ImmuneDEX: Development of a genomic prediction for immune competence for the Australian Angus cattle

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Based on previously described protocols (Hine et al. 2019), we measured both cell-mediated immune responses (Cell-IR) and antibody-mediated immune responses (Ab-IR) in a population of ~ 3,000 Australian Angus steers and heifers. These measures were combined into a single value and represent a trait we have called immune competence, that is a proxy for disease resistance. We compared two alternative methods to calculate immune competence. The first method, ZMEAN, is obtained from the average of the individual metrics after Z-score standardisation. The second, ImmuneDEX (IDEX) is a weighted average that considers the correlation between Cell-IR and Ab-IR, as well as the difference in ranking of individuals by each metric and uses them as weights in the averaging. Both simulation and real data were used to understand the behaviour of ZMEAN and IDEX.

Development of ImmuneDEX

ImmuneDEX was developed to represent the multifactorial nature of an immune response. The trait combines measures of both cellular (Cell-IR) and antibody (Ab-IR) response into a single value and is highly correlated with both metrics even when they might not be correlated, or negatively correlated. We present two methods :

1. ZMEAN is obtained from the average of the individual metrics after subjecting each to a Z-score standardisation by subtracting the mean and dividing by the standard deviation:

$$Z_{MEAN} = [Z_{CELL} + Z_{AB}]/2$$

where ZCELL and ZAB are the Z-score standardisation of Cell-IR and Ab-IR, respectively.

2. IDEX is an alternative to ZMEAN that considers the correlation (r) between Cell-IR and Ab-IR as well as the difference in ranking (dRank) of individuals for each metric, using them as weights in the averaging:

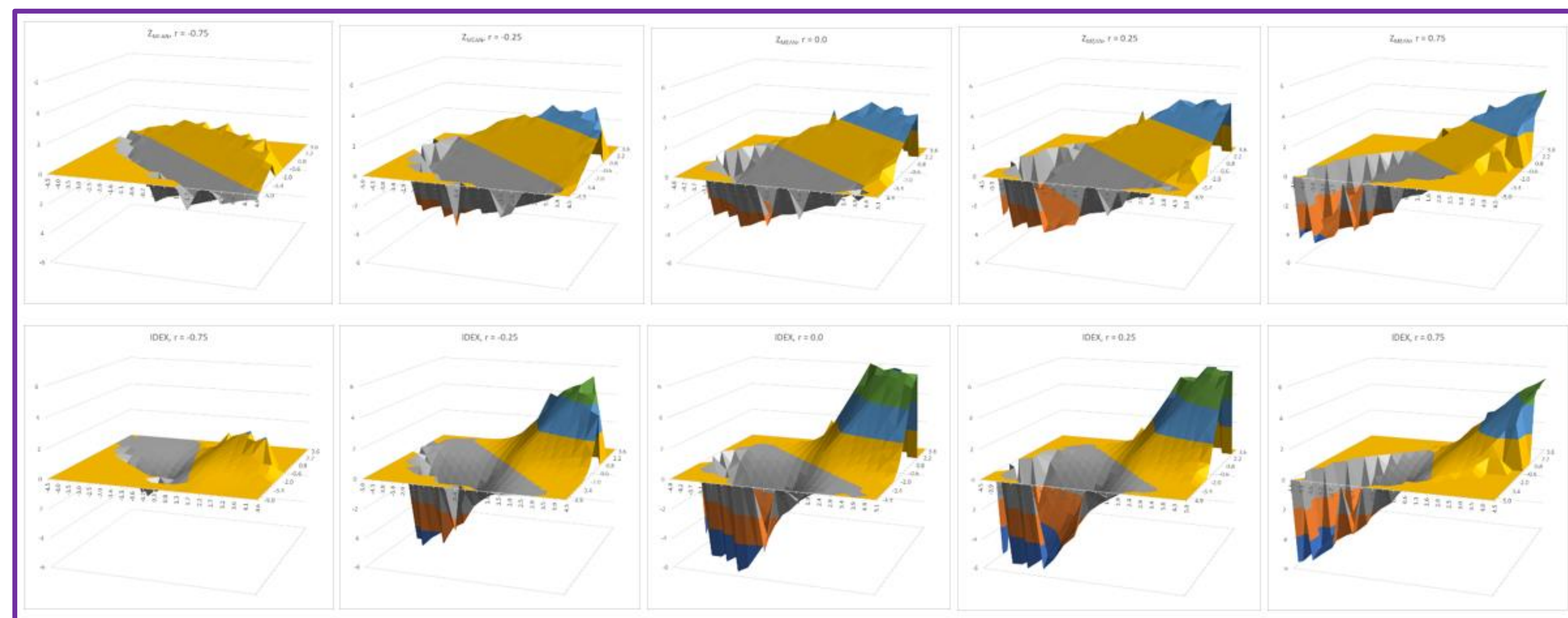$$IDEX = [Z_{CELL} + (1 - |r|)Z_{AB}]\left(1 - \frac{|dRank|}{n-1}\right).$$

Figure 1: Surface plots of values of ZMEAN (upper plots) and IDEX (lower plots) that can be expected as a function of the standardised values of Cell-IR and Ab-IR (width and depth axes, irrespective) and the correlation with each other being from left to right -0.75, -0.25, 0, 0.25 and 0.75.
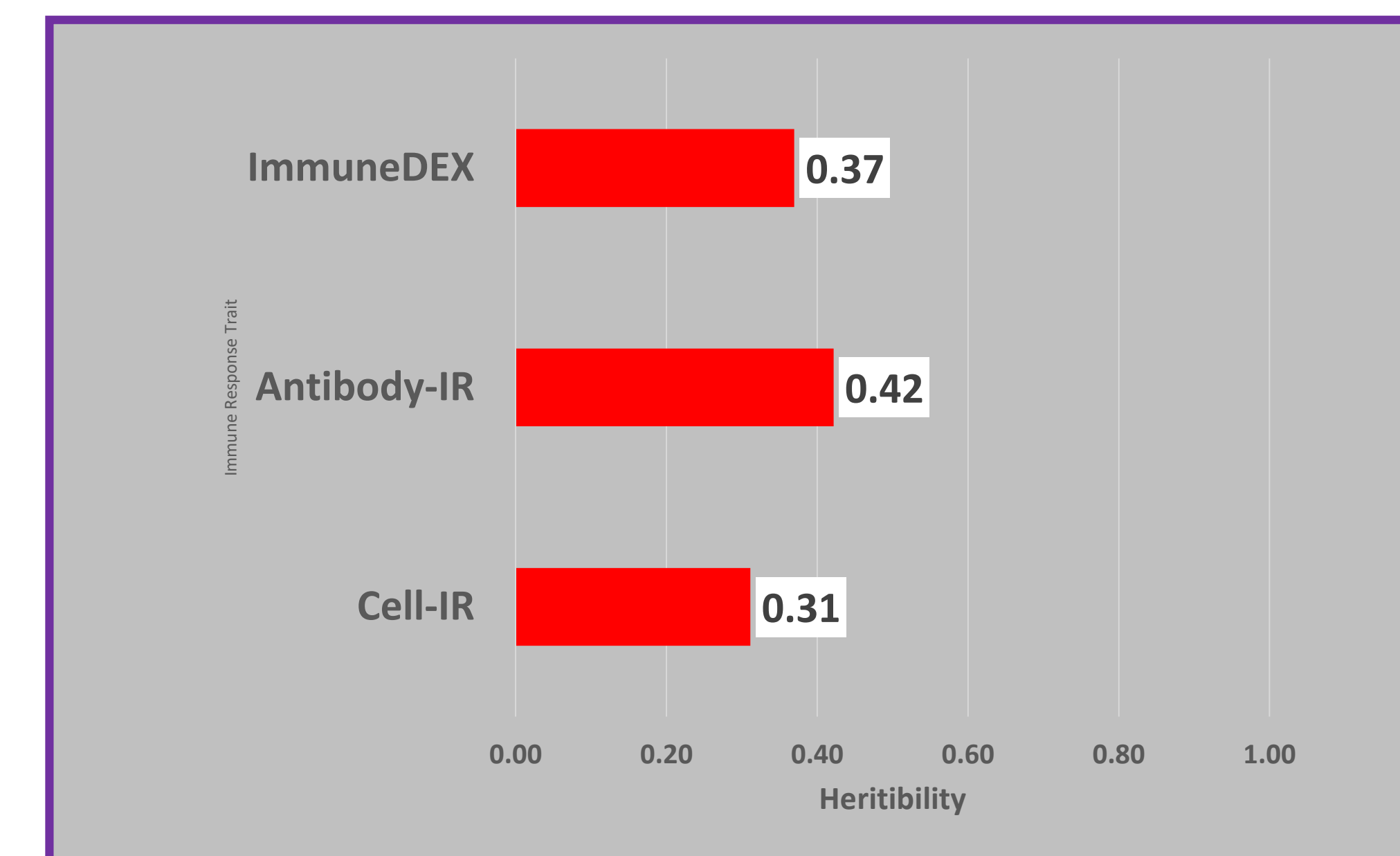

Figure 2: Estimates of heritability for ImmuneDEX, Antibody mediated immune response and Cell mediated immune response.
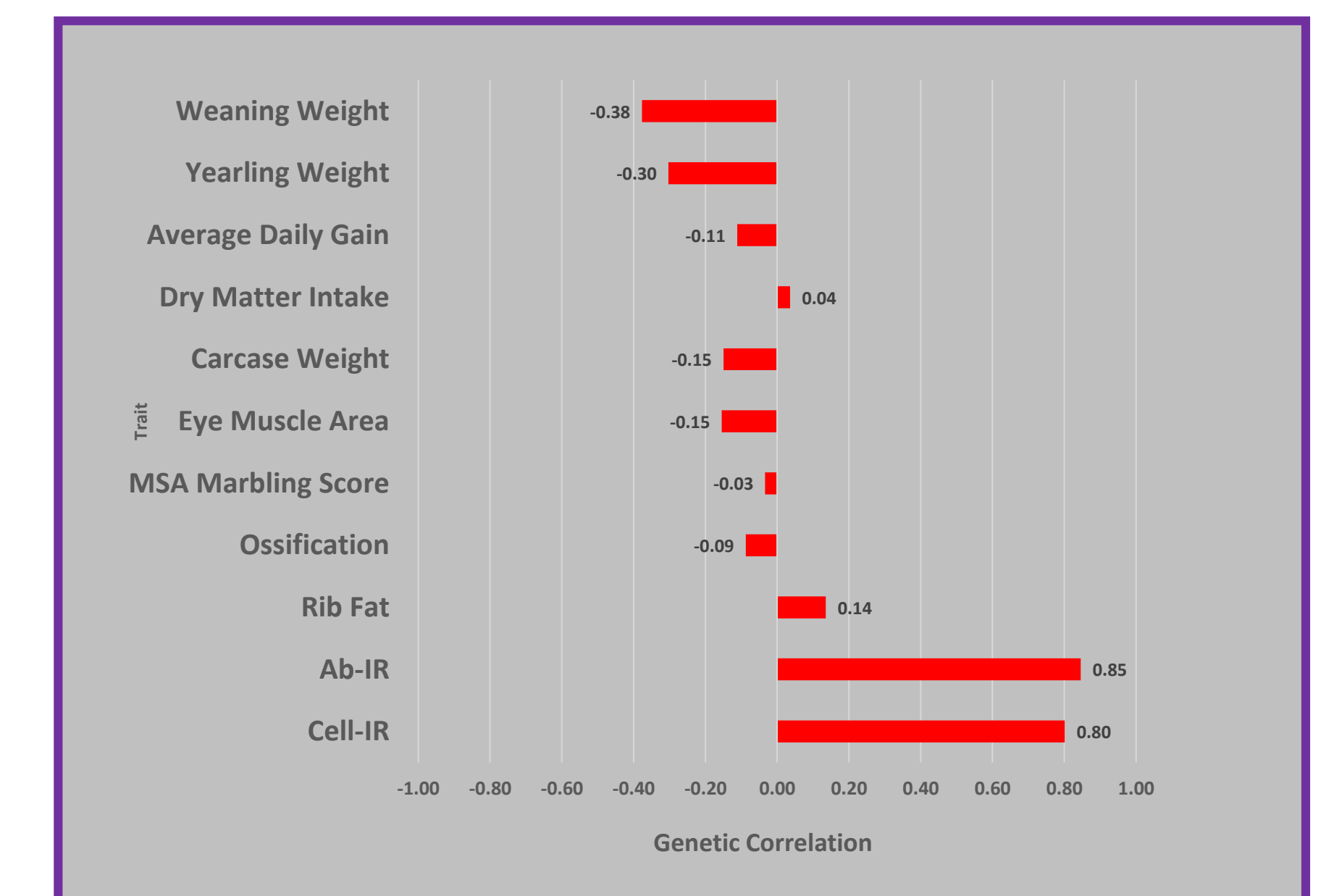

Figure 3: Estimates of genetic correlations between ImmuneDEX, component traits of immune competence and production traits.

Results and Conclusions

1. In agreement with the finding of Dominik et al. (2019), IDEX places greater emphasis on Cell-IR.

2. Simulation studies suggest a higher dynamic range of values for IDEX compared to ZMEAN (Figure 1).

3. ImmuneDEX and its component traits of Ab-IR and Cell-IR, are moderately heritable (Figure 2), being comparable to industry standard weight and carcase traits.

4. ImmuneDEX is generally negatively correlated with several production traits, particularly weaning weight and yearling weight. While a positive but weak relationship exists with rib fat (Figure 3).

5. As seen in other, more intensive livestock systems and species, this indicates that selection on performance traits alone, with no consideration of immune competence, may lead to a higher incidence of disease.

6. ImmuneDEX will provide a tool to underpin long-term genetic strategies aimed at improving the immune competence of animals in our production systems which in turn is expected to reduce the incidence of disease, reduce our reliance on antibiotics and improve animal welfare.