**Supplementary Table S1.** *Igenity scores for a range of beef, dairy and fertility traits from 199 animals genotyped by Merial (scores on a 1 to 10 scale).*

|  |  |  |
| --- | --- | --- |
| **Trait** | **Mean** | **SD** |
| **Beef traits** |  |  |
| Tenderness | 5.2 | 1.76 |
| Marbling score | 6.0 | 0.78 |
| Average daily gain | 4.1 | 0.83 |
| Red meat yield | 5.9 | 0.97 |
| Carcase fat | 5.1 | 0.86 |
| Ribeye area | 4.9 | 0.93 |
| **Dairy fertility etc.** |  |  |
| Heifer pregnancy rate | 4.1 | 0.97 |
| Longevity | 7.4 | 0.96 |
| Maternal calving ease | 3.1 | 1.12 |
| Docility | 7.6 | 0.87 |
| Productive life | 5.7 | 2.07 |
| Fertility | 4.3 | 1.78 |
| Somatic cell count | 5.0 | 1.91 |
| Dairy form | 6.5 | 1.64 |
| **Dairy production** |  |  |
| Milk yield | 6.4 | 1.14 |
| Fat weight | 6.0 | 1.75 |
| Protein weight | 5.8 | 1.63 |
| Fat % | 5.4 | 1.40 |
| Protein % | 6.0 | 1.03 |

**Supplementary Table S2.** *The final fixed effects and covariates used in the mixed model analyses for 11 recorded Gloucester traits.*

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Trait | Herd1 | Year | HYS | Mnth. | CWt. | Age | Sex | Lactation number | Days in milk | Herd x year |
| Total milk | X2 | X |  |  |  |  |  | X | X | X |
| Fat weight | X | X |  |  |  |  |  | X | X | X |
| Protein wt. | X | X |  |  |  |  |  | X | X | X |
| Fat % | X | X |  |  |  |  |  |  | X |  |
| Protein % |  |  | X |  |  |  |  |  | X |  |
| Log. SCC |  |  | X |  |  |  |  | X | X |  |
| Log. CI | X | X |  | X |  |  |  | X |  | X |
| Growth rate | X | X |  | X |  | X | X |  |  |  |
| Carcase wt. | X | X |  | X |  | X | X |  |  | X |
| Fat score | X | X |  |  |  | X |  |  |  |  |
| Conf. score | X |  |  |  | X |  |  |  |  |  |

1Column headings are identifiable factors which affected the recorded traits.

2X indicates a characteristic which was found to affect the trait shown (P < 0.05).

NB. HYS is herd/year/season group. Mnth was month of the year. CWt is carcase weight. SCC is somatic cell count. CI is calving interval.

Carcase weight, days in milk and age were fitted as covariates. Age was fitted as a 2nd order polynomial within sex.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Tender-ness | Marbl-ing score | ADG1 | Red meat yield | Carcase fat | Ribeye area | H. preg rate2 | Long-  evity | Calvi-ng ease | Docil-ity | Produ-ctive life | Fertili-ty | SCC3 | Dairy form | Milk yield | Fat wt. | Fat % | Protein wt. |
| Marbling score | -0.25 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ADG | 0.12 | -0.05 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Red meat yield | 0.07 | -0.10 | -0.19 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Carcase fat | -0.12 | 0.20 | 0.12 | -0.57 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Ribeye area | 0.07 | -0.01 | -0.17 | 0.23 | -0.22 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| H. preg rate | 0.15 | -0.05 | 0.11 | -0.06 | -0.07 | 0.03 |  |  |  |  |  |  |  |  |  |  |  |  |
| Longevity | 0.42 | 0.01 | 0.04 | -0.07 | -0.10 | -0.18 | 0.04 |  |  |  |  |  |  |  |  |  |  |  |
| Calving ease | 0.02 | -0.10 | 0.12 | -0.33 | 0.09 | -0.06 | 0.51 | 0.11 |  |  |  |  |  |  |  |  |  |  |
| Docility | -0.24 | -0.03 | -0.06 | 0.10 | -0.14 | 0.25 | 0.29 | -0.24 | 0.08 |  |  |  |  |  |  |  |  |  |
| Productive life | 0.28 | 0.04 | 0.34 | -0.15 | 0.25 | -0.11 | 0.06 | 0.18 | 0.04 | -0.26 |  |  |  |  |  |  |  |  |
| Fertility | 0.41 | 0.01 | 0.32 | 0.04 | 0.08 | 0.00 | 0.06 | 0.11 | -0.03 | -0.24 | 0.71 |  |  |  |  |  |  |  |
| SCC | 0.23 | 0.01 | -0.24 | -0.03 | -0.11 | 0.15 | 0.09 | 0.06 | 0.02 | 0.01 | -0.33 | -0.28 |  |  |  |  |  |  |
| Dairy form | -0.13 | 0.06 | -0.10 | -0.08 | 0.07 | -0.12 | 0.23 | 0.15 | 0.29 | 0.13 | -0.37 | -0.44 | 0.11 |  |  |  |  |  |
| Milk yield | 0.08 | -0.05 | -0.18 | -0.21 | 0.07 | 0.19 | 0.11 | -0.01 | 0.18 | 0.19 | -0.24 | -0.32 | 0.25 | 0.44 |  |  |  |  |
| Fat wt. | -0.01 | 0.10 | 0.12 | -0.07 | 0.17 | -0.03 | 0.09 | 0.29 | 0.34 | -0.07 | 0.32 | 0.05 | -0.12 | 0.48 | 0.11 |  |  |  |
| Fat % | 0.10 | 0.10 | 0.15 | 0.09 | 0.08 | -0.17 | -0.01 | 0.35 | 0.17 | -0.31 | 0.46 | 0.28 | -0.21 | 0.07 | -0.48 | 0.72 |  |  |
| Protein wt. | 0.20 | -0.15 | -0.14 | -0.37 | 0.11 | 0.14 | 0.13 | 0.07 | 0.22 | 0.03 | -0.16 | -0.25 | 0.46 | 0.33 | 0.71 | -0.07 | -0.46 |  |
| Protein % | 0.33 | 0.02 | -0.03 | -0.02 | -0.02 | -0.13 | -0.04 | 0.32 | 0.02 | -0.47 | 0.20 | 0.29 | 0.35 | -0.06 | -0.38 | 0.06 | 0.36 | 0.10 |

**Supplementary Table S3.** *Correlations between the Igenity scores for 19 Gloucester traits from 199 animals.*

1Average daily gain in weight. 2Heifer pregnancy rate. 3Somatic cell count.

NB. Standard errors for these correlations range from 0.0134 (correlation + or -0.9) to 0.07 (correlation + or – 0.1).

**Supplementary Table S4.** *The mean accuracy and SD of recorded cows and 3 generations of ancestors for a series of bivariate and trivariate BLUP calculations for milk traits calculated using an AI method.*

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Milk yield | | Fat weight | | Fat % | | Protein wt. | | Protein % | |
|  | Recorded  cows1 | Ancestors | Recorded  cows | Ancestors | Recorded  cows | Ancestors | Recorded  cows | Ancestors | Recorded  cows | Ancestors |
| Univariate BLUP | 0.573  ± 0.085 | 0.300  ± 0.093 | 0.467  ± 0.083 | 0.253  ± 0.077 | 0.629  ± 0.084 | 0.348  ± 0.091 | 0.474  ± 0.077 | 0.252  ± 0.079 | 0.634  ± 0.088 | 0.324  ± 0.103 |
| Bivariate with milk yield | NA | NA | 0.552  ± 0.085 | 0.282  ± 0.093 | 0.664  ± 0.090 | 0.334  ± 0.108 | 0.557  ±0.086 | 0.285  ± 0.094 | 0.648  ± 0.085 | 0.330  ± 0.105 |
| Bivariate with fat wt. | 0.574  ± 0.087 | 0.293  ± 0.096 | NA | NA | 0.629  ± 0.090 | 0.318  ± 0.104 | 0.488  ± 0.085 | 0.252  ± 0.086 | 0.665  ± 0.086 | 0.338  ± 0.107 |
| Bivariate with protein wt. | 0.569  ± 0.086 | 0.292  ± 0.096 | 0.488  ± 0.086 | 0.252  ± 0.086 | 0.619  ± 0.081 | 0.316  ± 0.101 | NA | NA | 0.643  ± 0.086 | 0.328  ± 0.104 |
| Bivariate with fat % | 0.636  ± 0.087 | 0.320  ± 0.104 | 0.499  ± 0.082 | 0.257  ± 0.085 | NA | NA | 0.605  ± 0.082 | 0.304  ± 0.099 | 0.641  ± 0.086 | 0.327  ± 0.104 |
| Bivariate with Protein % | 0.609  ± 0.080 | 0.309  ± 0.099 | 0.427  ± 0.078 | 0.223  ± 0.074 | 0.619  ± 0.081 | 0.316  ± 0.101 | 0.507  ± 0.075 | 0.261  ± 0.086 | NA | NA |
| Trivariate; milk yield,  fat and protein % | 0.645  ± 0.080 | 0.324  ± 0.104 |  |  | 0.654  ± 0.0832 | 0.328  ± 0.106 |  |  | 0.656  ± 0.084 | 0.334  ± 0.105 |

1N = 81 for recorded cows and 250 for ancestors back 3 generations.

**Supplementary Table S5.** *The mean accuracy of EBV for recorded cows and genotyped animals of milk traits estimated by BLUP and Genomic BLUP using an EM algorithm.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Recorded cows  N = 81 | | Genotyped animals  N = 199 | |
|  | Mean | SD | Mean | SD |
| Milk yield EBV accuracy (acc) | 0.593 | 0.076 | 0.316 | 0.092 |
| Milk yield GEBV acc | 0.590 | 0.076 | 0.307 | 0.097 |
| Fat wt. EBV acc | 0.483 | 0.072 | 0.270 | 0.070 |
| Fat wt. GEBV acc | 0.482 | 0.071 | 0.268 | 0.071 |
| Protein wt. EBV acc | 0.496 | 0.066 | 0.277 | 0.073 |
| Protein wt. GEBV acc | 0.496 | 0.066 | 0.273 | 0.077 |
| Fat % EBV acc | 0.603 | 0.075 | 0.324 | 0.094 |
| Fat % GEBV acc | 0.602 | 0.075 | 0.320 | 0.097 |
| Protein % EBV acc | 0.644 | 0.080 | 0.332 | 0.099 |
| Protein % GEBV acc | 0.643 | 0.080 | 0.328 | 0.102 |

**Supplementary Table S6**. *A summary of genetic analyses involving genomic breeding value estimation.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Additive genetic variance | Permanent environmental variance | Residual variance | Phenotypic variance | Heritability | Repeatability | Proportion of genetic variance explained by SNP |
| Milk yield (kg) | 175600 | 36710 | 190200 | 402510 | 0.44 | 0.53 | 0.035 |
| Fat weight (kg) | 146.7 | 38.66 | 467.7 | 653.06 | 0.22 | 0.28 | 0.03 |
| Protein weight (kg) | 107.4 | 66.54 | 237.8 | 411.74 | 0.26 | 0.42 | 0.03 |
| Fat % | 0.1114 | 0.02357 | 0.1396 | 0.27457 | 0.41 | 0.49 | 0.03 |
| Protein % | 0.02514 | 0.001436 | 0.02495 | 0.051526 | 0.49 | 0.52 | 0.035 |
| Log SCC ('000) | 0.009705 | 0.03471 | 1.341 | 1.385415 | 0.007 | 0.03 | 0.03 |
| Log CI (d) | 5.248E-05 | 0.001816 | 0.008454 | 0.010322 | 0.005 | 0.18 | 0.03 |
| Growth rate (kg/mo) | 1.293 |  | 3.132 | 4.425 | 0.29 |  | 0.035 |
| Carcase weight (kg) | 1673 |  | 644 | 2317 | 0.72 |  | 0.03 |
| Fat score | 0.6123 |  | 0.677 | 1.2893 | 0.47 |  | 0.03 |
| Conformation score | 0.01191 |  | 0.935 | 0.94691 | 0.01 |  | 0.03 |

**Supplementary Table S7.** *The mean accuracy of EBV for recorded cows, ancestors and genotyped animals of milk traits estimated by BLUP and bivariate BLUP including the Igenity score for that trait, and their difference.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Recorded cows  N = 81 | | Ancestors1  N = 250 | | Genotyped animals  N = 199 | |
|  | Mean | SD | Mean | SD | Mean | SD |
| Milk yield acc. | 0.573 | 0.085 | 0.305 | 0.091 | 0.285 | 0.098 |
| Milk yield acc. plus Igmilk | 0.616 | 0.077 | 0.359 | 0.113 | 0.609 | 0.030 |
| *Difference* | *0.043* |  | *0.054* |  | *0.324* |  |
| Fat wt. acc. | 0.467 | 0.083 | 0.256 | 0.075 | 0.236 | 0.077 |
| Fat wt. acc. plus Igfat wt. | 0.593 | 0.115 | 0.355 | 0.167 | 0.818 | 0.033 |
| *Difference* | *0.126* |  | *0.099* |  | *0.582* |  |
| Fat % acc. | 0.629 | 0.085 | 0.352 | 0.089 | 0.334 | 0.099 |
| Fat % acc. plus Igfat % | 0.648 | 0.081 | 0.365 | 0.111 | 0.571 | 0.041 |
| *Difference* | *0.019* |  | *0.013* |  | *0.237* |  |
| Protein wt. acc. | 0.474 | 0.077 | 0.256 | 0.077 | 0.239 | 0.081 |
| Protein wt. acc. plus Igprotein wt. | 0.579 | 0.091 | 0.370 | 0.129 | 0.740 | 0.032 |
| *Difference* | *0.105* |  | *0.114* |  | *0.501* |  |
| Protein % acc. | 0.634 | 0.088 | 0.329 | 0.100 | 0.301 | 0.107 |
| Protein % acc. plus Igprotein %. | 0.634 | 0.087 | 0.331 | 0.100 | 0.315 | 0.102 |
| *Difference* | *0* |  | *0.002* |  | *0.014* |  |

1Three generations back from recorded cows.