LEVELS OF LONG CHAIN OMEGA- 3 FATTY ACID IN MEAT FROM AUSTRALIAN LAMBS PRODUCED OVER THREE YEARS

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Abstract – The variation in levels of health claimable long chain omega-3 fatty acids, eicosapentaenoic acid (EPA, 20:5n-3) plus docosahexaenoic acid (DHA, 22:6n-3) across eight production regions of Australia were studied in 5726 lambs over 3 years. The median level of EPA plus DHA differed dramatically between locations and sometimes between slaughters from the same location. The ratio of EPA plus DHA from lambs with high values (97.5% quantile) to lambs with low values (2.5% quantile) also differed dramatically between locations, and between slaughters from the same location. Consistency between years, at a location, was less for the high to low value ratio of EPA plus DHA than for the median value of EPA plus DHA. Results suggest that to consistently obtain high levels of omega-3 fatty acids in Australian lamb, finishing diets must be appropriately constituted and these are likely to need a supply of alpha-linolenic acid (ALA, 18:3n-3) the precursor for EPA and DHA.

Key Words – Dietary background, Lamb production, Omega-3 fatty acids in meat

I. INTRODUCTION

Among the major fatty acid groups, polyunsaturated fatty acids such as omega-3 (n-3) and omega-6 (n-6) in foods have been highlighted due to their anti- and pro-effects on inflammatory and autoimmune diseases, respectively [1,2]. According to Australian standards, to claim meat as a source of omega-3, it must have 30 mg of long chain omega-3 fatty acids per 100 g of meat in the form of eicosapentaenoic acid (EPA) or docosahexaenoic acid (DHA). By contrast, the European standard for a source of omega-3 is 40 mg per 100 g (Commission Regulation (EU), 2010). Lamb production in Australia and some other countries is primarily based on year round extensive finishing systems. Under these finishing systems, animals are often finished on widely differing diets. These diets include both irrigated and dryland pasture, green and senesced pasture as well as feed supplements including hay, grain legumes, cereal grains, oil seed by-products or crop residues. It is known that diet has a major effect on the level of polyunsaturated fats in meat [3,4]. It has been reported that extensive lamb production sometimes produces meat with high levels of long chain omega-3 fatty acids, but not always [5]. This is not surprising because of the wide range of finishing diets used in extensive grazing systems. This paper documents the variation between location and slaughter times within location. It covers 87 slaughter times from 3 matings over 3 years, covering 8 lamb production locations. At each slaughter time the lambs were slaughtered at a similar target carcass weight (about 21-22 kg).

II. MATERIALS AND METHODS

This large research study was approved by 5 respective Animal Experimentation Committees across 4 states of Australia. The design of the Information Nucleus, including the procedure used to select the sires for AI mating with the flocks' base ewes is fully described elsewhere [6]. Sires were selected from a range of breeds used in the Australian sheep industry (Merino, maternal and terminal meat breeds). The base ewes, depending on the research site usually consisted of approximately 80% Merino ewes and 20% Border Leicester x Merino ewes. Lambs were generally maintained under extensive pasture conditions at 8 lamb production sites, but were fed grain, hay or feedlot pellets when the pasture supply was limited. Lambs were slaughtered in three

consecutive years, with between 28 and 30 kills in each year. The slaughter procedure was similar for all three years. During the years 2008-2010, *longissimus lumborum* (LL) muscle samples from approximately 5726 lambs were collected at 24 h post-mortem. There were several slaughter occasions at each location in each year (Fig.1).

These LL samples (~20 g) were dissected without any visible external fat (subcutaneous), freeze dried and ground using a FOSS Knifetech™ 1095 sample mill (FOSS Pacific, Unit 2, 112-118 Talavera Road, North Ryde, NSW 2113). The same grinding equipment was used across all laboratories. A homogeneous 0.5 g ground sample was used for fatty acid extraction, methylation and quantification by gas chromatography as described previously [7].

The median EPA plus DHA concentration for each location by slaughter time combination was obtained from the predicted mean value on the logarithmic scale with back-transformation. Asymptotic normal confidence intervals were calculated on the logarithmic scale and then back transformed to the original scale. The residual variation for each location by slaughter time combination is summarised as the ratio of EPA plus DHA from lambs with high values (97.5% quantile of EPA plus DHA) to lambs with low values (2.5% quantile of EPA plus DHA). The ratio is calculated as $\exp(2 \times 1.96 \times \sigma)$, where exp denotes the exponential function and σ is the estimated residual standard deviation obtained for a location by slaughter time combination using the REML analysis. Confidence intervals for the ratio were calculated using the asymptotic normal approximation for each σ and back-transforming to the ratio scale. A line showing how the ratio and median relate when exactly 95% of lambs at a slaughter time have EPA plus DHA < 23 mg/100 g (which is equivalent to 30 mg per 135 g serving) is calculated as,

Ratio = $\exp((2 \times 1.96 \times(\ln(23) - \ln(\text{median})))/\Phi^{-1}(0.95))$ where ln denotes the natural logarithm and Φ^{-1} denotes the inverse of the Gaussian distribution function.

III. RESULTS AND DISCUSSION

The median level of EPA plus DHA differed appreciably between locations, and sometimes between slaughter times from the same location ($P << 0.0001$, Fig. 1). There was a moderate degree of consistency between the 3 years at most locations, although the median EPA plus DHA at Kirby was substantially lower in the third year than the first and second years (Fig. 1a), and the EPA plus DHA at Hamilton was substantially lower in the first year than the latter 2 years (Fig 1b). The short 95% confidence intervals in Figure 1 indicate that the medians are, effectively, known without error.

There was no clear relationship of the median EPA plus DHA to the high to low ratio of EPA plus DHA for the 87 slaughter times at 8 production locations (Fig. 2). Only 2 locations (Turretfield and Katanning) had all slaughter times with the typical (median) lamb having EPA plus DHA less than 23 mg/100 g meat. At these two locations, a perennial green pasture finishing option (eg. lucerne [alfalfa] or ryegrass) was not available during late post-weaning, but dry annual pasture with grain or feedlot was offered. However, all of the 8 locations had at least some slaughter times where the typical (median) lamb had an EPA plus DHA less than 23 mg/100 g meat (i.e., 30 mg per 135g serving). At 2 production locations (Rutherglen and Cowra) it was estimated that, at the majority of slaughter times, more than 95% of lambs had EPA plus DHA greater than 23 mg/100g meat (Fig. 2). At these slaughter times the animals grazed lucerne (*Medicago sativa*) pasture late post-weaning.

In about one half of slaughter times the typical (median) lamb loin had EPA plus DHA levels greater than 23 mg/100g meat, but in only about 25% of slaughter times did the large majority (95%) of lambs produce EPA plus DHA above this level. This indicates that meat from many slaughters of Australian lamb achieves health claimable levels of omega-3 fatty acids, but certainly not the majority. In order for Australian lamb cohorts to achieve health claimable levels of omega-3, lambs need to have both a high average level of omega-3 fatty acids and a lower variability between lambs in omega-3 fatty acids as indicated in the lower right hand section of in Figure 2.

As the results vary greatly with slaughter time, and previous research has shown that levels of omega-3 fatty acids in meat are sensitive to an animal's diet [3,8,9], the most important component of these management strategies will be finishing diet. This is important with regards to both the availability of diet of the typical animal along with the length of time in a slaughter cohort.

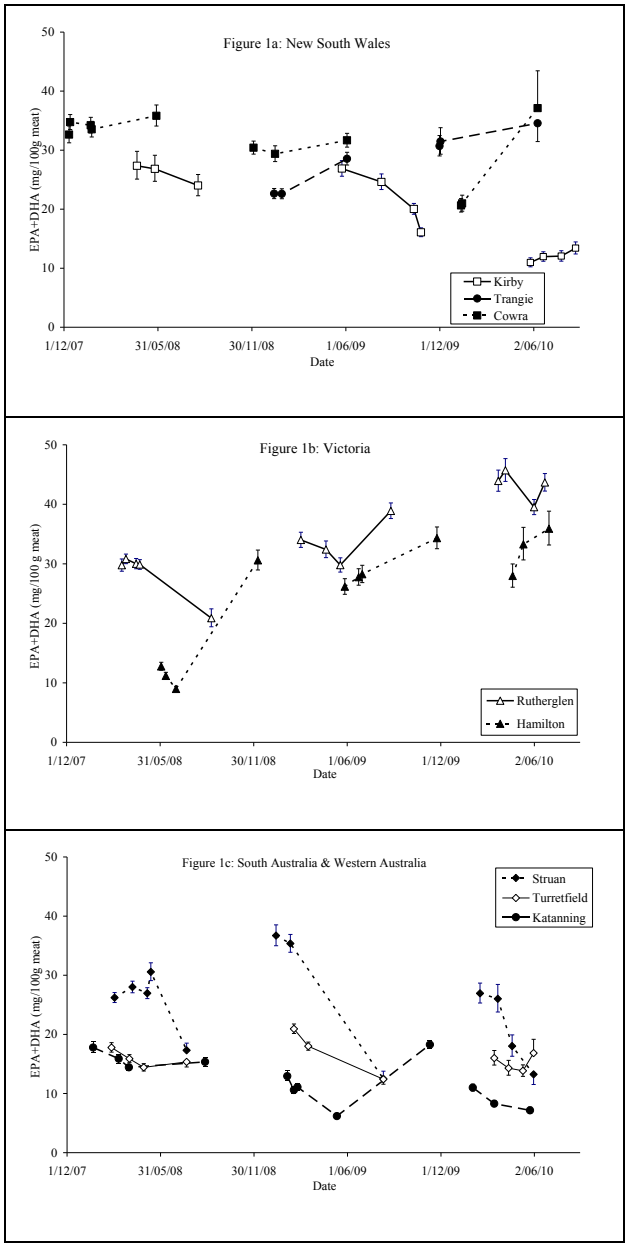

Figure 1. The predicted median concentration of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in meat for each slaughter from 8 locations, over 3 consecutive years

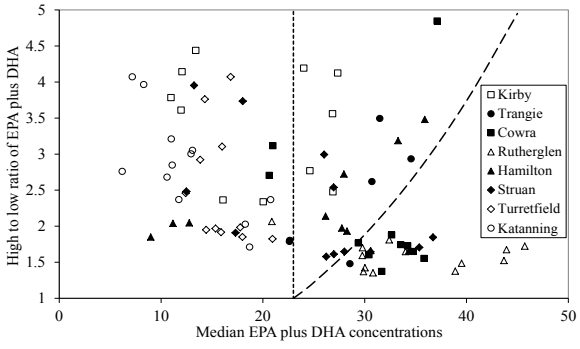

Figure 2. Comparison of the ratio of high value (97.5 % quantile) to low value (2.5% quantile) of EPA plus DHA to the median EPA plus DHA for each slaughter time from 8 locations over 3 years

IV. CONCLUSION

The results indicate that to consistently obtain high levels of omega-3 fatty acids from lamb in Australia, there must be a focus on the finishing diet. It is not only important to maintain high average levels of omega-3 fatty acids, but also important to achieve low levels of variability between animals within a slaughter cohort. Finishing with Lucerne (alfalfa) has been identified as very promising for consistently obtaining high levels of omega-3 fatty acids in meat. The efficacy of the latter strategy needs to be confirmed in a wide range of environments and management situations. Other finishing systems need to be identified, which may include the use of algal supplements, oilseeds containing linolenic acid, irrigated pasture and drought resistant perennial fodder species.

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REFERENCES

1. McAfee, A. J., McSorley, E. M., Cuskelly, G. J., Moss, B. W., Wallace, M. W., Bonham M. P., & Fearon, A. M. (2010). Red Meat Consumption: An overview of the risks and benefits. Meat Science 84: 1-13.
2. Simopoulos A. P. (2002). Review: Omega-3 fatty acids in inflammation and autoimmune diseases. Journal of the American College of Nutrition 21: 495-505.
3. Daley, C. A., Abbott, A., Doyle, S. P., Nader, A. G., & Larson, S. (2010). A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutrition Journal 9: 1-12.
4. Simopoulos, A. P. (1999). New Products from the agri-food industry: the return of n-3 fatty acids into the food supply. Lipids 34: 297-301.
5. Pannier, L., Ponnampalam, E. N., Gardner, G. E., Butler, K. L., Hopkins, D. L., Ball, A. J., Jacob, R. H., Pearce, K. L., & Pethick, D. W. (2010). Prime Australian lamb supplies key nutrients for human health. Animal Production Science 50: 1115-1122.
6. van der Werf, J. H. J., Kinghorn, B. P., & Banks, R. G. (2010). Design and role of an information nucleus in sheep breeding programs. Animal Production Science 50: 998–1003.
7. Ponnampalam, E. N., Butler, K. L., Jacob, R. H., Mortimer, S. I., Pethick, D. W., Ball, A. J., & Hopkins, D. L. (2013). Sources of variation of health claimable long chain omega-3 fatty acids in meat from Australian lamb slaughtered at similar weights. Meat Science: http://dx.doi.org/10.1016/j.meatsci.2012.11.039 (in press).
8. Ponnampalam, E. N., Sinclair, A. J., Egan, A. R., Blakeley, S. J., & Leury, B. J. (2001). Effect of diets containing omega-3 fatty acids on muscle long-chain omega-3 fatty acid content in lambs fed low- and medium-quality roughage diets. Journal of Animal Science 79: 698-706.
9. Scerra, M., G., Caparra, P., Foti, F., Cilione, C., Giorgi, A., & Scerra, V. (2011). Influence of stall finishing duration of Italian Merino lambs raised on pasture on intramuscular fatty acid composition. Meat Science 89: 238-242.