A review and meta-analysis of published genetic parameter estimates for carcass and image analysis traits of Japanese Black Wagyu

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Summary

Subjective carcass assessment methodology is inadequate to accurately assess high marbling Wagyu carcasses in Australia. Additionally it is unable to phenotype for marbling fineness, a trait which is becoming increasing desirable. This review summarises the published heritabilities of Japanese Black Wagyu carcass and image analysis traits and discusses the genetic correlations between traits. Weighted heritabilities of carcass and image analysis traits were all moderately to highly heritable (0.21–0.62) with the exception of coarseness index of largest marbling particle (0.08). Genetic correlations between marble score and subcutaneous fat depth were low while those between marbling percentage and overall marbling coarseness were high.

Keywords: genetic parameters, heritability, wagyu

Introduction

Marbling is quickly becoming an integral component of beef breeding programs due to its association with increased meat eating quality. Japanese Black Wagyu is an attractive breed having the highest propensity to marble of any beef breed in Australia. Carcass traits are currently assessed using subjective measurement protocols i.e. marbling and rib-eye area, inadequate for assessing high marbling Wagyu carcasses. This led to the development of meat image analysis technology as an objective measurement tool (Kuchida et al., 1997). Additionally meat image analysis allows the objective assessment of marbling fleck size and distribution within the rib-eye. This paper is a meta-analysis of heritability estimates relating to carcass and meat image analysis for the Japanese Black Wagyu breed.

Material and Methods

Heritabilities (h\textsuperscript{2}) were reported as both un-weighted and weighted and calculated as follows:

\textbf{Unweighted h}^2 =

\textbf{Weighted h}^2 =

Here, N is the number of estimates reported for the trait used from the literature and describes the i-th heritability for the trait. Weighted heritabilities were estimated such that, each individual heritability was weighted by its accompanying standard error (Koots et al., 1994). All reported standard errors (SE) were treated equally, regardless of the methodology used in their calculation. Where authors reported standard errors as a range, the largest
standard errors were assigned to each heritability estimate. Where authors reported no standard errors, heritability estimates were excluded from the calculation of weighted means.

**Results and Discussion**

**Carcass Traits**

Oyama (2011) reviewed heritabilities of carcass traits, for the Japanese Black, graded under Japan Meat Grading Association (JMGA) guidelines. Average unweighted and weighted heritabilities for carcass weight, rib-eye area, subcutaneous fat depth and marbling were calculated, finding moderate to high heritabilities (Table 1).

<table>
<thead>
<tr>
<th>Trait</th>
<th>Method</th>
<th>N</th>
<th>Range of h²</th>
<th>Unweighted mean h²</th>
<th>Weighted mean h²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcass Weight</td>
<td>JMGA</td>
<td>18</td>
<td>0.23-0.78</td>
<td>0.48</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>AUS-Meat</td>
<td>3</td>
<td>0.24-0.59</td>
<td>0.43</td>
<td>0.42</td>
</tr>
<tr>
<td>Rib Eye Area</td>
<td>JMGA</td>
<td>18</td>
<td>0.37-0.45</td>
<td>0.46</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>AUS-Meat</td>
<td>2</td>
<td>0.33-0.59</td>
<td>0.42</td>
<td>0.31</td>
</tr>
<tr>
<td>Subcutaneous fat thickness</td>
<td>JMGA</td>
<td>18</td>
<td>0.07-0.59</td>
<td>0.39</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>AUS-Meat</td>
<td>3</td>
<td>0.19-0.84</td>
<td>0.42</td>
<td>0.31</td>
</tr>
<tr>
<td>Marbling Score</td>
<td>JMGA</td>
<td>11</td>
<td>0.16-0.74</td>
<td>0.55</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>AUS-Meat</td>
<td>3</td>
<td>0.23-0.54</td>
<td>0.38</td>
<td>0.43</td>
</tr>
<tr>
<td>Camera rib-eye muscle area</td>
<td>MIA</td>
<td>4</td>
<td>0.33-0.62</td>
<td>0.46</td>
<td>0.47</td>
</tr>
<tr>
<td>% Marbling area</td>
<td>MIA</td>
<td>6(5)</td>
<td>0.37-0.76</td>
<td>0.54</td>
<td>0.62</td>
</tr>
<tr>
<td>Marbling coarseness index</td>
<td>MIA</td>
<td>6(5)</td>
<td>0.31-0.50</td>
<td>0.41</td>
<td>0.45</td>
</tr>
<tr>
<td>Coarseness index of largest marbling particle</td>
<td>MIA</td>
<td>5(4)</td>
<td>0.05-0.20</td>
<td>0.10</td>
<td>0.08</td>
</tr>
<tr>
<td>Marbling fineness index</td>
<td>MIA</td>
<td>4</td>
<td>0.38-0.55</td>
<td>0.48</td>
<td>0.42</td>
</tr>
</tbody>
</table>

1Subcutaneous fat thickness for AUS-Meat grading refers specifically to the P8 fat depth measurement (mm)

2Osawa et al., 2004; 2008; Oyama, 2011; Nakahashi et al., 2012; Maeda et al., 2014; Zhang et al., 2015; McEwin, 2016; Pitchford, 2016 Unpublished. N of weighted h² in brackets where different to unweighted h².

The heritability of similar carcass traits, estimated under the AUS-Meat grading system, has been published for Japanese Wagyu in Australia yielding similar results to Japanese publications (Maeda et al., 2014; Zhang et al., 2015; McEwin, 2016; Table 1). The heritability of carcass traits in Wagyu is consistent with reports from other breeds (Gregory et al., 1995). Unweighted and weighted heritabilities were similar for all traits except JMGA marbling score. Here, the weighted heritability was substantially lower than the unweighted heritability due to the influence of a low heritability estimate with a low standard error (Oyama, 2011).

Unweighted averages of genetic correlations between carcass traits in Wagyu populations have been summarised by Oyama (2011). Interestingly, ribeye area and marble score have a lowly-moderate to moderate positive correlation (0.24-0.43; Oyama, 2011; McEwin, 2016). This is a unique characteristic of Wagyu as estimates in other breeds have been zero or lowly negative (Gregory et al., 1995). McEwin (2016) demonstrated that the moderately positive correlation in Wagyu was perhaps explained by an excessive amount of
marbling, pushing the muscle fibre bundles apart, increasing the ribeye area measurement. A negative correlation (-0.37) was reported when IMF% in the rib-eye was accounted for (McEwin, 2016). Another unique Wagyu characteristic is the apparent lack of, or slightly negative, correlation between marble score and subcutaneous fat depth (-0.06, -0.05 respectively; Oyama, 2011; McEwin, 2016). In other breeds it is moderately positive (0.44; Gregory et al., 1995). This is an encouraging relationship in that higher marbling can be obtained without an accompanying increase in ‘trim-able or waste fat’ when finishing Wagyu.

**Camera Image Analysis Traits**

Image analysis methodology presents as an objective way to assess carcass quality characteristics such as marbling traits and can incorporate meat colour, brightness and symmetry. A description of the image analysis traits presented in Table 1 can be found in Maeda et al. (2014).

Weighted heritabilities for image analysis traits were calculated as being highly heritable (at least 0.40) with the exception of coarseness index for the largest marbling particle (0.08; Table 1). This is in contrast to the high heritabilities of percentage marbling area and marbling coarseness index (0.62 and 0.45 respectively), suggesting that an extremely large marbling particle is distributed in the muscle at random (Osawa et al., 2008). Weighted heritabilities differ little from the unweighted means, although this might be due to the smaller spread of studies included. Japanese Black Wagyu is the predominant breed involved in image analysis studies with few publications available to include in a weighted analysis of heritabilities. While more studies would be valuable, the high heritability of marbling traits, such as marbling fineness seen here, is promising for potential inclusion in breeding programs.

Osawa et al. (2008) described best the genetic correlations between some of the image analysis traits above. Camera rib-eye muscle area is lowly-moderately correlated with percentage marbling area, overall marbling coarseness and coarseness of maximum marbling particle (0.36, 0.39 and 0.24 respectively; Osawa et al., 2008). Similarly marbling percentage and coarseness of maximum marbling particle are lowly-moderately correlated (0.29) which could present as more evidence for coarser marbling particles to be distributed in the muscle at random. Unsurprisingly, marbling percentage and overall coarseness are highly correlated (0.69; Osawa et al., 2008).

In general, image analysis traits have high genetic correlations with their carcass trait counterparts i.e. Camera rib-eye muscle area and rib-eye muscle area (0.83-0.97) and marbling percentage and marble score (0.97-1.0; Osawa et al., 2008; Zhang et al., 2015). This suggests that image analysis traits would be an appropriate, objective substitute for the current subjective methodologies. Similarly it is likely that selection using these image analysis traits will not hinder gains in carcass weight or result in an accompanying increase of subcutaneous fat due to lowly negative and low to moderate correlations with subcutaneous fat and carcass weight respectively (Osawa et al., 2008). However an undesirable moderately-strong correlation exists between marble score and overall marbling coarseness (0.66, Osawa et al., 2008) suggesting increased marbling is accompanied by more coarse marbling flecks. This could be countered by selecting for marbling in conjunction with marbling fineness, which should be plausible given its high heritability (Table 1).

**Conclusion**
Marbling is quickly becoming an integral component within breeding objectives of Australian beef producers due to its association with meat eating quality, specifically tenderness, juiciness and palatability. Wagyu appear as an attractive breed to meet rising demand for higher marbled beef due to their genetic predisposition to produce high degrees of marbling. Currently there is a demand for finer marbled beef with the current subjective grading programs unable to capture variation in marbling fineness. This has led to the development of camera imaging technology (objective marbling assessment) to describe marbling fineness and coarseness indexes. Heritabilities of these new novel traits in Wagyu have been reported as moderately to highly heritable which suggests they could be implemented into successful breeding programs. Traits defined by meat image analysis have high correlations with their carcass counterparts.

List of References