Snapshot Report

Real-time identification of red meat provenance and quality attributes

Project Code
2019-1065

Prepared by
Robert Barlow, Kate McMillan, Anita Sikes, Adam Fitzgerald

Date Submitted
07/11/2022

Project Description

The red meat supply chain comprises a complex network that attempts to transfer a range of products from production to consumption in a safe and secure way. As a consequence there are points within the supply chain where fragmentation exists and vulnerabilities may be exploited. There is ever increasing demand to de-fragment these systems and ensure that Australian red meat products enter domestic or export markets with the desired quality, safety and provenance attributes. Novel technologies that can be incorporated across the red meat supply chain will be central facilitators in the evolution of the meat plant of the future. This study explored the capabilities of rapid evaporative ionisation mass spectrometry (REIMS) profiling with regard to classifying a range of product attributes relating to provenance as well as food safety and quality. REIMS technology is being utilised in international markets in response to recent food fraud episodes in red meat and seafood supply chains and has demonstrated capacity relating to species identification, location of production, production system, and slaughter and processing methods.

Project Content

All food products have a history and food provenance is about understanding this history and knowing about the events in the supply chain that have contributed to it. The applicability of REIMS to the classification of provenance-aligned attributes including production system, breed, brands, and combinations of breed and production system were evaluated as part of the study. A total of 192 *longissimus thoracis* samples comprising 123 grain-fed (59 Angus, 51 Wagyu, and 13 unknown) and 69 grass-fed, were sourced at retail (originating from at least 18 processing establishments) for analysis. All samples were subjected to REIMS analysis and then subsets were used to develop classification models for provenance-aligned attributes such as production system, breed, and brands using principal component analysis (PCA) and linear discriminant analysis (LDA) analysis. REIMS generates spectral profiles across the *m/z* 100-1200 range with models able to be constructed using the entire or parts of the spectral profile. All models were cross-validated, and LDA analysis of the *m/z* 600-900 range was shown to produce correct classification rates exceeding 90% for all provenance models confirming the potential of REIMS for real-time verification of red meat product attributes.

Meat quality and the subsequent sensory experience it achieves are key drivers of a consumer's ongoing purchasing decision. Marbling is a key indicator of quality and is associated with tenderness, juiciness and flavour. In addition, knowledge that a product has remain chilled and not frozen during its distribution or confirming the period of time elapsed since slaughter may be important in resolving market access issues. In the meat quality study, a total of 216 Angus and Wagyu loin steak samples comprising marble scores (MB) 2, 3 and 4 for Angus and 3, 5, 7 for Wagyu were sourced from an Australian export registered abattoir. Samples were stored at -0.5 °C for a period of up to 12 weeks and subjected to meat quality and REIMS analysis at weeks 1, 2, 4, 6, 8 and 12. The resulting REIMS spectral profiles were used to develop classification models to identify Angus and Wagyu products of varying marble scores and aged from between 1 and 12 weeks using linear discriminant analysis (LDA) analysis.

Test classification rates for the Angus models exceeded 90% regardless of whether marble score alone or marble score plus age was considered. The Wagyu model incorporating marble score and age was the best performing at 93.54%. A breed-independent model incorporating marble score and age performed well, producing a test result of 90.93%. In addition to models for the prediction of marbling scores, models that classify Angus, Wagyu, and grass-fed samples into their respective groups based on whether the product was fresh or frozen were also constructed. Testing of these models gave results of 84.57% to 87.54% depending on the spectral range used. Importantly, fresh product was never classified as frozen product, and vice versa.

Australian red meat processors verify hygiene performance and meet regulatory requirements for bacterial pathogens through a myriad of testing programs. REIMS was assessed for its ability to detect and classify the microorganisms *E. coli*, *Salmonella* and *Enterococci* which are relevant to trade, hygiene, and human health. In addition to assessing REIMS across food safety applications, there was also opportunity during the project to trial the RADIAN direct mass detector system. A total of 180 *E. coli*, *Salmonella* and *Enterococci* isolated from beef cattle-associated samples were included in the study. The REIMS and RADIAN systems were both able to develop classification models for bacterial genus, *E. coli* serogroups, *Salmonella* serovars, and *Enterococcus* speciation. All models were cross-validated with models generated using spectra profiles from REIMS resulting in correct classification rates for all models exceeding 93.33%. By comparison, models developed using spectra from the RADIAN system achieved correct classification rates exceeding 81.25%, albeit from a smaller subset of samples. The transition from using REIMS to assess beef samples for provenance and quality attributes to food safety applications proved challenging with large concentrations of bacteria and novel sampling approaches required. Transformative food safety applications would be required to detect very low concentrations of bacteria preferably without the need for prior growth of the organisms to have occurred. In contrast, the RADIAN system is likely to have strong applicability for food safety applications in red meat supply chains due to its simple non-destructive sampling approach and ability to detect bacteria of interest at much lower concentrations. The relatively straight forward analysis workflow that could be navigated by personnel with limited training makes RADIAN a suitable candidate for use in red meat processing environments.

Project Outcome

This study represents the first description of the use of REIMS on Australian foods and confirmed its capacity to accurately classify provenance, meat quality and food safety attributes of importance to the industry and its customers. REIMS has demonstrated capacity to sample and classify hundreds of products each day with a time to result of less than one minute. Furthermore, a single REIMS spectrum can be used across multiple classification models enabling the verification of several product attributes from a single test thereby providing advantages over technologies which are constrained to a specific attribute. Whilst it would be ideal to consider REIMS as a technology that can be deployed into processing plants, the need for skilled operators, high capital cost, and its destructive sampling approach perhaps makes it more applicable to commercial laboratories capable of offering a product verification service that augments a processing plant's quality assurance program for provenance and meat quality attributes. Further investigation of this type of service offering for the industry is warranted. Conversely, the applicability of REIMS to food safety applications that enable practice change via rapid detection of organisms of

interest during red meat processing is unlikely at present due to the issues associated with sampling small concentrations of bacteria. In this context, the RADIAN system is of interest, and it may be possible to identify opportunities where the RADIAN system could be used to simultaneously assess beef products in-line to confirm an attribute (e.g. Wagyu) and identify any food safety implications (e.g. the presence of STEC) using a single sample. Further investigation of the RADIAN as an in-line verification tool for the red meat industry should be commenced. In summary, ambient mass spectrometry systems continue to demonstrate promise for rapid verification of product attributes in the red meat industry. In a proof-of-concept setting, the REIMS and RADIAN (food safety) systems were able to demonstrate their utility for classification of provenance, quality and food safety attributes of high relevance to the red meat industry. As processing plants, and red meat supply chains more broadly, continue their evolution towards an environment of continuous assurance, there will be increasing focus of systems which can biologically verify the credentials of red meat products and work in conjunction with digital traceability and export systems. The potential to apply ambient mass spectrometry systems across several key areas in red meat supply chains bodes well for the continued development and deployment of models which support the objective classification of red meat products.

Benefit for Industry

Based on the outcomes of this proof-of-concept study, REIMS could be used by the Australian red meat industry to verify a range of attributes relating to provenance, meat quality, and food safety. The application areas evaluated align to attributes that are of significance to market access, product premiumisation, and customer and consumer choice. Further enhancement of the models developed in this study is required prior to commercial implementation, however, REIMS can be used to classify products without a need to establish a database of all known products and therefore has potential to support all producers and processors at a low entry cost. An additional technology offering (RADIAN) demonstrated potential as an in-line verification system that provides opportunities for red meat industry participants wanting to provide real-time continuous assurance of their products to others in the supply chain.

Useful resources

A review on the application of REIMS to the Australian red meat industry was published (https://www.mdpi.com/2218-1989/11/3/171) and was used to inform the objective and design of proof-of-concept studies.