



Final report

Compositional Traceability – Origin Fingerprints for Australian Beef and Lamb

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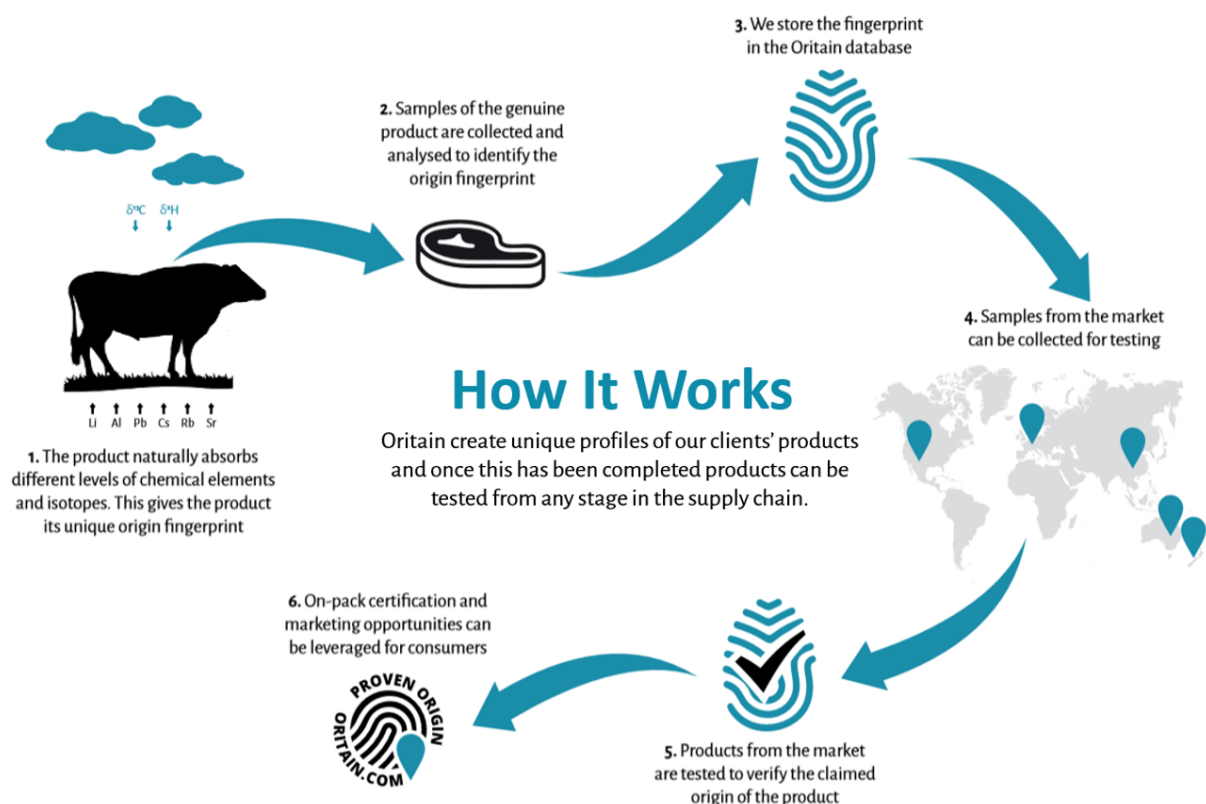
Abstract

In response to issues of rising product fraud and increasing demands for traceability and authenticated provenance claims, MLA Donor Company (MLA) partnered with Oritain, global leaders in verifying the true origin of products, in an R&D project to validate and demonstrate Oritain's ability to scientifically distinguish Australian beef and lamb from meat produced in other countries.

'Origin Fingerprints' for Australian beef and lamb have been developed through the chemical analyses of red meat samples from beef and lamb producing areas around Australia and the application of Oritain's proprietary scientific, analytical, and statistical capabilities. In order to evaluate Oritain's capability to verify the origin of Australian beef and lamb, Oritain and MLA conducted independent proficiency testing of the Origin Fingerprints by analysing a suitable external sample set of both Australian and international beef and lamb samples.

The red meat industry and its stakeholders are now able to test products from anywhere in global supply chains to objectively verify that Australian labelled beef and lamb are true to their claimed country of origin (Fig. 1.). Introducing a robust method of detecting fraud while communicating this to supply chain participants acts as a deterrent to dishonest behaviour and drives compliance of truthful labelling. In doing so, customer and consumer confidence and trust towards 'Product of Australia' and individual Australian brands can be both protected as well as further enhanced.

Figure 1: Compositional Traceability – Origin Fingerprints for Australian Beef and Lamb.



Executive summary

Background

In response to issues of rising product fraud and increasing demands for traceability and authenticated provenance claims, MLA Donor Company (MLA) partnered with Oritain, global leaders in verifying the true origin of products, in an R&D project to validate and demonstrate Oritain's ability to scientifically distinguish Australian beef and lamb from meat produced in other countries.

Beyond slaughter where NLIS tags are removed, traditional traceability systems (packaging, labels and bar codes etc) have known limitations and weaknesses. Global supply chain systems are not harmonious meaning there is no central/distributed platform to track products all the way through to a consumer. The accuracy of information is only as good as what's claimed on the box or label. Once packaging and labels are removed or tampered with traceability is lost, leaving Australian red meat brands and labelled product in export supply chains and markets vulnerable to counterfeit/substitution and the associated reputational risk.

Oritain are global leaders in scientifically verifying the origin of products to both protect and enhance reputations. With no reliance on packaging, bar codes, tag & trace, or additives, Oritain tests for the innate chemical "fingerprint" in products (focusing on trace elements and stable isotopes) which links them to their production or manufacturer origin, helping support provenance claims and identify substitution and counterfeit goods.

This R&D project was designed to apply Oritain's existing scientific, analytical and statistical capabilities to show red meat (beef and lamb) produced in Australia can be scientifically distinguished from other meat produced in other countries, by developing 'Origin Fingerprints' for Australian beef and lamb.

On completion, industry and industry stakeholders are now able to test products from anywhere in global supply chains to verify that products labelled as Australian beef and lamb are true to their claimed country of origin. In market auditing programs not only provide a means of detecting fraudulent activity, but more importantly act as a deterrent to dishonest behaviour. Introducing a robust method of detecting fraud and communicating this to supply chain participants drives compliance of truthful labelling. In doing so, customer and consumer confidence and trust towards 'Product of Australia' and individual Australian brands can be both protected as well as further enhanced.

Note: *Knowing that the risk of counterfeit and substitution in export markets is from non-Australian origins, fingerprints developed at Country of Origin level offer potential protection for all industry stakeholders.*

Objectives

The main objectives of this project were for Oritain to develop:

- a) A “fit for purpose” Origin Fingerprint for Australian Beef*
- b) A “fit for purpose” Origin Fingerprint for Australian Lamb*

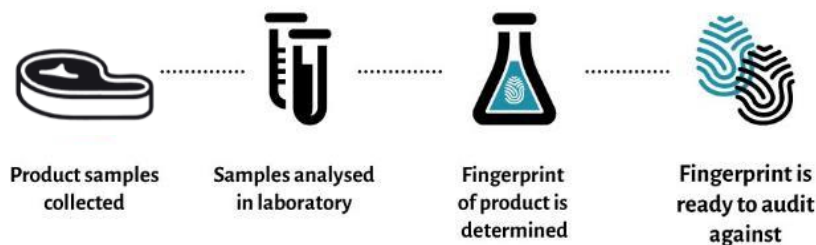
*A “fit for purpose” fingerprint is an origin fingerprint that meets Oritain’s requirements for geographical sample coverage, data quality and statistical model performance.

Objectives a) and b) were successfully achieved and meet Oritain’s “fit for purpose” criteria as detailed in Section 2, Objectives. Additionally, Oritain have successfully completed independent proficiency testing of a) and b) in order to evaluate Oritain’s capability to verify the origin of Australian beef and lamb.

Methodology

Oritain tests for the innate Origin Fingerprint in products (focusing on trace elements and stable isotopes) which links them to their production or manufacturer origin (Fig. 2.). The sample set collected for this project covers the geographic spread of Australia used in the direct production of beef and lamb. The sampling was completed at a frequency sufficient to fully account for the natural variance in the Origin Fingerprint.

Figure 2: Oritain tests for the innate Origin Fingerprint in products (focusing on trace elements and stable isotopes) which links them to their production or manufacturer origin.



Results/key findings

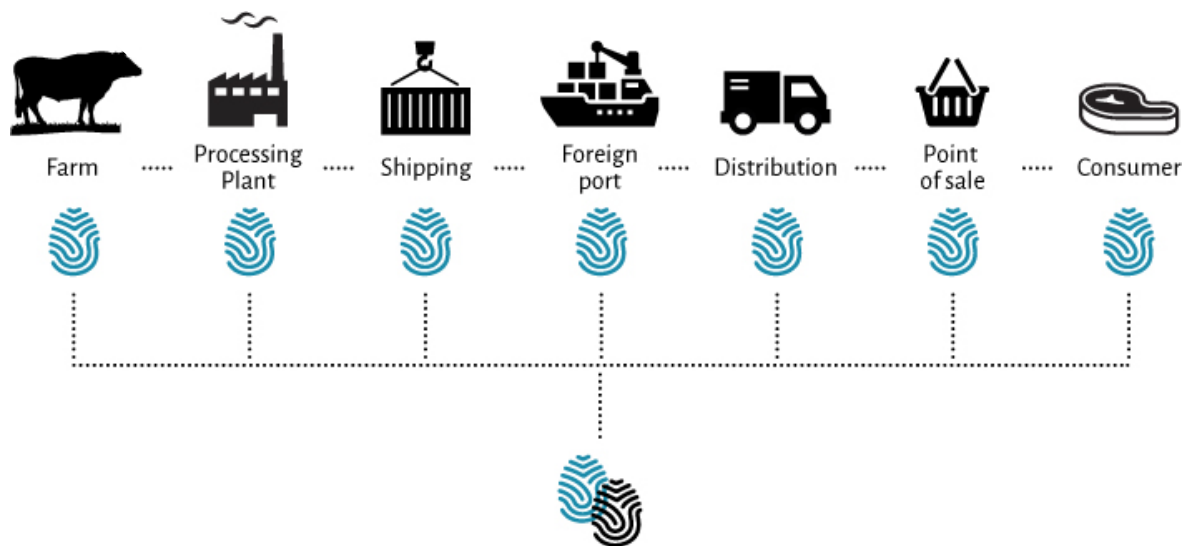
The project validates and demonstrates Oritain’s ability to scientifically distinguish Australian beef and lamb from meat produced in other countries:

1. Sampling of Australian beef and lamb was completed at a high frequency.
2. Origin Fingerprints for Australian beef and lamb were developed.
3. Sample analysis was completed and data was processed using propriety statistical methods.
4. Origin Fingerprints of beef and lamb were independently tested and meet “fit for purpose” requirements for origin verification of Australian beef and lamb.

Benefits to industry

Knowing the risk of counterfeit and substitution in export markets is from non-Australian origins, Origin Fingerprints developed at country of origin level offer potential protection for all of industry stakeholders. The red meat industry and its stakeholders are now able to test Australian beef and lamb products from any point in global supply chains to verify country of origin (Fig. 3.).

Figure 3: Products can be tested and verified from any stage in the supply chain.



Introducing a robust method of detecting fraud while communicating this to supply chain participants acts as a deterrent to dishonest behaviour and drives compliance of truthful labelling. In doing so, customer and consumer confidence and trust towards 'Product of Australia' and individual Australian brands can be both protected as well as further enhanced.

Future research and recommendations

- Extend the established capability to other red meat products, such as goat, as well as exploring potential applications for origin verification of other animal-related products, such as leather.
- Utilise the validated and demonstrated "fit for purpose" capability for Australian beef and lamb to quantify, define, and proactively manage the anecdotally acknowledged fraud problem for 'Product of Australia' in global markets and supply chains.

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1. Background

Recent research conducted by MLA (Project Code: V.MFS.0447 published August 2020) concludes:

‘Product of Australia’ provenance endorsement is a fundamental element in exporters achieving price premiums and where proprietary brands are traded, their value propositions are also heavily underpinned by the credibility of the Australian provenance. As such, systemic and ongoing fraudulent use of ‘Brand Australia’ on inferior red meat could erode customer and consumer confidence and compromise the ability to extract price premiums.

Given its potential significance to Australia’s red meat industry, the fraud issue warrants further investigation. In reality there is no robust understanding of the nature, extent and impact of fraud on brand owners across the industry at large. Because product integrity is the centrepiece of Australia’s competitive advantage in global markets, improved understanding of this issue is important.

Beyond slaughter where NLIS tags are removed, traditional traceability systems (packaging, labels and bar codes etc) have known limitations and weaknesses. Global supply chain systems are not harmonious meaning there is no central/distributed platform to track products all the way through to a consumer. The accuracy of information is only as good as what’s claimed on the box or label. Once packaging and labels are removed or tampered with traceability is lost, leaving Australian red meat brands and labelled product in export supply chains and markets vulnerable to counterfeit/substitution and the associated reputational risk.

Oritain are global leaders in scientifically verifying the origin of products to both protect and enhance reputations. With no reliance on packaging, bar codes, tag & trace, or additives, Oritain tests for the innate chemical “fingerprint” in products (focusing on trace elements and stable isotopes) which links them to the environment where a product was grown or produced, helping support provenance claims and identify substitution and counterfeit goods.

Oritain’s science originated in the criminal forensic fields. Developed to determine drug provenance and solve homicide investigations, the robustness of the science is well proven (Bergslien 2012, Casale et al. 2006). The science is now widely applied for verifying the origin of food (Ehtesham et al. 2017; Brereton, 2013; Kelly, Heaton & Hoogewerf, 2005; Forstel, 2007). It is peer-reviewed and subject to the scrutiny that comes with journal publications. Oritain have adapted this science to trace the origin of various food, fibre and pharmaceutical products.

This R&D project was designed to apply Oritain’s existing scientific, analytical and statistical capabilities to show red meat (beef and lamb) produced in Australia can be scientifically distinguished from other red meat produced in other countries, by developing “Origin Fingerprints” for Australian beef and lamb.

On completion, industry and industry stakeholders are now able to test products from anywhere in global supply chains to verify that products labelled as Australian beef and lamb are true to their claimed country of origin. In-market auditing programs not only provide a means of detecting fraudulent activity, but more importantly act as a deterrent to dishonest behaviour. Introducing a robust method of detecting fraud and communicating this to supply chain participants drives compliance of truthful labelling.

Note: *Knowing that the risk of counterfeit and substitution in export markets is from non-Australian origins, fingerprints developed at Country of Origin level offer potential protection for all industry stakeholders.*

The output of this project can now be used by industry and industry stakeholders to provide the following benefits:

1. Reduced industry and industry stakeholder risk via proactive protection measures.
 - Preventing / deterring fraud. Reduce the likelihood of being implicated in a food fraud issue by increasing the likelihood of detection. By introducing a method of detecting fraud, the likelihood of it occurring decreases. Randomly and scientifically auditing supply chains monitors their health and can act as an early detection of problems.
 - Protect brand. Food fraud severely damages brands that are impacted. The Australian red meat industry / its stakeholders would have the opportunity to identify if an issue was the result of mislabelled or counterfeit product and take legal action if desired. The same science has been used in forensics for 30+ years. Therefore, should the need arise, the science can stand up in a court of law to exonerate a brand.
 - PR management. If the Australian red meat industry / its stakeholders were to be associated with a fraud situation resulting in negative PR, an investment in this service would help reassure stakeholders that all necessary steps have been taken to avoid such an issue.
2. Increased industry and industry stakeholder competitiveness via enhanced reputation.
 - Differentiation. In markets where non-price attributes are important, Australian exporters can utilise a valuable integrity based non-price attribute to increase international market competitiveness. By not just relying upon price to win business, extra margin can be captured.
 - Increased market share. Create additional demand for Australian Red Meat as fraudulent substitution reduces.
 - Customer confidence. For certain markets where provenance and food safety are important, Oritain's offers a Unique Selling Point. Via independent third-party verification customers can be reassured of the integrity of the product with increased confidence - that what is claimed on the packaging is right every-time.
 - B2B and B2C Marketing. Oritain verification can be used across an array of marketing materials as appropriate and where there is perceived benefit to the Australian red meat industry / its stakeholders.

2. Objectives

2.1 Original project objectives

The participant will achieve the following objective(s) to MLA's reasonable satisfaction:

Oritain will develop and demonstrate:

- a) A “fit for purpose” Origin Fingerprint for Australian Beef
- b) A “fit for purpose” Origin Fingerprint for Australian Lamb

Where “fit for purpose” covers 4 facets:

INCLUSIVITY

- 1) The sample set covers the geographic spread of Australia used in the direct production of beef and lamb.
- 2) The sampling is completed at a high enough frequency to account for the natural variance in the Origin Fingerprint.

EXCLUSIVITY

- 3) The statistical models used to evaluate the data perform with a >95% True Positive rate and a suitable True Negative rate when evaluating the Australian Origin Fingerprint to other origins under cross classification.
- 4) A suitable external test set achieves or exceeds the cross-classification rates determined in 3) (above).

2.2 Completion status

The objectives set for this project were successfully met.

Oritain have developed and demonstrated:

- a) A “fit for purpose” Origin Fingerprint for Australian Beef
- b) A “fit for purpose” Origin Fingerprint for Australian Lamb

More specifically, Origin Fingerprints of beef and lamb were tested and met the performance requirements for origin verification of Australian beef and lamb.

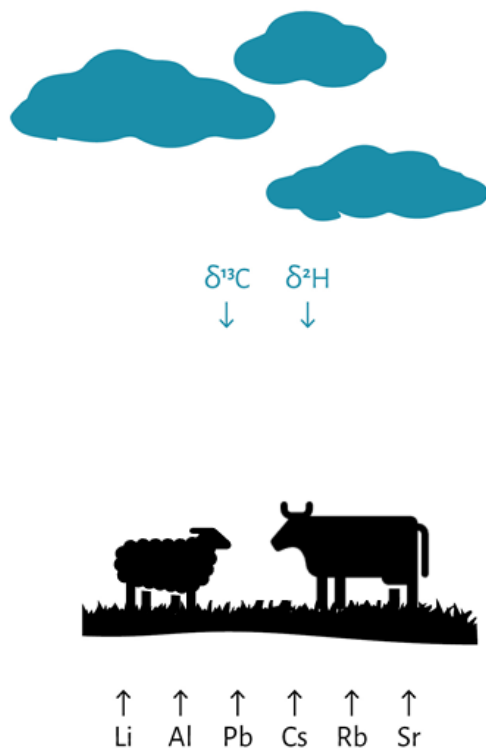
3. Methodology

3.1 Origin Fingerprint

Oritain's scientific traceability service measures a suite of naturally occurring chemical components within red meat. Animals absorb natural chemical properties from their environment, which vary according to location. We refer to these properties in beef or lamb as an Origin Fingerprint. This connection allows Oritain to scientifically link natural products to a specific origin.

The Origin Fingerprint in this instance describes the collective trace element concentrations or, where necessary, stable isotope ratios within a sample of meat (Fig. 4.). These parameters are influenced by environmental, geographical, and processing factors.

Figure 4: The Origin Fingerprint in this instance describes the collective trace element concentrations or, where necessary, stable isotope ratios within a sample of meat.



To perform an origin verification test, Oritain first builds a database of genuine reference origin samples to establish an Origin Fingerprint entirely unique to the origin and product in question. A product sample from anywhere in the supply chain or in market can then be tested and compared against this database using Oritain's proprietary statistical models.

3.2 Sampling

Oritain has developed and follows several strict procedures to perform sampling for the purpose of creating “fit for purpose” Origin Fingerprints, including:

- Samples must be collected as close to the source as possible. In the case of red meat, it is preferable that the samples are collected from abattoirs.
- All samples collected must meet Oritain’s requirements for size and quality (100g of lean meat at least 1 inch thick).
- Sampling must cover geographical and non-geographical sources of variability to be considered satisfactory to meet “fit for purpose” requirements. The non-geographical sources of variability include but are not limited to meat cut and animals’ diet.
- All samples have a robust chain of custody that provides an evidence of the origin of the samples.

3.3 Analysis

3.3.1 Sample Analysis

Sample preparation was performed per Oritain’s Standard Operating Procedures for red meat products. Sample analysis was completed following the methods established and tested by Oritain. Consistency of sample preparation and analysis ensures continuity of data, meaning the newly collected data is compatible with the Oritain’s existing red meat database, enabling origin verification for Australian beef and lamb.

3.3.2 Data Interpretation

Statistical modelling was utilised to discriminate the samples’ Origin Fingerprints. The statistical modelling is an intensive process of analysing the raw data using a series of propriety statistical methods and algorithms. Multiple statistical packages are used, utilising Oritain’s IP that has been developed over many years.

The model performance was verified for suitability for origin testing through internal testing and evaluation of model performance analytics. The performance is assessed using True Positive and True Negative rates.

The True Positive (TP) rate is the proportion of ‘positives’: true Australian beef or lamb, that are correctly identified as consistent with the Origin Fingerprints developed for Australian beef and lamb. In other words, it is the proportion of samples that have been classified into the group they are really from. The associated False Negative (FN) rate is the proportion of true Australian beef or lamb samples that are incorrectly identified as inconsistent with the fingerprint of Australia. TP and FN add to 100%.

The True Negative (TN) rate is the proportion of ‘negatives’: non-Australian beef and lamb, that are correctly identified as being inconsistent with the Origin Fingerprints developed for Australian beef and lamb. In other words, it is the proportion of beef or lamb samples from origins other than Australia that are correctly classified as not consistent with Australia. The associated False Positive (FP) rate is the proportion of international beef or lamb samples that are identified as consistent with Australia. TN and FP add to 100%.

To protect “consistency” claims (whether a sample is consistent with a specific origin), Oritain aim to minimise chances of falsely identifying genuine sample as inconsistent (i.e. falsely blaming the

innocent). The True Negative (ability to identify fraud) depends on a specific location and origin question. There is a trade-off between these two measures, where increasing one will decrease the other. Thus, the True Negative and True Positive performance depends on the specific risk and objectives of the program.

3.3.3 External Performance validation

The external proficiency testing included the following steps:

1. Test samples were supplied by MLA and sourced from Oritain's dataset.
2. Test samples were provided to an independent third party for selection and 'blinding'.
3. The independent third-party anonymised samples by assigning them a new sample ID and keeping the origin information confidential from both parties until the analysis results were released by Oritain.
4. Oritain released the analysis results of testing to MLA and the independent third party at the same time.
5. The true origins of the samples were then released to Oritain and MLA at the same time by the independent third party.
6. Suitability of the outcome and further actions were assessed by Oritain and MLA.

A total of 75 samples of beef and lamb were selected to validate the suitability of Oritain's Origin Fingerprints for verification of Australian beef and lamb. Origins selected for proficiency testing of the Origin Fingerprints of Australian beef and lamb included samples from Australia and comparative international origins.

Comparative international beef included: Argentina, Brazil, Canada, Indonesia, Italy, Japan, The Netherlands, New Zealand, Pakistan, Scotland, South Africa, Spain, USA, Wales.

Comparative international lamb included: Canada, England, Ethiopia, India, Kenya, New Zealand, Spain, Wales.

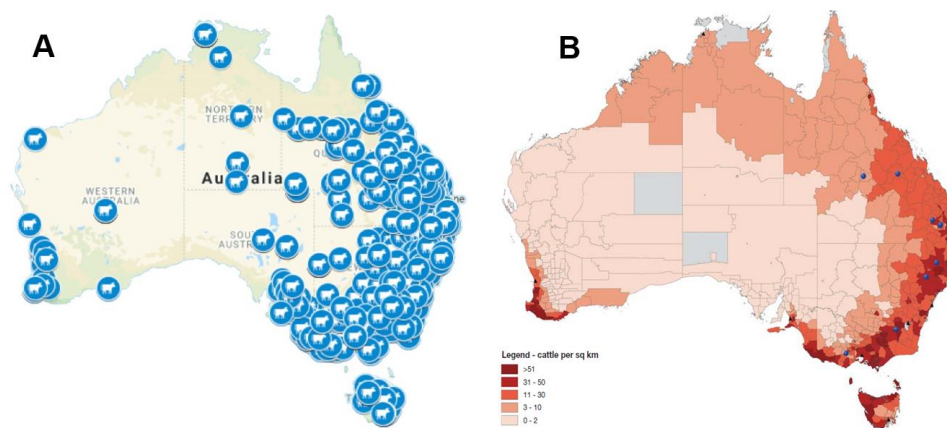
4. Results

4.1 Sampling Adequacy and Sample Analysis

Sampling has been completed to a sufficient frequency and coverage to fully account for natural variance of the Origin Fingerprint for the sampled areas. Analysis for trace element concentrations and stable isotopes has been conducted with the data used to develop amalgamated baseline Origin Fingerprints for the sampled regions as a representation of the Australian Origin Fingerprint for beef and the Australian Origin Fingerprint for lamb.

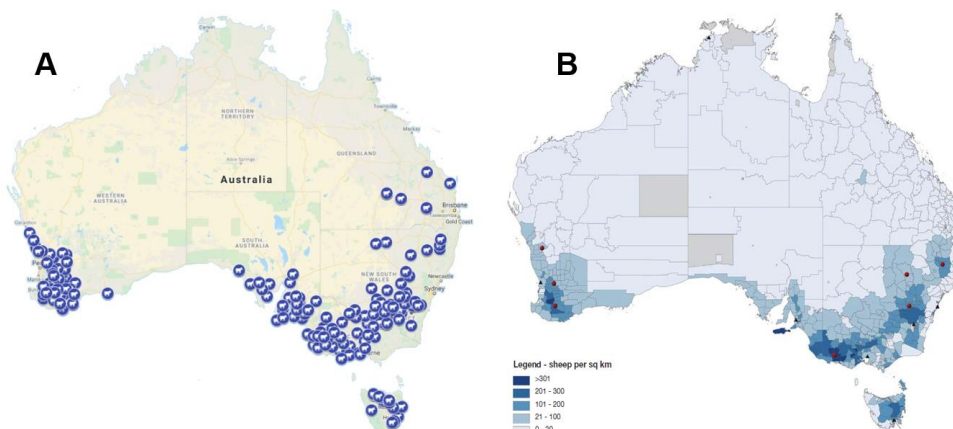
Beef samples collected in New South Wales, Queensland, Victoria, Western Australia, South Australia, Northern Territory and Tasmania covering livestock production areas in Australia (Fig. 5.).

Figure 5: (A) Origin of beef samples in Australia collected and analysed to date (Oritain database), and (B) Australian cattle density (adapted from Behrendt, 2015, commissioned by MLA).



Lamb samples collected in New South Wales, Queensland, Victoria, Western Australia, South Australia and Tasmania covering livestock production areas in Australia (Fig. 6.).

Figure 6: (A) Origin of lamb samples in Australia collected and analysed to date (Oritain database), and (B) Australian sheep density (adapted from Behrendt, 2015, commissioned by MLA).



4.2 Origin Fingerprint

4.2.1. Country of origin specifications

Statistical modelling was utilised to develop specifications of origin for Australian beef and lamb to differentiate the samples based on their country of origin. The Origin Fingerprints developed for Australian beef and lamb are distinct from other origins contained in Oritain's global database.

One of the models used to develop the specifications of origin of Australian beef and lamb is graphically displayed below respectively in Fig. 7. and Fig. 8.

Each data point represents a single sample (defined by concentrations of multiple trace elements and stable isotopes), with samples of the same colour representing the same country of origin. Points which cluster together have similar Origin Fingerprints and groups which are separate have different Origin Fingerprints.

Note: *This model exists in multi-dimensional space; though the Origin Fingerprints may appear to overlap in this 3-dimensional plot, they are resolved in higher dimensions.*

Figure 7: Beef

A statistical model differentiating a subset of origins within the global beef database. Australian beef is represented by dark blue dots. Although origins may occur to overlap in this 3D visualisation, they are resolved in higher dimensions.

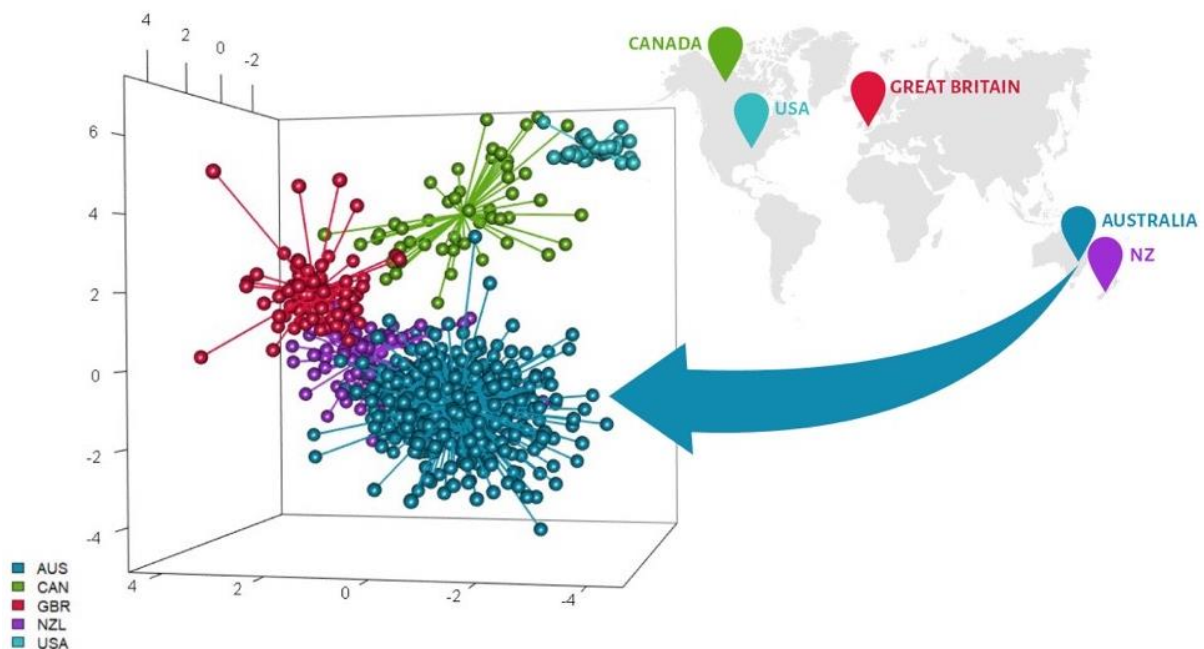
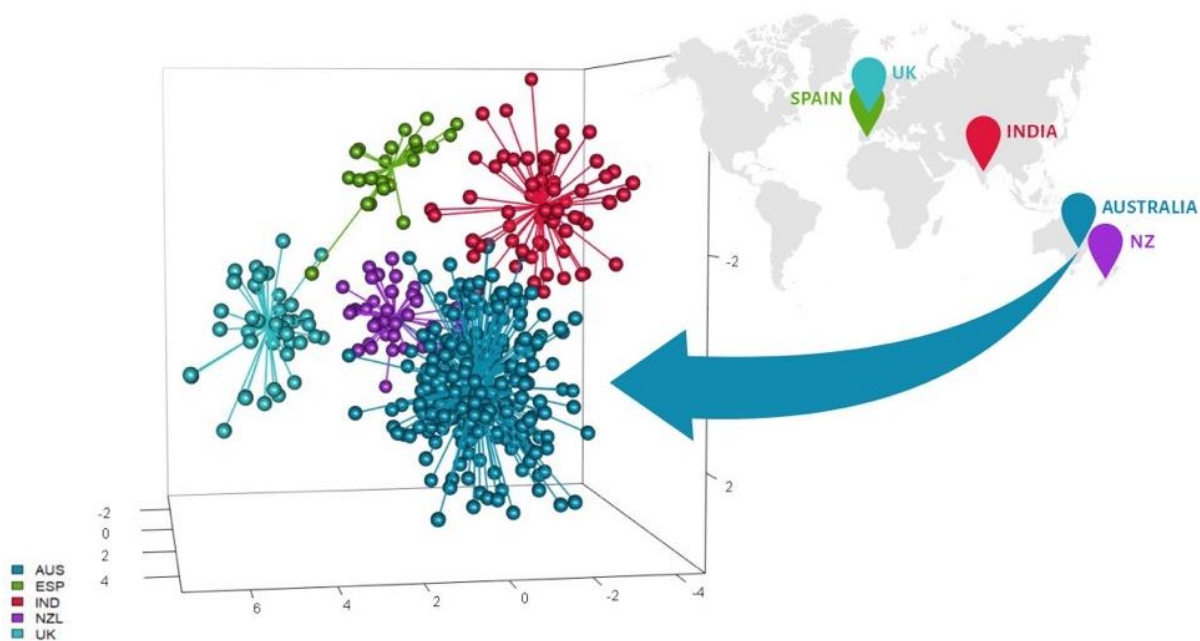


Figure 8: Lamb

A statistical model differentiating a subset of origins within the global lamb database. Australian lamb is represented by dark blue dots. Although origins may occur to overlap in this 3D visualisation, they are resolved in higher dimensions.



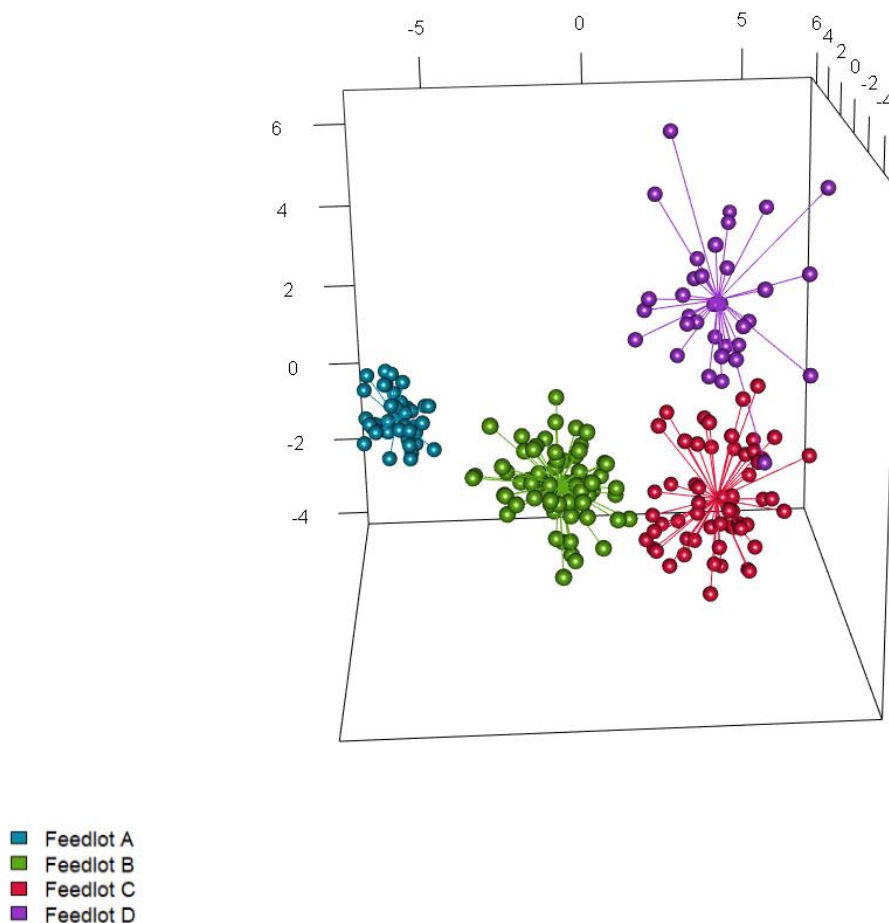
4.2.2. Sources of biogeochemical variability

Following the development of the Australian beef and lamb Origin Fingerprints, further investigations were undertaken.

Below is an example of Origin Fingerprints established based on feedlot of origin (Fig. 9.). These results showed strong potential for verification of origin at a smaller scale than country of origin, however, further development is required to establish feedlot of origin as a “fit for purpose” fingerprint.

Figure 9: Beef

A statistical model differentiating a subset of feedlots within the Australian beef database. Various feedlots are represented by groups of different colours. Although origins may occur to overlap in this 3D visualisation, they are resolved in higher dimensions.



4.3 External Performance Validation

The performance rates were calculated based on the external proficiency testing exercise (Table 1).

Table 1: Results of the external validation for Australian beef and lamb Origin Fingerprints.

	True Positive rate	True Negative rate	False Negative rate	False Positive rate
Australian Beef	100%	89%	0%	11%
Australian Lamb	100%	75%	0%	25%

The performance rates achieved in the external proficiency testing exercise were in line with the project objectives and provide additional evidence for Oritain’s capability to verify beef and lamb of Australian origin. Refer to section 3.3.2 and 3.3.3 above for further details.

5. Key findings

5.1. Sampling

Sampling of primary beef and lamb required to build the baseline Origin Fingerprint was completed successfully. Oritain was able to access a large number of abattoirs that provided samples with sufficient chain of custody to the location where an animal was reared before slaughter. By accessing a large number of abattoirs, Oritain was able to source samples from all major production areas in Australia with sufficient coverage of geographical variability.

5.2. Fit for Purpose

Origin Fingerprints for Australian beef and lamb were developed from the sampling and chemical analysis from an extensive number of samples from around Australia. Chemical data were processed using proprietary statistical methods to ensure that sampling intensities and geographic variabilities were sufficiently captured to determine an Australian country of origin specification for both beef and lamb.

Results of the external testing met the project objectives agreed and established a robust capability to verify Australian beef and lamb. The external validation simulated a real-life auditing scenario where a set of samples that has not been analysed was tested as blinds (origin of samples is unknown to Oritain). This testing confirmed that Oritain has developed “fit for purpose” capability to verify origin of Australian beef and lamb with a high degree of certainty.

6. Conclusion and recommendations

6.1. Capability

Oritain has developed “fit for purpose” Origin Fingerprints for Australian beef and lamb suitable for origin verification. Industry and its stakeholders are now able to test products from any point in the supply chain or in market to verify that Australian labelled beef and lamb are true to their claimed country of origin. Introducing a robust method of detecting fraud while communicating this to supply chain participants acts as a deterrent to dishonest behaviour and drives compliance of truthful labelling.

6.1.1. Australian Origin Fingerprint

In order to maintain the established Origin Fingerprints as “fit for purpose”, it is imperative to conduct regular re-sampling of Australian beef and lamb that will account for any changes due to temporal variability (including seasonal and interannual fluctuations), or other sources of non-geographical variability, such as feed type, that may have meaningful effects on chemical composition of meat. Frequency and scale of these updates will depend on the size of origin of interest and relative importance of non-geographical factors.

6.2. Global marketplace and supply chain monitoring

Recent research conducted by MLA (Project Code: V.MFS.0447 published August 2020) proposes a need to validate the fraud issue for Australian red meat in global markets and supply chains, and the preparation of an industry response, stating the nature and extent of fraudulent misrepresentation of Australian red meat is not accurately known.

Given the potential impact of fraud on the wider industry, it is important that the extent and source of the misrepresentation be quantified. Utilising Oritain’s local and global experience in the red meat industry as well as other industries, the developed “fit for purpose” capabilities for Australian beef and lamb can provide a highly accurate and scientifically valid methodology to quantify, define and proactively manage the problem.

Oritain works across a number of products globally including but not limited to red meat, pork, eggs, dairy, horticulture, aquaculture, wine, honey, leather, cotton, wool, mohair, palm, coffee, cocoa and soy. Via these above product categories, Oritain has vast experience in designing and undertaking such research across global jurisdictions.

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