Wool quality traits of purebred and crossbred Merino lambs orally drenched with Spirulina (Arthrospira platensis)

Benjamin W.B. Holman,1 Arash Kashani,1 Aduli E.O. Malau-Aduli1,2
1Tasmanian Institute of Agriculture, University of Tasmania, Hobart, Australia
2Faculty of Health, Medicine and Molecular Sciences, James Cook University, Townsville, Queensland, Australia

Abstract

The objective of this study was to evaluate the effect of Spirulina supplementation, sire breed and sex on the wool characteristics of purebred and crossbred Merino weaned lambs under a single pasture-based management system. Lambs sired by Merino, White Suffolk, Dorset, Black Suffolk breeds were randomly allocated into 3 treatments – the control group grazing without Spirulina (0 mL), low (100 mL) and high (200 mL) Spirulina groups. All lambs were kept as a single mob in paddocks, grazed for 9 weeks and wool samples analysed. Differences in wool quality between the control and supplemented groups were not significant (P>0.05). However, sire breed significantly (P<0.001) influenced fibre diameter, spinning fineness, comfort factor and fibre curvature with purebred Merinos having superior wool quality than crossbreds. Wethers grew higher quality wool than ewes. Spirulina has a potential as an alternative supplementary bioresource in dual-purpose sheep feeding because it does not compromise wool quality in supplemented weaner lambs.

Materials and methods

This study was conducted at the University of Tasmania Farm, Cambridge, Tasmania, Australia. All procedures had the University of Tasmania Animal Ethics approval and were conducted in accordance with the 1993 Tasmania Animal Welfare Act and the 2004 Australian Code of Practice for the Care and Use of Animals for Scientific Purposes.

Animal management and experimental design

A completely randomised experimental design in which 24 weaner lambs with an average live weight of 37.6±5.2 kg and body condition score of 3.1±0.4 at 6 months of age was utilised. The experimental lambs had an in-built factorial of 4 sire breeds (Merino, White Suffolk, Dorset, Black Suffolk) and 2 genders (ewes, wethers). Lambs were randomly allocated into 3 treatments (8 lambs per treatment) – the control group grazing and ad libitum drinking water only without (0 mL), or low (100 mL of Spirulina) or high (200 mL) content of Spirulina dissolved in water. The Spirulina was commercially purchased (TAAU, Darwin, Australia) as a powder and dissolved in water utilising a weight:volume ratio of 1 g:10 mL (low) and 2 g:10 mL (high) and the solution delivered to the lambs by oral drenching. Both control and Spirulina supplemented groups of lambs were kept in a single mob and had ad libitum access to the basal diet of ryegrass pastures and crushed barley whose nutrient composition is depicted in Table 2. Lambs in the low and high Spirulina treatment groups were individually drenched daily with Spirulina solution prior to being released with the control group of lambs (also drenched with water only) into paddocks sown with ryegrass pastures. The lambs were allowed 3 weeks of adjustment to the Spirulina drench prior to the experimental phase lasting 6 weeks. At all times, lambs had ad libitum access to clean drinking water.

Wool sampling and analysis

Midside wool samples of approximately 10 cm² were shorn from each lamb by an experienced shearer using Oster-Sunbeam electric shearing machine. The wool samples were washed for 5 minutes in lukewarm water and 5 minutes in cold water, and then dried for 24 hours in a warm place in darkness before wool characteristics were measured. Percent fibre diameter and spinning fineness were determined using a Micro Choice 5700 Fibre Analyzer (Model 5700; Microchoice, North Carolina, USA) and the comfort factor determined using a Comfortmeter (Flexmat 1 with a 150 g probe). The fibre curvature was determined using a 3D fibre scanner (FibreSCAN Microscope; Aegi3d product, Geilenkirchen, Germany). The wool samples were then washed in a detergent solution and air dried prior to being conditioned at 65% relative humidity and 20°C for 24 hours before being weighed to determine wool weight. The wool samples were then combed and measured for micrometre using a Micronaire instrument (model 201B; Micronaire Instruments Limited, Oxford, England) before being weighed to determine wool weight.

Introduction

Spirulina (Arthrospira platensis) is an edible microalga with potential as an alternative protein-rich lamb supplement due to its high protein content (60-70%; Becker, 2007). Spirulina is also rich in essential vitamins, minerals, fatty acids, amino acids and carotenoids (Table 1). Supplementary feeding with Spirulina has been previously tried with several animal species (Holman and Malau-Aduli, 2013), but to the best of our knowledge, there is presently no published information on the impact of Spirulina supplementation on wool quality traits in dual purpose lambs.

Across Australia, farmers have adopted dual purpose sheep systems with both wool and meat production goals (Rowe, 2010). This objective is generally achieved by mating meat-type rams to a core flock of purebred Merino ewes and exploiting heterosis to optimise lamb growth. Current lamb meat prices are high (Martin and Phillips, 2011), while wool prices are at a historical low (Gibbon and Nolan, 2011). Hence, profitability in dual purpose sheep systems is now mostly driven by lamb growth and early attainment of slaughter weight.

Lamb growth is commonly enhanced through protein-rich supplementation using canola meal, lupins, barley and wheat. Varying and inconsistent reports on the impact of these supplements on wool quality have been reported (Malau-Aduli and Akuoch, 2012; Masters and Mata, 1996). Any decline in wool quality due to supplementary feeding can affect total farm profitability. Therefore, we tested the hypothesis that the oral drenching of grazing purebred Merino and crossbred lambs with Spirulina supplement would not elicit a significant variation and decline in wool quality. The experimental objective was to evaluate the effect of Spirulina supplementation and interactions with sire breed and sex on wool quality traits in purebred and crossbred Merino lambs under a single pasture-based management.
Chemical analysis of the basal diet

Dry matter content of the basal diet was determined by drying samples to a constant weight at 65°C in a fan forced oven. Ash content was determined by combusting samples in a furnace at 550°C for 5 h. Neutral and acid detergent fibre contents were measured using an Ankom fibre analyser (ANKOM 220; Ankom Technology, Macedon, NY, USA) (van Soest et al., 1991). Total nitrogen (N) content was measured using the Kjeldahl method (van Soest et al., 1991) and the crude protein estimated by multiplying N by 6.25. Ether extract was determined by the Soxhlet methodology, while in vitro digestibility and metabolisable energy were estimated using near infrared reflectance spectroscopy (Garnsworthy and Unal, 2004).

Statistical analysis

All data were analysed using the ‘Statistical Analysis System’ software package (SAS, 2009). Initially, summary statistics by Spirulina supplementation level, sire breed and sex, were computed with means, standard deviations, and minimum and maximum values scrutinised for any data entry errors or outliers. Subsequently, multivariate analysis of variance in generalised linear model (PROC GLM) and mixed model (PROC MIXED) analyses (SAS, 2009) were used to fit the fixed effects of Spirulina supplementation level, sire breed, sex, and their second-order interactions on wool FD, CV, SD, SF, CF, CURV, and YIELD. Sire was fitted as a random effect in the Mixed Model. Significant differences and mean separations were carried out using Duncan’s multiple range and Bonferroni’s probability pairwise comparison tests (SAS, 2009) Pearson correlation coefficients between dependent variables were estimated using PROC CORR (SAS, 2009) with significance determined using Bonferroni’s probability pairwise comparison test (SAS, 2009).


## Results

### Effect of Spirulina supplementation level, sire breed and sex on wool traits

Spirulina supplementation level had no significant effect on any wool quality trait, compared to the control group (P>0.05; Table 3). However, wethers produced wool with lower FD (P<0.046), SD (P<0.046) and SF (P<0.019) than ewes. Comfort factor was lower in ewes than wethers (79.9±3.31 and 88.1±2.2%, respectively; Table 4).

**Table 3. Least square means and standard error of Spirulina supplemented crossbred and purebred Merino lambs’ wool quality traits.**

<table>
<thead>
<tr>
<th>Wool quality trait</th>
<th>Control</th>
<th>Spirulina supplementation level</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>FD, µm</td>
<td>23.7±1.1</td>
<td>24.6±1.3</td>
<td>24.3±1.2</td>
</tr>
<tr>
<td>SD</td>
<td>4.6±0.3</td>
<td>4.4±0.2</td>
<td>16.8±1.2</td>
</tr>
<tr>
<td>CV, %</td>
<td>19.5±0.8</td>
<td>17.8±0.5</td>
<td>5.1±0.8</td>
</tr>
<tr>
<td>CF, %</td>
<td>85.5±3.0</td>
<td>81.8±4.3</td>
<td>84.7±3.5</td>
</tr>
<tr>
<td>SF, µm</td>
<td>22.9±1.0</td>
<td>23.4±1.2</td>
<td>23.0±1.1</td>
</tr>
<tr>
<td>CURV, °/mm</td>
<td>71.4±2.8</td>
<td>71.4±2.3</td>
<td>73.8±2.3</td>
</tr>
<tr>
<td>YIELD, %</td>
<td>75.0±1.4</td>
<td>72.7±1.0</td>
<td>74.6±1.0</td>
</tr>
</tbody>
</table>

FD, mean fibre diameter; SD, standard deviation; CV, coefficient of variation; CF, comfort factor; SF, spinning fineness; CURV, fibre curvature; YIELD, clean fleece yield.

### Effect of interactions between Spirulina supplementation level and sex on wool traits

It was evident from Figure 1 that ewes receiving high Spirulina supplementation levels had higher wool YIELD than their wether counterparts (77.2±0.8 and 71.9±1.4% respectively).
Effect of sire breed and sex interactions on wool traits

Black Suffolk-sired ewe lambs had lower CURV than their wether counterparts, 67.8±2.0 and 80.8±3.0°/mm, respectively (P<0.032), as depicted in Figure 2. No other second-order interactions between sire breed and sex reached statistical significance (P>0.05).

Correlations among wool traits

Table 5 shows that there were highly significant relationships (P<0.001) between FD and SF (0.99), CF with both FD (-0.87) and SF (-0.88), FD and CURV (0.39), SF and CURV (0.37), and SD with YIELD (0.29). All other correlations were not significant (P>0.05).

Discussion

Wool growth and quality depend on the type of protein supplement, its nutritional value, and level of supplementation (Malau-Aduli et al., 2009b; Masters et al., 1998; Rowe et al., 1989). Protein-rich supplements vary in amino acid availability thus affecting follicular uptake and wool fibre proliferation (Li et al., 2008). Therefore, increasing amino acid availability within the body-pool by increasing protein-rich supplementation generally results in heightened follicular uptake that favours nutrient partitioning towards faster growth, but also coarser wool fibre synthesis in crossbred lambs (Malau-Aduli and Holman, 2010; Malau-Aduli et al., 2009a). This coarser fibre is characteristic of lesser quality wool (Holman and Malau-Aduli, 2012). However, in this study, there were no observable detrimental effects of *Spirulina* supplementation on wool quality traits. *Spirulina* has a lower content of sulphur-containing amino acids compared to other protein-rich lamb supplements (Ciferri and Tiboni, 1985; Volkmann et al., 2008). Methionine and cysteine are sulphur amino acids which are essential for wool proliferation (Liu and Masters, 2003). Cysteine plays a vital role in the sulphur metabolism of the hair follicle. This study shows that *Spirulina* supplementation can improve wool quality traits (Liu and Masters, 2003). The quality of wool produced when *Spirulina* was fed to crossbred lambs was comparable to that of purebred Merinos. This finding is in agreement with those of Masters et al. (2009), who reported that spirulina supplementation of purebred Merinos improved wool colour and curvature.

Table 4. Sire breed and sex least square means and standard error of *Spirulina* supplemented crossbred and purebred Merino lambs’ wool quality traits.

<table>
<thead>
<tr>
<th>Wool quality trait</th>
<th>FD, µm</th>
<th>CV, %</th>
<th>SD</th>
<th>CF, %</th>
<th>SF, µm</th>
<th>CURV, °/mm</th>
<th>YIELD, %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sire breed</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Black Suffolk</td>
<td>27.2±0.7*</td>
<td>19.4±0.9</td>
<td>5.3±0.2</td>
<td>74.5±4.3</td>
<td>26.1±0.6</td>
<td>74.3±3.0</td>
<td>74.2±1.3</td>
</tr>
<tr>
<td>Dorset</td>
<td>25.0±0.9*</td>
<td>18.1±0.7</td>
<td>4.6±0.3</td>
<td>85.4±3.8</td>
<td>23.8±0.9</td>
<td>75.2±2.7</td>
<td>74.1±1.2</td>
</tr>
<tr>
<td>Merino</td>
<td>18.0±1.1*</td>
<td>17.0±1.4</td>
<td>4.4±1.1</td>
<td>96.2±3.5</td>
<td>17.1±1.0</td>
<td>63.5±1.5</td>
<td>75.2±1.7</td>
</tr>
<tr>
<td>White Suffolk</td>
<td>26.7±0.4*</td>
<td>17.7±1.1</td>
<td>4.7±0.2</td>
<td>79.9±2.1</td>
<td>25.3±0.3</td>
<td>75.9±2.5</td>
<td>72.7±1.0</td>
</tr>
<tr>
<td>P</td>
<td>0.001</td>
<td>0.474</td>
<td>0.703</td>
<td>0.001</td>
<td>0.001</td>
<td>0.004</td>
<td>0.399</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ewes</td>
<td>25.1±0.9*</td>
<td>18.3±1.0</td>
<td>5.3±0.5</td>
<td>79.9±3.3</td>
<td>24.0±0.9</td>
<td>71.8±1.8</td>
<td>74.8±0.8</td>
</tr>
<tr>
<td>Wethers</td>
<td>23.4±0.9*</td>
<td>17.8±0.4</td>
<td>4.1±0.2</td>
<td>88.1±2.2</td>
<td>22.2±0.9</td>
<td>72.7±2.2</td>
<td>73.4±1.0</td>
</tr>
<tr>
<td>P</td>
<td>0.046</td>
<td>0.620</td>
<td>0.046</td>
<td>0.016</td>
<td>0.019</td>
<td>0.721</td>
<td>0.186</td>
</tr>
</tbody>
</table>

FD, mean fibre diameter; CV, coefficient of variation; SD, standard deviation; CF, comfort factor; SF, spinning fineness; CURV, fibre curvature; YIELD, clean fleece yield. *P<0.05; **P<0.01; ***P<0.001.

Table 5. Pearson’s correlation among wool quality traits.

<table>
<thead>
<tr>
<th>Wool quality trait</th>
<th>CV</th>
<th>SD</th>
<th>CF</th>
<th>SF</th>
<th>CURV</th>
<th>YIELD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CV</strong></td>
<td>0.12 (ns)</td>
<td>-0.21 (ns)</td>
<td>0.02 (ns)</td>
<td>0.21 (ns)</td>
<td>-0.88 (ns)</td>
<td>0.35*</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>0.17 (ns)</td>
<td>-0.18 (ns)</td>
<td>0.12 (ns)</td>
<td>0.37 (ns)</td>
<td>-0.07 (ns)</td>
<td>0.11 (ns)</td>
</tr>
<tr>
<td><strong>CF</strong></td>
<td>-0.87***</td>
<td>0.99***</td>
<td>0.39**</td>
<td>0.39**</td>
<td>0.29*</td>
<td>0.21 (ns)</td>
</tr>
<tr>
<td>** SF**</td>
<td>0.99***</td>
<td>0.39**</td>
<td>0.39**</td>
<td>0.29*</td>
<td>0.21 (ns)</td>
<td>0.21 (ns)</td>
</tr>
<tr>
<td><strong>CURV</strong></td>
<td>0.35*</td>
<td>0.11 (ns)</td>
<td>0.29*</td>
<td>0.21 (ns)</td>
<td>0.21 (ns)</td>
<td>0.21 (ns)</td>
</tr>
</tbody>
</table>

CV, coefficient of variation; SD, standard deviation; CF, comfort factor; SF, spinning fineness; CURV, fibre curvature; YIELD, clean fleece yield; FD, mean fibre diameter; *P<0.05; **P<0.01; ***P<0.001.

Figure 1. Interaction between *Spirulina* supplementation level and sex on clean fleece yield (YIELD) of grazing purebred and crossbred Merino lambs. Means (±standard error) within sire breeds with different superscripts are significantly different (P<0.05).

Figure 2. Interaction between sire breed and sex on fibre curvature (CURV). Means (±standard error) within sire breeds with different superscripts are significantly different (P<0.05).
role during the differentiation of intermediate filament- and keratin associated proteins during wool synthesis (Plowman, 2007). Furthermore, methionine acts as a source of cysteine in the trans sulphuration pathway (Liu and Masters, 2003). Spirulina’s relatively minor content of these sulphur amino acids could likely explain insignificant differences in wool traits between the unsupplemented control and Spirulina supplemented group of lambs.

Ewes generally have smaller live weights than wethers (Cam et al., 2010; Holman et al., 2012). This difference could result in considerable variation with other prioritised sinks requiring more of the available amino acids (Rogers and Schlink, 2010). Our sex and sire breed findings were similar to published literature that have demonstrated hormonal differences between sexes (Egan and Russell, 1981; Wallace, 1979) and wool follicle trait variations between sire breeds (Lee and Williams, 1993; Scales et al., 2000) as having major impacts on wool traits. Similarly, the correlations between wool traits is in line with published literature (Notter et al., 2007). The strongly positive correlation between FD and SF is expected as SF is calculated from FD and CV values (Butler and Dolling, 1992; Holman and Malau-Aduli, 2012). Likewise, CF represents the proportion of fibres over 30 μm (Holman and Malau-Aduli, 2012; Wood, 2003) and is a function of FD, thus the strong correlation between CF and FD. However, SF and CF had an antagonistic relationship, hence the negative correlation. The insignificant correlation between CF and YIELD with other wool traits has already been previously reported (Hatcher et al., 2010).

Conclusions

The hypothesis that Spirulina supplementation via oral drenching will not be detrimental to wool quality in grazing purebred and crossbred Merino lambs holds true and should be accepted. The responses of lambs of different sire breeds and sex to Spirulina supplementation in terms of interaction effects on wool traits add to our current knowledge of supplementing crossbred sheep. Finally, there is the need for further investigation into the underlying mechanisms behind our findings, particularly with regard to circulating plasma metabolites and proteomic profiles of supplemented lambs. This would provide a comprehensive understanding of Spirulina’s future applications as a protein-rich lamb feed supplement.

References


