1989. Linkage of the gene for the scrapie-associated fibril protein (PrP) to the Sip gene in Cheviot sheep. *Veterinary Record 124*: 364-366.

International Wool Textile Organisation 1989. Wool Statistics. Commonwealth Secretariat, London. James, W. P. T., Ferro-Luzzi, A., Isaksson, B. and Szostak, W. B. 1988. *Healthy Nutrition.* World Health Organisation Regional Publications, European Series, No.*24*.

Johnson, L. A., Flook, J. P. and Hawk, H. W. 1989. Sex preselection in rabbits: live births from X and Y sperm separated by DNA and cell sorting. *Biology of Reproduction 41*: 199-203.

Jones, R. J. and Megarrity, R. G. 1986. Successful transfer of DHP degrading bacteria from Hawaiian goats to Australian ruminants to overcome the toxicity of *Leucaena. Australian Veterinary Journal 63*: 259-262.

Jones, A. S. 1985. An agricultural approach to the new health policy. *Proceedings of the Nutrition Society 44*: 409-418.

Kay, R. N. B. 1985. Seasonal variation of appetite in ruminants. In: *Recent Advances in Animal Nutrition - 1985.* Eds W. Haresign and D. J. A. Cole. Butterworths, London, pp 199-210.

Kempster, A. J., Croston, D., Guy, D. R. and Jones, D. W. 1987. Growth and carcass characteristics of crossbred lambs by ten sire breeds, compared at the same estimated carcass subcutaneous fat proportion. *Animal Production 44*: 83-98.

Kyle, R. 1990. An antelope for all seasonings. *New Scientist 126* No.1711: 54-57.

Legendre, X, Bousseau, S. and Koyundjiev, S. 1988. Embryo collection from ewes by laparoscopy using a 3-way rigid catheter. *Theriogenology 29*: 269.

Leitch, I., Hytten, F. E. and Billewicz, W. Z. 1959. The maternal and neonatal weights of some mammalia. *Proceedings of the Zoological Society, London 133*: 11-28.

Lyon, G. 1989. Agriculture in New Zealand - surviving without subsidies. *Journal of the Royal Agricultural Society of England 150*: 76-84.

McKelvey, W. A. C., Robinson, J. J., Aitken, R. P. and Robertson, I. S. 1986. Repeated recoveries of embryos from ewes by laparoscopy. *Theriogenology 25*: 855-865.

McNatty, K. P., Henderson, K. M. and Thurley, D. C. 1989. Ovarian follicular development and the effects of gonadotrophins in the sheep. In: *Second International Congress for Sheep Veterinarians*, Massey University, Palmerston North, pp 117-129.

Mayne, C. S. and McCaughey, W. J. 1990. An evaluation of the effects of twinning in dairy cows on animal production. *Animal Production 50*: In Press.

Mepham, T. B. 1989. Criteria for the public acceptability of biotechnological innovations in animal production. In: *Biotechnology in Growth Regulation.* Eds R. B. Heap, C. G. Prosser and G. E. Lamming. Butterworths, London, pp 203-212.

Ministry of Agriculture, Fisheries and Food 1985-1989. *Food Safety Directorate and Food Facts.* MAFF, London.

Mizumachi, M., Voglmayr, J. K., Washington, D. W., Chen, C.-L.C. and Bardin, C. W. 1990. Superovulation of ewes immunized against the human recombinant inhibin α-subunit associated with increased pre and post ovulatory follicle-stimulating hormone levels. *Endocrinology 126*: 1058-1063.

Montgomery, G. W., Scott, I. C. and Johnstone, P. D. 1988. Seasonal changes in ovulation rate in Coopworth ewes maintained at different weights. *Animal Reproduction Science 17*: 197-205.

Morgan, P. J., Lawson, W., Davidson, G. and Howell, H. E. 1989a. Melatonin inhibits cyclic AMP production in cultured ovine *pars tuberalis* cells. *Journal of Molecular Endocrinology 3*: R5-R8.

Morgan, P. J., Williams, L. M., Davidson, G., Lawson, W. and Howell, E. 1989b. Melatonin receptors on ovine *pars tuberalis*: characterisation and autoradiographical localization. *Journal of Neuroendocrinology 1*: 1-4.

National Advisory Committee on Nutrition Education 1983. *A Discussion Paper on Proposals for Nutritional Guidelines for Health Education in Britain.* Health Education Council, London.

National Research Council 1988. Current trends in consumption of animal products. In: *Designing Foods.* National Academy Press, Washington, pp 18-44.

Page, G. 1989. Environmental effects on dairy research and development. In: *Dairy Research, The Winds of Change.* International Dairy Federation, Brussels pp 22-31.

Parkins, J. J. and Holmes, P. H. 1989. Effects of gastrointestinal helminth parasites on ruminant nutrition. *Nutrition Research Reviews 2*: 227-246.

Parry, M. L., Carter, T. R. and Porter, J. H. 1989. The greenhouse effect and the future of UK agriculture. *Journal of the Royal Agricultural Society of England 150*: 120-131.

Pollit, E., Hathirat, P., Kotchabhakdi, N. J., Missell, L. and Valyasevi, A. 1989. Iron deficiency and educational achievement in Thailand. *American Journal of Clinical Nutrition 50*: 687-697.

Poppi, D. P., Cruickshank, G. J. and Sykes, A. R. 1988. Fish meal and amino acid supplementation of early-weaned lambs grazing noa tall fescue (*Festuca arundinacea*) or huia white clover (*Trifolium repens*). *Animal Production 46*: 491.

Prentis, S. 1985. *Biotechnology*, A New Industrial Revolution. Orbis, London.

Rattray, P. V. 1989. Grassland Farming of Sheep. The advantages and disadvantages. In: *Second International Congress for Sheep Veterinarians, Massey University*, Palmerston North, pp 239-254.

Roberts, R. M., Schalue-Francis, T., Francis, H. and Keisler, D. 1990. Maternal recognition of pregnancy and embryonic loss. *Theriogenology 33*: 175-183.

Robinson, J. J. 1990a. Nutrition in the reproduction of farm animals. *Nutrition Research Reviews 3*: (In Press).

Robinson, J. J. 1990b. Nutrition over the winter period - the breeding female. In *New Developments in Sheep Production.* Occasional publication of the *British Society of Animal Production* (In Press).

Robinson, J. J., McDonald, I., Fraser, C. and Crofts, R. M. J. 1977. Studies on reproduction in prolific ewes. 1. Growth of the products of conception. *Journal of Agricultural Science, Cambridge 88*: 539-552.

Rogers, G. E. 1990. Improvement of wool production through genetic engineering. *Trends in Biotechnology 8*: 6-11.

Rowntree, P. R., Callander, B. A. and Cochrane, J. 1989. Modelling climate change and some potential effects on Agriculture in the UK. *Journal of the Royal Agricultural Society of England 150*: 153-170.

Russel, A. J. F., Maxwell, T. J., Bolton, G. R., Currie, D. C. and White, I. R. 1983. A note on the possible use of goats in hill sheep grazing systems. *Animal Production 36*: 313-316.

Sandles, L. D., Sim, Y. X., D'Cruz, A. G.C., McDowell, G. H. and Gooden, J. M. 1988. Responses of lactating ewes to exogenous growth hormone: short and long-term effects on productivity and tissue utilization of key metabolites. *Australian Journal of Biological Science 41*: 357-370.

Simm, G., Dingwall, W. S., Murphy, S. V. and Fitzsimons, J. 1990. Selection for improved carcass composition in Suffolk sheep. *Proceedings 4th World Congress on Genetics Applied to Livestock Production*, Edinburgh (In Press).

Smith, B. L. 1989. Mycotoxicoses associated with grassland farming of sheep. In *Second International Congress for Sheep Veterinarians*, Massey University, Palmerston North, pp 255- 267.

Smith, J. F., Andrews, W. G. K., Knight, T. W., McMillan, W. H. and Quinlivan, T. D. 1989. A review of technology used for out-of- season breeding with New Zealand Sheep Breeds. In *Second International Congress for Sheep Veterinarians*, Massey University, Palmerston North, pp 117-129.

Thomson, A. M. and Flint, H. J. 1989. Electroporation induced transformation of *Bacteroides ruminicola* and *Bacteroides uniformis* by plasmid DNA. *FEMS Microbiology Letters 61*: 101-104.

Vipond, J. E., Swift, G., Fitzsimons, J., McClelland, T. H., Milne, J. A. and Hunter, E. A. 1990. Evaluation of the use of a small leaved clover as an alternative to fertilizer-N on tetraploid and diploid perennial ryegrass swards grazed to controlled sward heights by ewes and lambs. *Animal Production 50*: (In Press).

Wallace, J. M., Robinson, J. J. and Aitken, R. P. 1989. Successful pregnancies after transfer of embryos recovered from ewes induced to ovulate 24-29 days post partum. *Journal of Reproduction and Fertility 86*: 627-635.

Wallace, J. M., Robinson, J. J., Wigzell, S. and Aitken, R. P. 1988. Effect of melatonin on the peripheral concentrations of LH and progesterone after oestrus, and on conception rate in ewes. *Journal of Endocrinology 119*: 523-530.

Wallace, R. J. 1989. Identification of slowly metabolized sugars and sugar derivatives that could be used to establish new or modified microbial species in the rumen. *Current Microbiology 19*: 271-274.

Wigzell, S., Robinson, J. J. and Aitken, R. P. 1986a. Melatonin reverses the breeding season of both non-lactating and lactating ewes. *Society for the Study of Fertility*. Winter Meeting, Nottingham, U.K. Abstract *82*.

Wigzell, S., Robinson, J. J., Aitken, R. P. and McKelvey, W. A. C. 1986b. The effect of the oral administration of melatonin at two times of the year on ovarian activity in ewes. *Animal Production 42*: 448-449.

Wilmut, I., Archibald, A. L., Harris, S., McClenahgan, M., Simons, J. P., Whitelaw, C. B. A. and Clark, A. J. 1990. Methods of gene transfer and their potential use to modify milk composition. *Theriogenology 33*: 113-123.

Wolf, B. T., Smith, C. and Sales, D. I. 1980. Growth and carcass composition in the crossbred progeny of six terminal sire breeds of sheep. *Animal Production 31*: 307-313.