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BREEDING AUSTRALIAN CATTLE FOR PRODUCTION IN THE YEAR 2050

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SUMMARY

Australia's beef and dairy industries will need to adapt very rapidly to projected climate change by 2050 if they are to remain productive. This review first highlights lessons learned in decades past in balancing productivity and adaptation, illustrated in a series of Vercoe and Frisch papers, that should not be overlooked as the industries push forward. New strategies made possible with genomics, including appropriately balanced selection for heat tolerance in dairy cattle to maximise productivity in projected future climates, are then described. Finally, a couple of novel strategies using genomic information, including sentinel herds, precision adaption traits, and chromosome segment stacking, are proposed.

INTRODUCTION

According to the International Panel on Climate Change Report (2021), the rate of change in temperature is accelerating and a 2°C increase from pre-industrial times is expected by 2050 for most regions of Australia. This will significantly impact beef and dairy production systems in Australia. For example, by 2050 the currently temperate dairying regions in southern Australia are expected to have average daily temperatures, humidity and rainfall more similar to Tenterfield in New South Wales (https://www.climatechangeinaustralia.gov.au/en/projections-tools/climate-analogues/). In northern Australia, summer temperatures are predicted to regularly exceed 50°C. Although the production systems are suited to current climatic conditions, this paper asks 'How can the Australian cattle industry adapt to a rapidly changing climate?' We address this question from the perspective of an animal breeder – with the knowledge that 28 years is a relatively short timeframe for genetic change (7 generations at most). The objective of this paper is to review strategies proposed to achieve this, and to propose some new strategies made possible with the availability of genomics.

This review is inspired by the framework described by Frisch and Vercoe (1984) for balancing adaptation and productivity potential. Frisch and Vercoe (1984), building on decades of elegant experiments with *Bos taurus* and *Bos indicus* cattle breeds and their crosses at Belmont Research Station in Rockhampton QLD, (Vercoe and Frisch 1969, etc), concluded:

"Each breed was best suited to one particular environment. The general principle that arises from this is that resistance to environmental stresses will affect the capacity of breeds to express growth potential and will result in a change of ranking in different environments that may arise in different years, different seasons or at different locations."

"The task of the animal breeder to combine the adaptation traits of the Brahman with the growth potential of Bos taurus breeds."

While Frish and Vercoe (1984) were largely concerned with growth, the other major component of productivity, fertility was being addressed at the same time in the same place by Turner (e.g. Turner *et al*. 1983).

CROSSBREEDING AND COMPOSITES TO OPTIMISE ADAPTATION AND PRODUCTIVITY

The insights of Vercoe, Frisch and Turner, and others, supported a major innovation in Australian cattle breeding, the creation and widespread introduction of composite breeds, both from Australia and overseas (e.g. Africander), in an attempt to balance adaptation and productivity. Composite cattle now dominate pastoral company holdings and are very widespread in Northern Australia.

Creation of composite breeds was also attempted for dairy cattle, with the Australian Friesian Sahiwal and the Australian Milking Zebu (Tierney *et al*. 1986, Hayman 1974). However, these composites could not compete on milk production with Holsteins from southern Australia, particularly following deregulation.

WITHIN BREED SELECTION FOR ADAPTATION AND PRODUCTIVITY

Another pathway to improved productivity in harsh environments is within breed selection. Frisch and Vercoe (1986) recognised this possibility *"In the case of the Brahmans there is no genetic alternative to selection unless other breeds that have higher resistance to environmental stresses, and ultimately, higher productivity, can be identified and imported. This avenue should be vigorously explored".* In other words, in particularly harsh environments, even composite cattle may not be sufficiently adapted, and selection within the most adapted breed becomes the only alternative. There are herds in Australia which exemplify this. For example, the Collins Belah Valley herd which has had sustained selection for high fertility, on both number of calves over the lifetime of cows and since it has been available, BREEDPLAN days to calving (the number of days to calving following bull in date). The genetic trend for days to calving in this herd is pronounced (Figure 1) and many of the cow herd produce a calf every year. It is interesting to note that these gains have been achieved by selecting for a productivity trait – days to calving, without selection for specific adaptation traits, in harsh environments. However, adaptation is of course indirectly strongly selected for, otherwise the cows would not survive to produce a calf.

It should be pointed out that while major gains for fertility have been achieved in the Collins herd, in other Brahman and indeed Northern Herds, gains for fertility have been modest at best (Figure 1). This is in part due to the difficulty of recording fertility in extensive conditions. Genomic prediction offers new opportunities for selecting for fertility traits in these situations. This requires large reference populations to be established where animals are both recorded for fertility and genotyped for genome wide DNA markers, ideally in the harsh commercial environment which most cattle experience or will experience in the future. In Australia, both the Repronomics project (Johnston *et al*. 2019) and the Northern Genomics project (Hayes *et al*. 2019) have been set up with this aim.

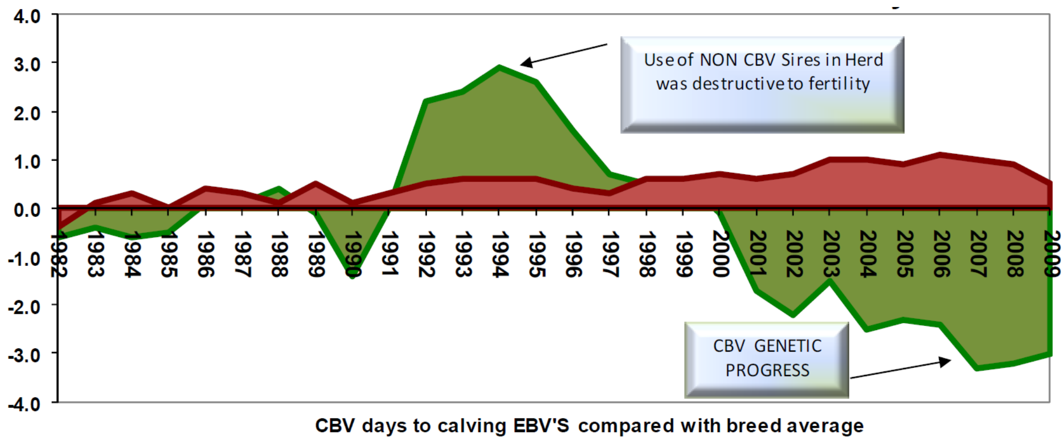

Figure 1. Genetic trend for days to calving for the Brahman breed and the Collins Brahman herd (source ABRI)

BREEDING DIRECTLY FOR FUTURE ADAPTATION – CAN WE BREED FOR 2050?

It could be argued, as Vercoe and Frisch (1990) and Frisch and Vercoe (1984) effectively did, that selection on productivity in a challenging environment automatically selects for the appropriate level of adaptation – if the animals were not adapted, they would not perform (as demonstrated by the Collins herd). While it is challenging to breed cattle for productivity in harsh environments, it is even more challenging to breed for productivity when the environment is in flux or the projected future environment is not within the currently (feasible) production areas? The challenge then becomes, what is the best approach for a breeder to maximise adaptation and profitability in future environments?

An interesting case study here is heat tolerance. Nguyen *et al*. (2016) described a web-based tool which allowed dairy farmers to appropriately weight heat tolerance in their selection decisions given projected climate on their farm in 2050 (using CSIRO and BoM projections (2015)). The heat tolerance trait they used was for each cow the regression of test day milk production on temperature humidity index on that test day (Nguyen *et al*. 2016). The GEBV were validated in a chamber experiment by Garner *et al*. (2017), in which cows high and low for heat tolerance GEBV were measured for milk production before and after a simulated heat wave event. To answer the question how much emphasis in a selection index should be placed on heat tolerance, in order to maximise future profitability, Nguyen *et al*. (2016) first estimated genetic correlations between key dairy traits. Milk production and heat tolerance were negatively correlated (-0.85) while fertility (six week in calf rate) and heat tolerance were positively correlated (0.39). Nguyen *et al*. (2016) then derived selection index weights (per dairy farm) for traits in the Balanced Performance Index (the Australian dairy selection index, Byrne *et al*. 2016), and heat tolerance, given projected future climates for individual dairy farms, as predicted by CSIRO and BoM (2015). Using this approach, Nguyen *et al*. (2016) could show predicted future profitability was higher as a result of including heat tolerance in the selection index.

Another approach to selecting for productivity in increasingly harsh conditions might be to dissect adaptation more precisely, and select for these precision traits. For example, differences in nitrogen metabolism are associated with animal adaptation to environmental stress. Heat stress increases water intake and nitrogen losses, with *Bos indicus* cattle being less vulnerable to increased nitrogen losses because of their ability to restrict urine output during high temperatures (Vercoe 1976). Together with the lower fasting metabolic rate of *Bos indicus* cattle (Frisch and

Vercoe 1977), it became clear that both energy and nitrogen metabolism were integral part of the breed adaptation to hot environments and low protein diets. Recently, Prada e Silva (2021) devised an isotope test for tail hair that could determine the proportion of dietary versus body derived nitrogen, and demonstrated this was correlated with both growth rates and fertility. Selection for simple and cheap proxy traits such as these may accelerate breeding of animals that perform well on low quality diets and are adapted to very harsh conditions.

NOVEL USES OF GENOMIC INFORMATION TO BREED CATTLE FOR PRODUCTION IN 2050.

The Australian beef industry, and to a lesser extent the dairy industry, has a unique advantage in responding to future climates. With a huge range of breeds and environments, the harshest environments can be used a proxy for future conditions in regions that currently have more moderate climates. The cattle in these harshest environments could be a “2050 genomic reference” population, to develop GEBV for performance in the future predicted environment, as part of Australia’s effort to ensure the ongoing productivity of the cattle industry. This could occur even though the studs where the selection is made are in much more moderate environments, as is common with the stud sector.

Finally, genomic information could also be used to deliver a twist on the Vercoe and Frisch vision of *combining the adaptation traits of the Brahman with the growth potential of Bos taurus breeds*. The genomic information can be used to produce breeding values for growth, fertility traits, nitrogen use efficiency, and adaptation traits for the *haplotypes* (unique chunks of the genome) in populations, rather than the individuals in those populations. For example regions of the genome associated with adaptation were recently identified by Kim *et al*. (2020), by identifying genome regions that had been selected for 1000s of years in *Bos indicus* x *Bos taurus* composite cattle in harsh environments in Africa. This haplotype information, combined with a breeding strategy to rapidly “stack” the most desirable haplotypes (Kemper *et al*. 2015) could be used to breed the “ultimate” composite cattle anticipating future climates.

CONCLUSION

Future climates will force many changes on the beef and dairy industries in Australia. This review has highlighted lessons learned in decades past, i.e. the Frisch and Vercoe opus of 1984, that should not be overlooked as the industries push forward. The use genomic tools offer new opportunities to realise their vision for optimising adaptation and productivity.

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