IMPROVING THE PRODUCTIVITY OF GRAZING ANIMALS

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ABSTRACT

Productivity of grazing animals is a function of the following components: reproductive, growth and survival rates and the quality of the marketable product. Constraints are imposed by climatic factors, particularly high temperatures, by parasites and diseases, and by the plane of nutrition, particularly in areas subject to frequent droughts. Improvement of productivity will be achieved by reducing the effects of these environmental constraints whilst simultaneously increasing or maintaining inherent levels of the components.

The effects of high temperatures and of parasites and some diseases will be overcome primarily by the use of better adapted and resistant genotypes, though other approaches are considered.

Ways of improving growth rate by growth promotants, metabolic depressants and manipulating the growth and composition of rumen microorganisms are discussed.

In improving reproductive rate, the administration of hormones and releasing hormones and/or immunoneutralization of suppressing hormones or peptides could be beneficial. Technologies involved in embryo transfer and embryo manipulation will enable an expansion of the gene pool via importations and in the long term by the direct incorporation of desirable DNA.

INTRODUCTION

Productivity of grazing animals is a function of reproductive, growth and survival rates and of the quantity and quality of the marketable product. The magnitude of each component of productivity is determined by both genetic and environmental factors and their interactions.

The environmental factors in the tropics and sub-tropics that act as major constraints to productivity are generally either directly related to climate, e.g. high temperatures and humidities, or associated with it viz. parasites and fluctations in the quantity and quality of available feed. The incidence of some infectious diseases is also climate dependent.

Genetic differences between animals determine differences in the inherent levels of the components of productivity and also in the levels of resistance to the environmental factors that reduce the expression of those inherent levels.

Improved productivity can be best achieved by increasing the inherent levels of each component and simultaneously minimising the detrimental effects of the environmental constraints.

The focus of this paper is on methods for environmental and genetic improvement of the growth component of productivity of beef cattle in the tropics.

MODIFYING THE EFFECT OF ENVIRONMENT ON GROWTH RATE

Heat

Provision of adequate shade, water and feed will only partly control the deleterious effects on productivity of high levels of solar radiation, temperature and humidity. Any increase in rectal temperature will depress both growth and fertility (Table 1). However, the environmental temperature that causes the same increase in rectal temperature differs between breeds. This is due primarily to differences in the efficiency of evaporative heat loss and the rate at which sweating and panting increase in response to a change in rectal temperature (Finch et al. 1982). Shade reduces the environmental heat load and the rate at which rectal temperature increases. However animals that seek shade have reduced grazing times and lower growth rates than those that do not (Bennett et al. 1985). The only practical solution to the problem of lowered productivity resulting from high environmental heat loads is the use of heat resistant breeds including the Brahman, Africander and their derived breeds. These breeds have lower inherent feed intake capacities than breeds such as Hereford and Shorthorn (Frisch and Vercoe 1982), but their other advantages offset this relative disadvantage.

TABLE 1
Effect of increased rectal temperature (T_r) on growth and fertility of different breeds (Turner 1982, 1984)

	18-month body weight (kg)	Fertility (%)
Herd mean	248	52
Decrease as T_r increases from 39 to 40°C	20.2	14

Parasites

Both internal and external parasites reduce productivity primarily by depressing feed intake (Bremner 1961; Seebeck et al. 1971), and also by affecting digestion and the utilization of metabolites (Dargie 1980). Their effect on growth is related to the numbers carried and so breeds and individuals that carry few parasites grow faster than those with high burdens. This is demonstrated in Table 2.

Breeds available in Australia are not completely resistant to either cattle ticks or gastrointestinal helminths. Consequently, when parasite loads are sufficiently high, productivity is reduced, even in breeds of relatively high resistance to parasites such as the Brahman. However, where relatively resistant breeds are used the chemical control of parasites is generally uneconomic. The use of animals of high resistance is therefore likely to remain as an

TABLE 2

Effect of ticks and worms on growth rate from weaning to 15 months for different cattle breeds (Frisch and Vercoe 1984)

Breed	Growth (kg/day)		Ticks (no./side)	Worms (e.p.g.)
	C*	T*	Untreated group	
Brahman (B)	0.49	0.57	4	340
B x HS	0.48	0.60	13	460
Hereford x Shorthorn (HS)	0.32	0.52	26	660

* C = no treatment; T = dipped and drenched every 3 weeks

economically attractive option for the long term control of parasites. Further genetic improvement of parasite resistance might be obtained either through the importation of more highly resistant breeds for use in crossbreeding or through selection in existing breeds. Selection in a breed of low tick resistance (Hereford x Shorthorn), primarily for growth rate in the presence of tropical environmental stresses over approximately 3 $^1/_2$ generations, has produced individual females that rapidly acquire complete resistance to cattle ticks. Furthermore the progeny from these animals and some close relatives are also highly, if not completely, resistant to ticks (J.E. Frisch, unpublished data). This suggests that very high levels of tick resistance could ultimately be achieved in all breeds.

Until more resistant breeds are available the control of parasites will continue to be dependent on chemotherapy despite the fact that resistant strains of parasites are evolving with increasing frequency (Nolan 1985). Recent work has demonstrated the potency and synergistic effects of combinations of chemical compounds, particularly pyrethroids and organophosphates (Nolan 1985). A basic understanding of the mode of action of chemicals and definition of potential new avenues of approach is essential to progress in this area. A new class of drug, the avermectins, which control a wide range of parasitic diseases (Nolan et al. 1981; Bremner et al. 1983) has recently been released.

With the discovery of highly potent chemicals there is a need to develop more efficient and safer methods for their administration. Slow release technology for either ruminal or implant applications and the prospects for pulsatile release over longer periods are rapidly improving. Pour-on and injectable methods of application for acaracides and anthelmintics are already available.

There is renewed interest in an immunological approach to parasite control. The recent isolation of crude antigens from cattle ticks and gastrointestinal helminths (Anon 1984) that give some protection against a subsequent parasite challenge holds promise for the future. The ability to produce antigens by monoclonal techniques has made immunological methods of control economically possible. If cattle can be successfully immunized against the cattle tick other ecto-parasites could probably be overcome by a similar approach.

Apart from the decreases in productivity associated with tick infestation *per se*, the tick borne diseases (babesiosis and anaplasmosis) cause losses. These diseases are amenable to immunological methods of control. Other diseases of economic consequence to the beef cattle industry include bovine infectious keratoconjunctivitis (BIK, "pink-eye") and ephemeral fever (3-day sickness). The former is a disease primarily of *Bos taurus* breeds. Field testing of a vaccine against the latter suggests that this is a potential control method. Improved and more economically produced vaccines using monoclonally produced antigens offer enhanced control of these diseases.

Thus, if a further reduction in the losses in productivity associated with parasitic and other diseases is possible by immunological methods, they may be sufficiently effective to obviate the need to increase the genetic component of resistance to the major parasitic diseases. However at present the most economic method of control is the use of breeds of very high resistance even though their inherent levels of productivity are lower than those of less resistant breeds.

Nutrition

Both the diet itself and the genotype of the animal affect the utilization of that diet. Dietary factors are being covered elsewhere in these proceedings.

Manipulation of the animal is possible through modification of both the digestive processes and their end products, as well as the synthesis of these end products into animal protein and lipid.

Different breeds respond differently to changes in the quantity and quality of the diet. The former is illustrated in Table 3 and has been discussed in more detail by Frisch and Vercoe (1977).

TABLE 3
Breed and nutrition interaction (Frisch and Vercoe 1984)

Breed	*Ad libitum*		Restricted
	Intake (g/kg)	Gain/day (kg)	Relative weight maintained (%)
Brahman (B)	27.8	0.84	100
B x HS	28.5	0.94	93
Hereford x Shorthorn (HS)	33.1	1.04	86

For any given diet, particularly those low in protein and high in fibre, the rate of passage of digesta (which is a determinant of feed intake) is controlled by the rate of digestion in the rumen, the rate of comminution of feed particles by chewing (rumination) and the frequency and amplitude of reticulo-rumen contractions. Of these factors the rate of digestion is most readily manipulated. The provision of rumen soluble N and S, for example, can have a marked effect on feed intake, the magnitude of the response depending on both the basal diet and the genotype of the animal (Table 4). The addition of molasses to a supplemented roughage may also result in a modest response. The principles involved in soluble N supplementation have been discussed in detail elsewhere (Kempton et al. 1977; Siebert and Hunter 1982; Hunter and Vercoe 1984). Supplementation with other macro-elements e.g. P, and micro-elements e.g. Co, may improve productivity via effects on feed intake. Some trace elements however act directly on host tissues e.g. Se (Siebert and Hunter 1982) . In general, supplementation should be aimed primarily at improving the environment in the rumen so that the synthesis of microorganisms is maximized for the particular basal diet. Animals then usually will respond to additional high energy and protein supplements, particularly if these are protected from fermentation in the rumen (Leng 1982; Leng and Preston 1983).

TABLE 4

Effect of rumen soluble N and S on feed intake (g/kg liveweight) of low quality roughage by different breeds (Hunter and Siebert 1985)

Breed	Spear Grass			Pangola Grass		
	USup.*	Sup.*	% Increase	USup.	Sup.	% Increase
Brahman	11.8	10.6	-10	16.1	18.5	15
Hereford	11.3	14.0	24	17.8	25.2	42

* USup. = unsupplemented; Sup. = supplemented

Manipulations to increase gut motility or the rate of comminution of feed particles by either increasing rumination time or chemically modifying the diet (e.g. alkali treatment) are not likely to be achieved easily in extensive grazing systems. Nevertheless, research should continue to assess the possibilities.

The factors discussed above are aimed at clearing the digesta more rapidly and thus increasing food intake. Other opportunities for improvement are through increasing the microbial cell yield per unit of organic matter digested or by changing the chemical composition of the cell yield in such a manner as to provide substrates that are used more efficiently by the host.

In situations where the yield of microorganisms is not limited by substrate availability, the amount of microbial organic matter available to the host may be increased by defaunating the rumen i.e. chemically removing the protozoal component of the microbial population. There is a body of evidence that suggests that protozoa are responsible for increasing the turnover of bacterial protein in the rumen (Leng 1982). Inevitably losses occur each time protein is degraded and resynthesised. If turnover in the rumen can be decreased more bacterial protein should leave the rumen and be available to the host as amino-acids from the small intestine. However, responses to defaunation of ruminants have been variable although some encouraging results have been obtained on low-protein roughages. A greater knowledge of the interactions between rumen protozoa and bacteria should enhance the predictability of the response. Whether different breeds respond differently to defaunation is not known although recent evidence indicates that there are differences in the proportions of protozoa and bacteria in the rumens of Brahman and British breed cattle fed the same diet (J.C. O'Kelly, unpublished data).

There is increasing circumstantial evidence that the chemical composition of rumen microorganisms differs in different breeds of cattle. Differences in the lipid metabolism of *Bos indicus* and *Bos taurus* cattle have been recognized for some time (O'Kelly 1968 *a*, *b*) but it is only recently that the rumen has been recognized as the possible source of these differences (O'Kelly 1985). Lipid is utilized with a higher energetic efficiency than other substrates. If indeed the microorganisms synthesized in the rumen of *Bos indicus* cattle have a higher lipid content, this could contribute to the differences in maintenance requirement between Brahman and British cattle (Frisch and Vercoe 1977, 1984); as well as the differences in blood lipid fractions and concentrations (O'Kelly 1968 *a*, *b*).

The importance of fungi in the biochemical transactions of the rumen has recently been recognized (Akin 1982), but how their role may be modified to improve productivity has yet to be defined.

There is considerable current interest in the potential for "genetic engineering" to improve ruminal digestion. The prospect of introducing genes that will enhance cellulolytic and delignification activity is exciting, but more subtle changes that increase lipid and/or protein content of the microflora may be equally rewarding. The work of Jones and Lowry (1984) in identifying and introducing bacteria to detoxify DHP (a toxic metabolite of mimosine) in the rumen indicates that natural or engineered microorganisms may overcome the losses in productivity associated with plant toxins.

Further improvements to productivity are possible by modifying the utilization of the absorbed end products of digestion. The benefits associated with the use of anabolic steroids (Zeranol, Compudose, Trenbolone etc.) are well documented for tropical and sub-tropical Australia (Nicol *et al*. 1984). They are being widely used commercially and produce best responses in conditions that favour high growth rates. Other types of regulators should be sought that depress metabolic rate and thus reduce weight loss and increase survival when nutritional conditions are poor. Because a major component of maintenance metabolism is thought to be associated with protein turnover (Buttery 1983), compounds that are capable of depressing protein degradation should decrease maintenance requirement and enhance survival when feed is of poor quality or in short supply. Preliminary research (R.M. Seebeck, pers. comm.) suggests that growth promotants used in association with drugs that regulate thyroid activity may be successful in reducing maintenance requirement.

This chemotherapeutic approach may be augmented by the identification and use of breeds that have an enhanced ability to increase and decrease their metabolic rate in response to variations in feed supply. The Africander derived breed in Australia, the Belmont Red, appears to have this ability to a greater extent than Brahman derived and British breeds (Frisch and Vercoe 1977). Hence it may be worthwhile investigating other African breeds in which the trait may be more highly developed.

Body composition can be altered by administration of β-adrenergic agonists e.g. clenbuterol. These reduce the fat content of carcasses without apparent detriment to the muscle (protein) content (Thornton 1984). The ability to direct the supply of nutrients to desired tissues or products will be more feasible as knowledge of the biochemical pathways becomes more complete.

At present, manipulations of growth and body composition are largely dependent on the administration of exogenous sources of hormones or drugs. There would, however, be public rejection of this sort of approach if undesirable side effects of their usage became evident. The use of hormone immunoneutralization technology, which should avoid the problems associated with the use of exogenous compounds, is showing great prospects for the future (Hoskinson and Djura 1984).

IMPROVING REPRODUCTIVE RATES

The scope for both genetic and environmental avenues to improve reproductive rate of cows is illustrated in Table 5. Except under very severe conditions, environmental influences have a negligible influence on the fertility of non-lactating cows. However, they have a marked effect on lactating cows and the effect varies with genotype. Thus, while modifying the physical environment markedly improved the fertility of the poorly adapted HS it had a relatively small effect on the well adapted Brahman. The response in the crossbred was intermediate. One option for improving the reproductive rate of the adapted breed is to alter the control of the processes involved in the reproductive cycle. The possibilities for the success of this option have been examined by identifying cows that have produced a calf every year regardless of the severity of environmental conditions, and then checking whether their female progeny exhibit the same reproductive capacity. To assist this process multiple ovulation and embryo transfer techniques have been used to increase the number of female progeny available from each highly fertile cow. Newly developed statistical methods e.g. BLUP, that increase the accuracy of selection of animals by utilizing information from performance pedigrees may also assist in the development of fertile lines.

Where reduced fertility of a breed can be linked with hormonal imbalance, the possibility for redress exists by using slow release implants or hormone immunoneutralization technology to disrupt feed-back mechanisms e.g. the use of Fecundin in sheep to increase ovulation rate (Cox 1984). As knowledge of releasing hormones increases, the possibilities of utilizing synthesized products and their analogues to control ovarian activity, even in extensive pastoral systems, improves. This approach may be particularly useful where the expression of lactation anoestrus is under genetic control (Table 5).

TABLE 5
Genetic and environmental effects on reproductive rate
(Frisch et al. unpublished data)*

Breed	% Calving			
	Above average years		Below average years	
	Lactating	Non-lactating	Lactating	Non-lactating
Brahman (B)	40	77	34	76
B X HS	55	76	45	71
Hereford x Shorthorn (HS)	78	78	47	75

* 10 years data, overall mean 61%

One promising way of improving reproductive rate is to import a breed that is well adapted to tropical environments but has a higher inherent fertility than breeds currently available in Australia. There is little doubt that such breeds exist. Breeds from southern Africa e.g. Tuli, Tswana, have a higher fertility than the Africander (Trail 1985). The Africander based breed (Belmont Red) in Australia has a higher fertility than Brahman based equivalents in Central Queensland (Rudder et al. 1981) and it is therefore likely that the introduction of other African breeds, including the Boran, could increase the fertility of the northern beef herd. Some heterosis may also occur when these breeds are crossed to Brahman based cattle. The establishment of Cocos Island Quarantine Station and the commissioning of the CSIRO Australian National Animal Health Laboratory has opened up access to the world gene pool.

GENETIC ENGINEERING

A paper of this nature must consider the possible contributions that genetic engineering holds for future improvements to animal productivity. The effective application of this technology depends on basic studies on gene function and regulation and the establishment of reliable gene maps. However, rat growth hormone has already been transferred to and expressed in mice, and it seems only a matter of time before similar transfers can be made into farm animals. How effectively such incorporations will be transmitted to progeny is unknown.

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