Contributed paper

REDUCING LAMENESS AND URINARY NITROGEN EXCRETION THROUGH SELECTION ON NEXT GENERATION NATIONAL DAIRY SELECTION INDICES

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SUMMARY

Improving cow health and efficiency is of economic importance. New health and efficiency traits need to be considered alongside traits which are already in the breeding objective. Thus, quantifying the correlated responses of novel traits to selection on the Australian national index, the Balanced Performance Index (BPI), is needed. Correlated responses of lameness incidence (LI) and milk mid-infrared spectroscopy predicted blood urea concentration (MIR-BUN), were estimated under selection on the current BPI and on an updated BPI, including these traits in the breeding objective, using the MT Index tool. Not all genetic correlations (r_g) for MIR-BUN were available, so missing values were assumed to be zero. Under the current BPI, LI and MIR-BUN increased undesirably, by +0.309%/year and +0.040mmol/L/year, respectively. A sensitivity analysis, varying r_g between LI, MIR-BUN and BPI traits, also found undesirable responses for these traits giving confidence they are moving in undesirable direction. Finally, the economic values required to achieve a desirable response (i.e., reduction) in these traits under selection on the BPI were calculated. We found large economic values of at least –\$350 and –\$91 were required before reductions in LI and MIR-BUN, respectively, were observed. While desired response is achievable, the economic value of LI found in this study exceeds previously reported cost of lameness. A greater emphasis on recording health and efficiency traits, especially in the genomic reference population, will support greater selection response for health and efficiency traits at more moderate economic values. While novel phenotyping approaches like MIR could increase the number of animals with direct and indirect records for traits of interest, like MIR-BUN, further work to understand the underlying biological mechanisms and true economic value of these traits in pasture-based herds is needed.

INTRODUCTION

Health, welfare and environmental traits are a key focus of breeding value development with a global shift in dairy cattle breeding objectives to incorporate more non-production phenotypes. This can be attributed, in part, to the compilation of datasets with enough health records for genetic parameter estimation of economically important, but lowly heritable traits, e.g., lameness (Khansefid *et al*. 2021). In addition, the development of new phenotypes and indicator traits is being facilitated by emerging technologies like mid infrared spectroscopy (MIR). For example, urinary nitrogen (UN) excretion is of environmental and economic significance to the dairy industry. While UN can be predicted from blood urea nitrogen (BUN) (Kohn *et al*. 2005), BUN is both cost and labour prohibitive to measure in large populations. However, as r_g between BUN and BUN predicted from mid-infrared spectroscopy of milk (MIR-BUN) is >0.95 (Van den Berg *et al*. 2021), BUN and MIR-BUN are genetically analogous to one another so MIR-BUN can be used as an indicator trait for UN excretion.

Currently the BPI, the Australian dairy industry's national selection index, includes production, longevity, fertility, health and conformation traits (Byrne *et al*. 2016, DataGene 2020). The BPI aligns the preferences of Australian dairy farmers across production, functional and type-focused traits along with their economic importance, to drive genetic gains towards the industry's national breeding objectives (NBO) (Byrne *et al*. 2016). As new measures of cow performance and their genetic parameter estimates become available, there is a need to understand how current selection practices are impacting these new traits. Our aim was to estimate the correlated response to selection for lameness and MIR-BUN, under selection on the current BPI and on an updated BPI, including these traits in the breeding objective.

MATERIALS AND METHODS

The selection index program MTIndex (van der Werf 2008) was used to estimate the correlated response of LI and MIR-BUN under selection on BPI and BPI adjusted to include either trait. The current BPI was constructed in MTIndex and populated with parameters reflective of the current Australian Holstein population sourced from Byrne *et al*. (2016) and DataGene (2020). LI was analysed as a binary trait, where a value of 1 indicated a cow who showed incidence of clinical lameness at any point during lactation, and a value of 0 indicating no incidence. MIR-BUN was measured as a continuous trait, MIR-predicted concentration of urea in blood (mmol/L) during early lactation. Genetic parameters for MIR-BUN and LI, shown in Table 1, were sourced from van den Berg *et al*. (2021) and Khansefid et al. (2021) and supplemented with correlations between EBVs from (Luke *et al*. 2019). Where no estimates were available r_g of 0 were assumed.

Table 1. Lameness (LI) and MIR-predicted blood urea nitrogen (MIR-BUN), phenotypic standard deviation (σ_p), accuracy (acc), heritability (h^2), and genetic correlations (r_g) with standard error in brackets

Trait (units)	σ_p	acc	h^2	r_g with traits in the BPI[1]									
				MY	PY	FY	SU	F	SC	OT	MS	UD	PS
LI (%)	1.74	0.38	0.006	0.31 (0.09)	0.26 (0.09)	0.15 (0.09)	-0.02 (0.09)	0.16 (0.08)	-	-0.18 (0.09)	-0.17 (0.10)	-0.05 (0.09)	0.02 (0.09)
MIR-BUN (mmol/L)	1.79	0.37	0.22	-0.16 (0.14)	-0.10 (0.14)	0.27 (0.14)	0.38 (0.10[2])	0.26 (0.10[2])	0.23 (0.10[2])	-	-	-	-

[1]Traits: MY: milk yield, PY: protein yield, FY: fat yield, SU: survival, F: fertility, SC: somatic cell count, OT: overall type, MS: mammary system, UD: udder depth, PS: pin set. r_g with feed saved, milking speed and temperament unavailable. [2]r_g from EBV correlations in Luke et al. (2019), standard error of 0.1 assumed

Due to the large standard errors and preliminary nature of r_g available, a sensitivity analysis was performed using $r_g \pm 2$ standard errors with key BPI traits. BPI traits were chosen on the criteria of having high contribution to the index (high economic value) or being of physiological importance to LI or MIR-BUN. The r_g with fertility, survival and protein yield were analysed for both traits; and with overall type for LI; and with fat yield for MIR-BUN. Finally, a desired gains approach was used to estimate the minimum economic value required to achieve selection response in the desired direction for LI or MIR-BUN.

RESULTS AND DISCUSSION

Under selection on the BPI, correlated responses of a 0.31% increase in LI incidence/year and a 0.04 mmol/L/year increase in MIR-BUN were seen (Table 2). The annual response of the BPI estimated here, \$29.98/year, is slightly higher than what is being achieved in the current population (DataGene 2020). This is likely due to factors other than the BPI influencing breeding decisions such as; semen cost and availability, prioritising other selection criteria and the use of overseas indices. The sensitivity analysis of r_g between BPI traits and LI and MIR-BUN showed LI and MIR-

BUN response increased in all scenarios, except when a weaker correlation (r_g – 2SE) with protein yield was assumed (Table 3). Thus, despite the preliminary nature of r_g we are reasonably confident LI and MIR-BUN are increasing under current selection practices. Assuming the breeding goal is to reduce LI and to reduce MIR-BUN to reduce UN, both traits are currently moving in the undesirable direction. To include LI and MIR-BUN in the BPI and reverse this trend large negative economic values would be required, -$350 and -$91, respectively (Table 2). A lower economic value of $187.13-$243.17/cow/calving interval has previously been reported for lameness (Byrne *et al.* 2016). To our knowledge no estimates of the economic value of UN or MIR-BUN exist for Australian conditions.

Table 2. Annual response to selection on the BPI, BPI + Lameness (LI) and BPI + MIR-predicted BUN and minimum economic values (EV) to achieve desired response in LI and MIR-BUN

Breeding objective	Current BPI		BPI + LI		BPI + MIR-BUN	
trait	Response	EV ($)	Response	EV ($)	Response	EV ($)
BPI ($)	29.98	-	29.38	-	28.05	-
Lameness (%)	0.309	-	–0.01	–$350	-	-
MIR-BUN (mmol/L)	0.04	-	-	-	–0.0004	–$91

Table 3: Annual correlated response to selection on the BPI for lameness incidence (LI) and MIR-predicted blood urea concentration (MIR-BUN) for a sensitivity analysis of genetic correlations (r_g) ±1 or 2 standard errors[1] (SE) between LI with fertility, survival, protein yield and overall type and MIR-BUN with fertility, survival, protein yield and fat yield

Trait	r_g with	Magnitude of r_g			
		r_g -2SE	r_g -1SE	r_g +1SE	r_g +2SE
LI (%)	Fertility	0.17	0.239	0.379	0.448
	Survival	0.198	0.253	0.365	0.42
	Protein yield	–0.118	0.095	0.523	0.736
	Overall type	0.332	0.32	0.298	0.289
MIR-BUN (mmol/L)	Fertility	0.029	0.034	0.045	0.051
	Survival	0.032	0.036	0.044	0.048
	Protein yield	–0.003	0.018	0.061	0.083
	Fat yield	0.024	0.032	0.048	0.056

[1]Trait r_g and SE reported in Table 1

This study assumed UN excretion could be improved through selection on MIR-BUN given the relationship between UN and BUN (Kohn *et al.* 2005) and the strong r_g between BUN and MIR-BUN (van den Berg *et al.* 2021). MIR-BUN is an example of novel phenotypes being developed through emerging phenotyping technologies. While the current dataset is small (n = 9158) which contributes to its low accuracy, as MIR-BUN is derived from a milk sample, in future it could be available on all cows with milk records. This and a moderate heritability could offer good opportunities for genomic prediction which could make MIR-BUN a more accessible indicator trait for UN excretion than BUN and a good candidate for including in the BPI. However, selecting for lower MIR-BUN concentrations may not always be desirable. A lower threshold of 1.7mmol/L BUN has been used as a biomarker (indicator) for metabolic health (Luke *et al.* 2019). While an opportunity may exist to improve UN excretion via selection on MIR-BUN without compromising animal health, the appropriate direction of selection pressure on BUN/MIR-BUN remains unclear, especially in pasture-based countries. More knowledge about the range and thresholds of BUN in Australian pasture-based herds and what the biological and economic consequences are for selecting on MIR-BUN is needed. Additionally, if there is a need to select for an optimum range of MIR-BUN, economic values may differ widely by region or herd making it better suited as a standalone EBV, allowing farmers to customise their breeding goals, rather than in the BPI.

As with many health traits, LI response to selection is limited by incomplete recording, low genetic parameter accuracies and low trait heritability. More robust methods for identifying and recording lame cows on farm (especially early detection) could improve management of lameness on-farm, reducing the direct and indirect costs of lameness, as well as improve genetic parameter estimates (Khansefid *et al*. 2021). LI selection response and accuracy could also be improved by combining direct and indirect health traits into a composite health trait (Khansefid *et al*. 2021), as implemented for mastitis resistance in Australian dairy herds (DataGene 2020).

Novel high throughput phenotyping technologies – like MIR – that produce a large amount of data which could be used for multiple purposes are an exciting new opportunity in animal breeding. They offer an opportunity to predict many traits from a single sample, the ability to capture direct and indirect phenotypes for hard or expensive to measure traits (i.e. lameness, BUN) and also develop novel phenotypes. As we continue into this data-rich era it is important to invest in understanding the economic importance and underlying physiological and biological actions of these traits to fully understand the implications for future breeding objectives.

CONCLUSION

This study shows selection on Australia's national selection index for dairy (known as BPI) is expected to result in more cases of lameness and an increase in urinary nitrogen excretion. While desired response is achievable using large negative economic values on LI and MIR-BUN within the BPI, these values exceed previously reported economic values for LI. True economic value for UN excretion or MIR-BUN is to be investigated. Novel phenotyping approaches like MIR may facilitate the rapid increase in animals with phenotypes for traits of interest. However, further work to understand the true economic and animal health costs associated with these new traits in an Australian dairy context is needed.

ACKNOWLEDGEMENTS

This study was undertaken as part of the DairyBio program, which is jointly funded by Dairy Australia, Agriculture Victoria and The Gardiner Foundation and was a MAgSc research project at the University of Melbourne

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