Prime Australian lamb supplies key nutrients for human health

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Abstract. This study investigated genetic and non-genetic factors affecting the iron, zinc and omega-3 fatty acid levels of fresh lamb meat. Results from the 2007 progeny of the Australian Sheep Industry Cooperative Research Centre Information Nucleus flock, \textasciitilde 2000 lambs, are presented here. The average level of iron and zinc in lamb muscle was 2.05 and 2.31 mg/100 g, respectively. The iron level was 103\% of that required to claim lamb as a ‘good source’ of iron for men of all ages and women older than 50 years, and the average level of zinc was 116\% of that required to claim lamb as a ‘good source’ of zinc for women, but was insufficient for a ‘good source’ claim for men. The iron and zinc content of muscle were affected (\(P < 0.001\)) by age at slaughter, sex, site at which the lambs were reared, and sire (independent of breed). Lambs from all sites reached the ‘source’ claim for iron for all adults and lambs from all sites, expect lambs from the Cowra and Hamilton sites, had greater iron levels than that required for a ‘good source’ claim for men and women over 50 years old. For zinc, all sites reached the ‘source’ and ‘good source’ claim for men and women, respectively. The major sources of variation in omega-3 fatty acid levels were site and kill group within site (\(P < 0.001\)), most likely reflecting nutritional differences associated with the availability of green feed. The eicosapentaenoic acid + docosahexaenoic acid values for all sites indicated that lambs from the Cowra, Rutherford and Struan sites had adequate levels for a ‘source’ claim of omega-3. The overall average level of eicosapentaenoic acid + docosahexaenoic acid in lamb meat was 23.5 mg/100 g, which is higher than the level required to claim lamb as a ‘source’ of omega-3. The effect of sire on omega-3 fatty acid level was small, but statistically significant (\(P < 0.001\)). These results confirm that lamb can represent a ‘source’ or ‘good source’ of these nutrients.

Additional keywords: genetic, human nutrition, lamb meat, minerals, non-genetic, omega-3.

Introduction

Achieving levels of iron, zinc and omega-3 fatty acids that comply with recommended dietary guidelines (i.e. a ‘good source’) has been proposed as a key marketing tool for red meat in the future (Pethick et al. 2006). Red meats, especially beef and lamb, have always been assumed to contain substantial concentrations of iron and zinc and accordingly marketing campaigns often use these attributes to differentiate it against other meats. However, few studies have been conducted on the levels of these nutrients in lamb using datasets of sufficient size to benchmark these levels and to identify factors that affect them.

Nutritional claims are based on one serving of a food. One serving of cooked meat is defined as 65–100 g (Kellett et al. 1998; NHMRC 2003). This equates to 93–143 g of fresh meat, assuming a 30\% moisture loss during cooking (Huffman et al. 1982). Hence, several studies refer to 135–140 g of fresh lamb as a single-serve size (Williams 2007; Ponnampalam et al. 2009; Kitessa et al. 2010). Nutrient levels in one serving of food must account for 10 or 25\% of the recommended daily intake (RDI) to achieve a ‘source’ or a ‘good source’ claim. For iron, this equates to 0.8 mg/100 g (‘source’) and 2 mg/100 g (‘good source’) of fresh meat for men and women over 50 years old (RDI = 8 mg). However, for pre-menopausal women, the RDI is 18 mg (NHMRC 2006), which means that a ‘good source’ would have to contain an iron level of 4.5 mg/100 g. For zinc, the RDI for adults is 8 mg for women and 14 mg for men (NHMRC 2006; Williams 2007). In an attempt to increase iron and zinc levels in meat, both pigs (Apple et al. 2007; Jayasooriya et al. 2007) and lambs (Field et al. 1985; Prabowo et al. 1988) have been fed diets high in iron and zinc, but with little effect.
Therefore, research is needed to identify sources of variation that can be manipulated to increase the muscle content of these minerals.

Nutrient reference values indicate that most Australians should increase their intake of long-chain omega-3 polyunsaturated fatty acids to reduce the risk of chronic diseases (Howe et al. 2007). These fatty acids include eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and docosapentaenoic acid (DPA), although DPA cannot currently be included in a nutrient content claim for omega-3 under the Food Standards Code (Howe et al. 2007). Based on current data, the levels of all three fatty acids in 135 g of lean lamb is between 95 mg (Howe et al. 2007; Ponnampalam et al. 2009) and 115 mg (Williams 2007), with an adequate intake ranging from 90 to 160 mg/day for women and men, respectively (NHMRC 2006). Nutrient reference values indicate that a food containing 30 or 60 mg of EPA + DHA per serve can be categorised as a ‘source’ or a ‘good source’ of omega-3, respectively (FSANZ 2003). However, the level of omega-3 does vary between various cuts of meat (Ponnampalam et al. 1997, 2009; Howe et al. 2007; Williams 2007; Kitessa et al. 2010). It is apparent that nutritional manipulation can be used to alter the levels of EPA and DHA in muscle (Sinclair 2007), but biohydrogenation of fatty acids limits this approach. Genetic manipulation is another potential approach for increasing muscle omega-3 levels (De Smet et al. 2004).

The Australian Cooperative Research Centre (CRC) for Sheep Industry Innovation has compiled an Information Nucleus Flock (INF), which produces ~2000 slaughter lambs each year. The overall objectives of the INF are to measure a range of biological and production parameters and to produce heritability estimates and genetic correlations for a range of new traits such as the content of iron, zinc and omega-3 fatty acids. Given that INF has flocks present across important production regions of Australia (Fogarty et al. 2007) the environmental effects on these nutrients can be assessed. The objectives of this study were to determine the levels of iron, zinc and omega-3 fatty acids in lamb from diverse genetic backgrounds and production systems and to quantify genetic and non-genetic factors affecting the content of these nutrients in muscle. Results from the first year of progeny (2007) from the INF are presented here.

Materials and methods

Experimental design and slaughter details

Details of the design of the Sheep CRC’s INF were presented by Fogarty et al. (2007). Briefly, ~2000 lambs were produced in 2007 from artifically inseminated matings of 4500 Merino and crossbred ewes located at seven research sites across Australia (Katanning, WA, Cowra and Kirby, NSW, Struan and Turrettfield, SA, Hamilton and Rutherglen, Vic.), which represent a broad cross-section of Australian production systems. The lambs (Merino, Border Leicester × Merino, Terminal × Merino and Terminal × Border Leicester-Merino) were the progeny of 94 key industry sires, representing the major production types in the Australian sheep industry. The sires included Terminal sires (Hampshire Down, Poll Dorset, Suffolk, Texel, White Suffolk), maternal sires (Border Leicester, East Friesian, White Dorper), and Merino sires (Merino, Poll Merino). Lambs were mainly maintained under extensive pasture grazing conditions. Grain, hay or feedlot pellets were fed when feed supply was limited. Lambs were yarded the day before slaughter, held for 6 h and then weighed and transported to one of five commercial abattoirs, where they were held in lairage overnight and slaughtered the following day at a target average carcass weight of 21.5 kg. All carcasses were electrically stimulated and trimmed according to AUS-MEAT specifications (Anon. 1992). Carcasses were chilled overnight (4°C) before sampling.

Sample collection and measurements

At 24 h post-mortem, the M. longissimus thoracis lumborum was excised from the carcasses. Subcutaneous fat and silver skin were removed, and two 40-g samples of muscle were collected for mineral and fatty acid analysis. The samples were then frozen at −20°C and freeze-dried using a Cuddon FD 1015 freeze dryer (Cuddon Freeze Dry, Blenheim, New Zealand).

For the mineral analysis, samples containing 0.2 g of dry matter were prepared according to the USEPA method (USEPA 1991). Iron and zinc concentrations were determined using a Vista AX CCD simultaneous ICP-AES (Varian Australia Pty Ltd, Mulgrave, Vic.).

Homogeneous 0.5-g freeze-dried samples were used for analysis of fatty acids. A rapid modified procedure developed from the method reported by O’Fallon et al. (2007) was used to determine fatty acid composition. Details of fatty acid extraction, preparation of fatty acid methyl esters and the quantification process are reported elsewhere (Ponnampalam et al. 2010a). Fatty acid level in muscle is expressed in mg/100 g muscle, as this is consistent with the Food Standards Australia & New Zealand method for describing nutritional information on food labels.

Statistical analyses

Mineral data were analysed using a linear mixed effects model in SAS (SAS version 9.1, SAS Institute, Cary, NC). Fixed effects included site, sex, birth and rearing type (combined effect of animals born as single, twin or triplet and reared as single, twin or triplet), sire type (maternal, Merino or terminal), dam breed within sire type, and kill group (slaughter groups) within site. Sire and dam identification were included as random terms and all relevant first-order interactions between fixed effects were tested; terms were removed by stepwise regression if they were not significant (i.e. $P > 0.05$). In addition, a second model was run in which kill group within site was removed and age at slaughter was included as a covariate together with its first-order interactions with fixed effects to determine the effect of age on iron and zinc levels. Sire estimates (random effect estimates) for iron and zinc concentrations, obtained from the linear mixed effects model, were analysed for their association with sire Australian sheep breeding values (ASBV) for post-weaning weight (PWWT), C-site fat depth (PFAT), and eye muscle depth (PEMD) using a general linear model (SAS version 9.1). This model included sire type as a fixed effect, sire ASBV for PWWT, PFAT and PEMD as covariates and the first-order interaction between sire
type and ASBV. Interactions were removed from the analysis if non-significant ($P > 0.05$) by stepwise regression.

For the fatty acid analysis, restricted maximum likelihood models were developed for the logarithm of various fatty acids and combinations of fatty acids. All statistical analyses were conducted using the GENSTAT statistical package (GENSTAT release 12.1, VSN International Ltd, Hemel Hempstead, UK). Effects examined included sire, dam, site, kill group within site, sire type, sire breed, dam breed, birth type, rearing type, age at slaughter, age of dam, sex, intramuscular fat and separate residual variation of lambs between sites and kill groups. The Kirby site was excluded from the analysis because levels of several fatty exhibited a mixture distribution (with suggestion of a multi-modal mixture distribution at each kill) and the application of restricted maximum likelihood models was considered inappropriate.

**Results**

**Levels of iron, zinc and omega-3 fatty acids**

Descriptive statistics for iron, zinc and omega-3 fatty acids levels in the *M. longissimus thoracis lumborum* are presented in Table 1. The average level of iron in lamb muscle was 2.05 mg/100 g (s.d. = 0.440). All lambs contained iron levels equal to or more than that required to claim lamb as a ‘source’ of iron and 48% of samples had a muscle iron content of 2 mg/100 g or more, sufficient for a ‘good source’ claim based on an RDI of 8 mg for men of all ages and for women more than 50 years old. For pre-menopausal women, 70% of samples exceeded the ‘source’ claim, but only 0.05% attained the ‘good source’ claim. The average level of zinc in lamb muscle was 2.31 mg/100 g (s.d. = 0.395). Given the zinc RDI for women of 8 mg, 81% of samples exceeded the amount required to claim lamb as a ‘good source’ of zinc, and 100% exceeded the amount required to claim lamb as a ‘source’ of zinc. Likewise, for men (zinc RDI = 14 mg), 99% of samples exceeded the ‘source’ claim, and 1% exceeded the ‘good source’ claim.

The average level of health-claimable omega-3 fatty acids (EPA + DHA) was 23.5 mg/100 g (s.d. = 9.32), 107% of that required to achieve a ‘good source’ claim (based on an RDI of 8 mg); lambs at Kirby had the highest levels and lambs at Cowra and Hamilton had the lowest levels. The iron concentration of samples from females was 4% higher than that of samples from males.

For analysis of mineral data, 1965 observations were used. Site, sex and kill group within site had significant ($P < 0.001$) effects on iron level (Table 2). Meat from lambs at all sites (site range, 1.84–2.38 mg/100 g) had iron levels greater than that required to claim lamb as a ‘source’ of iron and had on average 104% of that required to achieve a ‘good source’ claim (based on an RDI of 8 mg); lambs at Kirby had the highest levels and lambs at Cowra and Hamilton had the lowest levels. The iron concentration of samples from females was 4% higher than that of samples from males.

Site, sire type and kill group within site had significant effects on zinc levels ($P < 0.01$) (Table 2). Lambs from all sites had greater zinc levels than that required to claim lamb as a ‘good source’ of zinc (based on an RDI of 8 mg for women). On average, lambs from the Kirby (2.49 mg/100 g), Struan (2.46 mg/100 g) and Turrefield (2.44 mg/100 g) sites had 10% more zinc compared to from the other sites. Lamb from Cowra had the lowest zinc level. Maternal sired lambs had 5% more zinc compared to Merino and terminal sired lambs.

At each site the iron and zinc content of lamb differed between kill groups (individual data not shown for the kill groups). This appeared to reflect age, as animals of kill groups killed later during the year had an average higher age than those killed in earlier kill groups, and always contained higher levels of iron and zinc. As such we attempted to quantify the age effect by conducting a second analysis in which the kill group within site term was replaced with an age covariate. The effect of the age covariate was highly significant ($P < 0.001$; Fig. 1) and increased iron and zinc concentrations by 50 and 24%, respectively, across the age range.

The main effects ($P < 0.001$) on fatty acid levels were site and kill groups within site (Fig. 2). As observed for α-linolenic acid (ALA) (data not shown), the health-claimable long-chain omega-3 fatty acid levels (EPA + DHA) were significantly different between sites and kill groups within site (Fig. 2a). Sites with high levels of ALA tended to produce greater levels of long-chain derivatives and vice versa. The EPA + DHA values for the various sites ranged from 13.7 to 34.7 mg/100 g. Lambs from the Cowra (34.7 mg/100 g), Rutherglen (28.8 mg/100 g) and Struan (26.2 mg/100 g) sites had higher EPA + DHA levels than required to claim lamb as a ‘source’ of omega-3 (30 mg/135 g)

### Table 1. Iron, zinc and omega-3 fatty acid content of lamb (uncorrected data)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Number of samples</th>
<th>Mean (mg/100 g)</th>
<th>s.d.</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>1997</td>
<td>2.05</td>
<td>0.440</td>
<td>0.812</td>
<td>4.51</td>
<td>0.194</td>
</tr>
<tr>
<td>Zinc</td>
<td>1997</td>
<td>2.31</td>
<td>0.395</td>
<td>1.18</td>
<td>4.49</td>
<td>0.156</td>
</tr>
<tr>
<td>ALA</td>
<td>2052</td>
<td>37.6</td>
<td>17.4</td>
<td>6.52</td>
<td>101</td>
<td>304</td>
</tr>
<tr>
<td>EPA</td>
<td>2004</td>
<td>16.3</td>
<td>7.19</td>
<td>3.14</td>
<td>37.2</td>
<td>52.0</td>
</tr>
<tr>
<td>DHA</td>
<td>2000</td>
<td>7.20</td>
<td>2.67</td>
<td>1.44</td>
<td>18.8</td>
<td>7.24</td>
</tr>
<tr>
<td>EPA + DHA</td>
<td>2004</td>
<td>22.5</td>
<td>8.85</td>
<td>6.02</td>
<td>55.8</td>
<td>78.3</td>
</tr>
<tr>
<td>EPA + DPA + DHA</td>
<td>2000</td>
<td>23.5</td>
<td>9.32</td>
<td>4.58</td>
<td>56.0</td>
<td>86.8</td>
</tr>
</tbody>
</table>
serve), whereas lambs from Hamilton (13.7 mg/100 g), Turret Field (15.5 mg/100 g) and Katanning (15.5 mg/100 g) had EPA + DHA levels ~62.3–70.5% of the level needed for a 'source' claim. When the non-health-claimable omega-3, DPA, was included, EPA + DHA + DPA values for the various sites ranged from 23.8 to 67.7 mg/100 g (Fig. 2b). All sites had greater EPA + DHA + DPA levels than that required to claim lamb as a 'source' of omega-3. The corresponding values for Cowra, Rutherglen, Struan, Hamilton, Turret Field and Katanning sites were 67.7, 43.5, 54.2, 23.8, 35.2 and 34.2 mg/100 g, respectively. Other factors such as sire breed, rearing type, birth type, dam breed, intramuscular fat, sex, age of dam and age at slaughter had minor or no effects.

### Sire effects on iron, zinc and omega-3 levels

There were significant differences between sires, independent of sire breed, for both iron and zinc level ($P < 0.01$); sire progeny means differed by as much as 23% for iron (data not shown) and 16% for zinc (Fig. 3). For zinc, these sire progeny means also showed a significant association with PEMD ASBV, such that for every unit increase in PEMD ASBV, the zinc level was reduced by 0.0172 mg/100 g ($P < 0.05$) (Fig. 3). There were no associations between sire progeny means for iron and the corresponding sire ASBV. Sire effects on fatty acid content were small, but statistically significant ($P < 0.001$).

### Discussion

#### Iron and zinc

At the average concentrations observed in this study, lamb can be claimed as a ‘good source’ of iron (2.05 mg/100 g) for men of all ages and women more than 50 years old, but it can only be...
claimed as a ‘source’ of iron for women less than 50 years old. For zinc (2.31 mg/100 g), lamb can be claimed as a ‘good source’ for women of all ages, but only as a ‘source’ for men. In our study, the mean iron content of lamb was similar to that quoted in the official Australian tables used by dieticians (2.30 mg/100 g iron; NHMRC 2003), but the mean zinc value in our study was lower than the NHMRC (2003) value (3.40 mg/100 g). This discrepancy is likely due to the sampling procedures used when the Australian dietary tables were generated, as their data were sourced from studies in which only 10–30 animals were sampled (e.g. Williams

Fig. 2. (a) Predicted means with 95% confidence intervals across sites and kill groups for eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) levels. (b) Predicted means with 95% confidence intervals across sites and kill groups for EPA, docosapentaenoic acid (DPA) and DHA levels.
Fig. 3. Effect of post-weaning eye muscle depth (PEMD) Australian Sheep Breeding Values (ASBV) on sire estimates of zinc. The corresponding sire type mean (see Table 2) was added to the sire estimates which were obtained from the linear mixed effects model by fitting sire as a random term (random effect estimates), for Merino, maternal and terminal sires to reflect their true values.

2007; Williams et al. 2007), whereas 2000 animals were used to generate the means in our experiment.

Official Australian Food Composition tables (http://www.foodstandards.gov.au, verified 28 October 2010) and other dietary tables are often based on the analysis of a small number of retail samples. These samples are frequently purchased from retail stores (supermarkets, butchers) as a single collection and within a narrow time frame. However, such small sample numbers of lamb cuts are insufficient to identify genetic and production effects (particularly age) on levels of nutrients in muscle and are therefore unlikely to provide a true estimate of these nutrient levels.

Given that a ‘good source’ claim cannot be made for iron in younger women (RDI = 18 mg) and zinc in all men (RDI = 14 mg), this would suggest that there is room for improvement. Furthermore, Gardner et al. (2006) showed that selection for muscling, which is a focus for some breeders in the Australian lamb industry, reduces muscle aerobicity and myoglobin levels, which is likely to further reduce iron and zinc content. As such, direct selection pressure for iron and zinc may be required to maintain these nutrient levels. Nonetheless, when compared with pork, which contains 0.7 mg iron per 100 g of fresh meat (http://www.pork.com.au, verified 28 October 2010), and chicken, which has an iron content half that of pork (Charlton et al. 2008), red meat is a superior source of iron.

There were differences in iron and zinc levels between sites. Samples from most sites had iron levels close to or greater than that required to claim lamb as a ‘good source’ of iron and samples from all sites had zinc levels greater than that required to claim lamb as a ‘good source’ of zinc (RDI = 8 mg for both minerals) (Table 2). Lamb from the Cowra site appeared to have relatively low iron and zinc levels, most likely due to the relatively young mean slaughter age of the animals (204 days) compared with the mean slaughter age for the other sites (277 days). This was confirmed when age was used as a covariate in the analysis, as this adjustment eliminated the differences between Cowra and the other sites. Increasing age is associated with a more oxidative muscle type (Greenwood et al. 2007) and greater expression of myoglobin (Gardner et al. 2007). Given that the iron in myoglobin accounts for a large proportion of the iron in muscle (Hazell 1982) and the association of zinc with antioxidant cascades and the electron transport chain (Powell 2000), both of which are elevated in aerobic muscle, levels of both of these minerals would be likely to increase with age. Lamb meat from the Hamilton site also had a low iron level, but the difference was not accounted for by age. Likewise, lamb from the Kirby site had relatively high iron and zinc concentrations, and although the lambs were older than most at slaughter, inclusion of the age covariate did not account for these differences either. This implies that other environmental factors such as nutrition or parasite burden may have an effect on iron and zinc levels, but this could not be confirmed because of the design of this experiment.

The higher level of iron in lamb from females than males, and the elevated levels of zinc in lamb from maternal-sired lambs compared with Merino- and terminal-sired lambs are both likely to be due to a more oxidative fibre type (Gardner et al. 2007). Analysis of markers of aerobicity in these samples is planned to confirm this. Nonetheless, all sire types had zinc levels that exceeded the amount required for a ‘good source’ claim.

There was a significant negative relationship between the zinc content of lamb and sire PEMD ASBV (Fig. 3). Selection for muscling has been shown to increase the proportion of type IIX muscle fibres (Greenwood et al. 2006), resulting in reduced aerobicity (Gardner et al. 2006), which may explain this result. Given this relationship, information on the genetic correlation between muscularity and zinc level in lamb is required if zinc levels are to be maintained while improving muscularity through genetic selection. This trait requires attention because of the current industry focus by some breeders on selecting sires with high PEMD. The sire estimates did not correlate with any of the sire ASBV for iron. However, previous studies have demonstrated that increased genetic potential for muscling decreases muscle aerobicity because of a less oxidative muscle fibre type (Greenwood et al. 2006), and is thus likely to affect muscle iron content (Pearce et al. 2009). Pearce et al. (2009) demonstrated that iron levels increased in redder muscle types (more oxidative fibre types) such as the M. semimembranosus and M. longissimus compared with whiter muscle types such as the M. semitendinosus. However, the M. longissimus is more typical of the muscle fibre types in lamb than the M. semitendinosus and is therefore more representative of the carcass. Further studies with greater numbers of highly muscled sires are needed to elucidate the biology of iron in the progeny of these sires and to confirm that selection for muscling does not affect muscle iron concentration.

Age at slaughter had the main non-genetic effect on iron and zinc levels in the M. longissimus thoracis lumborum. These results indicate that age at slaughter is a key determinant of iron level, which increased by 50% across the age range studied, and to a lesser extent of zinc level, which only increased by 24% across the same age range. One concern with the current analysis is that the oldest animals slaughtered at each site were predominantly sired by Merinos because of their slower growth to target slaughter weight (Merino, average slaughter age = 366 days; terminal/maternal, average slaughter
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age = 234 days). Thus, the apparent age effect could have been a Merino sire-type effect. To confirm the association with age, an additional analysis was conducted in which all Merino-sired lambs were excluded. The age effect was still significant for iron and zinc, and the slopes of these responses (2.64 × 10^{-3} ± 3.75 × 10^{-4} mg/100 g of muscle per day and 1.59 × 10^{-3} ± 3.50 × 10^{-5} mg/100 g of muscle per day, respectively), were the same as the slopes when the Merino-sired lambs were included (2.73 × 10^{-3} ± 1.90 × 10^{-4} mg/100 g of muscle per day and 1.64 × 10^{-3} ± 3.05 × 10^{-5} mg/100 g of muscle per day, respectively), confirming that the Merino lambs were merely following the same age continuum as the maternal and terminal breed-sired lambs. In further support of this notion, a study by Gardner et al. (2007) demonstrated that, when compared at the same age, Merino lambs did not have greater myoglobin levels than crossbred lambs, and thus were likely to have had the same iron levels. Thus, selection pressure for PWWT ASBV will result in lambs that reach slaughter weight at a young age and as such muscle iron concentrations will be reduced.

Omega-3 fatty acids

The main sources of variation in the long-chain omega-3 fatty acid content of lamb were site and kil categories within site. The mean level of EPA + DHA was higher than that required to claim lamb as a ‘source’ of omega-3, whereas the level of EPA + DPA + DHA would be higher than that required to claim lamb as a ‘good source’ of omega-3 if DPA were to be considered a claimable fatty acid (Table 1). However, previously reported values for EPA + DHA and for EPA + DPA + DHA ranged from 40 to 41 mg/100 g and from 70 to 85 mg/100 g, respectively (Droulez et al. 2006; Williams 2007; Ponnampalam et al. 2009), significantly higher than the levels found in this study, particularly in the case of EPA + DHA. These previous studies involved low numbers of animals (6–40) compared with the 2000 animals used in our study, which could account for the discrepancy. Age may also have affected these levels because the animals used by Ponnampalam et al. (2009) were 14-month-old hoggets that had consumed green grass during two spring seasons before slaughter.

Concentrations of the parent omega-3 fatty acid, ALA (18:3 n-3), and the longer chain derivatives, EPA, DPA and DHA, varied significantly between sites and between kill groups within sites. A serve of lamb (135-g portion) from the Cowra, Rutherglen and Struan sites could be claimed as a ‘source’ of omega-3 (EPA + DHA) and these levels were similar to recently reported results (Ponnampalam et al. 2010a, 2010b). However, lambs at Hamilton, Turrettfield and Katanning had omega-3 levels that were 62.3–70.5% of the level needed for a ‘source’ claim, which was similar to levels reported by Kitessa et al. (2010). Lambs from Cowra had the highest EPA + DHA + DPA level, which was 53.9% more than that required to claim lamb as a ‘good source’ of long-chain omega-3 fatty acids. Lambs from Rutherglen and Struan contained 11.4% more than that required to claim lamb as a ‘good source’ of omega-3, and Hamilton, Katanning and Turrettfield meat contained 70.6% of the EPA + DHA + DPA level requirement for a ‘good source’ omega-3 fatty acids claim. Overall, all lambs at all sites had greater EPA + DHA + DPA levels than that required to claim lamb as a ‘source’ of omega-3 (30 mg/135 g serve). Although DPA is currently not included in the nutrient content claim for omega-3 (Howe et al. 2007), this puts lamb still a ‘source’ of omega-3 when only EPA + DHA is claimed.

The nutritional quality of the diets of the lambs in our study may explain a major proportion of the variation in the long-chain polyunsaturated fatty acid concentration of the meat. The parent omega-3 fatty acid, ALA, is an essential fatty acid (Christie 1981). Green pasture diets contain higher levels of ALA than dry roughage and grain diets and previous studies have demonstrated that pasture-finished lambs have higher levels of ALA, and thus EPA, DPA and DHA, than lambs fed commercial finishing pellets (Kitessa et al. 2010). Therefore, the higher concentration of long-chain omega-3 fatty acids in meat from the Cowra, Rutherglen and Struan lambs was probably due to the availability of green perennial pasture (Cowra) and annual pasture (Rutherglen and Struan) for most of the grazing period before slaughter. Lambs from Hamilton, Turrettfield and Katanning produced meat with low levels of omega-3 most likely because the diet of these lambs was supplemented with grain and low quality hay before slaughter.

Conclusions

Meat from the 2007 INF lambs contained sufficient levels of iron, zinc and omega-3 fatty acids to claim that lamb is a ‘source’ or ‘good source’ of these nutrients. Age was a strong determinant of mineral content and nutrition had the greatest effect on omega-3 fatty acid content. Although several other genetic and non-genetic factors affected the levels of these nutrients, more data is needed to make definitive conclusions about them. This is particularly important for differentiating sheep meat from other types of meat for marketing purposes.

Acknowledgements

The CRC for Sheep Industry Innovation is supported by the Australian Government’s Cooperative Research Centre Program, Australian Wool Innovation Ltd and Meat & Livestock Australia. The authors gratefully acknowledge the contributions of staff and resources provided at each site for the INF: Industry & Investment NSW (Primary Industries), University of New England, Department of Primary Industries Victoria, SA Research & Development Institute and the Department of Agriculture and Food WA. The Meat program also benefits from the contribution of staff employed by CSIRO and Murdoch University.

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Manuscript received 26 July 2010, accepted 18 October 2010

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