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GENETIC ANALYSES ON CARCASE CHARACTERS OF AUSTRALIAN WAGYU BEEF CATTLE

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SUMMARY

Producers of Wagyu beef have unique opportunities to assess high value markets, where carcase value is determined primarily on marbling score. To date, there have been limited genetic studies of this breed, especially in Australia. Newly developed image analysis equipment could be a useful tool to analyse carcase characters. This study estimated genetic parameters for carcase traits measured by both the AUS-MEAT method and camera image analysis. Most carcase traits were moderately to highly heritable. The genetic correlation between AUS-MEAT marbling score and the image analysis marbling trait was very high, and similarly for the two measures of eye muscle area. It was concluded that image analysis of carcase traits is a feasible basis for selection in Australian Wagyu beef cattle.

INTRODUCTION

Wagyu is a collective term for Japanese beef breeds (Japanese Black, Japanese Brown, Japanese Shorthorn and Japanese Polled), accounting for 97% of Japanese cattle (Hirooka 2014). Wagyu cattle typically exhibit high marbling levels. Genetic evaluation for Wagyu cattle has been well reported but mostly for cattle in Japan and the USA. Production of Wagyu beef cattle in Australia started in the 1990s and was initiated from frozen semen and embryos, and live animals imported from Japan via the USA. The breeders' association, the Australian Wagyu Association (AWA, http://www.wagyu.org.au/), provides BREEDPLAN genetic evaluation services to Australian Wagyu breeders. While there has been increasing interest in the market potential for Australian Wagyu beef there have to date been limited genetic evaluation studies for characters of Australian Wagyu cattle. Newly developed measurements of beef quality using imaging analysis traits of carcases have been tested in Australian Wagyu cattle on a small scale (Maeda *et al.* 2014). Maeda *et al.* (2014) compared the AUS-MEAT measure and the image analysis traits of carcase characters in Australian Wagyu cattle. The preliminary results demonstrated that the image technology is a useful tool to substitute for visual assessments of carcase characters. The aims of this study were 1) to estimate genetic parameters for carcase characters of Australian Wagyu cattle measured using these image analysis traits and conventional AUS-MEAT (AUS-MEAT Ltd 2005) visual assessment; 2) to estimate genetic correlations between a subset of traits to facilitate implementation of genetic evaluation of Australian Wagyu cattle; and 3) to examine the feasibility of using image analysis traits of carcase characters as a substitute for, or to complement, the conventional AUS-MEAT grading.

MATERIALS AND METHODS

Animals and Phenotypes. Animals evaluated in this study had carcase records and were progeny of 336 sires, with progeny per sire ranging from 1 to 153. Forty-nine sires had a single offspring and 135 had fewer than 5 progeny; 6 sires had more than 100 progeny. The phenotypes and pedigree were extracted from the Wagyu BREEDPLAN database, with ancestors tracing back to the 1960's.

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Carcase traits. Carcase traits were measured in accordance with the AUS-MEAT grading system by certified graders, and included hot carcase weight, marbling score, rib and P8 fat depths, intramuscular fat, and eye muscle area.

Image analysis traits. The image analysis traits were obtained in two steps: 1) taking digital images of carcase cross-section from between the 5th and 6th ribs using the photography device (HK-333, Hayasaka Rikoh, Sapporo Japan, Kuchida *et al.*. 2001 and Takahashi *et al.* 2006); 2) analysing the images using image analysis software (BeefAnalyserII, Hayasaka Rikoh, Sapporo Japan) to generate a set of traits based on pixel sizes, counts and colours. In brief, the muscle in the rib eye area was identified by a border line (line width of 1 pixel), this border line was semiautomatically drawn using the image analysis software and manually corrected where necessary. The image was partitioned into lean parts in white and fat (or marbling) sections in black. Fine marbling particles (fat flecks) were defined as those with an area between 0.01 and 0.5 cm^2. The image for coarse marbling particles (or fat flecks > 1 pixel) was created by further thinning the marbling image and removing hairlines of 1 pixel wide. Details of these processes have been reported previously (Kuchida *et al.* 2001). Ten image analysis traits were analysed: 1) eye muscle area (cm^2), 2) percentage of marbling area (%), 3) percentage of the coarse fat flecks (%) or marbling coarseness index as other reported (Maeda *et al.* 2014), 4) percentage of the largest fat flecks (%), 5) percentage of the largest 5 fat flecks (%), 6) percentage of the largest 10 fat flecks (%), 7) marbling fineness index or number of fat flecks per cm^2 (count/cm^2), 8) total number of fat flecks in rib eye area, 9) average luminance of the lean rib eye area and 10) ratio of minor to major axis in rib eye area.

Statistical Models. Data were analysed using an animal model fitted with fixed effects and covariates to estimate breeding values, genetic variances and heritability for traits with reasonable numbers of records and, subsequently, genetic correlations for specific pairs of traits. The fixed effects included in the analysis for carcase weight were contemporary groups (defined by herd, original owner, management group and date of slaughter), sex, and age at slaughter and age of dam were fitted as covariates. In addition to those effects the carcase character traits (measured either through AUS-MEAT or via image analysis traits) were adjusted for carcase weight instead of age at slaughter. The model used was $\mathbf{y = Xb + Za + e}$, where $\mathbf{y}$ represents the vector of observations, $\mathbf{X}$ is the incidence matrix relating fixed effects/covariate (e.g. contemporary group, sex and age at slaughter) in $\mathbf{b}$ with observations in $\mathbf{y}$, $\mathbf{Z}$ is the incidence matrix relating the random additive genetic effects in $\mathbf{a}$ with observations in $\mathbf{y}$, and $\mathbf{e}$ is the vector of random residual effects. The random effects in the model were assumed to be normally distributed with zero mean and variances as $\mathbf{Var\ (a) = A\sigma_a^2}$ and $\mathbf{Var\ (e) = I\sigma_e^2}$, where $\mathbf{A}$ is the numerator relationship matrix across all animals and derived from the available pedigree information, and $\mathbf{I}$ is an identity matrix. $\boldsymbol{\sigma_a^2}$ and $\boldsymbol{\sigma_e^2}$ are the components of variance for additive and residual random effects, respectively. Bivariate analyses were performed for pairs of traits of importance, and with sufficient data to estimate the genetic and phenotypic correlations. These included correlations between AUS-MEAT and image analysis traits for marbling, eye muscle area and fatness measures, respectively; and between carcase weight and meat quality traits (marbling, fatness and eye muscle area). The random effects in these models were assumed to be normally distributed with zero mean and variance as $\mathbf{Var(a) = G_0 \otimes A}$ and $\mathbf{Var(e) = R_0 \otimes I}$, where $\mathbf{G_0}$ and $\mathbf{R_0}$ are the additive genetic and residual covariance matrices among traits respectively, and where $\otimes$ is the Kronecker product.

RESULTS AND DISCUSSION

Descriptive statistics for traits are showed in Table 1. These cattle had an average carcase weight of 417kg, AUS-MEAT marbling score of 7.5, eye muscle area of 89 cm^2 and age at slaughter of 980 days. Image analyses of carcase characters showed lower eye muscle area (63 cm^2) with a greater variation than the AUS-MEAT grading measure. An average of 27.3% of the rib eye area was intramuscular fat, with 6.8% coarse fat flecks, 4.4% (or 5.4%) the largest 5 (or 10) fat flecks and 2.68 fine fat particles per cm^2 of rib eye area. The largest fat particle accounted for 2.8% of the rib eye area and the average total number of fat particles in the rib eye area was 990 with very large variation.

Genetic parameters. Genetic parameter estimates are shown in Table 1 for carcase AUS-MEAT traits and image analysis traits. AUS-MEAT carcase traits were moderately to highly heritable. However, heritability estimates for measures of fat content traits were low; in particular, the estimate for carcase rib fat was abnormally low, with a possible explanation being irregularity in data collection (e.g. fat trimming). The estimates for carcase weight, eye muscle area and marbling are in line with the average of estimated heritability for carcase traits reported by Oyama (2011). Heritability estimates for intramuscular fat and P8 fat were similar, and the estimate for intramuscular fat was in the range summarized by Oyama (2011).

Most image analysis traits of carcase characters were moderately to highly heritable. For example, marbling percentage, marbling particle fineness and coarseness (percentages of coarse fat flecks), and number of marbling particles were very highly heritable. The brightness of eye muscle was also moderately heritable. Image analysis traits for the shape of eye muscle area (ratio of minor to major axis) and for the percentage of the largest marbling particle had low heritability. These findings are similar to those previous reported (Osawa *et al.* 2008). The current results are similar to those reported by Maeda *et al.* (2014), but with lower standard errors.

Table 1. Descriptive statistics and genetic parameters for carcase traits (including image analysis traits and AUS-MEAT measures of carcase) of Australian Wagyu cattle

Trait	N	Mean	s.d.	V_a	V_p	h^2	s.e.
Image analysis traits							
Eye muscle area (cm^2)	2095	63.0	26.6	45.5	73.5	0.62	0.11
Marbling percentage (%)	2095	27.3	7.75	13.1	35.6	0.37	0.09
Fineness Index (count/cm^2)	1856	2.68	0.62	0.13	0.26	0.50	0.11
Fat particles (%)	2095	6.82	4.53	3.13	10.3	0.31	0.09
The largest fat particle (%)	2041	2.75	2.37	0.21	4.29	0.05	0.05
The 5 largest fat particles (%)	845	4.43	3.01	4.82	6.15	0.78	0.16
The 10 largest particles (%)	845	5.43	3.43	6.41	7.56	0.85	0.15
Total number of fat particles	845	987	702	131633	164074	0.80	0.03
Minor major axis ratio	1856	0.83	1.12	0.01	0.06	0.08	0.06
luminance of muscular part	1135	80.3	8.22	22.6	57.0	0.40	0.14
AUS-MEAT traits							
Hot standard carcase weight (kg)	5269	417	61.2	646	1363	0.47	0.07
AUS-MEAT marble score 0-9	3066	7.41	1.66	1.18	2.26	0.54	0.09
Carcase eye muscle area (cm^2)	1423	88.8	18.8	52.1	88.1	0.59	0.12
Carcase rib fat depth (mm)	1303	15.0	7.00	1.48	27.6	0.06	0.05
Carcase P8 fat depth (mm)	1860	26.8	10.6	11.1	43.6	0.25	0.11
Carcase intramuscular fat (100+%)	866	134	70.7	385	1794	0.23	0.15

Genetic correlations. The genetic correlations from the bivariate analyses are shown in Table 2. The genetic correlation between values for eye muscle area measured by image analysis traits and by the traditional method is very high (0.83), and the distributions of the two measures are very similar. The genetic correlation for the carcase marbling between AUS-MEAT measure and image analysis trait was unity. Other estimates were either small or associated with high standard errors.

Table 2 Genetic and phenotypic correlations between traits

Trait1	Trait2	N*	r_g	s.e.	r_p
Carcase Weight	Image marbling%	2095	0.21	0.17	0.02
Carcase Weight	AUS-MEAT marbling score	3066	0.32	0.13	0.04
Carcase Weight	Image eye muscle area	2095	-0.15	0.14	-0.02
Carcase Weight	Carcase eye muscle area	1423	0.10	0.19	0.01
Image marbling%	AUS-MEAT marbling score	2073	1.00	0.01	0.77
Image marbling%	Image eye muscle area	2095	-0.04	0.17	0.18
Image marbling%	Image eye muscle area	1112	0.09	0.22	0.18
AUS-MEAT marbling score	Image eye muscle area	2073	-0.26	0.14	0.16
AUS-MEAT marbling score	Carcase eye muscle area	1423	0.03	0.17	0.21
Image eye muscle area	Carcase eye muscle area	1112	0.83	0.08	0.64
Carcase intramuscular fat	Carcase P8 fat	806	-0.09	0.49	-0.11

*N is the number of records common for two traits; r_g and r_p are the genetic and phenotypic correlations. s.e. is the standard error for r_g.

CONCLUSIONS

High genetic correlations show that both image analysis and AUS-MEAT measures for marbling or for eye muscle area are essentially the same traits. Image analysis of carcase characters captures useful genetic information as evident in their moderate to high heritability estimates. Thus they may be useful for selection in Australian Wagyu beef cattle. Prior to including these image analysis traits in Wagyu genetic evaluation, it is necessary to ascertain both their economic value and their genetic correlations with other traits.

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