PE3.05 Meat authentication – what did the animal eat? 288.00

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***Abstract*—the research demonstrates the application of stable isotope ratio (SIR) analysis in meat authentication, specifically in the determination of the pre-slaughter diet history and geographical origin of animals. Stable isotope ratio analysis of muscle and other tissues (blood, tail hair) was conducted using isotope ratio mass spectrometry. Based on differences between the carbon (C) SIR of C_3 and C_4 plant materials, the data show that C SIR in muscle can be used to differentiate between beef from animals fed maize (C_4)-based diets compared to animals fed grass or barley (C_3)-based diets. Seasonal differences in the C SIR of organic *vs* conventional beef and differences in the C SIR of beef from different countries of origin can also be attributed to differences in the C_4 content of the animal feed. While C turnover in muscle following a diet switch is slow, with half-lives of >150 days in beef cattle and >75 days in lambs, incremental tissues such as hair respond rapidly (half life ~1.7 days) to a diet switch. The data show that SIR analysis of meat can be related to pre-slaughter diet. Relating muscle SIR data to animal diet requires consideration of tissue turnover in response to diet switches; hair provides a valuable fixed archive of such pre-slaughter diet switches.**

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***Index Terms*—meat, authentication, stable isotope ratio.**

I. INTRODUCTION

It is well established that the pre-slaughter diet of animals influences the nutritional and elemental composition of meat [1]. It follows that analysis of meat can elicit information retrospectively about the pre-slaughter diet of animals. From an authentication perspective, this information is particularly relevant to-day when consumers and regulators are ever more concerned about the connection between animal diet and the safety and nutritional quality of meat.

Information on the dietary background of animals is also important in validating claims around the production of branded products such as "grass-fed" beef or "corn-fed" chicken. In addition, the pre-slaughter diet of animals can yield important information about the geographical origin of meat because the elemental composition of the diet consumed by animals is influenced by the climatic and geological conditions that prevail where the food was produced [2].

Among a variety of techniques, light element stable isotope ratio (SIR) analysis (SIRA) is a powerful tool for obtaining information about the dietary background and geographical origin of food animals [3]. The objective of this paper is firstly to demonstrate, based on a number of studies conducted by the authors, the usefulness of SIRA in yielding information about the dietary background and geographical origin of meat and its application in meat authentication. Secondly, the impact of pre-slaughter diet switches and tissue turnover on the interpretation of SIR data for authentication purposes is explored.

II. MATERIALS AND METHODS

A. Meat (and other tissue) samples

Beef and lamb samples were obtained from studies undertaken in Ireland at University College Dublin and Teagasc (The Irish Agriculture and Food Development Authority) [4-7] or from commercial sources [8-9]. All samples were stored at -20°C until preparation for SIRA.

In study 1, beef samples were obtained from groups of 15 cattle fed either a grass silage based diet, a maize silage-based diet or a 50:50 mixture of the two [4].

In study 2, beef (as well as blood and tail hair) samples were obtained from groups of 10 animals which were either maintained on a barley-based diet for 168 days, maintained on a maize-based diet for 168 days or maintained on the barley-based diet and then switched to maize-based diet for 14, 28, 56 or 112 days before slaughter [5,6].

In study 3, lamb samples were obtained from 28 lambs fed a barley/maize-based diet and then switched, in groups of 4, to a full maize diet for 0, 14, 28, 56, 98, 154 or 231 days before slaughter [7].

In study 4, organic (n=127) and conventionally (n=115) produced beef was obtained from supermarkets in the Dublin area on a weekly basis over a 1 year period [8].

In study 5, beef samples were obtained from the U.S. (Nebraska) (n=10), Brazil (n=10) and Europe (Belgium, France, Germany, Ireland, Italy, the Netherlands) (n=35) [9].

B. Stable isotope ratio analysis

Natural abundance stable isotope ratios of C ($^{13}C/^{12}C$) and N ($^{15}N/^{14}N$) in muscle, blood, hair and feed were measured by isotope ratio mass spectrometry [3]. Isotope ratios are expressed in delta notation [δ per mille (‰)] according to the formula:

$$\delta\ (‰)=[(R_{sample}/R_{reference})-1] \times 1000$$

where R is the ratio of the heavy to light stable isotope in sample (R_{sample}) and standard ($R_{reference}$). Results are referenced to Vienna Pee Dee Belemnite (VDPB) for $\delta^{13}C$ and air N_2 for $\delta^{15}N$.

III. RESULTS AND DISCUSSION

In study 1, stable isotope ratio analysis is clearly useful in differentiating meat from animals fed C_3 (grass) and C_4 (maize) plant material (Figure 1). This difference could be attributed to differences in the $^{13}C/^{12}C$ ratios of the grass ($\delta^{13}C$ = -28.5‰) and maize ($\delta^{13}C$ = -15.8‰) -based diets fed to the animals. From the data we calculated that that each 10% change in dietary C_4 carbon (from maize) resulted in a 0.9-1.0‰ shift in $\delta^{13}C$ value of muscle.

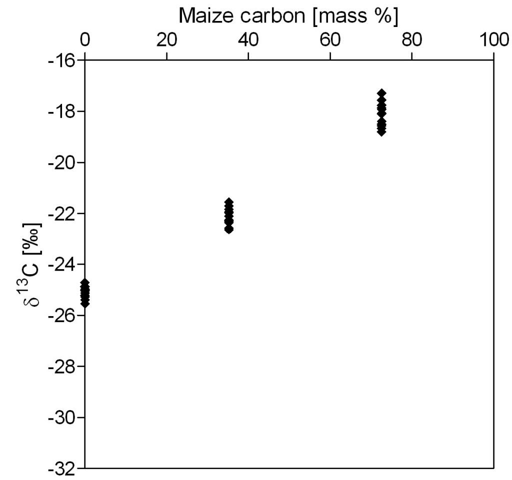

Figure 1: Relationship between maize carbon in the diet and $\delta^{13}C$ of muscle [4].

While the animals in study 1 were fed different diets for 167 days pre-slaughter, an important question arises regarding the time taken for a change in diet to bring about a change in isotope ratios in meat, i.e. how long does it take for C or N in muscle to turnover in response to a diet switch? In study 2, in which beef cattle were switched from a barley to a maize-based diet, we calculated half lives of 151 and 157 days for C and N, respectively, in *M. longissimus dorsi* [5]. Similarly in study 3, we calculated shorter half lives for lamb muscle with values of ~76 days for C in *M. longissimus dorsi* (Figure 2).

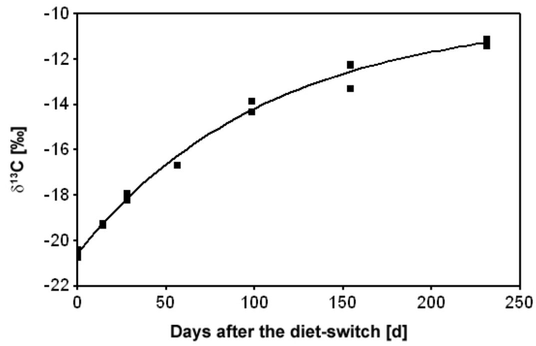

Figure 2: $\delta^{13}C$ values of *M longissimus dorsi* of lambs switched from a barley/maize-based diet ($\delta^{13}C$ = -22.6‰) at day 0 to a maize-based diet ($\delta^{13}C$ = -12.5‰) for 14, 28, 56, 98, 154 or 231 days before slaughter [7].

In contrast to muscle, C and N turnover in blood is faster, with half-life values of 29 and 36 days for C and N in bovine blood plasma, respectively [10]. But in terms meat authentication, the usefulness of blood is limited, particularly if a diet switch occurs within a month of slaughter.

Incremental animal tissues, such as hair, wool or hoof, if archived at slaughter, offer distinct advantages over integrating tissues, such as muscle, in reconstructing the pre-slaughter diet history of animals. In bovine hair (study 2) the response to a C_3 to C_4 diet switch was rapid, with a half life of 1.7 days for turnover of the fastest and largest C pool (Figure 3). This rapid response enabled the detection of an unplanned switch in the pre-slaughter diet of cattle [6], highlighting the usefulness of incremental tissues in reconstructing the diet histories of human foods of animal origin, such as meat.

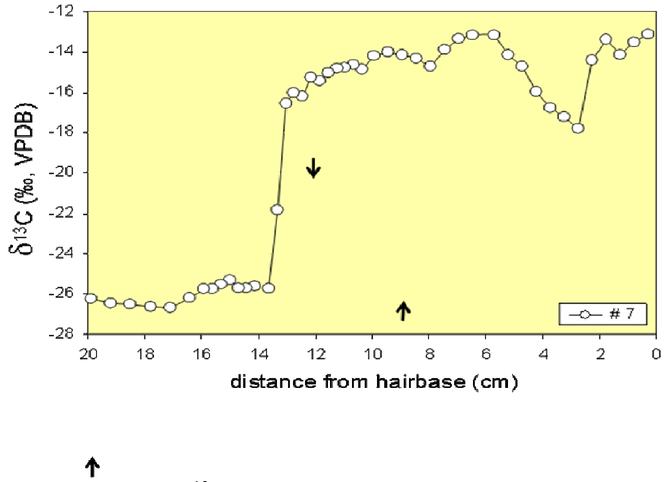

Figure 3: $\delta^{13}C$ values of bovine hair (of animal #7) switched from a barley ($\delta^{13}C$ = -28.7‰) to a maize ($\delta^{13}C$ = -14.7‰) -based diet 167 days pre-slaughter (~13.5 cm from hairbase). An unplanned switch to a diet somewhat depleted in maize (~6 cm from hairbase) and back to the full maize-based diet (~2.5 cm from tail base) is evident [6].

In the survey of Irish beef labeled organic or conventional (study 4) SIRA showed significant differences between mean $\delta^{13}C$ values for organic and conventional beef in winter, spring and summer but not in autumn (Figure 4). The absence of a significant difference due to production system in autumn beef was attributed to the feeding of similar (grass-based) diets to all animals in late spring and summer, an effect manifested in autumn due to the slow muscle turnover effects discussed above. In autumn and winter particularly animals receive feed supplements, with the conventionally-raised animals more likely to receive C4 (maize-based) supplements than animals raised on organic systems [8].

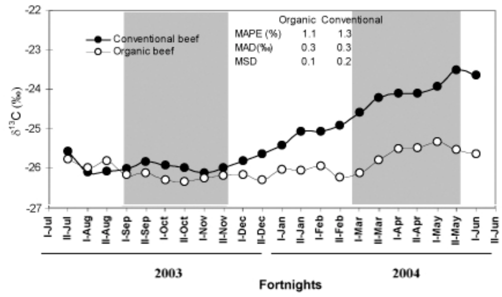

Figure 4: Time series moving average plots of $\delta^{13}C$ of organic and conventional Irish beef. MAPE=Mean absolute percent error, MAD=Mean absolute deviation, MSD=Mean square deviation. First (I) and second (II) fortnights of the months are shown. Seasons are defined as follows - Autumn: September to November; Winter: December to February; Spring: March to May; Summer: June to August [8].

In a survey of beef from different countries (study 5), SIRA led to a clear differentiation of meat samples from North or South America and meat samples from Europe. The differentiation was attributed to the increased likelihood of beef animals from the American continent receiving C_4 as opposed to C_3 forages. Within Europe $\delta^{13}C$ values indicated some maize feeding to cattle, with a lower prevalence of maize feeding in Ireland.

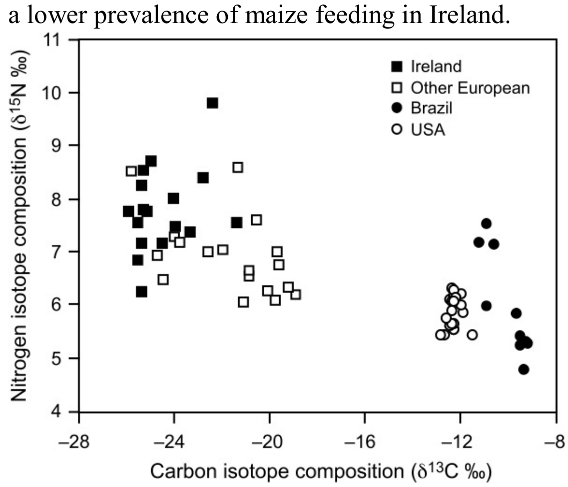

Figure 5: C and N stable isotope ratios in bovine muscle from different countries of origin [9].

IV. CONCLUSION

Stable isotope ratio analysis of meat yields information about the pre-slaughter diet of animals, with C SIR being a particularly useful indicator of consumption of C_4 plant foods, such as maize. In interpreting muscle SIR data, however, the slow tissue turnover in response to a diet switch must be considered. While C and N SIRA does not provide foolproof evidence of country of origin of meat or of production system (e.g. organic *vs* conventional), it is useful in supporting claims concerning country of origin or production system. Incremental tissues, such as hair, offer a potentially valuable archive of the previous diet history of animals and pre-slaughter diet switches.

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REFERENCES

[1] Moloney, A.P., Mooney, M. T., Kerry, J. P., & Troy, D. J. (2001). Producing tender and flavoursome beef with enhanced nutritional characteristics. Proceedings of the Nutrition Society, 60, 221-229.

[2] Camin, F., Bontempo, L., Heinrich, K., Horacek, M., Kelly, S.D., Schlicht, C., Thomas, F., Monahan, F.J., Hoogewerff, J. and Rossmann, A. (2007). Multi-element (H,C,N,S) stable isotope characteristics of lamb meat from different European regions. Analytical and Bioanalytical Chemistry, 389, 309-320.

[3] Kelly, S. D. (2003). Using stable isotope mass spectrometry (IRMS) in food authentication and treceability. In M. Lees, Food Authenticity and Treceability (pp. 156-183). Cambridge: Woodhead.

[4] Bahar, B., Monahan, F.J., Moloney, A.P., O'Kiely, P., Scrimgeour, C.M. and Schmidt, O. (2005). Alteration of the carbon and nitrogen stable isotope composition of beef by substitution of grass silage with maize silage. Rapid Communications in Mass Spectrometry, 19, 1937-1942.

[5] Bahar, B., Moloney, A.P., Monahan, F.J., Harrison, S.M., Zazzo, A., Scrimgeour, C.M., Begley, I.S., Schmidt, O. (2009). Turnover of C, N and S in bovine Longissimus dorsi and Psoas major muscles: implications for isotopic authentication of meat. Journal of Animal Science, 87, 905–913.

[6] Zazzo, A., Harrison, S.M., Bahar, B., Moloney, A.P., Monahan, F.J., Scrimgoeur, C.M. and Schmidt, O. (2007). Experimental determination of dietary carbon turnover in bovine hair and hoof. Canadian Journal of Zoology, 85, 1239-1248.

[7] Harrison, S.M. (2009). PhD thesis, University College Dublin (in preparation)

[8] Bahar, B., Schmidt, O., Moloney, A.P., Scrimgeour, C.M., Begley, I.S. and Monahan, F.J. (2008). Seasonal variation in the C, N and S stable isotope composition of retail organic and conventional Irish beef. Food Chemistry, 106, 1299-1305.

[9] Schmidt, O., Quilter, J.M., Bahar, B., Moloney, A.P., Scrimgeour, C.M., Begley, I.S. and Monahan, F.J. (2005). Inferring the origin and dietary history of beef from C, N and S stable isotope ratio analysis. Food Chemistry, 91(3), 545-549.

[10] Bahar, B. (2006). PhD thesis. University College Dublin.