Product fraud: Impacts on Australian agriculture, fisheries and forestry industries

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In aspiring to reach the National Farmers’ Federation’s target of $100 billion in farm gate value by 2030, Australian producers need to be able to mitigate incidents of product fraud to ensure that trust is maintained with consumers and that producers can capitalise on changing consumer and market trends.

This report, written by Deakin University, explores the range of product fraud cases – from simple substitution or incorrect labelling of a product to more sophisticated methods that result in consumers paying a premium price for a counterfeit product. High-value products such as beef and seafood are particularly at risk of substitution, as well as the use of fillers to increase volume and mislabelling about provenance and quality. The drivers behind product fraud are commonly linked to shortages or constraint of supply in raw ingredients, and while our ability to detect fraud continues to improve, there is a need for a whole-of-supply-chain approach to combat the problem.

But while the problem is real, and on the rise, the report highlights technology solutions that exist and are ready to be deployed along the supply chain, to reduce the incidence of fraud. A plethora of solutions are needed to make an impact on global fraud. A coordinated supply chain approach is an important first step to mitigate the potential risks and protect Australia’s reputation in domestic and global markets.

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Foreword

Maintaining the quality and safety of Australian food and fibre products for domestic and export markets is paramount. Product fraud is on the rise and has the potential to cause significant harm to Australia’s reputation for producing high-quality goods and ultimately reduce returns at the farm gate. Globally, food fraud is becoming a significant challenge, estimated to cost $40-50 billion a year, and $2-3 billion in Australia alone.
Executive summary

Overwhelming evidence indicates that product fraud is a serious issue that has come under increased scrutiny, and that is generally considered to be a growing concern for businesses, governments and law enforcement agencies.

Australians, regulators, producers, retailers and consumers all have an interest in safeguarding products and ensuring they are genuine, and of the highest quality. This study identified that at present there is no consistent definition for product and food fraud. However, it is commonly accepted that ‘product fraud’ and ‘food fraud’ are committed when food is illegally placed in the market with the intention of deceiving the consumer, usually for financial gain. The scale and nature of product fraud in the Australian market is largely unknown and presents major challenges for Australia’s agriculture, fisheries and forestry industries with regards to protecting brands and reputation, and minimising risks to consumers. The objectives of the study were to quantify the current size of the product fraud issue facing Australia’s rural industries and highlight opportunities that exist both domestically and internationally to overcome this problem.

The study ascertained six fraudulent practices based on the internationally recognised broad types of fraud: adulteration, concealment, counterfeiting, dilution, mislabelling and substitution. The scope of analysis and quantification included not only dominant agricultural products but also fisheries, seafood products and wood products. Among those products, beef and veal, wine, and fish, crustaceans and molluscs were identified as having the highest vulnerability to product fraud.

For those industries, the economic costs to Australian agriculture, fisheries and forestry were estimated to be $500m to $650m for meat, $95m to $120m for dairy products, $75m to $100m for fish, crustaceans and molluscs. Estimated costs were also high for sheep meat ($105m to $200m), dairy products ($80m to $160m), wool ($65m to $125m), horticulture ($80m to $120m), and wheat ($85m to $110m), despite their lower vulnerability to fraud. This was in part, because of the volume of product produced, so lower vulnerability to fraud still resulted in high estimated costs.

For those products most vulnerable to product fraud, meat products were prone to substitution of products, use of fillers (i.e. to increase weight or volume) or mislabelling as to provenance, quality or attribute (e.g. halal, organic, free range). There were also instances of expiry date fraud. Wine was commonly subject to counterfeiting, dilution, adulteration and mislabelling of provenance and variety of grapes. Fraud involving fish, crustaceans and molluscs most commonly involved species substitution, but mislabelling of provenance and attribution (e.g. farmed versus wild caught, frozen or fresh) also occurred.

Drivers of product fraud included shortages or constraint of supply in raw ingredients, supply chain complexities, technology (e.g., the use of online trading platforms, which are poorly regulated) and weak penalties. Detection of product fraud has focused on scientific analyses to detect and test the authenticity of products, and broader mitigation strategies such as traceability systems, vulnerability assessment tools and intelligence gathering.

The study found that products are most vulnerable where there is a large difference in value depending on provenance or attributes, and where they are sold in a form that makes verification of the labelling claims (e.g. cuts compared with a whole recognisable item) difficult.

Product fraud results, as with other criminal activities, where opportunities are present, where there is a motivation to cheat and where laws and control systems are absent or insufficient to deter fraudulent practices. Australian food standards laws and regulations seem not to be supported by active surveillance and targeted product authentication testing to beat or deter fraudsters.

No process can guarantee that a product and its supply chain are not the target of fraudulent activity but authenticity testing places emphasis on early detection and prevention, rather than reaction to fraud, allowing Australia’s agriculture, fisheries and forestry industries to have better control of potential fraud.
Internationally, definitions of food and product fraud vary, creating complexity and confusion in addressing the issue. Attempts are being made in Europe to standardise terminology and definitions. Similarly, food safety certification has led to large improvements in the safety and quality of food and food sector ingredients, but the range of schemes in place results in many businesses undertaking multiple audits.

The Global Food Safety Initiative was created to harmonise standards across the global supply chain. This initiative has recently included food fraud in its remit and requires companies to complete a food fraud vulnerability assessment and have a food fraud control plan. A range of databases, guidance documents and other tools exist to assist in the detection and minimisation of food fraud. Similarly, different countries have different legislation and regulations in place to govern food quality and authenticity.

A number of case studies of ways industry and businesses are tackling food fraud and authentication exist. One such example is Beston Global Food Company, which simultaneously has a reputation for producing premium quality dairy products and investing in technology to enable customers to authenticate its products.

Based on our analysis of the landscape with respect to product fraud and authentication, we make a series of recommendations to consider:

- An official Australian protocol and definitions should be set out for fraud types, so that fraud can be more accurately documented and trended.
- An in-depth analysis of fraud detection and prevention measures within selected Australian agriculture, fisheries and forestry industry supply chains should be undertaken to create a more holistic understanding of vulnerabilities.
- An in-depth and comprehensive review of genetic authenticity testing capability of products in Australia should be completed.
- In the UK, Centres of Expertise (CoEs) in food authenticity testing have been established to capture the network of companies and organisations that have the capacity to undertake food authentication services (foodauthenticity.uk/about-centres-of-expertise). The establishment of, and funding for, a similar model should be considered for Australia.
- A research program should be initiated to genetically barcode all Australian-grown grape varieties from all major wine grape-growing regions, and develop and test the latest genetic barcoding methods, to identify effective gene regions for DNA barcoding-based variety identification as a tool for Australia wine authentication.
- Comprehensive surveys investigating levels of food and agriculture product adulteration and species substitution in Australian marketplaces and internationally for exported Australian agriculture species should be urgently undertaken.

Recent studies, including this one, demonstrate that many fraudulent incidents continue to be reported, even in industries/products that are known to be particularly vulnerable to fraudulent practices. Apparently, previous measures taken by companies and government authorities have been shown to be insufficient. Australian agriculture, fisheries and forestry industry responses to our research revealed inconsistent approaches and strategies. Some said they had product fraud prevention measures in place, others seemed less concerned and were unwilling to discuss the fraud issue as it could jeopardise consumer trust in their products.
Attempts by some business operators to obtain unfair advantages over competitors by deceiving them (and/or consumers), and the extension of organised groups’ crime portfolio to cover food and drink, have led to a series of prominent food product fraud cases such as the horse meat scandal in Europe in 2013. The digital dimension (e-commerce of food) further creates opportunities for deceptive and dishonest practices, allowing action from ‘abroad’. The resulting fraud incidents affect confidence in the global food system, with an immediate impact on the functioning of the internal market. The cross-border dimension is often strong as fraudulent operators seek more profit on the biggest-possible scale.

The complex nature of our globalised agriculture, fisheries and forestry supply chains, and the economic motivation to provide cheaper products, increase the possibility of fraud. Faced with this phenomenon, control authorities are losing credibility, companies are losing money and consumers are losing trust, particularly in food products.

Here, we aimed to assess and quantify the vulnerability of Australian food products to determine the aggregate extent of the food fraud issue and provide a quantitative assessment of the impact and cost of food fraud to the Australian agriculture, fisheries and forestry industries, as well as their value chains.

The objective of the study was to quantify the size of the product fraud problem facing Australia’s rural industries and highlight opportunities that exist both domestically and internationally to overcome this problem. The scope of analysis and quantification included not only dominant agricultural products but also fisheries, seafood products and wood products. We focused on assessing and ranking specific products according to their food fraud vulnerability risk perspective against each of the six internationally recognised category classifications of fraud. As well as documenting the extent of known fraud activities and evaluation of product vulnerability, we consolidated data and information collected to provide a quantitative assessment of the impact and cost of product fraud for the Australian agriculture, fisheries and forestry industries.
In completing the study, we used the following five-step approach:

**Step 1: Collect data and information on a product basis**

We assessed and ranked products according to their fraud vulnerability risk perspective. We then evaluated the risk of fraudulent practices occurring against each of the fraud category classifications, as detailed above. Additional factors included were the origin of the product and its physical qualities and composition (solid, liquid, powder or another granular substance), as well as the value and price fluctuation of the product and its ingredients.

**Step 2: Undertake quantitative analysis (volume and value) to quantify the impacts and cost of fraud for each product category**

Using the quantitative data and information on food fraud vulnerability collated in Step 1, and information derived from stakeholder consultations, we prepared a set of parameters that represented the lower and upper bound estimates of fraud for relevant industry product categories.

These parameter estimates are in the form of percentages relative to the total quantity and/or value of what is being produced, traded or consumed over a specified period of time (e.g. seasonally, annually) and in a specific location (e.g. state or regional level), as observed, assessed or assumed. The estimates incorporate activities that likely or plausibly fall within the food fraud category types (substitution, mislabelling, adulteration, counterfeiting, dilution, concealment).

**Step 3: Conduct a ‘stocktake’ of ways industries are currently considering and addressing the fraud issue**

One of the greatest challenges for companies in Australia is product fraud detection. This step identified new and emerging anti-food fraud tools, innovative technologies and authentication detection systems being used and developed by industries. Further, we examined domestic and international policy and regulatory options for governments, industry and the broader value chain to address the product fraud challenge, from the perspective of producers, traders and consumers. This analysis was used to highlight and suggest practical, plausible and doable fraud mitigation measures that can be potentially used in the Australian context.

**Step 4: Identify case studies of ways industry is addressing the fraud issue**

We included a number of selected case studies to highlight current approaches industry and business are taking to combat the fraud issue.

**Step 5: Investigate international initiatives of product fraud mitigation**

These particularly relate to international food standard initiatives being undertaken by organisations such as the Global Food Safety Initiative, among others. This step included research to evaluate the effectiveness of the Australian traceability standard in tracing product movements one step backwards and one step forwards at any point in the supply chain.
What is product fraud?

There is no single, global, statutory definition of product fraud. Product fraud is committed when product is illegally placed in the market with the intention of deceiving the consumer for financial gain.1,2 To put it simply, product fraud deceives consumers by providing them with lower-quality product, against their knowledge and will.

As mentioned, the scale and nature of product fraud in Australian remains largely unknown and presents major challenges for Australia’s agriculture, fisheries and forestry industries in protecting brands and reputation, and minimising risks to consumers. Countries and companies also suffer reputational damage.

This study defines product fraud as a collective term used to encompass food, natural fibre and forestry products. Product fraud can take place at multiple points along the supply chain. To quantify the current impact of product fraud, a careful classification is necessary to assess and determine vulnerability of Australian agriculture, fisheries and forestry product categories, based on internationally recognised broad types. These include:

- Substitution – An ingredient of high value is replaced with one of lower value. This includes, for example, replacing honey with sugar syrup, or extra virgin olive oil with lower-value oil.
- Mislabelling – A product is marketed or labelled to incorrectly portray its quality, safety, species, or geographic origin, for example, by claiming a product is organic when it is not.
- Adulteration – An undeclared ingredient is included in a product to lower production costs or fake its quality, for example, melanine added to baby formula to increase its apparent protein content.
- Counterfeiting – A known brand’s name and packaging is copied and counterfeit product is presented as a legitimate product.
- Dilution – The dilution of milk, premier wines and fruit juices.
- Concealment – For example, marketing non-halal products as halal.

4.1 What product fraud is not

Product fraud is not related to work in the area of Hazard Analysis Critical Control Points (HACCP). HACCP is about the prevention of unintentional or accidental food safety adulteration. HACCP work is science-based and focuses on food contamination and food safety.

Product fraud is also different from and separate to food defence, which is about the prevention of intentional ideologically motivated adulteration, such as would happen in a case of sabotage or bioterrorism.

4.2 Drivers of product fraud

As for other criminal activities, product fraud results where opportunities are present, where there is motivation to cheat, and where control systems are absent or insufficient to deter fraudulent practices.

Fraudulent practices can occur at different points in the supply chain – by individuals, businesses or criminal groups. For example, in 2019, Europol reported the seizure of 150,000 litres of fake olive oil. The criminals, who were raking in up to $12 million each year in criminal profit, modified the colour of low-quality oils to sell them on the Italian and German markets as extra virgin olive oil. Factors that contribute to or facilitate fraudulent practices include:

- Pressure on supply – Shortages of raw ingredients can drive prices up and increase the use of alternative ingredients in product production. The concentration of retailers in global chains can cause pressure on product and food prices, meaning suppliers may cut corners to compete for contracts.
- Supply chain complexities – The length and complexity of today’s global supply chains can lead to a lack of traceability, making product fraud harder to detect.
- Technology – Criminals may use internet online selling platforms to carry out illegal trade or pose as a legitimate business in order to infiltrate products and their supply chains.
- Penalties – Penalties for fraud-related crimes are generally lower than for other criminal activities.
Section 5

Australian agriculture, fisheries and forestry industries

5.1 Overview

Australian agriculture, fisheries and forestry industries employ about 325,400 people (ABS seasonally adjusted data, February 2021), or about 2.5% of the total workforce. Over the past five years, employment in the industry has increased by 2.6%. The value of agriculture, fisheries and forestry production was about $69 billion in 2018-19. Figure 1 profiles the market share claimed by each of the three industries, further broken down by product commodity.

Australia exports more than 70% of the total value of agriculture, fisheries and forestry production.

- For the year 2018-19, the export value of agriculture products was $48.7 billion.
- For the year 2018-19, the export value of fisheries products was $1.5 billion.
- For the year 2018-19, the export value of forestry products was $3.9 billion.

The value of agriculture, fisheries and forestry exports has grown over the last 20 years. Meat and live animals has been the fastest-growing export segment, growing 79% in value over the 20 years, followed by forest products (up 53%) and fruit and vegetables (up 52%).

Export intensity varies across industry commodities – about 95% for wool and cotton, 76% for beef and veal, 71% for wheat, 41% for dairy and 18% for horticultural products. China is Australia’s single largest export market for the agriculture, fisheries and forestry industries, valued at about $16 billion in 2018-19. Asian demand is expected to double between 2007 and 2050, providing opportunities for Australian exporters of high-value, high-quality agricultural and food products. Figure 2 profiles agriculture, fisheries and forestry exports by value (2018-19) for those product categories selected for the study.

The major destinations for agricultural, fisheries and forestry products in 2018-19, as based on value of exports to that country, are shown in Figure 3.
5.2 Product incident, vulnerability and impact assessment

Unanticipated and unintended consequences beyond traditional product/food safety risks must be considered in a product fraud vulnerability assessment. The term “vulnerability” is used instead of “risk” or “likelihood” in the context of this study. Our chosen approach for assessing product fraud vulnerabilities and estimated impacts across agriculture, fisheries and forestry industries is summarised below.

In this study, we used the number of negative media reports relating to product fraud activities as a measure of fraud prevalence. Our primary assumption is that consumers rely on, and are affected by, media information when making purchasing decisions. We conducted a robust literature search investigating reported fraud issues and incidents.

As many experts have acknowledged, a thorough understanding of food fraud should begin with a review of previous reports.5,6 Reviewing historical product fraud reports provides information on global fraud incidents and an understanding of what, where and how fraud is occurring. This study uses information from four databases: Food Fraud Advisors, Rapid Alert System for Food and Feed (RASFF), HorizonScan, and Food Adulteration Incidents Registry (FAIR). These were selected as each has been used in previous studies that have focused on identifying and analysing product fraud, and are widely used by industry and international government agencies.

Limitation of fraud incident sources

Due to the veiled nature of product fraud, the actual frequency of occurrence remains largely unknown.6,7 Reputable sources such as RASFF, HorizonScan and FAIR are essential in providing a better understanding of product fraud incidents and occurrences. However, it is unlikely that all cases of product fraud in global supply chains are captured in these sources given that there will be many incidences of product fraud that will remain undetected or unrecorded. It can be assumed that more product incidents are occurring than are detected, and that all types of fraud are occurring. The scale and type of fraud continually change; as a result, fraudsters continue to operate under the radar and remain undetected, further contributing to detection difficulties.

There are a number of publicly available tools and systems to help companies identify product fraud vulnerabilities in their product supply chains. For the purpose of this study, our method is based on reviewing four commonly published key contributing factors known to be helpful in predicting fraud vulnerability and occurrence.6,8 These contributing factors can be summarised as follows:

**Fraud incident history**

The history of fraud for a particular product can be indicative of future vulnerabilities. This factor generally characterises the potential for product fraud based on the pattern and history of reported fraud occurrences for that product, and the validity or degree of evidence available to substantiate the legitimacy of the fraud reports. Reported fraudulent incidents, often accompanied by media attention, indicate opportunities for fraud.

The volume of fraud reports and incidents related to a product is one factor to consider when assessing its vulnerability. Another factor is the validity or degree of evidence to substantiate the legitimacy of reported fraud issues. Carrying out this assessment is often difficult given the limited information available in the media and public reports, and the often disconnected nature of different reports on the same issue.

**Price**

An important factor when estimating the vulnerability and cost impact of fraudulent practices is knowing how price differences can motivate offenders to commit fraud. Wherever there is a large price difference between different types of a product, there is a risk that cheaper types will be substituted for more expensive types. Market price, especially for products where costs are rising or supplies are tight, has been an indicator in prior fraud research, including into animal and vegetable products.

Given that product fraud is driven by economic opportunity, price can help with assessing the vulnerability of a product to fraud. When prices are uneven or are rising unequally across a class of foods, there is an opportunity for fraudulent product substitution, such as buffalo or horse meat for beef. It is reasonable to assume that high-value products at the producer, wholesale or retail levels are relatively susceptible to fraudulent practices.

**Physical qualities and composition**

According to Wageningen University (The Netherlands) and PricewaterhouseCoopers (PwC),8 for any given food product or ingredient, its physical composition, qualities, production process and supply chain are factors that determine its vulnerability to product fraud. For example, product fraud is generally easier to achieve with liquids than solids, and complex foods with multiple ingredients generally offer greater fraud opportunity than simple, single-ingredient foods or products.

**Prevalence of corruption**

The more prevalent corruption and organised crime are in a country, the more plausible it is that fraudulent ingredients and/or products will pass through any food control systems in place in that country. Several resources are available that provide corruption and organised crime indices by country/region, along with crime threat assessments. For the purpose of this study, we have used Transparency International’s Corruption Perception Indices.4

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Figure 4. Methodology used to assess product fraud vulnerabilities.
### Table 1
Framework for assessing product fraud vulnerability

<table>
<thead>
<tr>
<th>Contributing factor</th>
<th>Vulnerability</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraud incident history</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have fraudulent incidents of similar final products been reported?</td>
<td>No fraudulent incidents related to the product are known</td>
<td>A few fraudulent incidents have occurred specific to the product</td>
</tr>
<tr>
<td></td>
<td>No documented evidence/information of fraud is known</td>
<td>Many fraudulent incidents have occurred specific to this product</td>
</tr>
<tr>
<td></td>
<td>Limited documentation and few media reports are available</td>
<td>Incidents are well known and documented, and have received substantial media attention</td>
</tr>
<tr>
<td>Price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there unusual price differences across products?</td>
<td>Stable pricing and ready product supply that meets the demand</td>
<td>Modest price volatility and variable product supply and demand</td>
</tr>
<tr>
<td>Is there unusual discounted pricing?</td>
<td>High product price</td>
<td>Unusual level of discounted pricing</td>
</tr>
<tr>
<td>Physical qualities and composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is the nature of the product composition?</td>
<td>Solid</td>
<td>Powder or refined substances</td>
</tr>
<tr>
<td></td>
<td>Single-ingredient, primary product</td>
<td>Processed product</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multiple ingredients, complex product</td>
</tr>
<tr>
<td>Prevalence of corruption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>According to the Transparency International Corruption Perception Index, what is the corruption level in the importing countries?</td>
<td>The product is exported to countries with low levels of corruption (rated 1–25 on the index)</td>
<td>The product is exported to countries with medium levels of corruption (rated 26–75 on the index)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The product is exported to countries with high levels of corruption (rated 76 and above on the index)</td>
</tr>
</tbody>
</table>

### 5.4 Framework for assessing the potential economic impacts of product fraud

A useful approach to assessing the impacts of product fraud involves using detailed knowledge and information on how product prices might be expected to behave in response to an increase in quantity supplied as adulterated or as a fraudulent product in a given market. Generally, the availability of adulterated or fraudulent products has the effect of expanding the ‘supply’ of product in a given market in a particular time period.

According to Fairchild et al., the degree of economic impact resulting from the supply-expanding dimension of food product fraud or adulteration would be affected by:

- The percentage of total amount of product adulterated in a given time period
- The percentage of adulterant contained in the adulterated product
- The price elasticity of demand for the product

For any amount of a product identified or determined to be adulterated, a combination of these factors yields an array of percentage unit price changes at the producer and retail levels. A higher percentage of adulteration, and a higher percentage of adulterants contained, would be associated with a greater supply expansion and therefore potentially significant price impacts.

The analytical framework used in this study to assess the likely economic impacts of product fraud in Australian agriculture, fisheries and forestry industries is based on the empirical work undertaken by Fairchild et al. in relation to the economic effects of adulteration of bee honey in the United States. This mainly involves making plausible assumptions about the percentage of total amount of adulterated product in a given time period and the percentage of adulterant contained in the adulterated product.

We then used the empirically estimated price elasticities of demand for the relevant products within this framework to undertake our analysis. It is hoped that such an analysis will foster discussion among Australia’s Rural Research and Development Corporations (RDCs), producers and government agencies, and result in improved understanding of the extent of the fraud issue and its economic impact, fraud monitoring, and measures to mitigate the economic adulteration of products.
### Table 2
Estimated economic cost of product fraud to Australian agricultural and fisheries industries in 2018-19

<table>
<thead>
<tr>
<th>Product</th>
<th>Estimated cost ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef and veal</td>
<td>500 – 900</td>
</tr>
<tr>
<td>Sheep meat</td>
<td>105 – 200</td>
</tr>
<tr>
<td>Pig meat</td>
<td>3 – 6</td>
</tr>
<tr>
<td>Chicken meat</td>
<td>1.5 – 2</td>
</tr>
<tr>
<td>Dairy products</td>
<td>80 – 160</td>
</tr>
<tr>
<td>Wheat</td>
<td>90 – 110</td>
</tr>
<tr>
<td>Coarse grains</td>
<td>60 – 70</td>
</tr>
<tr>
<td>Oilsseeds</td>
<td>25 – 30</td>
</tr>
<tr>
<td>Sugar</td>
<td>38 – 45</td>
</tr>
<tr>
<td>Wine</td>
<td>150 – 205</td>
</tr>
<tr>
<td>Wool</td>
<td>105 – 125</td>
</tr>
<tr>
<td>Cotton</td>
<td>65 – 70</td>
</tr>
<tr>
<td>Horticulture</td>
<td>60 – 120</td>
</tr>
<tr>
<td>Fish</td>
<td>20 – 35</td>
</tr>
<tr>
<td>Crustaceans and molluscs</td>
<td>55 – 105</td>
</tr>
</tbody>
</table>
In 2019, there were 89,400 agricultural businesses, up 5% from 2018. There were 384 million hectares of agricultural land, up 2%. The gross value of Australian agriculture production was $61 billion in 2018-19, despite drought conditions.

### 6.1 Beef and veal

#### 6.1.1 Sector overview

- The Australian beef cattle herd was 22.4 million head in 2018-19.
- Australian beef cattle farmers produced 2.35 kt of beef and veal in 2018-19.
- Australia produces only 4% of global beef production, but accounts for about 16% of world trade and has consistently been one of the top three largest exporters for several decades.
- Ongoing drought conditions limited growth of Australian livestock numbers in 2018-19. As at 30 June 2019, the national beef cattle herd fell 6% to 22 million following drought-related destocking.
- Townsville become Australia’s largest cattle export port in the 2019-20 financial year, overtaking Darwin for the first time in a formal 12-month period.
- Global beef consumption is forecast to grow at an average rate of 1.1% a year out to 2023.
- Data to March 2020 indicates that the overall impact of COVID-19 on Australia’s beef exports has been small.
- Organic beef products, which generally attract higher prices and profit margins, represent a potential growth area for domestic beef cattle farmers.
- According to the ABS (Beef Retail Prices, 25 March 2020), the average retail price of beef for 2019 was a new record, at $20.64/kg. This was a $1.20/kg rise (6.3%) on the previous year. Retail beef prices have risen since 2014, and experienced growth in 23 of 25 quarters. As a point of reference, since 2013, the average retail price of beef has increased 35%, while pork has gone up only 12% and chicken only 1% over the same period.

#### 6.1.2 Reported incidents of product fraud

- Two fraudulent horse meat shipments intended for unauthorised sale were seized in the Netherlands and Denmark. The seizures reinforced concerns among food safety experts that criminals will target food supply chains disrupted by the COVID-19 pandemic (7-5-20).
- A study of beef fraud incidents over a 20-year period (1997-2017) found that counterfeiting is the most common type of fraud for beef. The researcher explained that for beef, counterfeiting refers to illegal production, namely beef produced in unapproved premises, without inspections and/or with missing or fraudulent documentation, such as health certificates or entry certificates. The same study reported that the most vulnerable part of the supply chain was primary processing, which is where the animal is slaughtered and non-food parts removed, including hide, hooves and head (24-4-20).
- Twenty-six per cent of beef sausages in a survey of pork, chicken and beef sausages in China were found to be mislabelled or adulterated. The most common adulterant was duck meat (13-1-20).
- Two meat processor executives in the US pleaded guilty to selling more than US$1 m worth of ‘ground beef’ that was illegally adulterated with cow heart. They admitted hiding cow hearts from government inspectors (26-9-19).
- A meat wholesaling business in New York allegedly spent years removing USDA ‘Choice’ grade stickers from its beef and replacing them with counterfeit ‘Premium’ grade stickers (24-9-18).
- A 2019 study in Egypt identified a rate of 87% contamination of ground red meat products (presumed beef with chicken or donkey meat).
- More than one-fifth of meat samples from 487 retail businesses tested in the United Kingdom in 2017 were found to contain meat species other than the one on the label. Minced beef meat was the most common adulterant across all samples (5-9-18).
- In China, a 2018 study found 35% of buffalo meat products had been adulterated with beef, pork meat or duck meat.
- A 2018 study in Canada using DNA barcoding analysis detected contaminating or undeclared meat species and labelling errors in 20% of sausage products. Noteworthy was the finding that 6% of beef sausages also contained pork, and one pork sample was found to contain horse meat.
An Irish company was fined for falsely declaring that imported meat imported from India for slightly lower prices than beef but transported under fraudulent cargo waybills (14-11-16). Fraudulent paperwork supplied by veterinarians and sale of the Authorities. It included animal theft, illegal slaughtering, organic status and premium breeds of beef, are considered highly vulnerable. Misrepresentation of meat species is a common type of food fraud and is expected to continue, illegal slaughtering is also common in some countries. Switching of inspection labels is thought to be common in many countries and is easily accomplished by criminals seeking financial gain. Vulnerability to fraudulent practices is expected to remain high as long as the large price difference remains.

Changing expiry dates on frozen food is a relatively easy way to commit and one that is difficult to detect. This type of fraud is likely to continue, especially for high-value frozen meat products. Australian cattle and beef prices are expected to soar as herd numbers drop very low. As local beef prices rise, there is an increased risk of fraudulent activity for this food type. Because of the low price in other markets, there is a risk of illegal imports and misrepresentation of country of origin. As prices rise, the vulnerability risk of fraudulent activity rises, with a high likelihood of substitution of lower-quality meats and cheaper species for more expensive meats. Specialty meats, including organic, halal and premium breeds of beef, are considered highly vulnerable. Misrepresentation of meat species is a common type of food fraud and is expected to continue, illegal slaughtering is also common in some countries. Switching of inspection labels is thought to be common in many countries and is easily accomplished by criminals seeking financial gain. With cattle beef meat about twice the price of buffalo meat, there is a very significant risk of fraudulent misrepresentation of buffalo as beef in Asian markets. Buffalo meat and cattle beef meat are similar, and the availability and price of buffalo in Asia makes it a perfect adulterant, diluent or substitute for beef. Where there is a price difference between locally raised beef and imported Australian beef, there is a vulnerability of fraudulent practices, particularly misrepresentation of country of origin. Media reports have stated that formalin (to extend shelf life) is routinely used to help preserve meat in countries with a lack or absence of refrigeration, but the extent of this practice is unknown. This type of illegal adulteration is believed to be common and is expected to continue in some developing nations while enforcement remains a challenge. It is thought to be relatively uncommon in more developed countries. PriceWaterhouseCoopers (PwC) Agribusiness Leader Craig Heraghty said: “It is notoriously difficult to put a finger on the exact meat fraud figure” (November 2019).

### Table 3

<table>
<thead>
<tr>
<th>Fraud type</th>
<th>Examples of known fraudulent activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mislabelling</td>
<td>False labelling regarding the country of origin, variety (e.g. Wagyu), organic status and animal-raising practice (e.g. grass-fed)</td>
</tr>
<tr>
<td>Tampering with frozen beef use-by dates</td>
<td></td>
</tr>
<tr>
<td>Adulteration and substitution</td>
<td>Buffalo meat as an adulterant for beef</td>
</tr>
<tr>
<td>Adulteration of minced beef product with cheaper meats or fillers</td>
<td></td>
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<tr>
<td>Addition of ground offal to ground muscle meat</td>
<td></td>
</tr>
<tr>
<td>Undeclared or illegal veterinary drugs</td>
<td></td>
</tr>
<tr>
<td>Addition of illegal chemicals such as formalin to meat products to increase shelf life</td>
<td></td>
</tr>
<tr>
<td>Dilution</td>
<td>Addition of water and other fillers to increase the weight and/or volume of beef product</td>
</tr>
<tr>
<td>Concealment</td>
<td>Marketing non-halal beef meat as halal</td>
</tr>
</tbody>
</table>

Fraud types and examples of how they are carried out for beef

#### 6.1.3 Vulnerability of beef andveal to fraud

Beef is highly vulnerable to food fraud practices in most parts of the world. Beef is most vulnerable to the fraudulent practices of mislabelling and adulteration with cheaper meats. Fraud vulnerability is likely to remain high, especially in food service where the purchaser cannot easily verify the source of the meat. Reports have revealed that buffalo meat has emerged as a popular adulterant for cattle meat in Asia, and this is likely to impact Australian-exported beef products. Buffalo meat is also reportedly a common adulterant or replacement for beef in South East Asia, while donkey meat is an emerging concern in the Middle East and horse meat remains a potential adulterant in Europe. Australian grass-fed beef continues to attract much higher prices than conventional beef. Where there is a large price difference between different types of meat, there is a risk that cheaper types will be substituted for more expensive types. As the demand for grass-fed beef continues to grow, this risk will increase. This type of fraud is considered difficult to detect. Organic beef is significantly more expensive than conventional beef and is at risk of food fraud – conventional beef can be misrepresented as organic beef. Other types of fraud include misrepresentation of the grass-fed/pasture-raised/grain-fed status, the variety (e.g. Wagyu, Angus), and the origin. Wagyu, cheaper buffalo meat substituted for cattle beef meat is very high in Indonesia. In addition to species misrepresentation, claims about the fresh/Frozen status and the provenance are at risk of being fraudulent. Wagyu beef has become very popular with consumers. Japanese Wagyu is purebred and competes with meat from Australia that is not purebred Wagyu. More than 95% of Australian Wagyu cattle are crossbred with other breeds. Japanese Wagyu is double the price of Wagyu from other countries, including Australia. There is a very high likelihood that unscrupulous traders, wholesalers and restaurateurs will substitute cheaper half-Wagyu or even non-Wagyu beef from other countries for Wagyu.
6.2 Sheep meat

6.2.1 Sector overview

- There were 66 million sheep and lambs in Australia (down 7%) as at 30 June 2019. In 2018-19, Australia produced 732 kt of sheep meat (lamb and mutton). Australia produces a small portion of the world’s sheep meat supply but accounts for almost 40% of exports and is the largest supplier to the global market.
- In most markets, lamb and mutton are niche components of consumer diets compared with beef, poultry and pork. In 2018-19, 489 kt (about 67% of the sheep meat Australia produced) was exported, with the remaining used for domestic consumption.
- ABS Lamb Retail Prices: The average retail price of lamb for 2019 was a new record at $117.76/kg. This was a $1.89/kg rise (12%) on the same period in the previous year. Retail lamb prices, similar to beef, have risen since 2014 and experienced growth in 16 of 20 quarters, according to the ABS. Retail lamb prices have increased by 40% since 2013 and lamb has developed a growing premium between it and protein rivals, such as pork and poultry.
- Australian sheep meat (lamb and mutton) export volume to China increased from 121 kt in 2017-18 to 150 kt in 2018-19, a 24% increase.

6.2.2 Reported incidents of product fraud

- The consumers’ association of the Netherlands reported that a survey of 150 fraud-sensitive food products found more than 20% were not as they should be. Manuka honey, lamb and extra virgin olive oil were the worst affected (27–9–16).
- According to research conducted in the Netherlands, lamb is not always 100% lamb. Six out of 57 butcher shops were found to be selling unpackaged lamb that they had mixed with turkey meat or beef (2016).
- In the UK, consumer organisation Which? reported that 40% of 60 takeaway meals that were supposed to contain lamb contained other lamb (2014).13, 15, 16

6.2.3 Vulnerability of sheep meat to fraud

Lamb is considered highly vulnerable to product fraud. Reported incidents indicate that misrepresentation of meat species occurs especially in minced lamb products. Species substitution, organic lamb status, halal lamb status, age of animal (mutton/lamb), animal-raising practice (e.g. grass-fed) and adulteration of minced lamb with other species or fillers are all possible.

Goat meat is reported to be commonly substituted for lamb in markets where goat is cheaper. In markets where goat is more expensive, sheep meat is commonly substituted for goat. In markets where lamb has high value, it should be considered at high risk of product fraud. In markets where lamb has a high price, it is vulnerable to fraudulent adulteration with cheaper meats when in minced form. The likelihood of this type of fraud occurring is expected to remain high. New Zealand lamb attracts a premium in some Asian markets and is at risk of being counterfeited (replaced by cheaper lamb from other sources).

6.3 Pig meat

6.3.1 Sector overview

Nationally, there were two million pigs in Australia in 2018-19 (down 8%), with the herd size impacted by decreasing pig meat prices and rising feed costs. In 2018-19, Australian pork farmers produced 444 kt of pig meat.

6.3.2 Reported incidents of product fraud

- In China, 26% of meat sausages in a survey of pork, chicken and beef sausages were found to be mislabelled or adulterated. The most common adulterant was duck meat (13–1–20).
- Fake export certificates for Canadian pork meat were found to contain banned drugs (29–6–19).
- US border authorities intercepted 500,000 kg of prohibited pork products being smuggled from China. Pork imports from China are prohibited to protect the US pork industry from African swine fever, which is present in China (15–3–19).
- More than one-fifth of 665 meat samples from 487 businesses tested in the UK in 2017 were found to contain meat species other than the one on the label. Pig meat was among the samples most affected (5–9–18).
- An advertisement from a leading Australian smallgoods producer was challenged by the Australian Competition and Consumer Commission after the campaign was accused of misleading consumers to think its pork product is at risk of adulteration with cheaper meats or fillers. Frozen meat is at risk of expiry date fraud and smuggling. Fraudulent origin claims (‘local’ product) and claims about genetically modified food sources are considered highly likely for pork and smallgoods products. A large supermarket chain in Britain has pledged to sell only pork and meat products raised without genetically modified feed. There is a risk that products raised using genetically modified (GM) feed will be misrepresented as being raised without genetically modified feed. Amid growing consumer demand for pork raised in better animal welfare conditions, a large Danish pork supplier has called on its farmers to provide more ‘higher welfare’ animals. The demand for humanely raised animals is expected to continue to grow in the developed world. Where there is a large price differential between ‘humane’ and conventionally raised meat, there is an incentive for fraudulent misrepresentation of growing conditions. This trend is expected to continue.

Consumer demand for locally grown pork products is increasing in the US. Where a premium price is charged for ‘local’ foods, fraudsters will be tempted to misrepresent the origin of their pork products.

6.3.3 Vulnerability of pig meat to fraud

Pork is generally reported to be at medium risk of food fraud in countries where it has a high value. Where there is a price difference between locally raised pig meat products and imported pig meat products, there is a risk of fraudulent misrepresentation of origin. Like other forms of meat, minced pork product is at risk of adulteration with cheaper meats or fillers. Fraudulent origin claims (‘local’ product) and claims about genetically modified feed sources are considered highly likely for pork and smallgoods products. A large supermarket chain in Britain has pledged to sell only pork and meat products raised without genetically modified feed. There is a risk that products raised using genetically modified (GM) feed will be misrepresented as being raised without genetically modified feed.
6.4 Chicken meat

6.4.1 Sector overview
The chicken meat sector has a strong presence in rural and regional communities across Australia, directly employing about 58,000 people. The chicken meat industry purchases about 5% of all grain grown in Australia. Australian chicken meat production was 1,240 kt in 2018-19. The Australian chicken meat industry is worth $2.87 billion (gross value of production 2018-19), up from $2.75 billion in 2015-16. The industry has a domestic retail value of about $6.6 billion. There is a primary focus on meeting the demands of domestic consumers. Growth in production and demand for free-range chicken meat has been particularly strong over the past five years (about 15% of the total market) and this trend is expected to continue.

Chicken meat production in Australia is dominated by a small number of large, vertically integrated, privately owned businesses, Ingham’s Enterprises (public company) and Baiada Poultry (private company). Sales of meat and related species (e.g. turkey).

6.4.2 Reported incidents of product fraud
- A chicken wholesaler in the UK was found to have relabelled frozen chicken to make it appear two years fresher than it was (10-1-19).
- In a Canadian study, 100 raw meat sausage sold from retail outlets as single-meat species products (beef, pork, chicken or turkey) were analysed. Chicken was found to have been substituted for turkey in five turkey sausage products that contained no detectable turkey. Conversely, 20% of chicken sausages contained turkey and 5% contained beef (2018).
- A poultry supplier in Belgium was accused of falsely claiming ‘organic’ status and tampering with expiry dates (14-5-18).
- Authorities found an unrefrigerated vehicle overloaded with raw chicken in Ottawa, Canada. The chicken processor was charged with breaching food regulations (25-1-17).
- A poultry producer in Ontario, Canada appeared in court after being charged with fraudulently misrepresenting conventional chicken meat as ‘certified organic’ (24-10-16).
- A study in Italy detected bovine DNA in 20 out of 36 chicken sausages, and conversely five out of 12 pork-bovine pâté products contained chicken (2015).
- In Iran, a study collected samples of raw hamburgers, presumed to be beef, from 915 restaurants and supermarkets. Results showed that 98% of the hamburgers contained undeclared chicken meat. The primary reason for this type of adulteration was thought to be the lower price of chicken meat compared with beef, and the ready availability of chicken waste products (2014).
- In a comprehensive analysis of goat dairy products from Italy, 80 samples, including cheeses, yogurts and milks, were examined. The study found a mislabelling rate of 80%. (2017).
- Six people in Australia were arrested for their roles in a large and long-term criminal operation that stole Australian baby formula and exported it for illegal sale in China, where it sells for approximately three times its Australian price (21-10-19).
- In Pakistan, 5,200 litres of impure, adulterated milk was disposed of by authorities after it was found to contain polluted water, urea and harmful chemicals (3-6-20).
- A study conducted in Greece investigated the region of origin for cow and goat dairy products. Forty goat dairy products commonly consumed in Greece were tested. Various concentrations of cow milk, from 0.01% to 90%, were detected in the goat milk samples. Only two samples out of 40 contained only goat-specific product, with 36 (90%) found to include cow-specific products in addition to goat product (2018).
- Regulators in Armenia uncovered sour cream adulterated with undeclared vegetable oil (8-4-19).
- Fake paneer cheese made with cottonseed oil and skim milk powder was found in India (18-9-19).
- Whole milk powder of a certain brand was banned for sale throughout Argentina after it was found to have incorrect protein and fat content, and was therefore deemed inauthentic (14-3-19).
- Nineteen people were arrested in China, accused of producing and long-term criminal operation that stole Australian baby formula and exported it for illegal sale in China, where it sells for approximately three times its Australian price (21-1-19).
- In Brazil, a company was prosecuted for selling cheese adulterated with added water and maize starch (19-3-19).
- Counterfeit brands of baby formula were seized in China, with nine suspects arrested (10-4-16).

6.4.3 Vulnerability of chicken meat to fraud
Chicken, as one of the most inexpensive meat commodities, is reported to be frequently used as an adulterant in other higher-value meat products, but is occasionally adulterated with related species (e.g. turkey).

The likelihood of food fraud for chicken depends heavily on local prices, local demand and biosecurity incidences like bird flu. In most countries, the risks are generally lower than for other types of meat. Pheasant countries in tropical areas are expected to have trouble raising chickens profitably as climate change worsens, and this will increase the risk of food fraud for chicken in these areas over the long term.

In developed countries, the most likely forms of fraud are misrepresentation of organic status, sustainable status, ethical (anti-slavery) or animal welfare status, and, for some markets, country of origin. Frozen chicken has been affected by expiry date fraud.

Organic products are considered to be at very high risk of fraud and this risk is expected to remain high in the medium-to-long term. Purchasers of organic food should carefully verify certification documents with the certifying body to minimise exposure to this type of fraud.

6.5 Dairy products

6.5.1 Sector overview
There are over 6,000 dairy farms in Australia. The national herd is estimated at 1.7 million dairy cows. Australian domestic production of dairy product in 2018-19 was:
- Milk: 8,795 ML
- Butter: 73.3 kt
- Cheese: 381 kt
- Skim milk powder: 177 kt
- Whole milk powder: 475 kt

Dairy farmers produce 9,539 million litres of whole milk per year, with the farm gate value of milk production being $4.3 billion. Australia exports about 34% of its annual milk production (Dairy Australia, Farm Facts 2016). Dairy is the third-largest agricultural industry in Australia, and had exports worth $3 billion in 2015-16 (Dairy Australia, Farm Facts 2016). Australia accounts for 6% of the world trade in dairy products, behind New Zealand (38%), the European Union (33%) and the US (12%). About 36% of milk produced in Australia is exported...

6.5.2 Reported incidents of product fraud
- In Pakistan, 5,200 litres of impure, adulterated milk was disposed of by authorities after it was found to contain polluted water, urea and harmful chemicals (3-6-20).
- A study conducted in Greece investigated the region of origin for cow and goat dairy products. Forty goat dairy products commonly consumed in Greece were tested. Various concentrations of cow milk, from 0.01% to 90%, were detected in the goat milk samples. Only two samples out of 40 contained only goat-specific product, with 36 (90%) found to include cow-specific products in addition to goat product (2018).
- Regulators in Armenia uncovered sour cream adulterated with undeclared vegetable oil (8-4-19).
- Fake paneer cheese made with cottonseed oil and skim milk powder was found in India (18-9-19).
- Whole milk powder of a certain brand was banned for sale throughout Argentina after it was found to have incorrect protein and fat content, and was therefore deemed inauthentic (14-3-19).
- Six people in Australia were arrested for their roles in a large and long-term criminal operation that stole Australian baby formula and exported it for illegal sale in China, where it sells for approximately three times its Australian price (21-1-19).
- In Brazil, a company was prosecuted for selling cheese adulterated with added water and maize starch (19-3-19).
- Whole milk powder of a certain brand was banned for sale throughout Argentina after it was found to have incorrect protein and fat content, and was therefore deemed inauthentic (14-3-19).
- Nineteen people were arrested in China, accused of producing and long-term criminal operation that stole Australian baby formula and exported it for illegal sale in China, where it sells for approximately three times its Australian price (21-1-19).
- In a comprehensive analysis of goat dairy products from Italy, 80 samples, including cheeses, yogurts and milks, were examined. The study found a mislabelling rate of 80%. (2017).
- An examination of alteration of sheep milk products in Iran found high levels of substitution with milk from other species. Using species-specific DNA analysis, only 28% of the yogurt samples and 20% of the cheese samples contained pure sheep milk, with both cow and goat milk identified as adulterants (2016).
- Eighteen people in Australia were arrested in China, accused of re-packingaging expired milk powder into smaller packages for resale (25-10-16).
- Counterfeit brands of baby formula were seized in China, with nine suspects arrested (10-4-16).
6.5.3 Vulnerability of dairy products to fraud

Dairy products are extensively reported to be at high risk of fraudulent adulteration, substitution and dilution in Asia, with incidents frequently reported in India, Pakistan and China. The study identified that fraud in dairy products varies significantly from market to market and across different places. Probiotic dairy products are reported to be at medium-to-high risk.

Baby formula
Baby formula and its main ingredient milk powder are considered to be at very high risk of food fraud. Fraud types include adulteration with materials that increase the apparent protein content (famously melamine but there are others). Date code tampering and counterfeiting of popular brands is also reported to be extremely common. The illegal procurement, smuggling and supply of baby formula is a common type of food fraud. Black and grey market operations are common, as is counterfeiting of premium brands and frauds that involve changing expiry dates. Baby formula remains at high risk of food fraud and this is expected to continue.

Cheese
Cheese is reported to be at varying risk of food fraud in different markets and at different times. In developed countries, the biggest risks are for cheeses marketed with specific claims, such as vegetarian, halal or organic, or with a country-of-origin claim. Reports suggest that species substitution is likely to occur for non-cow cheeses such as sheep milk cheese and goat milk cheese.

Probiotics
Probiotic dairy products such as yogurt command a premium price and are considered highly vulnerable to fraudulent practices, as the probiotic components are indiscernible to consumers. Experts predict that there is a real and growing risk of a greater number of probiotic products that don’t live up to what is claimed on the packaging entering the marketplace.

6.6 Wheat

6.6.1 Sector overview
Wheat is one of Australia’s major crops and one of the most important grain crops in world commerce. Wheat is a cereal grain used for human consumption and animal feed. Australia produced about 17 million tonnes in 2018-19, with a gross production value of $6.2 billion.

While wheat remains the largest broadacre crop in Australia, production was down 16% from 2017-18 and at its lowest level since 2008. Production varied across the country, decreasing in all states except Western Australia. In 2018-19, Australia had an average about 10 million hectares under production, of which 9.8 million tonnes was exported (92%).

6.6.2 Reported incidents of product fraud
Wheat fraud incident reports are often related to smuggling, government subsidy scheme fraud and fraudulent trade documents, such as forged organic certificates.

- A survey of Argentine durum wheat pasta found that 75% of samples contained non-durum wheat (1-6-20).
- Reports of fraud and theft at government ration stores surfaced in India. The reports suggested that grains were stolen and that rotten and expired grain products, including wheat and rice, were sold (29-2-20).
- In India, a report determined that high-quality wheat that was destined to be distributed to the poor in India was extracted from storage facilities belonging to a government procurement agency (30-8-18).
- In Italy, 11,000 tonnes of conventionally grown durum wheat was found to be misrepresented as organic, by using fraudulent certification documents. By the time the fraud was uncovered, the wheat had been made into pasta and shipped to customers in Europe and the US (9-10-16).

6.6.3 Vulnerability of wheat to fraud

There are large differences between the prices of high-quality wheats and the lowest-quality wheat in the Australian market, with high-protein lines selling for more than $50 per tonne more than lower-protein milling grains. Wherever there is a large price difference between different grades of wheat, there is a risk that cheaper grades will be blended with more expensive grades, because even very low levels of adulteration can be very profitable in large-volume commodities.
6.7.2 Reported incidents of product fraud

- In the US, a Missouri farmer pleaded guilty to selling conventional corn and soybeans as organic over a two-year period (19-12-18).
- The European Rapid Alert System for Food and Feed reported fraudulent animal feed adulteration with ruminant feed additives such as yeast and urea, added to increase the apparent protein content (27-9-18).
- Worrying levels of mycotoxins of various types were found in maize destined for animal feed in Poland (15-1-18).
- One of the larger organic certifiers in the US announced it would require pre-warning for all shipments of imported organic grain following the detection of fraudulently certified ‘organic’ corn and soy imports (2017).
- Legal action was taken against an animal feed manufacturer which is dangerous to animal health (3-1-17).
- Analysis of 86 maize samples in Poland found that about 50% of the samples contained detectable levels of mycotoxins, which are dangerous to animal health (3-1-17).
- In the UK and Ireland, 64% of samples of wheat for animal feed were found to contain mycotoxins (7-12-16).
- In China, a major distributor of specialty animal feed was sued by its Californian supplier for selling locally made counterfeit feed. There were also claims that some of the feed was adulterated with locally grown soybean meal (4-10-16).
- More than 90 cases of mislabelled animal feed were identified by authorities in Ireland (18-6-16).

6.7.3 Vulnerability of coarse grains to fraud

Coarse grains are considered generally to have low- to medium vulnerability to fraud, except for non-genetically modified and organic maize in North America, where demand is significantly outstripping supply. The European Union has approved 11 strains of genetically modified maize for human and animal feed, although in practice the maize is expected to be used only for animal feed. With more GM maize being grown in Europe, there is an increased risk of it being fraudulently used within non-GM supply chains. There has been a huge increase in the number of gluten-free food products launched worldwide in the past few years; this trend is expected to continue. The prices of specialist gluten-free grains such as buckwheat, quinoa, sorghum and millet, and sugar-replacement products are expected to rise as demand increases dramatically. As prices rise, there is an increased risk of fraudulent activity, especially in specialty flours that can be diluted with cheaper substitutes to improve profitability.

More commentators are warning that organic grain fraud is “rampant” in the US, threatening non-GM meat and dairy producers. Breadfruit is predicted to become the next superfood, with breadfruit flour being a naturally gluten-free alternative to traditional baking flours. Breadfruit trees take about five years to begin producing fruit and there are limited commercial crops, so if breadfruit products become popular, there are likely to be supply issues, which can provide an incentive for fraudulent adulteration or misrepresentation. Counterfeiting of specialty products and dilution with cheaper fillers such as soybean meal are both considered common types of food fraud.

6.8 Wine

6.8.1 Sector overview

Wine production in Australia was 1,314 ML in 2018-19. Domestic consumption was 510 ML. Australia has more than 2000 wine exporters and globally it is the fifth-largest exporter of wine. About 60% of total production is exported. Export growth has been strong in higher-priced products, reflecting growing demand for Australian premium wines.

6.8.2 Reported incidents of product fraud

- Authorities in Italy, working with Europl as part of Operation GPSION IX, seized a counterfeit premium wine operation. Empty bottles of premium wines were collected from restaurants, then refilled with cheap wine. The ‘fakes’ were sealed with corks and counterfeit capsules and seals. The bottles were sold using an online auction platform for up to €1000 per bottle (30-6-20).
- A wine supplier in China was found guilty of infringing trademark laws. Almost 10,000 bottles of fake Bordeaux wines were seized from a trade show in China (May 2019).
- 750,000 litres of Prosecco wine were seized by authorities in Italy after two winemakers were found to have added diluents during production (13-12-18).
- More than 14,000 bottles of counterfeit Australian Penfolds wine were seized by police in Shanghai following complaints from Australia’s Treasury Wine Estates (TWE) to Alibaba that some of its retailers were charging “extraordinarily low prices”. The fake Penfolds wine was being sold through Alibaba’s online market Taobao. Five online retailers were charged with selling fake Penfolds wine to karaoke bars (28-3-18).
- A raid on a warehouse in Zhengzhou province in central China uncovered more than 50,000 bottles of counterfeit Australian Penfolds wine, worth 18 million yuan (€2.3 million) (28-3-18).
- A New Zealand wine company and three of its directors were charged with export fraud (a total of 156 wine fraud charges). The charges related to sauvignon blanc and pinot noir varieties from Waipara and Marlborough estates made between 2011 and 2013. Among the allegations were that false statements were made about the vintage of a wine, or where it was produced, when the company was applying to send product overseas. The wines were reported to have been exported to Australia, the UK, Japan, Fiji and Thailand by Southern Boundary Wines (3-1-17).
- A Forbes article described persistent wine fraud as an epidemic in China, claiming that 50% of wine exceeding US$35 per bottle in the country is counterfeit, and that an estimated 30,000 bottles of bogus wine are sold every hour in China (2017).
- In the US, wine fraudster Rudy Kurniawan was sentenced to 10 years in jail and ordered to pay US$20 million for his role in selling millions of dollars’ worth of fake wine. In 2006 alone, it is believed he sold up to 12,000 bottles at auction, worth US$24.7 million. The fake wines are believed to have been produced in Indonesia (7-4-14).
- A wine supplier in China was charged with export fraud (a total of 156 wine fraud charges). The charges related to sauvignon blanc and pinot noir varieties from Waipara and Marlborough estates made between 2011 and 2013. Among the allegations were that false statements were made about the vintage of a wine, or where it was produced, when the company was applying to send product overseas. The wines were reported to have been exported to Australia, the UK, Japan, Fiji and Thailand by Southern Boundary Wines (3-1-17).

6.8.3 Vulnerability of wine to fraud

For high-priced specialty liquid products such as wine, there is a high risk of fraudulent dilution and substitution, and experts expect this to increase as demand increases. Common types of wine fraud include counterfeiting, dilution, adulteration and mislabelling of the country of origin or the variety of grapes.

Wine can be adulterated with undeclared or illegal additives such as dyes or preservatives, or with the addition of alcohol from non-grape sources. China is one of the fastest-growing wine-consuming countries in the world and an increasingly important market for foreign wine suppliers. France and Australia are the two dominant wine suppliers to the Chinese market. The reported prevalence of fraudulent wine in the Chinese market creates uncertainty among consumers and can damage the reputation of Australian producers and suppliers.

Australia’s wine exports to China alone are valued at $1 billion. According to some estimates, counterfeiters are an even bigger business. Experts predict that potential losses to the global wine industry due to counterfeiters could reach an estimated US$3 trillion by 2022. In China alone, some experts claim up to 70% of bottles sold are fraudulent. For exporting countries like Australia, counterfeited wines displace market share, damage foreign brand reputation and cause distrust in consumers who are becoming increasingly aware of counterfeit problems throughout the country.

Australian company Treasury Wine Estates (TWE) reported that it continues to work tirelessly with its local China partners and brand protection agencies and local authorities to protect its intellectual property rights and ensure its portfolio of premium brands has its integrity preserved at all times. TWE stated that it continues to increase its investment in brand protection in China. Tax rates on wine imports to China are high. Wine bottles brought into the country are supposed to carry import stamps that serve to protect legitimate importers’ goods from being replaced by counterfeiters, as well as to prove their legality. But many criminals are one step ahead, with counterfeiters getting very good at removing unique identifiers that brands place on their bottles. Treasury Wine Estates stated that its premium brands are highly vulnerable to fraud.

There is also reported issues of deception, where a copy of a label is taken and slightly tweaked to trick drinkers into buying a copycat wine. ‘Benfolds’, a Chinese rip-off of Australian brand Penfolds, is one example. Experts have predicted an increase in wine fraud especially associated with regional provenance claims and production methodology claims as climate change causes wine grape production to fall in important regions, including Bordeaux, Rhone, Tuscany, Napa Valley and Chile.
6.9 Wool

6.9.1 Sector overview

Wool production for 2018-19 was 379 kt, with a gross value of $4.5 billion. Wool is Australia’s second-largest export by value. In 2018-19, the gross value of Australian wool exports (including dead wool and wool on skins) was $4.15 billion. The price of Australian wool price entered 2018-19 at a record high, driven higher by strong Chinese demand. However, the value of Australian wool exports was expected to decline significantly in 2019-20, driven by both a continued easing of prices and a decline in production. Prices are declining due to weaker demand from China, a trend which is expected to continue for as long as the current global economic uncertainty persists. Australian Merino wool is considered the world’s finest and softest wool. As a natural fibre, it is used in the manufacture of luxury clothing and high-performance sportswear. Wool is classified into three main categories based on the diameter (micron) of each fibre:

- Fine wool – Merino sheep with the finest micron (high value)
- Medium micron wool – used in a variety of woven apparels and cloths
- Broad wool – from sheep breeds raised for meat and wool, used in carpets

6.9.2 Reported incidents of product fraud

- At least 18 bales of Australian wool, worth tens of thousands of dollars, were seized at mills in China after they arrived containing wool vastly different from that tested by authorities in Melbourne. It was alleged that the bales were tampered with somewhere between testing in Australia and unpacking in China, with high-value fine wool stolen and replaced with significantly lower-value product (4-10-17). 12, 13, 14, 15

6.9.3 Vulnerability of wool to fraud

Global wool retail apparel sales are worth about $80 billion a year. It is estimated that 8% of this product is marked with the Woolmark logo. Australian Wool Innovation (AWI) estimates that about 1% ($64 million) is counterfeit, with illegal use of the logo by retailers.
6.11 Horticulture and honey

6.11.1 Sector overview

For the year 2018-19, Australia produced 6.7 million tonnes of horticulture products.
- All vegetables: 3.7 million tonnes (55%)
- All fruits: 2.8 million tonnes (42%)
- All nuts: 216,000 tonnes (3%)

Annual honey production in Australia from 2015 to 2019 was estimated to be 37,000 tonnes.

6.11.2 Reported incidents of product fraud

**Fruit**

- A 2019-20 survey of avocado oils purchased in the US revealed that many contained oils other than avocado. Three of the samples were almost 100% soybean oil (18-6-20).
- Sicilian blood oranges (moretto, tarantol and sanguinella varieties) have a Protected Geographical Indication (PGI). Blood oranges grown in South Africa were alleged to have been passed off as Sicilian (20-12-19).
- Chinese-grown raspberries worth US$12m were seized by Chilean customs agents as they were being exported from Chile to Canada. They were labelled as Chilean and organic (24-8-19).
- Officials launched legal action after uncovering misrepresentation of geographical origin in kiwi fruit in Europe over a three-year period, with 12% of kiwi fruit claimed to be grown in France actually grown in Italy. French-grown kiwi fruit attract higher prices than Italian-grown kiwis, and the fraudsters were alleged to have made a €6m profit from the fraudulent claims. Authorities were alerted to the fraud by the unexpected availability of French kiwis at a time when the French growing season had ended (26-3-19).
- Chinese authorities charged 13 people for applying fraudulent labels with brand names such as Dole, Zespri and Sunkist to more than 1.1 million pieces of fruit sold in Shanghai, China (23-1-18).
- Kiwi fruit that had been misrepresented as belonging to a premium New Zealand brand was found in Shanghai, China. New Zealand kiwi fruit brands attract higher prices in China and are therefore highly vulnerable to counterfeiting (23-2-17).

**Vegetables (including herbs and spices)**

- Potato starch, sweet potato starch and corn starch samples were found to be adulterated with cassava starch by researchers in China. The researchers found 30% of sweet potato starch samples, 25% of corn starch samples and 40% of potato starch samples were adulterated and purchased from large supermarkets and farmers’ markets (26-2-20).
- In a large global study, a substantial proportion (27%) of 5,957 herbal product samples tested were found to be adulterated. The products were tested using DNA methods against their claimed, labelled ingredient species. Contaminants and adulterants included substitute species and filler species. In some cases, products contained none of the labelled species (24-10-19).
- It was alleged that some Italian tomato paste companies owned by Chinese interests were selling imported Chinese tomato paste labelled ‘Made in Italy’. It was also alleged that the imported pastes include unauthorised or undeclared ingredients such as maltodextrin and starch (2-10-18).
- Whole fresh garlic is considered to have low vulnerability for fraudulent adulteration. However, as with other similar products, there is a medium to high fraud vulnerability of its origin or organic status being misrepresented in markets where consumers pay a premium based on those characteristics. For garlic, claims about chemical treatments, such as bleaching, are also at risk of being misrepresented. Smuggling of garlic into countries that impose import tariffs has been reported. Huge volumes of very cheap Chinese garlic are thought to be crossing borders illegally in Asia and Europe (2018).
- The Thai army was called in to help stop illegal imports of cheap Chinese garlic. This caused the price of garlic in Thailand to plummet, with local farmers suffering. New penalties meant anyone in Thailand found with illegal garlic faced five years in prison (12-6-18).
- A Canadian company was charged with offences relating to falsely claiming its canned tomato paste was organic when, in fact, it was made with regular tomatoes. The owner of the company was accused of lying to a federal inspector about the products (12-10-17).
- Beetroot (canned or in jars) containing unapproved dye Rhodamine B was found in Germany. Adulteration with undeclared and illegal colorants was reported to be a common type of food fraud for beetroot and is expected to continue (10-2-17).
6.11.3 Vulnerability of horticulture and honey to fraud

Fresh fruit, vegetables, nuts, processed fruit and vegetables are considered to be at varying degrees of vulnerability to product fraud in different countries and for different reasons. Fresh vegetables are most vulnerable to fraud where they are marketed with a particular country of origin or organic status. Processed vegetables are considered to be at higher fraud vulnerability when they are processed into powders, pastes or granules. Fresh vegetables are generally thought to be at relatively low risk of food fraud, however, as with all fresh produce, their provenance and organic status can be misrepresented.

Agriculture
The European Commission food fraud report for 2019 showed a significant increase in fruit and vegetable fraud occurrences, which the report authors said may be due to an increase in organic fraud. The report claimed that the number of fraud incidents for fruit and vegetables for 2019 was approximately three times the number reported for 2018.

Mislabelling of country of origin is considered to be one of the most common types of fraud for fresh fruit and vegetables, particularly where locally grown products are more expensive or more sought-after by purchasers.

Generally speaking, whole fresh fruits and vegetables in developed countries are at low risk of being fraudulently adulterated when they are whole or in recognisable pieces. They are, however, very susceptible to other types of fraud, especially with respect to organic status and provenance claims. Production is at risk from climate change and prices are affected by extreme weather events, which will become more frequent with climate change. Peaks and surges in prices, unexpected supply issues and big differences between prices in different countries all increase the vulnerability of fraud, especially fraud related to misrepresentation of origin and organic status.

Whole canned fruit is considered to have generally low fraudulent vulnerability risk. From discussions with industry stakeholders, Australian cherries, grapes and citrus fruits are considered highly vulnerable to fraudulent misrepresentation and product counterfeiting in China. Fruit juice concentrates are considered to be highly vulnerable to fraudulent practices, particularly fraudulent adulteration, dilution, substitution and mislabelling. As for other frozen foods, frozen fruit concentrates are considered to be at risk of having their expiry dates tampered with.

Specialty and wild-foraged mushrooms are considered to have medium-to-high fraud vulnerability, particularly fraudulent practices relating to their provenance and species. Key fraud vulnerabilities for fresh whole tomatoes are mislabelling of country of origin or organic status. Tomato purées are considered highly vulnerable of being diluted with cheap fillers or extra water. Other possible adulterants are sugar or acidity regulators and undeclared colorants. There is a history of country of origin being misrepresented for tomato paste in Europe.

Adulteration with undeclared sweeteners and flavouring agents is thought to be common, as is dilution with (undeclared) water and, in some countries, unsafe water. The juice of fruits with fluctuating supply such as pomegranate is at high risk because of pressures to meet demand. Juices for which right, deep or intense colour is an indicator of quality or taste – and hence value – are at risk of being adulterated with undeclared colouring agents.

Table grapes are considered vulnerable to fraudulent adulteration or dilution, with consumers willing to pay much higher prices for grapes of a certain provenance. Given this, there is a risk that the cheaper grapes will be misrepresented with respect to their origin.

In developing countries, there are reports of fruits and vegetables being fraudulently labelled as being from premium imported brands as well as being dyed with illegal colourants to improve their apparent value. Authorities in Europe recently warned that the illegal use of copper sulphate as a green colour-enhancer is on the rise.

Peanuts are considered to be at low risk of food fraud, however they are frequently used as an adulterant or diluent (cheap filler) in more expensive nut products such as tree nut flours, tree nut pieces and nut meal.

Special fruit and plant concentrates and extracts such as pomegranate, elderflower and birch water are reported to become vulnerable to fraud as demand continues to outstrip supply.

Olive oil

Olive oil is considered to be one of the most vulnerable products to food fraud, being at extremely high risk of fraudulent adulteration, substitution and dilution. It is also at risk of fraudulent claims, especially those related to provenance and origin. There are reports that there has been long-term involvement of organised criminal gangs in the olive oil industry, particularly in Italy, and it is likely that those crime gangs control or have links to supposedly legitimate importers and exporters of olive oil around the globe. It has been reported that European olive oils imported to the US frequently can be traced back to supply chains linked to European crime groups.

Extra virgin olive oil is at particularly high risk to fraud because of its high price. It is most commonly adulterated by the addition of other vegetable oils, such as soybean or canola. Lower grades of olive oil such as olive pomace oil are also used to adulterate (dilute) extra virgin oil to increase profits. Undeclared colorants such as chlorophyll may be added to make the colour of diluted extra virgin oil look more authentic.

Hersbs and spices

The high value of herb and spice products (on a weight basis) and the degree of processing create the opportunity for fraud and mislabelling, and makes the need for larger-scale and more frequent authenticity testing a high priority for this group of products.

Ensuring plants species used in the herb and spice industry are authentic and products are not adulterated or substituted is considered a major challenge due to the nature of this industry. Raw materials in the industry are mostly in the form of dried, fragmented or powdered leaves, flowers, seeds, bark, roots and fruits that quickly lose their physical observable diagnostic traits, which makes them highly susceptible to fraudulent activities. Further, many of these products are blended and sold as mixed species, adding to the complexity of authenticity and therefore presenting an elevated risk of adulteration with undeclared ingredients.

Spices are considered to be at extremely high risk of fraud, with the risk expected to remain high for the long term. Ground spice powders and blends are commonly adulterated (diluted) with fillers such as semolina or additives to enhance their apparent value such as colouring agents.

Fresh herbs are at low risk of adulteration, however they can be misrepresented with respect to origin or organic status. Dried herbs are thought to be very frequently adulterated (diluted) with cheaper leaves or twigs. There have been a number of studies on dried oregano recently that have found high proportions of samples to be adulterated with other leaves, including olive leaves and sumac. There is a rapid authenticity test for oregano, which is why it has been tested often. Other dried herbs are likely to have similar adulteration patterns.

Herb supplies are less vulnerable to climate change than other plant foods because they generally grow quite quickly and crops can be easily established in new growing areas as climate patterns change.

Extra virgin olive oil is at particularly high risk to fraud because of its high price. It is most commonly adulterated by the addition of other vegetable oils, such as soybean or canola. Lower grades of olive oil such as olive pomace oil are also used to adulterate (dilute) extra virgin oil to increase profits. Undeclared colorants such as chlorophyll may be added to make the colour of diluted extra virgin oil look more authentic.

Chilli powder and flakes

Chilli powder is considered highly vulnerable to fraud and is expected to remain high for the long term. Chilli powder can be affected by unauthorised enhancements such as the addition of colourants, including colouring agents, red oxide pigment and rhodamine-B-dye. Chilli powder is also adulterated (diluted) with cheap fillers to increase its weight, including dust and chilli stalks.

A mobile food testing laboratory in India found rhodamine-B and Sudan dye in chilli powder (28–4–18). More fraudulent chilli powder was seized in India. This powder contained the crushed stems of chillies rather than the Fruits (24–2–18). A chilli factory was shut down in Pakistan after authorities found adulteration, standard food material and forgery (12–1–17). Eight of 10 samples of chilli powder tested in India, during a crackdown by authorities, were found to be contaminated with hazardous substances. Almost 683 tonnes of chilli powder was seized. India produces a significant proportion of the world’s supply of chilli powder. Authorities found during testing including chilli stalks. Sudan dye, red oxide pigment and rhodamine-B-dye (10–12–16).

Cinnamon

Like other spices, cinnamon is considered highly vulnerable to food fraud, particularly in ground form. Cinnamon also has reported issues around identity, as both ‘true cinnamon’ (Cinnamomum verum) and ‘cassia cinnamon’ (Cinnamomum cassia) are legally sold. ‘True cinnamon’ is also known as Ceylon cinnamon. Cassia cinnamon contains much higher levels of naturally occurring coumarin (a toxic benzopyrone) than true cinnamon. There are legal limits for coumarin levels in foods in Europe.
A Danish survey in 2013 found more than 50% of bakery items such as cinnamon buns (n=35) contained illegal levels of coumarin, which was thought to come from the use of cassia cinnamon. Synthetic coumarin, which has a pleasant sweet, fresh scent and is not permitted to be used as a food additive due to its toxicity, is a potential adulterant in ground cinnamon and cinnamon-containing products. Cassia bark, which resembles cinnamon bark, was reported to have been imported to India from China in large quantities as a substitute for genuine cinnamon. Cassia bark is toxic (25-2-17).

Cumin

Local authorities in India seized “artificial” cumin seeds made by coating fennel seeds with white and brown soil or dust, using local sugar as a binder. It is alleged that disl seeds were also used to dilute genuine cumin seeds to increase profits (31-7-18). There was a recall of ground cumin in the US due to the presence of lead. The lead was reported as lead chromate, which is used (illegally) to boost the yellow colour of spices (15-7-17).

Ginger

Like other spices, ginger is considered highly vulnerable to fraud, particularly when in powdered form. Powdered ginger is vulnerable to being adulterated (diluted) with cheap fillers.

Oregano

Forty per cent of oregano samples purchased in Norway (n=10) were adulterated with other leaves. Adulteration levels were between 30% and 50% and the adulterants included myrtle and olive leaves (19-10-17). Oregano was recalled in Norway after it was found to be adulterated with significant quantities of other leaves (28-8-17).

Around one-third of 33 oregano samples purchased from supermarkets in the US were found to be adulterated with other plant material. A similar study in the UK 2016 reported similar results (21-1-17). The Australian government warned oregano suppliers to improve the authenticity of their products following bad results in a survey earlier in 2016. Suppliers were investigated for selling oregano that was adulterated with significant quantities of sumac and olive leaves, and court orders were raised against two suppliers, with one supplier fined.

Saffron

Saffron is considered highly vulnerable to food fraud. The most common type of saffron fraud is said to be adulteration with non-stigma parts of the crocus flower, sometimes with the addition of dyes. Misrepresentation of origin can also occur. Recently, it was reported that saffron in Europe was replaced with or enhanced by pigments derived from gardenia fruit, which are chemically similar to the yellow pigments in saffron.

Spanish authorities uncovered a clandestine saffron operation where saffron stamens were mixed with pure saffron fibres, this adulteration being against food purity laws (24-3-19). A survey of saffron in India found that 44% of samples (n=36) were adulterated with non-stigma parts of the saffron plant or parts of other plants. In the same survey, none of the samples met ISO quality grades I or II (22-10-18).

Saffron was found to be the most frequently adulterated or inauthentic spice in a French survey conducted in 2018. One sample was 100% safflower. Of the saffron samples tested (n=unknown), 81% had anomalies with authenticity (25-6-18). Spanish saffron is gaining a reputation as being of better quality and flavour than saffron from Iran, the major producer. Given the large price differential between Spanish saffron and Iranian saffron, there is a risk of fraudulent misrepresentation of origin.

Truffles

Truffles are rare and very expensive and the industry is said to be rife with fraud. Provenance of black truffles is considered to be an ongoing problem, with cheaper Chinese truffles closely resembling black French truffles being substituted and mislabelled.

Turmeric

Turmeric is considered highly vulnerable to food fraud, with frequent incidents of contamination with lead chromate (a yellow colourant) reported. A study found that seven of nine turmeric-growing areas in Bangladesh showed evidence of turmeric adulteration with lead chromate. Levels of lead exceeded national limits by up to 500 times (24-9-19).

Warnings were published about the scale and types of adulteration in turmeric, with the American Botanical Council publishing a bulletin on turmeric. The bulletin reported that in its powdered form, turmeric is “susceptible to mixing with extraneous, lower-cost botanical ingredients, starches, chalk powder, cassava, and synthetic dyes”. The Council also reported that extracted whole roots have been used to adulterate unextracted roots. Whole roots have also been adulterated with species from the same genus containing curcumin, e.g., C. zedoaria (white turmeric). Colours used to adulterate powdered turmeric include lead chromate, metanil yellow, acid orange 7 and Sudan Red B. According to the bulletin, turmeric is also diluted with yellow soapstone powder, a natural mineral (4-6-18).

In 2016, the US FDA released a detailed import alerts for lead-adulterated turmeric, naming importing companies and the country of origin. All were from Bangladesh and India (17-12-16).

Vanilla

Vanilla is considered highly vulnerable to food fraud. The price of natural vanilla is high and continues to rise, with a greater-than-10-fold increase over the past five years and poor crops from most growing areas in recent years. Demand exceeds supply and this is expected to be the case in the long term.

Honey

Australia is the fourth-largest exporter of honey in the world after China, Argentina and Mexico. Australian honey varieties are recognised for their high quality and unique flavours, affected by the bees feasting on a wide range of wild nectars. Well known Australian varieties include yellow box, grey box, river red gum, stringy bark and red box. The Australian honey production industry is a huge contributor to the economy of many rural Victorian districts. Some 85% of our unique Australian honey is harvested from the nectar of native flora, especially blossoming eucalypts.

Honey is considered to be highly vulnerable to fraud, with a long history of adulteration, dilution, substitution, misrepresentation of source and fakery (non-bee products being added). Misrepresentation of organic status is an ongoing problem, with cheaper Chinese products being substituted and mislabelled. Other common types of honey fraud include adulteration and substitution of ingredients, misrepresentation of origin, and misrepresentation of source and fakery (non-bee products being added). Misrepresentation of organic status is an ongoing problem, with cheaper Chinese products being substituted and mislabelled. Other common types of honey fraud include adulteration and substitution of ingredients, misrepresentation of origin, and misrepresentation of source and fakery (non-bee products being added). Misrepresentation of organic status is an ongoing problem, with cheaper Chinese products being substituted and mislabelled. Other common types of honey fraud include adulteration and substitution of ingredients, misrepresentation of origin, and misrepresentation of source and fakery (non-bee products being added). Misrepresentation of organic status is an ongoing problem, with cheaper Chinese products being substituted and mislabelled. Other common types of honey fraud include adulteration and substitution of ingredients, misrepresentation of origin, and misrepresentation of source and fakery (non-bee products being added). Misrepresentation of organic status is an ongoing problem, with cheaper Chinese products being substituted and mislabelled. Other common types of honey fraud include adulteration and substitution of ingredients, misrepresentation of origin, and misrepresentation of source and fakery (non-bee products being added).
7.1 Industry overview

Seafood is the most valuable and highly traded food commodity in the world. Global fish production is about 180 million tonnes and is made up of a high diversity of species and complex supply chains, and provides food, non-edible products, nutrition and employment. Global fisheries harvesting, aquaculture production and fish consumption are all rising.

In Australia, fisheries and aquaculture annual production is 273 kt and has an estimated value of more than $3 billion, with over 50% by value exported. Like other agriculture sectors, Australian export seafood species and products attract a high price due to their association with harvesting from pristine environments, high standards of product handling and quality (freshness), and food safety.

In the Asia-Pacific region, Australia is ranked highest for safety and quality. Volume of imports is significantly greater than volume of exports. Imports include a variety of products mostly in processed form, from fish fillets and shredded prawns to those with value added, such as crumbed or ready-to-cook products (e.g. marinated sauces). There are also imports of non-edible products such as fish meal and fish oils.

Aquaculture makes up an increasing proportion of the world’s fish food production, and while making up a relatively small proportion of domestic production, it is significant for various imported products (e.g. white shrimp and catfish).

7.2 Reported incidents of product fraud

- The US FDA updated an import alert for mislabelling of fish and other seafood, species, including those labelled as different varieties of crab, snapper and salmon. They have also listed commonly used fictional seafood names and companies that have a history of seafood mislabelling (4-2-20).
- A survey of 449 fish samples purchased from retail outlets and restaurants in the US found 21% mislabelled. One-third of establishments visited for sampling sold at least one item that was mislabelled. Restaurants and small markets were reported to be more likely to be selling mislabelled seafood than large grocery chains. As well, species fraud, the study uncovered origin fraud, including in Great Lakes perch, which were actually cheaper Asian fish (12-3-19).
- A survey by the Attorney General’s office in New York State found very high levels of mislabelling of species for fish purchased at supermarkets. Twenty-seven per cent of 286 samples tested were affected, with higher rates in New York City. Certain fish species were affected much more than others, with red snapper, grouper, lemon sole and wild caught salmon among the worst impacted (1-12-18).
- An extensive survey conducted by Oceana, the seafood watchdog, of Canadian fish from retailers and restaurants found 44% of 382 fish products tested were mislabelled. In this study, 100% of snapper, yellowtail and butterfish were mislabelled. High proportions of sea bass, tuna, halibut and sole were also affected (11-8-18).
- A seafood salesman was convicted of smuggling US$68 million worth of eels through the UK, and a large smuggling ring worth €37 million was stopped. It was estimated that roughly €3 billion worth of eels are smuggled every year (19-7-18).
- In Canada, high rates of species misidentification were found in a study of 208 fish samples using DNA barcoding. Snapper was the most commonly mislabelled species – of 34 samples of snapper in the study, 31 of them were mislabelled. Samples sourced from restaurants were the most frequently mislabelled at 29%, followed by wholesale stores (24%) and sushi bars (22%) (19-6-18).
- A small study in the United States determined that one-third of seafood meats were mislabelled with respect to fish species. Chilean sea bass, tuna and rock shrimp were adulterated to increase their weight (8-5-17).
- An Oceana survey of fish in Ottawa found 33% of 98 samples from grocery and retail outlets were affected by species substitution. Restaurants and sushi outlets were the worst affected (2017).
- Brazilian authorities uncovered illegal imports of fish from China, including pangasius, hake and pollock that had been adulterated to increase their weight (16-5-17).
- Researchers in California published results of a study that showed nearly half of all sushi in Los Angeles restaurants was mislabelled (12-1-17).
- Farmed seafood exported from China was alleged to have contained dangerous levels of undeclared, and in some cases illegal, antibiotics (15-12-16).
- A UK study reported concerns that the EU Fisheries Council’s easing of quotas would negatively affect fish stocks. The study reported that fish are highly vulnerable to fraudulent activity and fraud would increase if fish stocks decreased further. Mislabelling of species, misdeclaration of origin and misrepresentation of farmed/wild status were reported to be the common types of fraud for fish in the UK (1-12-16).
- In 2016, Oceana published a report on fraud within the seafood industry. More than 25,000 samples from 56 countries on every continent were included in the study. Twenty per cent of fish were mislabelled. Some species and some countries had mislabelling of up to 98%. Just over half of all substitutions were of species that pose a health risk. The fish most commonly substituted for more valuable species were Asian catfish and hake (7-9-16).
- Australian Food News identified imported catfish (basa) sold as doré; South American flounder sold as Australian flounder; Asian sea bass as domestic barramundi and snapper sold as red emperor (2016).
- A Victorian study identified mislabelling of Nile perch as barramundi and red emperor (2008).
- A multi-state study (PSANZ, 2003) found 35% of fish were mislabelled; barramundi was correctly labelled 86% of the time, but red emperor was correctly labelled at a rate of only 59% (15-11-14).

7.3 Vulnerability of fisheries products to fraud

Fish is at very high risk of food fraud, with almost all types of fish very vulnerable to various types of fraud, including misrepresentation of species, origin, farmed or wild caught status, and fresh or frozen status. Globally, seafood is consistently ranked in the top two to four agricultural sectors most vulnerable to food fraud and is widely recognised as one of the four major food and food ingredient sectors targeted for fraudulent activities.19 Overseas studies estimate that fish fraud generally is in the order of 20–30%, with some product and product forms found to be mislabelled 90% of the time. The overall vulnerability of fraud across the whole seafood sector can be expected to be high for the long term, although there have been recorded improvements in some areas, notably for fish in Europe.19, 20 Fish species substitution is reported to be very common, especially at the food service level. This type of fraud is expected to continue. There is a lack of information and investigations into potential fraud in both export and import supply chains, which would determine the scale and nature of mislabelling and potential illegal activities, as highlighted by the paucity of studies listed above. Based on discussions with Australian seafood stakeholders and a review of the relevant literature, seafood fraud and the need for better authentication is a major concern for the Australian sector and should be considered a priority for research, traceability and surveillance.19 The premium value of Australian seafood makes it a target for fraudulent activities in both export and domestic markets, with incorrect labelling of species and country of origin particular concerns; counterfeiting of overseas-derived seafood product as Australian-exported product was raised, as were the vulnerability of supply chains involving the import and subsequent re-export of product as Australian origin, and conversely the export and subsequent re-import of Australian product for processing and value adding.

There is high level of vulnerability of fraud at the food services sector level, where adherence to accepted fish names and country of origin is not considered to be nearly as strong as other parts of the food market. Species fraud at the retail level, including food service, is said to occur at rates of 50% in some countries. The higher vulnerability of imported products is due to the high level of processing and value-adding, and makes the authentication of species labels challenging without recourse to laboratory methods such as DNA barcoding or elemental or isotope-based analyses. The extent to which IUU (illegal, unregulated and unreported) product enters seafood supply chains is of high concern to the public and the sector in Australia, and is largely unknown, both domestically and especially in the international markets that Australian companies sell their legally harvested or grown products into. Undetected mislabelling of products can also have health risks to consumers, creates biosecurity issues, contributes to the targeting of endangered species (listed by the International Union for Conservation of Nature (IUCN)), and supports the profitability of illegal fishing.
8.1 Industry overview

ABS industry data indicates that employment levels in Australian forestry and logging have fluctuated significantly over the last 10 years. Employment levels for forestry and logging are expected to remain relatively steady at around 5,300 to 2024. In 2018-19, total Australian forestry production was 32,713 thousand cubic metres. Hardwood products were 15,335 thousand cubic metres and softwood products were 17,379 thousand cubic metres.

Australia’s forests are classified nationally into three categories – native forest, commercial plantations and other forest. Australia’s native forest category is dominated by the forest types eucalypt (77% of the total native forest area), Acacia (8%) and Melaleuca (5%), and a small area is rainforest (3%).

Australia's trade in wood products has grown strongly since 2012-13. The value of both exports and imports reached record levels in 2018-19 and total merchandise trade (exports plus imports) reached a record $9.9 billion.

8.2 Vulnerability of forestry products to fraud

Substitution and mislabelling are the most common types of product fraud issues as mentioned by Simon Dorries, CEO of Responsible Wood. Based on his vast experience he stated the following:

“The amount of misrepresentation in relation to compliance with Australian Product Standards is significant. Australian building codes have requirements for wood products to meet Australian Standards. Unbranded products are unable to be used and cannot be sold in applications covered by National Construction Codes. It has become the ‘normal’ business model of many overseas manufacturers and their Australian customers to simply brand Australian Standards numbers on non-complying products to provide fraudulent access to the building products market.

“In a former role as GM of the Engineered Wood Products Association of Australasia, we ran a market surveillance program for several years where products would be purchased from the open market and tested in our NATA-accredited laboratory. The failure rate in products from some Asian countries labelled as complying with Australian Standards was 80%. The non-compliant import was typically priced 40% below the Australian-compliant alternative. The result has been a very significant reduction in profitability as the market price was set by the import. This had resulted in the closure or downscaling of five Australian plywood mills. In terms of sales, in a single product line, formwork plywood, the reduction in Australian manufactured sales is $50 million.”

Any forest product that has a high component of value add or labour is a target for, and at risk of, misrepresentation. This includes engineered wood products and preservative-treated products. Both can be substituted with non-complying product that appear identical to compliant products but can only be detected by laboratory testing. A consumer has no way of knowing that the product is non-complying. Often, the non-compliance relates to durability that does not become evident for several years when premature failure takes place. Illegal logging, especially overseas, is a very serious concern that was raised by most industry stakeholders.
9.1 Product authenticity testing

The concept of using authenticity testing is shifting the fight against product fraud from reactive to early-detection and prevention, thus allowing Australasian agriculture, fisheries and forestry industries to have better control over the fraud issue. Research and technological advances are revolutionising the process of product and food authenticity testing, although they cannot be used to identify all types of fraud.

The purpose of authenticity testing is to assure the true state of a product. According to the International Food Authentication Assurance Organisation (FAAO), “food authenticity is the process of irrefutably proving that a food or food ingredient is in its original, genuine, verifiable and intended form as declared and represented”. Authenticity testing is used to prove the content of products are authentic and the way they are presented is correct and accurate.

Although authenticity testing is not a new concept, it has received considerable attention in recent years due to increasing numbers of product fraud incidents reported worldwide. For example, the number of reports made to the UK National Food Crime Unit increased from 796 in 2015 to 1193 in 2019.17

A number of analytical methods that have been applied to food, natural fibre and timber product identification require access to well-equipped laboratories, technical expertise and a suitable reference collection of samples or controls from species that have been taxonomically or genetically verified. Analytical methods use intrinsic biological or chemical properties of the products under study and apply one, or more, of several analytical tools to determine DNA/RNA, proteins/amino acids, lipids/fatty acids and other small, low-molecular-weight molecules and elements. The most common analytical methods that have been used to detect food, natural fibre and timber fraud have been taxonomically or genetically verified. Analytical methods are developed using specific- and non-specific methods. Non-targeted methods are developed to create a ‘(bio-) chemical fingerprint’ of authentic food as a reference standard. For example, spectrometry has been used to create a fingerprint of cheeses and grape variety authenticity. NMR spectroscopy is used for molecular profiling of honey, wine and olive oil. DNA forensic techniques are used as molecular tools to authenticate many species and have been shown to be successful on mixed species and herbs and processed seafood products (e.g. fish balls). Isotopic analyses and fingerprinting can be used to verify organically grown food and the geographical origin of various food products. The main limitation of this approach is that it requires the simultaneous analysis of a comprehensive set of reference samples.

With the increasing complexity of global supply chains and the continuing rise of e-commerce trading, the risk of product fraud practices is likely to increase. Therefore, there is a need for sensitive and accurate authenticity methods to combat product fraud and help Australian agriculture, fisheries and forestry industries keep pace with new fraud tricks that may threaten product supply chains.

**DNA testing**

DNA testing is used to analyse the species-specific genetic profiles of species present within a food product, enabling the identification of species substitution or adulteration. The most widely used method is the PCR method, a targeted approach, whereas many non-targeted methods are developed to detect the presence of a specific species from the sample being tested, by comparison with reference samples. There are also non-targeted DNA methods used for testing whereby DNA sequences are compared with public databases of DNA sequences to establish the unique animal or plant species present in the product. DNA analysis has also been used to detect the presence of genetically modified product, microbial pathogens or undeclared allergens. Comprehensive reference sequence libraries are needed for DNA testing, and most of these are publicly available for all common food species.

Genetic-based methods that use the PCR testing approach are now widely recognised as powerful, convenient and cost-effective authenticity testing tools that make use of the intrinsic properties of products, namely the natural variation in DNA. The most common approach in recent years, used broadly in biology and for food authenticity testing, is DNA barcoding, supported by the Barcode of Life Data System and associated databases. Nearly nine million species-specific barcodes are available as part of the Barcode of Life Data System (BOLD; – www.barcodinglife.org) and specific databases are available for fish at www.fishbol.org. Developments in molecular genetics and genomic methods over the past 20 years since the sequencing of the human genome have been as significant as any area of scientific endeavour.

Specifically, very rapid progress in DNA sequencing technologies have occurred and made significant contributions to fields as diverse as human genomics, pharmaceutical production, selective breeding of commercial plants and animals, and ancient and environmental DNA.

Methods developed from the broader fields of molecular genetics and genomics have been increasingly tested and applied to the authentication of products in the marketplace. These have been used to support consumer confidence in plant and animal products, and the effectiveness of government control programs and associated policies and legislations. The successful application of genetic methods to product authentication depends on two properties of DNA: (1) stability and (2) variability.

The DNA molecule is extraordinary stable, which is an essential requirement for its use as the genetic material for both inheritance and gene expression and regulation in living cells. DNA progressively breaks down over time in the environment, but this is slower in relatively colder, drier and sterile environments, and even with significant degradation short fragments in length can be studied by PCR and related methods. As a result, DNA can be extracted from many kinds of products even when subject to various types and levels of processing (freezing, drying, salting, pickling, cooking and canning).

The first major breakthrough allowing routine genetic-based profiling and species detection was the development of PCR, which allowed the amplification of targeted DNA fragments using what are usually referred to as universal primers (short, conserved DNA fragments, upstream and downstream of the gene region of interest). Even with only a few copies of the gene in a sample, PCR can generate millions to billions of copies (referred to as amplification) within a matter of hours, allowing a highly purified sample of DNA large enough for detailed studies by downstream applications such as direct DNA sequencing.

Targeted authenticity testing involves specific analysis to test the authenticity of food to verify compliance with labelling and compositional standards. Non-targeted analytical methods are developed to create a ‘(bio-) chemical fingerprint’ of authentic food as a reference standard.
Comparisons of early DNA application methods focused on common products such as red meat and poultry, where there is a limited number of targeted species (both known and unknown). However, all these methods possess certain limitations because the full range of unknown species (i.e., potential substitutions) needs to be known in advance (targeted testing), a full set of reference samples needs to be included as controls for every analysis, and detection limits may be limited and difficult to estimate. With increasing demand for stricter control and monitoring of product labelling and species assurance, genetic technologies offer the best opportunities for developing effective, low-cost and accurate product analytical and authenticity testing. The more recently developed technologies, such as next-generation DNA sequencing, DNA chips and lab-on-a-chip technology, offer great potential for effective, low-cost, rapid and on-site authenticity testing for a broad range of food products.

The immediate challenges in product authentication are determining the most suitable DNA methodology for a particular product type or food, the continued development of faster and inexpensive methods, and using these methods for routine product testing and surveillance. Active surveillance is essential to determining the true levels of mislabelling and fraud, giving industry a reliable estimate of the impact of fraud in the supply chain, and ensuring public confidence in products. For the Australian context, consideration should be given to the establishment of one or more Centres of Excellence for product authenticity, for both development and application of cutting-edge technology, training and product testing.

**DNA barcoding**

DNA barcoding is increasingly being used for product authentication testing as it is a very powerful method to accurately identify unknown species for food products and has the advantage that studies do not (usually) require the use of a reference set of samples, as species are identified from international databases. As such, it is a non-targeted testing method. The DNA barcoding concept was first published and popularised by Poinar, Hebert and his colleagues. They proposed that a universal genetic barcode could be used to identify animal species to support species identification, taxonomy and biodiversity studies. Hebert’s concept involves the sequencing of a gene fragment, which can then be compared with online databases, including the National Centre for Biotechnology Information (NCBI). While originally tested on insects, the method has been successfully applied to fish and seafood product identification. It has now become the de facto standard genetic identification tool for animals by virtue of the size of the reference databases (approximately six million sequences).

DNA barcoding has been applied during product testing to identify species, including red meats, poultry and seafood, and consequently identified intentional or unintentional mislabelling of all of these products in many countries. The principal advantage of DNA-based barcoding is the substantial online database referred to as the Barcode of Life Data System (BOLD) that allows the accurate identification of unknown samples to the species or genus level. This database now contains reference sequences for most edible and traded animal species, and a large number of fish species. In addition to species identification, DNA barcoding can also be used to identify sub-species, varieties and populations. This is relevant where quality standards, such as the Protected Designation of Origin (PDO) label established by the European Union, trace the food ingredient or product to a specific geographical region or country.

There are, however, some limitations and complexities to the use of the DNA barcoding approach. Some animal groups have been less well studied, so important food species may not be represented in DNA sequence databases. Further, high-diversity products such as fish, invertebrates and fungi plants are more challenging to study due to deficiencies in reference DNA sequence databases and the greater variety of genes to be targeted. Conventional DNA barcoding also cannot be applied to food products made from more than one species (e.g. fish cakes and mixed herbs), especially if the species are closely related. In addition, while DNA methods are remarkable for detecting the presence of species in very small quantities, and can be used to obtain DNA barcodes (sequenced DNA) from a range of product forms (fresh, frozen and cooked), these methods can fail if high levels of processing and certain preservation methods result in highly fragmented DNA. However, newer methods (described below) can overcome these challenges.

**DNA sequencing**

The development of next-generation DNA sequencing technologies (NGS) over the past few years can be viewed as a game changer for food, natural fibre and timber product authentication. While this method is widely used in genomic studies, it has only been recently applied to product and food-related studies. NGS takes advantage of existing developments and resources (e.g., DNA databases) and can be applied to both mixed-species products and degraded DNA, and can provide a semi-quantitative estimate of species representation.

NGS is able to sequence millions of small DNA fragments simultaneously on a random or shotgun basis. In general, the individual fragment lengths are small, which means the technique works on samples that have degraded DNA, but still allows sample identification by comparison with reference species in genomic databases. This shotgun approach is called metagenomics or meta-barcoding, and can be applied to any sample from which sufficient DNA can be extracted. Thus, the power of NGS is that it can detect very low levels of contamination, allows identification of non-target species and is especially suited to the analysis of mixed-species products.

The combination of DNA barcoding and NGS technologies has been successfully used to authenticate fish and seafood species and meat species in processed food products. Likewise, animal species origins can be detected in dairy products, which can also include a number of undeclared species. Similarly, this method can identify plant species contributing to juice formulations and honey products. NGS will progressively revolutionise product fraud research and approaches to authentication testing, especially for processed food products with mixed species and high complexity (e.g., cheeses, yogurts, wines, fermented products, mixed herbs and spices and organic food additives).

The cost of NGS is rapidly declining on a per sample basis (currently several hundred dollars per test) but requires access to expensive laboratory infrastructure and equipment. However, new and emerging technological developments and authenticity testing service providers are reducing the cost and size of equipment and consumables and the ease with which sequences can be obtained. An important development is the new MiSeq sequencer from Oxford Nanopore Technologies (ONT), which is smaller than a smartphone and able to produce data within minutes. The portable MiSeq unit costs less than $1100 and enables the processing of samples on-site, with species identifications in real time via access to online databases.

**“DNA barcoding is increasingly being used for product authentication testing as it is a very powerful method to accurately identify unknown species for food products.”**

Other DNA-based technologies that have potential application in product authentication as part of identifying food species present in mixed samples are DNA microarrays and DNA chips. Microarrays consist of many individual fragments of synthetic DNA (potentially thousands) that can be analysed and compared with complimentary target DNA sequences from species of interest within the test samples. These species can be animals, plants and microbes.

Microarrays are widely used in human genetics for genotyping patients to identify rare genetic diseases and by geneology companies (e.g., Ancestry.com) to establish genetic relationships. The use of microarray technology is a potentially powerful approach to detecting and characterising both animal and plant food species and microbial species (including in complex cultured products such as yogurts, cheeses and probiotics) with a high degree of specificity. The cost of development and design of the initial DNA is relatively high and requires significant existing genomic knowledge on the target species, but routine production and sample-based costs are reasonable, and the approach works best for larger-scale routine sample screening for well-known and high-value products, such as those in the meat, dairy and seafood industries.

In addition, the combination of PCR-based approaches with other technologies such as biosensors or nanotechnology has great potential for on-site authenticity applications. A portable PCR system to detect beef, pork, chicken, rabbit, horse and mutton in processed foods is in development. An optical-thin-film biosensor test that can monitor and distinguish up to eight meat species down to 0.001% has also been developed and tested. These technologies are often referred to as ‘lab-on-a-chip’, however they are still in their infancy and generally require more research and development to reduce costs and need to be appropriately tailored for the targeted products and industries.
The full scope of DNA methods used for traceability and authentication in the food sector is difficult to determine from the public scientific literature. In general, it appears the food industry and genetic service companies have been slow to apply or develop tailored genetic solutions to support food authentication and traceability. One exception is IdentiGEN, a spin-off company from Trinity College Dublin, which was recently purchased by Merck Animal Health. IdentiGEN originally played a leading role in food testing during the horse meat substitution scandal in 2013 and uses in-house DNA-based diagnostics and data analytics in an animal traceability solution, called DNA TraceBack, to trace beef, seafood, pork and poultry accurately and precisely from farm to table. This allows industries to have confidence in the integrity of their supply chains and food safety, and meet customers’ concerns about where and how animals are raised, processed and sourced. The company manages very large projects with large multinational companies (e.g., Tyson Fresh Meats) and countries (e.g., Switzerland).

Eurofins, a multinational company that conducts testing and diagnostics for life science-based industries and consumers, promotes a similar product—the Eurofins TAG™ genetic traceability system. Eurofins TAG™ is designed for stakeholders involved in the meat industry: farmers, abattoirs, processors and distributors. The system uses reference samples taken from animals upstream of the primary processing plant, with this genetic information stored in a database for comparison with samples taken later at points of purchase by consumers.

There are a number of general life science testing companies that provide diagnostic testing for food authentication; however, their services predominantly focus on allergen and microbial pathogen detection. These companies use a mixture of older and newer technologies. There is a general gap in the market for a service that focuses on low-cost and routine genetic-based product authenticity testing. Despite the recognised utility of genetic-based methods for food authentication and testing globally, there appears to be a general lack of support for coordinated and routine testing from either governments or industry, which is required to support law enforcement and public confidence.
9.1.1 Emerging innovative technologies

Current techniques for authenticity testing require specialist laboratories and are seeking to develop quicker, cheaper and more portable methods of analysis. Examples include:

- **Advances in DNA analysis techniques** to offer improved speed, accuracy and portability at a lower cost.
- **Portable mass spectrometry** to screen for small molecules that avoids methods involving sample preparation.
- **Non-invasive testing methods**, which can detect adulterants through food packaging.

**Authentication in red meat species and testing for the presence of pork**

Analytical procedures, including sophisticated DNA methods, have been developed for, and applied to, the identification of species contributing to red meat products, especially processed food products (e.g., minced meats and sausages) for some time. The application of DNA methods to this group of species in Australia can be straightforward, due to the relatively small number of target species and because genomic information on agricultural animal species is well developed.

Due to the European horse meat scandal, concerns of mislabelling of red meat products rank high in the public consciousness and several studies specifically target the detection of equine DNA. While there have been a number of studies globally to test for red meat species substitutions, it is somewhat surprising, given these public concerns, that there has not been a larger number of red meat species authentication studies in Europe, North America and Australia.

An additional consideration when investigating substitutions and adulterations in red meat products is the increasing range of target species including pork, horse, beef and others at very low levels on the basis of religious and cultural practises. This requires an understanding of the detection limits defined. However, there is great variation among studies, as target genes can vary and include a wide range of DNA methodologies used. A number of exemplar studies are summarised below.

A study of 72 packaged meats in Italy, published in 2015, used standard PCR-based methods for cattle, pork, chicken and horse meat detection. All 72 samples were horse-negative, however 20 out of 38 chicken sausage samples were pork and beef-positive, nine out of 12 pork sausage samples were also beef-positive, and five out of 12 meat pâté samples labelled as pork and beef included chicken.

Limitations to studies that use standard DNA methods include: (1) detection limits for adulteration are usually in the range of 0.1–1%, which is not sufficient for detecting low-level contamination of species considered prohibited on religious and cultural reasons; (2) the detection of a restricted number of targeted species; and (3) inability for the method to be applied to mixed-species product forms. These limitations can be overcome using newer NGS methods.

For example, a market survey to identify animal species in 27 mixed meat and poultry products sold in China using NGS identified a mislabelling rate of 33% for all products examined. DNA reads from a beef product indicated the presence of four species: cattle, chicken, wild yak and sheep. A smoked horse meat product included both horse and sheep meats, which was likely a deliberate substitution as mutton is cheaper than horse meat in China. A camel meat product only contained beef and sheep reads. Finally, a lamb sausage contained only pork reads.

Cottenet et al. undertook a similar NGS-based study using technology developed by Thermo Fisher Scientific (Illumina) to identify mammalian and avian species in mixed food products. Authors examined 49 ground meat samples sourced from European and Asian markets and determined that 18% showed evidence of adulteration with undeclared meat species. Goat was detected in all lamb samples, while 30% of chicken was detected in one of the samples. Two poultry samples were found to contain high levels of pork (10%) and one of them also contained 15% beef. Animal known to be prone to adulteration, the majority of beef-based samples complied with the label, except two samples that contained 3% and 5% of chicken. Finally, 10% pork was detected in a chicken-based sample and one lamb sample was estimated to be adulterated with a substantial proportion of chicken (30%).

An increasing number of commercial enterprises now offer testing services targeting meat products and supply chains, including Identigen, DNA Catcher, Eurofins and FBMZ-Environment.

**Authentication in poultry species and products**

Similar to red meats, a range of molecular genetic methods have been applied to the identification of poultry species in processed products. In many reported studies, poultry species identification has been included with red meat species products. Published authentication testing studies have mostly targeted both raw and cooked poultry products, including ground meats, sausages and nuggets. Methods range in sophistication from straightforward PCR using species-specific DNA fragments to DNA barcoding (direct sequencing). Very recent studies are exploring the utility of NGS-based methods.

High-value sausage meats in Portugal (2018), labelled as derived from game meat species (partridge, pheasant and quail), were investigated using PCR. The authors found adulteration of game bird sausages with undeclared poultry in at least 44% of samples, which supports earlier studies of similar products that detected a substitution rate of 61% with bovine-derived products.

The highest-value poultry products are pâté and foie gras produced from goose and mule duck liver, and are therefore likely to be the target of fraudulent species substitution. While methods have been developed and validated to identify duck and goose species, no published studies investigating the occurrence of possible fraud in the preparation of these products could be found.

Xing and colleagues (2019) investigated the potential of NGS to identify mammalian and avian species in mixed-food products. Validation experiments using meat samples demonstrated this method has the potential to determine high and low representation of animal species in mixed products. A market survey to identify animal species in 27 mixed meat and poultry products sold in China using the DNA barcoding approach resulted in a mislabelling rate of 33% in the products examined.

**Authentication in dairy products**

Perhaps the most common alteration of dairy products for financial gain is via the substitution of, or dilution of, a higher-value milk with a cheaper non-declared milk. Such situations can be difficult to detect without sophisticated analytical methods, but can be addressed through the application of several DNA methods. Similar situations exist for products that are developed from further downstream processing, including butters, creams, yogurts and cheeses, some of which attract high prices as specialty items from highly reputable brands and regions. The range of species involved in traditional milk products include cattle, goats, buffalo, sheep and camels, and alternative milk products include soy, walnut, almond, rice and coconut species.

Recent studies have enabled the identification of specific molecular profiles using NGS technologies, which can also simultaneously detect undeclared species used as adulterants or present as contaminants. These molecular profiles have the potential to determine the region of origin, variety and even brands of cultured dairy products. This would thereby support EU legislation, and similar regulations, regarding Protected Designation of Origin (PDO), Protected Geographical Indication (PGI), and Traditional Specialities Guaranteed (TSG), among others. In addition, information on product history (frozen, unfrozen) can also be obtained from NGS-based profiling.

“**The most commonly used DNA approaches to red meat species authentication include relatively simple multiplex PCR and HRM, which are effective when the number of target species is known and low.**”

In one canned luncheon meat sample labelled as chicken, sequencing reads indicated the presence of meat samples with 46% of reads mapping to tuna, 15% mapping to chicken and 14% mapping to sheep.
DNA-based methods are the preferred choice for grapevine varietal identification. DNA-based methods have the added advantage of simplicity and they can allow identification through online databases using DNA barcoding.

Authentication of grape species in wines and grape products

The Australian wine sector regularly attracts fraudulent practices and counterfeiting that targets high-priced wines and brands. Wine adulteration and product fraud include dilution with water, addition of alcohol or colouring/flavouring substances, and, most commonly, the blending with a wine of lesser quality and the mislabelling and misrepresentation of grapevine varieties and geographical origin.

In Australia, there are few published accounts of research or systematic testing for wine authentication using DNA-based methods. There have been a few reported cases in the popular media where there has been confusion about the correct identity of imported varieties or cultivars, which is important when it comes to appropriate naming and marketing of products. A key recommendation is that a research program should be initiated to genetically barcode all Australian-grown grape varieties from all major wine grape-growing regions, and to develop and test the latest methods of NGS to identify effective gene regions so DNA barcoding-based variety identification can become a tool for Australia wine authentication.

There are two main requirements when assessing wine authenticity: determination of grapevine varietal identification, and determination of geographic origin. The site of production is directly linked to the quality of product characteristics and, hence, price. Therefore, in addition to identifying genetic or chemical markers that allow vine variety identification, traceability systems that enable authenticity to be determined on a regional or product basis are highly desired, especially in countries such as Australia that produce premium and high-value products. In Europe, traceability systems that can be used to authenticate wines are included under Protected Designation of Origin (PDO), Protected Geographical Indication (PGI), and Traditional Specialties Guaranteed (TSG) regulations.

A number of chemical and genetic-based studies have assessed wine variety and origin of production. Assessment of wine authenticity has been made using chemical testing and analysis methods, such as amino acid, protein and mineral composition and isotope identification. However, while some can also be used for geographical origin, the chemical and metabolic composition of grapes and wines is influenced by environmental conditions, climatic differences and the production systems and processing methods used. As a result, DNA-based methods are the preferred choice for grapevine varietal identification. DNA-based methods have the added advantage of simplicity and they can allow identification through online databases using DNA barcoding.

DNA barcoding is potentially constrained for wine variety identification, as this requires the sequencing of genes with the necessary intra-species variability and because barcoding markers in plants are generally more conserved and less informative than in animals. Thus, DNA barcoding requires further development to identify suitable genetic markers that allow the discrimination of wine grape varieties. Nevertheless, the combination of HRM analysis, DNA barcoding and PCR has been applied to the authentication of wines. In a key study described by Pereira and colleagues (2018), 13 grapevine varieties could be differentiated in wines, and this method could be potentially useful for protecting PDO for wines.

As PCR-based approaches can be problematic when DNA is fragmented, and information on suitable barcoding of genes is lacking, NGS applied to wine samples shows great promise. NGS can take advantage of the growing databases that are accumulating genomic information on grape varieties. NGS can accommodate the analysis of blended wines and can also consider the genetic profiles of yeast and microbes that may have diagnostic signatures associated with grape varieties, region, and country of origin, and even the winemaker and brand.

There is, therefore, an urgent need to evaluate the application of NGS methods for wine authentication given the potential power and flexibility of this approach. In addition to identifying grape variety, NGS can build a profile of yeast and other microbes that enables a wine to be associated with a specific region or winemaker. In addition, given the high value of wine products and the potential for counterfeiting, the development of grape variety DNA microarrays can provide a fast, reusable, continuous, selective, and sensitive detection system for fraudulent wine products. DNA microarrays consist of multiple species or variety-specific probes that produce distinct fluorescent patterns depending on the species/variety present in the sample.

Detecting product fraud
Authentication in herbs and spice products

As with other plant-based food products, a number of chemical and related methods have been used for authentication, but increasing attention is being paid to the potential of DNA-based methods. DNA barcoding is an attractive proposition. However, the application of this method is more problematic to herbs and spices due to the slower pace of development of this concept and suitable tools for plants. To date, a single gene region of suitable variability flanked by a single set of universal primers that can be used across the 200,000+ plus plant species has not been identified. A number of potential markers have been tested and, currently, the use of the matK-rbcL gene is recommended as a potential barcode for land plants, with an option to supplement it with one or two other markers, psbA-trnH or ITS, as it does not always have sufficient discriminatory power.

The application of a range of DNA barcoding and related methods (HRM and PCR) have demonstrated widespread mislabelling and adulteration in the herb and spice products. As with other products where there is a higher degree of processing (e.g. streaming, grading, vacuum drying and extraction using solvents at high temperatures and high pressure), DNA will be degraded, and this limits the usefulness of some genetic methods. Another complication is the presence of secondary metabolites such as phthalates, pigments, resins and tannins, which are present in high levels in plants and may interfere with DNA extraction and PCR methods, thus creating more potential problems for conventional DNA-based methods for authentication.

Nevertheless, DNA, albeit degraded, has been extracted from processed herbal mixtures, botanical extracts and oils, making analyses based on mini-DNA barcodes possible. Further, as with other product forms, the power of newer NGS methods to generate diagnostic sequences from short reads and from mixed-species product forms has not been widely applied but has been shown to be an extremely useful approach. For example, the approach was demonstrated in a study of Ayurveda herbal products in Europe using DNA barcoding. In this study, analysis revealed that only two out of 12 single-product ingredients contained one species as labelled, eight out of 27 multiple-product products contained none of the species listed on the label, and the remaining 19 products contained one to five of the species listed on the label, along with many other species not specified on the label. The conformity for single-ingredient products was only 67%. The overall authenticity for multi-ingredient products was 21%, and for all products 24%. This high level of mislabelling raises very serious concerns about the integrity of such products.

A recent review of DNA-based methods for authentication has concluded that adulteration of herbal products, sold worldwide as medicines or foods, is widespread on a global scale.25 An Australian study by Coghlan et al in 2015 (also using NGS) reached a similar conclusion by finding that 50% of the samples of traditional Chinese medicines contained undeclared products of animals and plants, including an endangered species of snow leopard.

Apart from Coghlan’s study, there seems to have been few studies in Australia on the authentication of herb and spices formulations. However, a study commissioned by Choice using analytical chemical methods found widespread adulteration of the culinary herb oregano in products available in supermarkets. This study showed that of the 12 samples evaluated, only five were 100% oregano. The other seven contained ingredients other than oregano, including olive leaves (in all seven samples) and sumac leaves (in two samples). Ingredients other than oregano made up between 50% and 90% of the adulterated samples. This is similar to other studies from Europe and the UK, which also used genetic-based methods.

Authentication in commercial fish and shellfish species

The global seafood industry is widely recognised as one of the largest and most complex primary food-based industries. It is characterised by the highest diversity of species of any food sector, consisting of thousands of species of fish, molluscs (scallop, clam, mussel, abalone, snail, squid and octopus), crustaceans (crab, lobster, crayfish and shrimp) and other invertebrates, algae and some mammals.

The industry also includes products originating from fisheries and aquaculture sectors, with the former vulnerable to illegal, unreported and unregulated harvesting, which can include the capture of endangered species deliberately or accidentally. Products can also be highly diverse, from whole animals to highly processed products, some of which are difficult to identify to species level (e.g. fish fillets, cakes, Roe) and many of which are highly vulnerable to substitution of higher-valued species with lower-value ones.

With the advent of molecular identification methods, such as DNA barcoding and NGS, the possibility exists for far greater transparency in the fish and shellfish supply chain. Fish traceability is key to combating fish fraud, enforcing food safety regulations and ensuring high standards of sustainable fisheries management. Traceability is also critical for ensuring the quality of fish products and minimising health risks for consumers. The higher specificity, molecule stability and sensitivity of PCR, due to its amplification power, make DNA a perfect target molecule for food authenticity purposes, allowing the detection of mislabelling and food fraud even at trace levels and in processed foods. The advantage of DNA barcoding is that it can be applied consistently in different laboratory settings and does not require the inclusion of reference samples, as identification can be achieved through searches submitted to online genomic databases. The value of DNA barcoding for seafood species is becoming widely recognised by government and market regulators, such as the EU and the US FDA.

As a result, there have been many authentication studies that have applied genetic markers and genomic methods to identify fish and shellfish species. These studies have indicated that fish species substitution and fraudulent practices in wholesale and retail markets are common throughout the world, including in some markets in Australia. Genetic methods applied to seafood species have included both PCR and a range of DNA barcoding approaches, and, very recently, NGS methods.

Reported studies have typically focussed on a particular species group and used limited sampling from usually a limited geographic area. Overall, studies have identified mislabelling rates from 0 to 100%, depending on the species and product form examined,24 with the most common rates falling between 10% and 40%. A small number of studies have been conducted to validate and apply NGS to mixed seafood samples, which shows great promise as it does with other complex food products. Not only can this approach address the problem of analysis of mixed products, but it also gets around the problem of unknown unknowns in a sample, including processed products. Despite these advantages, NGS is still relatively slow and requires access to well-equipped laboratories.

With the advent of molecular identification methods, such as DNA barcoding and NGS, the possibility exists for far greater transparency in the fish and shellfish supply chain.

A newer ground-breaking NGS approach to seafood authentication has been recently published by a Singapore-based group26 using Oxford Nanopore sequencing, which is implemented on small and portable MinION sequencers. These are relatively inexpensive and powerful, and enable on-site and essentially real-time species identification within minutes with internet access. In the first study of seafood species authentication testing, these authors found a 39% rate of mislabelling for mixed-species samples (39%). Cuttlefish and prawn balls were found to contain pig DNA and all but one of the mixed samples labelled as containing crustaceans (crab, prawn, lobster) lacked a signature of crustacean DNA reads. The authors concluded that there is a need for more regular testing of seafood samples and suggested that, due to its speed and low cost, MinION would be a good instrument for this purpose, and this instrument should be considered the default for food authentication using DNA barcoding.

Published studies of seafood fraud in Australia using DNA-based methods are limited compared with the international literature. Those that have been done have used mostly classical genetic methods and DNA barcoding. In 2015, a study seeking to investigate labelling accuracy in seafood retailers in Tasmania using DNA barcoding of 38 samples found that no products were mislabelled. There were a few cases of naming discrepancies or ambiguity, with broad or obsolete fish names being used. A second Australian DNA barcoding-based fish authentication survey was a citizen science project, a collaboration between a secondary school (Sydney Grammar) and a scientific research institute (Australian Museum). This study sequenced 68 fish from two retailers in Sydney and confirmed the retailers’ identifications for 93% of samples and 90% of species sampled, although 40% of fish names were not compliant with the Australian Fish Names Standard (APFN).

The most comprehensive study of fish authenticity in Australia was conducted by Sally-Anne Williamson (Molecular Genetic Approaches to the Identification of Commercial Fish Species, PhD Thesis, Deakin University, 2008), and remains largely unpublished. This study investigated the use of DNA barcoding of the 16S rRNA gene for fish species identification and authentication of 116 fish filament samples for markets in south-eastern Australia. This study found widespread mislabelling, including of trevally, red emperor, flake, dory, bream, orange roughy, barramundi, snapper and cod fillets, and indicated more comprehensive if not routine studies are required.
The development and application of newer DNA technologies to authenticate timber products produced in Australia or imported is considered a major priority given the uncertain identity and provenance of the species involved.
### 9.2 Australian testing capacity

A scan of government and commercially available testing laboratories has identified the following. Most seem to focus on compliance and standards testing as required by regulatory and quarantine authorities. As consequence, these laboratories are resourced and staffed to undertake a range of routine testing for chemicals (e.g., organic, metals, pesticides, and residues), biological parameters (e.g., protein, fats, allergens), and microbial species. Laboratories did not generally have the resources for the more sophisticated analytical chemical and genetic testing required for food authenticity and provenance testing. These more niche and specialist services are usually provided by universities, research organisations or large overseas companies. In the UK, Centres of Expertise (CoEs) in food authenticity testing have been established to capture the network of companies and organisation that have the capacity to undertake food authentication services (food authenticity, risk management, gene technology, etc.). A similar model should be considered for Australia.

#### Food and agriculture testing services

The Australian Government’s Department of Industry, Science, Energy and Resources, through its National Measurement Institute (NMI), offers an extensive range of chemical, microbiological and sub-contracted tests. NMI laboratories located in Sydney and Melbourne hold a National Association of Testing Authorities (NATA) accreditation for chemical and biological testing.

The Department of Agriculture, Water and the Environment monitors imported food at the border for compliance with Australian standards. If you import food, you are legally responsible for meeting the standards that apply to your products to ensure they are safe and suitable for their intended use under the Imported Food Control Act 1992.

### 9.3 Product fraud prevention and mitigation

The following sections detail strategies to prevent or mitigate product fraud, and case studies of where these have been successfully implemented.

#### 9.3.1 Vulnerability assessment and certification

Over the years, Australian industry and regulators have developed food safety management systems. These systems are not specifically designed to detect or mitigate product fraud, and case studies of where these have been successfully implemented.

The Oritain method is robust and provides reassurance that other traceability services cannot. When you partner with us, you are choosing a new benchmark for product traceability and safety. The company provides product verification services across a range of product categories, including dairy, meat, horticulture, honey, cotton, wool, aquaculture (including prawns) and eggs.

According to Oritain, “When it comes to produce, the only absolute truth lies within the product itself and the unique chemical profile that product owes to the distinct environment it was grown or reared in. Oritain test these unique properties, creating a specific fingerprint for a product’s origin, and then use this fingerprint to verify the origin of that product at any point throughout the supply chain. With the many complexities and variables in a supply chain, the one thing that remains consistent is the product. A product-focused verification method, therefore, negates all other supply chain variables and provides a more robust answer to consumer demands.”

Other

There are also a range of university-based laboratories that provide genetic sequencing and NGS product authenticity testing services. These include:

- Deakin Genomics Centre, Deakin University
- The Ramaciotti Centre for Genomics, UNSW, the largest genomics facility at any Australian university.

Merieux NutriSciences Australia

We were unable to contact Merieux NutriSciences directly. Its website states that consumers today want to be sure about the quality and origin of the foods they eat. To protect their customers in the food and food-supply chain from fraud and brand damage, Merieux NutriSciences offers advanced methods of food authenticity testing.

Eurolabs Scientific

The global network of European company Eurolabs provides the Australian food industry with brand protection through a portfolio of world-leading authenticity testing. With an office in Melbourne, it indicates that it uses both DNA methods and analytical chemistry-based approaches.

SSA agriculture and Food

SSA agriculture and Food is a European company described as the world’s leading inspection, verification, testing and certification company. It offers a comprehensive range of food safety, quality and sustainability solutions to help grow consumer confidence and a sustainable business, mitigate risk, and improve efficiency at every stage of the value chain. For example, it offers an ‘All Species ID’ service: a single test to identify all species within a food sample. This service uses next generation sequencing (NGS) of DNA and is a powerful tool for food analysis, food authenticity testing and the identification of ingredients, pathogens, allergens and potential adulteration, even in highly processed food products.

The company has an office in Melbourne and appears to be one of the more sophisticated operations, but it is not clear what its capacity is within Australia.

AUSLABS

AUSLABS is an Australian company with an international footprint. ALGS states that it is a global leader in providing laboratory testing, inspection, certification and verification solutions. It provides the following services: meat speciation; halal verification; and genetically modified food (GMO) verification. Food authenticity testing appears to be only a small part of its portfolio.

Oritain

Oritain is a New Zealand-based company, its vision is to be the most trusted company in the world at scientifically verifying origin. Its website states that “The Oritain method traces actual products back to their true origin using advanced science.”

### Timber fraud

Substitution and mislabelling are the most common types of product fraud issues as mentioned by Simon Dorries, CEO of Responsible Wood. Based on his vast experience he stated the following:

“The amount of misrepresentation in relation to compliance with Australian Product Standards is significant. Australian building codes have requirements for wood products to meet Australian Standards. Unbranded products are unable to be used and cannot be sold in applications covered by National Construction Codes. It has become the ‘normal’ business model of many overseas manufacturers and their Australian customers to simply brand Australian Standards numbers on non-complying products to provide fraudulent access to the building products market.

In a former role as GM of the Engineered Wood Products Association of Australasia, we ran a market surveillance program for several years where products would be purchased from the open market and tested in our NATA-accredited laboratory. The failure rate in products from some Asian countries labelled as complying with Australian Standards was 80%. The non-compliant import was typically priced 40% below the Australian-compliant alternative. The result has been a very significant reduction in profitability as the market price was set by the import. This had resulted in the closure or downsizing of five Australian plywood mills. In terms of sales, in a single product line, formwork plywood, the reduction in Australian manufactured sales is $50 million.”

Oritain

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The Oritain method is robust and provides reassurance that other traceability services cannot. When you partner with us, you are choosing a new benchmark for product traceability and safety. The company provides product verification services across a range of product categories, including dairy, meat, horticulture, honey, cotton, wool, aquaculture (including prawns) and eggs.

According to Oritain, “When it comes to produce, the only absolute truth lies within the product itself and the unique chemical profile that product owes to the distinct environment it was grown or reared in. Oritain test these unique properties, creating a specific fingerprint for a product’s origin, and then use this fingerprint to verify the origin of that product at any point throughout the supply chain. With the many complexities and variables in a supply chain, the one thing that remains consistent is the product. A product-focused verification method, therefore, negates all other supply chain variables and provides a more robust answer to consumer demands.”

Other

There are also a range of university-based laboratories that provide genetic sequencing and NGS product authenticity testing services. These include:

- Deakin Genomics Centre, Deakin University
- The Ramaciotti Centre for Genomics, UNSW, the largest genomics facility at any Australian university.
The common factor in many cases of product fraud is that the adulterant is neither a food safety hazard nor readily identified (as this would defeat the aim of the fraudster).

The rise in reported fraud incidents has highlighted the need to reinforce companies’ abilities to combat fraud within their own organisation and across the entire product supply chain. Product fraud guidance and self-assessment tools have been developed by a number of organisations (see section 10.1) to help companies undertake their own vulnerability assessments and implement appropriate control plans.

More recently, methods and tools have been specifically developed to assist companies assess, prevent and mitigate product fraud. A number of regulatory and certification organisations, such as the Global Food Safety Initiative (GFSI), specifically require a vulnerability assessment and compliance to be conducted using Vulnerability Assessment and Critical Control Point (VACCP). The use of VACCP approaches and the implementation of associated mitigation plans are designed to help protect product supply chains from fraudulent practices. It is now widely accepted that vulnerability assessment is an important first step in addressing the product fraud issue.

9.3.2 Product traceability systems

Traceability is the ability to track any product through all stages of production, processing and distribution. A traceability system is the “the totality of data and operations that is capable of maintaining the desired information about a product and its components through all or part of its production and utilisation chain.” A traceability system collects and records data points to perform real-time tracking of a product’s movement through the supply chain from origin to its final destination. Currently traceability systems vary widely in their scope and sophistication. They can range from individual firm-level systems capturing transactions within their own supply chain to multi-stakeholder platforms capable of tracking a product across the end-to-end product supply chain.

The Australian Government Department of Agriculture, Water and the Environment’s National Traceability Project commenced in 2017 with the aim to develop a National Traceability Framework and Industry Action Plan. Traceability is defined as “the ability to follow the movement of a product through stages of production, processing, and distribution” (ISO 2007).

End-to-end product traceability systems are challenging and expensive to implement. The private sector is the main driver of traceability and investments are typically motivated by consumer demands, risk mitigation, standards compliance, efficiency gains, or some combination of these incentives. Additionally, traceability systems often require advanced technological and record-keeping capacities that SMEs often lack. To complicate matters further, products produced are often combined at the wholesale collector or intermediary level, presenting a key challenge for traceability systems.

In developing countries, the inherent challenges of establishing traceability can be further exacerbated by deficient physical and technological infrastructure, poor access to electricity and internet, poor digital literacy, and fragmented informal supply chains. Despite these challenges, traceability systems can prove supplier compliance with standards and regulations, and/or verify product geographic origin.

Food Standards Australia New Zealand

The Food Standards Australia New Zealand (FSANZ) website defines traceability as “The ability to track any food through all stages of production, processing and distribution (including importation and at retail). Traceability should mean that movements can be traced one step backwards and one step forward at any point in the supply chain”. Standard 3.2.2 – Food Safety Practices and General Requirements in chapter 3 of the Food Standards Code covers the “one step back and one step forward” element of traceability under Clause 5 (2) – Food receipt and Clause 12 – Food recall.
Case study 2  →  Beston Global Food Company

Beston Global Food Company (BGFC) is a South Australian multi-award-winning company primarily focused on:

- Marketing and distribution of premium Australian dairy and nutrition products into local and international markets.
- Production of milk, high-margar Cheddar, Colby, Romano, Pepato, Gouda, Parmesan and Mozzarella cheeses and other dairy-related products, including dairy nutraceuticals.
- Development and commercialisation of end-to-end food traceability and anti-counterfeit technology.

Beston’s dairy operations are located in South Australia, with two factories located at Murray Bridge and Jervois, and the company provides employment for about 300 employees. In 2018, the company commenced operations at its new $26 million state-of-the-art Mozzarella plant at Jervois. BGFC products are predominantly sold in Australia, the Philippines, Vietnam, Malaysia and China.

Since its establishment in 2015, Beston has been transitioning into a company focused on the production and supply of the premium Australian dairy and nutrition products (especially high-margar products, Mozzarella and lactoferrin nutraceuticals) to both the domestic and export markets. This transition has been underpinned by the company’s commitment to the highest-quality food safety standards, demonstrated through its third-party-audited accreditations, including the Global Food Safety Initiative’s Safe Quality Food (SQF) Level II Certification for manufacturing, processing and distribution.

Within this same timeframe, BGFC has built a reputation, both domestically and internationally, for producing premium-quality dairy products, including BGFC’s multi-award-winning ‘Edwards Crossing’ Australian cheese range.

BGFC fraud prevention strategy: Traceability and anti-counterfeit technology

As well as making major changes in the supply side of the business, BGFC has also focused on the demand side by investing in technology that enables consumers to authenticate BGFC products, and track and trace the ingredients.

Beston’s Chairman, Dr Roger Sexton, revealed that: “When BGFC was established, we expected that we would be able to purchase some existing off-the-shelf technology for the purposes of providing our consumers with the ability to check for ‘fake’ products and ingredient verification. However, when we learned that we could not source the right technology anywhere in the world, we set about building our own technology solution.”

In order to achieve this, BGFC in 2018 established a separate subsidiary company, Beston Technologies Pty Ltd, which is wholly owned by BGFC. Since its creation, Beston Technologies has successfully developed a technology platform that has been awarded 13 patents, including a blockchain patent from the US.

The Beston Technologies system comprises two separate technologies that can be delivered on a mobile device and provide consumers with the ability to verify the source and ingredients in BGFC’s food products and obtain assurance that the product they are purchasing or consuming is authentic:

1. BRANDLOK anti-counterfeiting is a BRANDLOK packaging seal attached to a product that contains data trace indicators that can be identified at point of consumption, to verify that the product is authentic.

2. OZIRIS end-to-end traceability is an app that scans traceability-enabled labels to provide details to consumers on the origin of the product and the ingredients and processes used in the manufacture of the product. Using the OZIRIS app, consumers can scan BGFC products via QR or barcode and OZIRIS will authenticate the product and trace it back to its source.

In 2019, BGFC commissioned an independent review of its technology by the technology-consulting firm Readify Pty Ltd (a subsidiary of Telstra Corporation). The review concluded that the Beston Technologies platform (combining BRANDLOK and OZIRIS):

- Utilises fit-for-purpose technologies and presents functionality via attractive easy-to-use interfaces on appropriate mobile devices.
- Solves verification and authenticity of the ‘actual food product’ while in the hands of the consumer.
- Provides a powerful model to market, based on the OZIRIS app being available on iOS and Android devices and displaying content in English, Mandarin and Arabic.

The review also identified a number of areas for technology enhancements, particularly in relation to cyber security protections. It is understood that these are currently being developed and implemented by Beston Technologies.

In June 2020, BGFC signed an agreement with the US technology company Digimarc Corporation to develop and offer an integrated e-commerce traceability and anti-counterfeiting software-as-a-service (SaaS) solution to customers across a range of industries.

BGFC has stated that: “The aim of the agreement is to establish Beston Technologies as a value-added re-seller of fraud prevention solutions comprising both Beston Technologies and Digimarc software.”

BGFC also states that it is confident that the technology embodied in the Digimarc platform is extremely complimentary to the Beston Technologies system, and when combined, the objective is to achieve commercialisation of the technology as a comprehensive and proven solution for Australian businesses seeking anti-counterfeiting and provenance verification solutions for their products.
In June 2020, Meat & Livestock Australia (MLA) launched its Red Meat Traceability Information Hub. MLA’s traceability information hub aims to provide detailed traceability information, including:
- Possible technology solutions.
- A project initiated to pilot country-of-origin marker technology.
- Commercial case study technology trials to determine the best way to provide customers and consumers with confirmation of the authenticity of product.
- Funding opportunities for market research.

In January 2021, MLA announced that the following three reports were now available on the Red Meat Traceability Hub:

1. Product safety and integrity issues in Australian red meat reports in international databases
   - To identify actual and potential food safety risk and fraud arising from the use of Australian red meat products in Australian and export markets, MLA has subscribed to the Food Forensics Newsletter, Fera HorizonScan, Descemis Horizon Scanning and Risk Plaza. For the Australian red meat industry, this report reassures that our strict regulatory system conforms with major exporting partners, as evidenced by the lack of reported issues related to Australian red meat products. In addition, it also shows Australia has very good hygiene standards.

2. Compositional Traceability — Origin Fingerprints for Australian Beef and Lamb
   - In response to rising product fraud and increasing demands for traceability and authenticated provenance claims, The MLA Donor Company partnered with Britain in an R&D project to validate and demonstrate Britain’s ability to scientifically distinguish Australia beef and lamb from meat produced in other countries. The red meat industry and its stakeholders are now able to test products from anywhere in global supply chains to objectively verify that Australia-labelled beef and lamb are true to their claimed country of origin.

3. Cutting room traceability
   - Meat (primals, trim, offals) leave processing establishments in a carton with a label that provides detailed information about the product, and a unique GST-compliant barcode. The most vulnerable point in supply chain integrity for a product’s journey to a consumer is when the contents of the carton are prepared for retail sale (trimming, portioning, offcuts etc.). This project documents the steps and procedures that are in place within Australian export-licensed plants to mitigate the above risk – both systems in operation now and hypothetical ones.

Case study 4 → Trackable barcoding for beef

PricewaterhouseCoopers (PwC) has developed an electronic etching procedure that creates an invisible, trackable barcode for beef based on edible, non-toxic silicon dioxide. This beef tagging technology approach starts in the abattoir, where sides of beef are sprayed with particles of silicon dioxide and refracts back a wavelength signature, or what PwC says is “a unique serial number on a piece of steak.” PwC is currently working with researchers to enable scanning by smartphone cameras, and this will be followed by similar devices for wine and dairy products as part of a Food Trust Platform developed by PwC. Initially, the micro tag will be embedded in the beef’s primary packaging only; Silicon dioxide is approved as a food additive by FSANZ.

Case study 5 → Australian Pork Limited (APL) traceability system

Physi-Trac® is a robust traceability system for pork. It works by identifying the trace elements of an unknown sample and comparing this with known reference samples. Physi-Trac® can be used effectively to validate the country, state and farm of origin of fresh pork and liver. For processed ham and bacon, it is used to verify whether the product was made from Australian pork or not. This system extends pork and product traceability to a final, unpackaged product, including pork that does not have any identifying labels.

Case study 3 → Meat & Livestock Australia’s Red Meat Traceability Hub

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9.3.3 Blockchain

Blockchain is also often oversold as a ‘guarantee’ of product authenticity and anti-counterfeiting in general. A blockchain is a chain of recorded transactions used as a digital register, which records transactions between two parties. It is important to recognise that this is not the ultimate solution to the problem of product fraud. The only legitimate and legal way to guarantee product authenticity is through analytical authenticity testing of the product itself.

However, a range of product sectors are already integrating blockchain into their operations. IBM’s blockchain-based traceability platform, Food Trust Network™, incorporates more than 80 retailers and suppliers, including major multinational food companies such as Carrefour, Walmart and Nestle. Food traceability technology startups such as Pips.IO, Provenance, and FoodLogIQ are also crowding into this space with their own proprietary platforms. The advantage of blockchain lies in its strong protection against manipulation. Every modification to the blockchain is traceable. However, a blockchain alone cannot guarantee the integrity of data it contains. This is still the responsibility of the person entering the data to ensure those data stored in the blockchain are correct and authentic. Currently, an increasing number of food companies are starting blockchain projects. Walmart was a pioneer with a blockchain for leafy greens (see case example below). In this pilot project, consumers were able to gain insight into the supply chain all the way to the producer by scanning a QR code printed on the product label with their mobile phone.

Anyone who deals more intensively with blockchain technology will, sooner or later, come across the term ‘smart contract.’ Smart contracts automatically check whether certain conditions are met that parties negotiated and agreed on before. They can be organised in a legally binding way. For example, upon delivery, a product is automatically prepared for laboratory testing. Results are then automatically compared with contractually agreed specifications. Finally, the delivery is automatically released, and payment for the delivery is automatically initiated. In the light of advancing automation and the Internet of Things, this may be an important approach in the future.

→ Blockchain and product provenance

Software companies often claim that they ‘track provenance’. Product provenance refers to geographic source or origin and is determined by authenticity testing, not software. As a hypothetical example, say we have cherries in Tasmania that are sold online (e-commerce platform) and go to market as ‘Product of Australia’. Fraudsters could pack the cherries in cartons labelled as Tasmanian-grown to enhance the illusion of being Australian-sourced product. When the cherries are tested for their authenticity, the species and their carbon fingerprint prove they are indigenous to, and were grown in, a particular region of China. This is product fraud and classified as counterfeit product where a cheaper cherry product is sold as a more expensive premium Australian product. Blockchain will not solve this, because human behaviour is the variable. Only analytical authenticity testing laboratories can address this issue.
The IBM Food Trust Network™ system uses Hyperledger. According to Walmart, the program aims to increase a safer and more sustainable food ecosystem. The system claims to allow digitisation of transactions in real time. This sharing of data in a secure, trusted manner, allowing more open access to information gathered by suppliers. “Blockchain enables digitised transparency in the food system and create shared value for the entire leafy green farm-to-table supply chain. Walmart believes that the system will provide suppliers with the ability to trace fresh, leafy produce from farm to table in real time, using the IBM Food Trust Network™. Walmart will require their suppliers of fresh, leafy greens to implement real-time traceability of products back to the farm. Walmart states that: “Blockchain enables digitised sharing of data in a secure, trusted manner, allowing more open access to information gathered by suppliers.”

The IBM Food Trust Network™ system uses Hyperledger. Hyperledger is an open source, private, permissioned blockchain developed by the Linux Foundation. The aim is to allow all approved network participants to contribute to a safer and more sustainable food ecosystem. The system aims to digitise transactions in real time. This enables it to provide a more efficient way of working across the supply chain – from the leafy green growers, to the processors, shippers, retailers (Walmart), regulators, and finally the end consumers.

According to IBM’s Ramesh Gopinath (VP Blockchain Solutions), GS1 standards are used to make sure all participants are speaking the same language. Mr Gopinath stated: “Some players in the Walmart food supply chain will provide serialised numbers at the case level, some at the pallet level, and some only at the lot level as not everyone is at the same level of maturity, and there are data gaps.” So by using Blockchain, Walmart hopes to achieve speed of traceability and transparency, with information captured on-farm with a handheld system. The net effect should be greater trust.

A critical question is whether the traceability initiative will have legs. Walmart imposed a RFID obligation on its 100 largest suppliers in 2005. Suppliers saw this as providing value for Walmart but being counterproductive for them. They believed the initiative provided little value to their supply chains but was certain to increase their costs. Not surprisingly, the RFID program failed. So the question then becomes, how much does it increase Walmart’s costs? Once Walmart starts to generate data, it will have to see how increased costs surrounding the food trust system are balanced by lower costs in, for example, product recalls; how much prices for produce will need to increase; whether those price costs can be passed along; and similar cost-benefit trade off questions. In short, the viability of blockchain for the Walmart traceability initiative is not assured yet.

IBM is taking an interesting approach to pricing its Food Trust Network™ traceability system solution. Companies that want to join the Food Trust Network™ will be able to provide traceability data for free. These companies will need to inform IBM on who they are, the products they want tracked, and who they will be interacting with from a one-up, one-down perspective using GS1 standards. According to IBM, companies will need to make sure they can provide clean data, and figure out how that data will be sent to the blockchain. IBM proposes to charge a subscription fee to share certificates. For example, a farmer may claim that they offer organic strawberries, an auditing firm verifies this, and IBM charges for uploading the organic certification to the blockchain.

Quick response codes

Quick response (QR) codes are computer-generated images that can be printed on products and packaging. Basically, a QR code is an extension of a traditional barcode and works in the same way as a barcode at the supermarket. It is a machine-scannable image that can be scanned by consumers using any modern-day smartphone and directs them to a website to access additional product information. Quite simply, a QR code is an encoded piece of data.

Case study 6  →  Walmart Food Traceability Initiative

In 2019, US retail giant Walmart unveiled a new food safety program that requires suppliers of fresh leafy greens to use a blockchain-based solution called the ‘Walmart Food Traceability Initiative’. The company told its suppliers: “Walmart believes the current one-step-up and one-step-back model of food traceability is outdated and that, by working together, we can do better.” Paper-based ledgers mean it may take seven days to track down a product’s source, and a typical grocery store stocks 70,000 food items.

According to Walmart, the program aims to increase transparency in the food system and create shared value for the entire leafy green farm-to-table supply chain. Walmart believes that the system will provide suppliers with the ability to trace fresh, leafy produce from farm to table in real time, using the IBM Food Trust Network™. Walmart will require their suppliers of fresh, leafy greens to implement real-time traceability of products back to the farm. Walmart states that: “Blockchain enables digitised sharing of data in a secure, trusted manner, allowing more open access to information gathered by suppliers.”

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Case study 7  →  Counterfeit wine in China

Australian companies such as Treasury Wine Estates and its flagship brand Penfolds have been plagued by the problem of counterfeit wines in China. In November 2019, police in China’s Henan province arrested 11 people and seized more than 50,000 bottles of fake wine, bottled as Australia’s Penfolds and China’s Changyu.

Following the discovery of 14,000 bottles of fake Penfolds wine for sale in China in 2018, Wine Australia had to concede it can’t keep track of the extent counterfeit Australian wine is being sold in the country. “It is extremely hard to work out how much is going on. There are a range of anti-counterfeit technologies available to exporters – Wine Australia doesn’t support any particular solutions because we see there is strength in diversity,” Sydney Morning Herald, 2018.

One possible solution to the problem has been developed by Australian Sydney-based business YPB, which has created a specially designed serialised QR code with an embedded covert tracer. The “ProtectCode” covert tracer enables wine producers to track and trace every bottle and batch of wine throughout the entire supply chain using a small handheld scanner. According to YPB, an end consumer can then use their smartphone to scan the code to determine whether the wine is fake or authentic.

Accolade Wines, whose brands include Hardy’s, is working with YPB to become the first Australian company to trial the ‘ProtectCode’ system. In October 2019, YPB signed a deal with Accolade to provide it with “YPB’s integrated brand protection and customer engagement technology suite” as stated in the agreement. ‘ProtectCode’ will first be implemented on Accolade’s Grant Burge range of wines, and may be rolled out to the company’s other premium ranges if it proves successful.

The Financial Review (February 2020) reported that Peter Yates, a former Macquarie banker and ex-CEO of Kerry Packer’s PBL, had joined forces with ASX-listed Israeli supply chain integrity technology firm Security Matters to launch a new company focused on eliminating counterfeit wines and spirits. The new joint venture company will be called Security Matters Beverages. Security Matters Beverages will licence Security Matters asset tracking technology, created by the Israeli government at the Soreq Nuclear Research Centre.

The technology permanently ‘marks’ any object in solid, liquid or gas form, verifying its origins and making it possible to track it through the supply chain. It comprises an invisible liquid-based barcode system, a reader that can identify the codes and a blockchain-based record that stores and protects ownership data.
9.4 Smart packaging

Smart packaging, an emerging technology in the food packaging industry, links the physical world with the digital world. It is important to recognise that consumers do not purchase packaging; they purchase food products that happen to have packaging built into the product offering. In principle, smart packaging describes packaging with extended functions. There are usually two types of smart packaging – active packaging and intelligent packaging.

9.4.1 Active packaging

Active packaging is packaging that interacts with the contents and thus improves the shelf life or quality of the contents during storage. Either certain substances are released into the medium or certain substances are removed from the medium or its immediate surroundings. This is achieved by using light-filtering materials, oxygen and ethylene absorbers, antimicrobial surface coatings or moisture-regulating materials. The active component can be integrated into the packaging or added separately in the form of inserts.

A typical example is beer in a plastic bottle, which contains an oxygen absorber in the screw cap. This extends the shelf life from three to six months. Another example is film packaging with ethylene absorbers. The ripening hormone ethylene is absorbed during the storage of the food and thus ensures a longer shelf life.

9.4.2 Intelligent packaging

Intelligent packaging is packaging that offers an additional benefit that goes beyond the mere packaging task. The ‘intelligence’ of packaging essentially results from ‘communication’ with the outside world. This can include diagnostic and indicator functions that use indicators or sensors to monitor the condition of the product and provide information on, for example, tightness, storage time, temperature or freshness. Alternatively, the indicators or sensors can be integrated in the packaging, placed on the outside or inside the packaging.

Thanks to these integrated freshness, time and temperature indicators, retailers and consumers can see whether a critical temperature limit value has been exceeded. For example, a colour change in the packaging indicates an interruption in the cold chain, a leaky packaging or an unwanted proliferation of Salmonella.

Furthermore, intelligent packaging also includes information or protective functions, for example through barcodes, LEDs, augmented reality, near-field communication (NFC), loudspeakers, radio chips or displays. One example is intelligent drug packaging with built-in radio-frequency identification (RFID) chips. LEDs and tiny loudspeakers that register the removal of pills and sound an alarm if they are taken incorrectly or even inform the doctor treating the patient. The same applies to packaging with NFC chips, which, using an NFC reader (e.g. smartphone), make it possible to read out the package insert and reorder the medication.

9.4.3 Extended packaging

Extended packaging offers smartphone users additional product information on origin, production conditions or ingredients. By scanning QR codes or RFID chips, the information can be called up in conjunction with a suitable app on the internet.

At the same time, this technology can, of course, also be used for logistics and marketing purposes. For example, the Johnnie Walker Blue Label bottle uses extremely thin electronic sensors that transmit when the bottle has been opened, or where it is in the distribution chain. In addition, Diageo can upload promotional offers while the bottle is in the store.

Wine bottle recycling

There are reports (some anecdotal) of an underground industry that trades in used wine bottles. A hotel or restaurant worker may be incentivised to collect and sell empty premium and/or vintage wine bottles, which can then be re-sold for thousands of dollars, often with fake security features. According to a 2017 Forbes article, an estimated 30,000 bottles of fake imported wine are sold in China every hour.

Solution providers are making technology advances and incorporating security features that create obstacles on the bottle itself, including tamper-evident features and fraud alerts for multiple scans of the serialised QR code identifier. Despite the technology improvements and their functionality, the only way to legally guarantee the wine is genuine is through forensic testing of the wine bottle contents against the reference samples taken from the harvested crop or the final blended mix. The storage of reference samples by harvested batch may become a regulatory requirement in Australia.
Internationally, there is an increased vulnerability to product fraud, with global supply chains faced with rapid innovation driven by technology advances and market changes, as consumer choices and preferences evolve.\[10\]

International regulations and standards particularly covering food products are also evolving to keep up with these changes in the marketplace, aimed at protecting the consumer. To add to this complexity, there are many terms and definitions that have overlapping, conflicting or often confusing interpretations, including product fraud, food fraud, product and food authenticity, economically motivated adulteration, food protection, product and food crime, food security, and others. The use of the terminology internationally is often subjective and frequently depends on traditional usage, regulatory changes and company-specific terminology.

To assist with communication and understanding among many governments, stakeholders and trading partners, it is recognised that there is a need for harmonisation and benchmarking of key terms based on a common and well-recognised terminology framework. Recent and current international research on product and food fraud prevention extends beyond the traditional science disciplines and now includes social and behavioural sciences and criminology. This has led to alternative and sometimes confusing definitions and uses.\[10\]

Different countries have different food fraud regulations and often they even define the words according to their own unique priorities. Below are four examples of how countries around the globe define product/food fraud differently.

- **Australia** - Gaining a financial advantage or causing a financial disadvantage through deception or dishonesty.
- **Canada** - The deliberate and intentional substitution, addition, tampering or misrepresentation of food, food ingredients, or food packaging for economic gain.
- **United Kingdom** - The deliberate and intentional substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging, or false or misleading statements made about a product for economic gain.
- **United States** - The intentional adulteration from acts of terrorism targeting the food supply. The hazard may be intentionally introduced for purposes of economic gain.

Each country has its own set of regulations in place to protect consumers from what its government has defined as product/food fraud. The Norwegian Institute of Food, Fisheries and Aquaculture Research (Nofima) has led a European initiative with the objective of making communication regarding food fraud more precise. Together with food fraud experts (including from the Food Authenticity Network Team) from several European countries (including the UK), a European standard has been created that defines many of the English terms and concepts used in connection with food fraud.

The standardisation was coordinated as part of the EU-funded Authent-Net and FoodIntegrity projects. It was published in January 2019 by Standard Norway, and it is also being distributed by several other national standardisation bodies in Europe; currently Estonia, the Netherlands and the UK. This standard represents an important first step in the global standardisation of these terms, which will help facilitate trade, combat food fraud and better secure food supply chains.

### 10.1 International food standard initiatives

Over the past few decades, food safety and quality has greatly improved in the food and food ingredient sectors. The main driving forces for this improvement have been the various food safety standards that have provided food operators with a framework for managing product safety throughout their entire manufacturing process. There are currently several food safety management systems owners, now known as food safety Certification Programme Owners (CPOs), available internationally, all of them recognised by leading retailers and manufacturers worldwide. Examples of CPOs include International Featured Standards (IFS), British Retail Consortium (BRC) Global Standards, Safe Quality Food (SQF), and GlobalGAP (Good Agricultural Practices).

A food operator can be certified compliant to one or more of these standards through regular audits carried out by a certification body, itself authorised to conduct the audit through a formal agreement with the CPO.

Given the number of different schemes in place, many food operators have found themselves having to undergo multiple audits, each one associated with a different standard. Faced with this situation, leading food companies got together to see how they could help manage costs for food businesses by reducing duplication of audits while continuing to provide safe food to consumers across the globe. In the early 2000s, the Global Food Safety Initiative (GFSI) was created with the aim of harmonising standards across the global supply chain; its goal was “once certified recognised everywhere”. This was achieved by establishing equivalency between the different CPOs through a set of clear benchmarking requirements that each CPO must include in their standard in order to obtain GFSI recognition.

GFSI’s primary mission is to provide safe food to consumers and, as such, its main focus has been on reducing food safety risk. However, with a growing awareness that food fraud was on the increase and could have possible detrimental effects on public health, the GFSI took steps to include this concern in its remit.

In 2012, the Food Fraud Think Tank was set up with the support of GFSI, to explore how food fraud could be incorporated into existing CPOs. The work of the think tank gained further credence when, in early 2013, the horse meat scandal hit the headlines. In 2014, GFSI published its position on “Mitigating the Public Health Risk of Food Fraud”,\[31\] where it accepted the think tank’s recommendations and included two key elements as part of its benchmarking requirements. These were:

1. Companies should perform a Food Fraud Vulnerability Assessment in which information collected at specified points in the entire supply chain (supply chain mapping) is evaluated based on the potential for food fraud.
2. Companies should put in place a Food Fraud Control Plan consisting of a set of mitigating measures, including a monitoring and testing strategy, specifications management, supplier audits and anti-counterfeit technologies.

These recommendations have since cascaded down into the CPOs via the GFSI’s (2017) ‘Benchmarking Requirements Version 7.1’.\[32\]

With these requirements now in place, food companies have been seeking help with implementing the vulnerability assessment required by the CPOs. There are now a number of tools available to help companies with this that have been developed either independently from or specifically in reply to the new GFSI requirements for food fraud mitigation. The two main tools that are freely available to food operators are the US Pharmacopoeia (USP) Food Fraud Mitigation Guidance Document\[33\] and the SSAFE/PwC Vulnerability Assessment Tool.\[4\]

It is worth noting that, in all cases, the tools that have been developed are described as ‘living’ or dynamic tools. Food fraud and associated vulnerabilities do not remain static but evolve over time, often influenced by changing environmental conditions, the emergence of new markets, fluctuating economic conditions, the appearance of new adulterants, and so on. It is therefore important that the vulnerability assessment process be carried out on a regular basis.

All the vulnerability assessment tools identified in our research rely on obtaining up-to-date information on previous food fraud incidents and possible mitigation measures. Recognised international organisations and industry groups actively involved in fraud assessment and prevention include:

- **The Safe, Secure and Affordable Food for Everyone (SSAFE) Organization**

First established in 2006, SSAFE is a global non-profit organisation set up to promote food safety across supply chains and improve public health and wellbeing. SSAFE board members are McDonald’s, Nestlé, Danone, Zestia, Cargill, Coca-Cola, Fonterra, Keystone, Kellogg’s, Kerry and SABMiller. SSAFE continues to foster the improvement of internationally recognised food protection systems and standards through public-private partnerships by integrating food safety, animal health and plant health across the global food system.
SSAFE aims to advance the continuous improvement and global acceptance of internationally recognised food safety systems and standards. What makes SSAFE somewhat unique is its focus on driving cooperation between government and the private sector to improve the integrity of food supply chains.

The Global Food Safety Initiative (GFSI)

The Global Food Safety Initiative (GFSI) is an industry-driven group of food companies whose mission is to harmonise, strengthen and improve food safety management systems necessary for safety along the supply chain. GFSI specifies the recognition of food safety management schemes to defined requirements. GFSI was created in 2000 to find collaborative solutions to collective concerns, notably to reduce food safety risks, audit duplication and costs while building trust throughout the supply chain.

The GFSI community works on a volunteer basis and is composed of the world’s leading food safety experts from retail, manufacturing and food service companies, as well as international organisations, governments, academia and service providers to the global food industry. The GFSI provides direction and approval to organisations that create food safety management systems. A GFSI-approved food safety standard is internationally recognised and represents international best practice.

The British Retail Consortium Global Standard (BRCGS)

The British Retail Consortium Global Standard (BRCGS) for food safety was first developed in 1998 by the British Retail Consortium (BRC), to assist retailers with meeting legal food protection systems and standards. What makes BRCGS somewhat unique is its focus on driving cooperation between government and the private sector to improve the integrity of food supply chains.

Safe Quality Food (SQF)

SQF is a Food Safety Management Certification Scheme created and managed by the SQF Institute that was established to control food safety risks. The SQF Food Safety Certification Scheme provides third-party auditing and certification for companies in the food industry. Edition 9 is the current version of the Safe Quality Food Code and was released in October 2020. It is a GFSI-recognised food safety certification.

ISO 22000

ISO is the International Organization for Standardization. It has thousands of standards across many different businesses, products and systems. ISO 22000 is the ISO standard for food safety management systems. Like other major food safety management systems, it is based on the principles of Hazard Analysis Critical Control Point (HACCP) and Hazard Analysis Risk-based Preventive Control (HARCP).

FSSC 22000

FSSC 22000 is a company-level food safety management system standard similar to ISO 22000 but with extra requirements incorporated to meet the requirements of GFSI standards. The FSSC 22000 standard helps organisations ensure the supply of safe food and beverages. Certifications are awarded by FSSC 22000 through licensed third-party certifying bodies.

10.2 Fraud alert databases

Information and data sharing are considered to be key components in the fight against product fraud. The US FDA has a national food fraud database to detect emerging patterns of fraudulent activity and to act as a resource for local authorities conducting investigations into food fraud incidents. The US Pharmacopeial Convention (USP) has a searchable online database that acts as a repository for food fraud reports and associated analytical detection methods. Also in the US, the National Center for Food Protection and Defense (NCFPD) EMA (economically motivated fraudulent adulteration of food ingredients) incident database has been documenting incidences of food fraud since 1980. It provides information about the food product, adulterant, type of adulterant, health consequences, and how the incident was discovered.

Other examples of similar databases include:

Rapid Alert System for Food and Feed (RASFF)

This is the European Commission’s online database of food and feed safety notifications. It can be accessed at www.wgbase.ac.europa.eu. Information can be searched by date, type of product and, under the Hazard/Category, type of adulteration/fraud.

Food Adulteration Incidents Registry (FAIR)

The Food Adulteration Incidents Registry (FAIR) database is compilation of historical and current events involving economically motivated and intentional adulteration of foods on a global scale. The database was developed by the Food Protection and Defense Institute (FPDI), a department of the Homeland Security Centre of Excellence in the United States. Data is collected from publicly available sources and include food adulteration incidents motivated by fraudulent economic gain. The database includes a user-friendly dashboard; a variety of search capabilities; fraud incident summaries; interactive graphics; maps and references. Information and data related to events that occurred more than five years ago are accessible free of charge; more recent information is available by subscription.

Food Integrity Knowledge Base

The Food Integrity Project has built up a comprehensive knowledge base linking each food product and its potential fraud or integrity issues to appropriate analytical strategies that can be used for food fraud detection or authenticity testing. The knowledge base contains information on the type, frequency and impact of the fraudulent practice and the analytical methods available, including their use and performance criteria.

FARNHub: Food Authenticity Research Network Hub

The Food Authenticity Research Network Hub (FARNHub) is an online information hub for resources pertaining to food authenticity. The FARNHub contains an updated overview of scientific publications, past and ongoing research projects, online resources (e.g. databases, web tools), funding bodies, regulations and news stories all concerning food authenticity. The FARNHub was developed in the EU-funded research project Authent-Net, is open access, and can be accessed through farnhub.authent.cra.wallonie.be.

10.3 Fraud vulnerability guidance documents and tools

Recent food fraud crises have highlighted the need to reinforce companies’ ability to combat fraud – within their own organisation and across the entire food value chain. Companies are expected to work proactively towards mitigating the risk of food fraud. Guidance and self-assessment tools have been developed by a number of organisations (e.g. US Pharmacopeia, SSAFE, BRC) to help food companies undertake their own vulnerability assessments and implement appropriate control plans.

There is growing awareness in the food sector of the need for a preventive approach to mitigate the risk of food fraud. While analytical methods such as those described in this report play an important role in detecting adulteration, they are not the only solution to preventing food fraud and sometimes provide no solution at all. A more efficient approach is to look at the entire value chain and identify not risks but vulnerabilities in the supply chain and of the product itself. This means taking into account various aspects of the whole chain.

USP Food Fraud Mitigation Guidance

The United States Pharmacopeial Convention (USP) is a non-profit organisation that creates product authenticity and integrity standards for food ingredients and food chemicals, as well as for medical drugs.

First published in 2016, the USP’s Food Fraud Mitigation Guidance provides a practical framework to help food companies set up a preventive management system for food fraud and identify areas throughout the supply chain where their business may be vulnerable to fraud. The document is designed to be generally applicable to any type of food product and includes a system for identifying fraud vulnerabilities, an impact assessment and a control plan to mitigate fraud risks, set out in four main steps as shown below.

Food Chain HorizonScan

Food Chain HorizonScan is a paid subscription service that provides alerts on adulteration and fraud, as well as food safety and contamination incidents.
A vulnerability assessment identifies the main factors that may be useful for identifying the susceptibility of a food ingredient to fraud. These contributing factors include:

- Supply chain and its complexity.
- The company’s relationship with its supplier and associated audit strategy. Does the audit specifically address anti-fraud measures?
- The frequency and type of analytical methods used to detect fraud and ensure compliance with specifications. Are the methods used able to detect known adulterants?
- The fraud history of the ingredient in question. Has it been implicated in any recent, validated reports?
- Geopolitical considerations linked to the geographic origin of the product and unexpected price fluctuations.

**SSAFE/PwC Vulnerability Assessment Tool**

The SSAFE/PwC Vulnerability Assessment Tool was developed specifically to help companies implement the new FSANZ requirements. SSAFE is a non-profit organisation with global food companies as members. Together with PricewaterhouseCoopers and in collaboration with Wageningen UR and VU University Amsterdam, they developed a science-based tool to assess a company’s food fraud vulnerabilities. This is available as a free tool and can be used by food operators across the food supply chain, irrespective of size, geographic location or type of food business. It can be downloaded as an Excel file from www.ssafe-food.org or completed online by visiting www.pwc.com/foodfraud.

The SSAFE/PwC tool has several components starting with a general information sheet in which the user can enter details of the company and the person or team responsible for filling in the questionnaire. It also provides a decision tree that can be accessed at www.fdf.org.uk. Food and Drink Federation (FDF) in the UK, primarily with the interests of small and medium food business in mind. It can be downloaded as an Excel file from www.ssafe-food.org or completed online by visiting www.pwc.com/foodfraud.

**Pre-screening Identification**
- Recognise potential issues based on criteria, e.g., history of adulteration

**Step 1: Vulnerability Assessment**
- Identify vulnerabilities that could lead to fraud

**Step 2: Impact Assessment**
- Determine public health and economic impact

**Step 3: Overall Risk Assessment**
- Define risk level based on vulnerabilities and impact

**Step 4: Preventative Control Plan**
- Establish a plan to mitigate risk and meet regulatory requirements

**10.4 International standards for authenticity testing**

Numerous food fraud initiatives and programs have been funded across the globe to define quality principles, develop analytical methods and set standards for food authenticity testing.

The Food Authenticity and Fraud Programme (FAF), launched by the Association of Official Agricultural Chemists International (AOAC), aims to identify and develop standard reference methods, for both targeted and non-targeted approaches, for quality control and compliance of food materials. Several research institutions and networks across the EU are collaborating to define terminologies related to food authenticity, in order to harmonise the use of methodologies and approaches to authenticity testing, including the PFAO and Codex Alimentarius.

The UK Food Authenticity Programme, led by the Department for Environment, Food and Rural Affairs (DEFRA), is tasked with developing ‘fit for purpose’ methods for official control laboratories involved in food authenticity testing. The Authenticity Methods Working Group report, in response to recommendations from the Elliott Review on integrity and assurance of food supply networks, sets out the UK’s national framework for food authenticity testing. The report also provides guidance for sampling, and analysis requirements for all laboratories of food authenticity testing.

**Other fraud vulnerability assessment tools**

- **EMAlert™** – Economically Motivated Adulteration
  Vulnerability Assessment Tool is a software tool developed by Battelle in partnership with GMA (an association of food, beverage and consumer products companies). It can be accessed at www.EMAlert.org. As an interactive tool, which is continuously updated, the software provides a company with a quantitative assessment of its vulnerabilities to food fraud in its specific commodity sector. It works on a subscription basis.

- **DF Food Authenticity Guide – Five Steps to Help Protect Your Business from Food Fraud**. This guide was developed by the Food and Drink Federation (FDF) in the UK, primarily with the interests of small and medium food business in mind. It can be accessed at www.fdf.org.uk.

**Australia**

In Australia, food is regulated under a number of regulatory frameworks for food safety, food integrity and biosecurity. All three levels of governments in Australia – the Commonwealth, state and territory and local governments – are involved in food regulation. The food regulation system in Australia is overseen by the Australia New Zealand Forum on Food Regulation and established through an intergovernmental agreement between the Australian, state and territory governments (the Food Regulation Agreement). All the food-related legislation and regulation are governed by the Australia New Zealand Food Standards Code, the Food Standards Australia New Zealand Act 1991 and the Food Standards Australia New Zealand Regulations 1994. The Australia New Zealand Food Standards set legal requirements for the labelling, composition, safety, handling, and primary production and processing of food in Australia.

The standards developed by Food Standards Australia New Zealand are gazetted and those food standards or any variations are adopted automatically, by reference and without amendment, into state and territory food laws. The regulation of food produced at the farm level is usually covered by state and territory primary production legislation, while food Acts usually cover processing and sale requirements.

Accordingly, in Australia, the main bodies governing food businesses are Food Standards Australia New Zealand (FSANZ) and the Australian Business Licence and Information Service (ABILIS) on a national level. As food and drink is a complex and rapidly evolving area, these policies and regulation differ across the country and there are a number of Commonwealth and state-specific food production, manufacturing, trade and consumption-related legislations and regulations, which are overseen by various Commonwealth and state government departments. These regulations are mostly enforced by the local council in which the business exists.

The statutory objectives of FSANZ in developing or reviewing food regulatory measures are explicitly prioritised in the following descending order:

- The protection of public health and safety
- The provision of adequate information relating to food to enable consumers to make informed choices
- The prevention of misleading conduct

**International definitions of product fraud**
Canada

The Canadian Food Inspection Agency (CFIA) is very active in food fraud prevention and detection. In July 2019, the agency received $24.4 million in new food fraud funding after announcing that 12,800 kg of adulterated honey was prevented from entering the Canadian market. Honey adulteration is the process of cutting pure honey with fillers and cheaper sweeteners, including corn syrup.

The CFIA states that it tackles potential food fraud by:
- Analysing food samples
- Conducting inspections at different levels of the food supply chain, including domestic and imported foods
- Verifying that the composition of food products complies with regulations
- Following up on validated complaints by inspecting establishments, products and labels
- Conducting environmental scans to identify product vulnerability and those of highest risk to fraudulent practices
- Working with industry to promote compliance and awareness, which includes providing an ‘industry food labelling tool’ that can be used to help find information on labelling requirements
- Offering a ‘consumer labelling tool’ to help consumers better understand food labels
- Investing resources to proactively monitor food product authenticity
- Enhancing and adopting new innovative scientific techniques to detect authenticity
- Working with other federal government departments, provincial governments and other countries when issues of food fraud are identified across jurisdictions

The CFIA has several enforcement instruments it can apply to offenders, including administrative monetary penalties, licence suspension or cancellation and criminal prosecution. In 2017, the University of Guelph’s Biodiversity Institute, in partnership with the CFIA, received $320,000 in government funding to develop better genomics and DNA barcoding tools, including portable devices. DNA barcoding allows researchers to match animal and plant DNA to their species.

The Safe Food for Canadians Act (known as the SFCR) and the Canadian Food Act establish Canadian laws. A provision of the Food and Drug Act states:

“No person shall sell an article of food that (a) has in or on it any poisonous or harmful substance; (b) is unfit for human consumption; (c) consists in whole or in part of any filthy, putrid, disgusting, rotten, decomposed or diseased animal or vegetable substance; (d) is adulterated; or (e) was manufactured, prepared, preserved, packaged or stored under unsanitary conditions.”

Another section of the act declares:

“No person shall label, package, treat, process, sell or advertise any food in a manner that is false, misleading or deceptive or is likely to create an erroneous impression regarding its character, value, quantity, composition, merit or safety.”

European Union

The safety compliance of food products is covered under the European Commission General Food Law. Article 14 (1) of Regulation (EC) 178/2002 clearly states “food shall not be placed on the market if it is unsafe”. The enforcement of food and feed regulations, including authenticity, is covered under Regulation (EC) 882/2004. The official controls for food and feed legislation are laid down under Regulation (EU) 2017/625. Food safety controls and food standard controls are mandatory to protect consumers from two main types of risks. The food safety risks cover microbiological, chemical, physical, radiological or allergen contaminations and standard risks, including misleading labels.

Operation OPSON

Operation OPSON® is a Europol-INTERPOL joint operation targeting fake (counterfeit) and standard risks, including authenticity control. Food products are defined as any item or substance intended to be, or reasonably expected to be, ingested by humans or animals. Beverages are defined as drinkable liquids, that is to say liquids intended to be, or reasonably expected to be, ingested by humans or animals.

Food products do not include live animals (unless being prepared for sale in a market), plants prior to harvesting, medicinal products, cosmetics, tobacco and tobacco products, narcotic or psychotropic substances, or residues and contaminants. A counterfeit food product is defined as a food product infringing an Intellectual Property Right. All intellectual property rights defined under national and European law are included. A standard food product is defined as a product that does not meet the criteria required by European and national laws regarding its production, packaging, storage and distribution. Generally speaking, it is a product of a quality inferior to that which is legally required under European and national standards.

“The 2020 Europol and INTERPOL OPSON operation has been targeting the trafficking of counterfeit and substandard food and beverage products. The ninth operation of its kind, running from December 2019 to June 2020, involved law enforcement authorities from 83 countries and was supported by the European Anti-Fraud Office (OLAF), the European Commission, the European Union Intellectual Property Office (EUIPO), national food regulatory authorities and private sector partners.

This year’s operation OPSON led to the dismantling of 19 organised crime groups involved in food fraud and the arrests of 406 suspects. More than 26,000 checks were performed and approximately 12,000 tonnes of illegal and potentially harmful products worth about €28 million were seized. With more than 5,000 tonnes seized, animal food was reported as the most seized product, followed by alcoholic beverages (more than 2,000 tonnes), cereals, grains and derived products, coffee and tea, and condiments. Large amounts of saffron were also seized: 90kg in Spain and 7kg in Belgium with an estimated value of more than €306,000.

Media report, July 2020

Law enforcement authorities reported the dismantling of 19 food and beverage crime groups, with huge seizures of animal food, alcohol and dairy products. The 2020 Europol and INTERPOL OPSON operation has been targeting the trafficking of counterfeit and substandard food and beverage products. The ninth operation of its kind, running from December 2019 to June 2020, involved law enforcement authorities from 83 countries and was supported by the European Anti-Fraud Office (OLAF), the European Commission, the European Union Intellectual Property Office (EUIPO), national food regulatory authorities and private sector partners.

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Alcohol and wine

Participating countries: Bulgaria, Italy, France, Greece, Portugal, Switzerland. Dairy product resulted in the seizures of 320 tonnes of smuggled or substandard dairy products. National authorities seized rotten milk and cheese which posed a threat to consumer health. Additionally, 210 tonnes of cheese were seized, which were mislabelled as to their country of origin. A Bulgarian investigation into an unregistered warehouse revealed seven samples of cheese tested positive for starch and E.coli.

Olive oil

Participating countries: Albania, Croatia, France, Germany, Greece, Italy, Iceland, Jordan, Lithuania, Norway, Portugal and Spain. A total of 149 tonnes of cooking oil was seized as a result of a food fraud targeted action led by Greece. About 88 tonnes from the seizures were olive oil and were reported by Albania, Croatia, France, Greece, Italy, Jordan, Lithuania, Portugal and Spain. In Italy, during a check on a company producing olive oil, inspectors found a surplus of products which was not registered in the official documents of the company, thus more than 66 tonnes of olive oil were seized.

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United Kingdom

A range of laws and regulations contribute to preventing food fraud. Food and drink is a devolved area, so policy and regulation differ across the UK. In England, Wales and Northern Ireland, the Food Standards Agency (FSA) is responsible for enforcing food regulations. In Scotland, food regulations are overseen by Food Standards Scotland (FSS).

Legislation – The majority of law relating to food in the UK is based on the Food Safety Act 1990. The Act specifies offences in relation to food safety, quality and labelling. It prohibits food which is not of the nature, substance or quality that consumers would expect, and describing or presenting food in a false or misleading way. Other legislation that affects the production and marketing of food includes the Animal Health Act 1981, the Consumer Protection Act 1987, and the Consumer Rights Act 2015.

Regulation – The FSA and FSS work with local authorities to enforce food regulations. The Department for Environment, Food and Rural Affairs (DEFRA) is the government department responsible for policy and enacting regulations. A full detailed overview of UK legislation relating to food and feed is given in the FSA Food and Feed Law Guide. Some key UK regulations relevant to food fraud (transposed from EU regulations), include:

• The Food Information Regulations 2014 applies to all food businesses and specifies the information that must be provided on pre-packaged food products (such as best/use before dates and ingredients).

• The General Food Regulations 2004 amended the Food Safety Act 1990 to align it with EU regulation. It outlines criminal offences for breaches of certain food laws, specifying penalties such as fines and imprisonment.

• The Food Safety and Hygiene (England) Regulations 2013 set out required food safety and hygiene controls throughout the food supply chain. Similar legislation exists in the devolved nations.

• The National Food Crime Unit (NFCU, part of the FSA) is responsible for intelligence gathering and investigation of food crime incidents.

• DEFRA is responsible for policy and legislation on food labelling (not relating to food safety or nutrition) and composition. It is also responsible for the Government’s food authenticity research program, which identifies risks to food authenticity and develops and validates food-testing methods. The Department of Health and Social Care is responsible for nutritional labelling and policy on food health claims (advised by the FSA).

• The UK Government Chemist provides food expert opinion and has a statutory function as a referee analyst by arbitrating in any analytical disputes between a local authority and a food business operator.

United States

Multiple compliance requirements are in effect in the US, including the Global Food Safety Initiative (GFSI) Certification, Food Safety Modernisation Act (FSMA), Food Drug & Cosmetic Act (FDCA), Codex Alimentarius (CODEX), International Standardization Organization (ISO) and others. Since 1 January 2018, the GFSI compliance requires a Food Fraud Vulnerability Assessment and Food Fraud Preventative Strategy for all types of food frauds and for all products.

As outlined earlier, the United States Pharmacopeial Convention (USP) published a guidance document, which provides companies with a systematic procedure for vulnerability assessment and evaluating risks in the food supply chain.

• Michigan State University and the US Organic Trade Association (OTA) have published a free online course in organic fraud prevention. It is US-centric but contains fraud detection and prevention strategies that can be applied anywhere.

• The USDA is also proposing new rules to increase enforcement of the organic program in that country. It has also published a list of fraudulent organic certificates to help expose bad operators in the sector.

Combatting organic product fraud

Sales of organic food have increased since the global coronavirus pandemic started. Sales in the US were up 50% in March 2020. An Organic Trade Association poll of “likely organic shoppers” found 90% of respondents think buying organic has become more important because of the virus. This is presumably because of an increased focus on health and healthy eating.

As organic food becomes ever-more popular, organic frauds are likely to occur more often. It can be impossible for a consumer to know whether food is authentically organic or not. This makes organic fraud easy for criminals to get away with. Organic foods are frequently affected by food fraud, almost topping the Decernis Food Fraud Database ranking for fraudulent label claims, behind falsified expiry dates.

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The USDA is also proposing new rules to increase enforcement of the organic program in that country. It has also published a list of fraudulent organic certificates to help expose bad operators in the sector.
This study identified adulteration, counterfeiting, substitution and mislabelling were the biggest threats to Australian agriculture, fisheries and forestry industries in relation to fraud type. Widespread product fraud was detected in almost all studies internationally. Given the complexity of global supply chains and the rapid expansion of online selling, the risk and occurrence of fraudulent practices is likely to increase.

Important sectors in the Australian agriculture, fisheries and forestry industries are highly vulnerable to food fraud. Beef and veal, wine, fish and molluscs and crustaceans were all found to be vulnerable to food fraud, with a combined estimated economic cost of $700 million to $1.3 billion for those industries. Furthermore, estimated economic costs of fraud were also high for industries that were at lower risk, likely due to their high volume and value. Across the sheep meat, dairy products, wheat, wool and horticulture sectors, estimated economic costs of fraud were estimated to be a further $400 million to $700 million. Types of fraud varied among the various sectors. Substitution, adulteration and mislabelling were common types of fraud and counterfeiting, and dilution was also common in the wine industry. Timber fraud is also a major issue, given the impact of illegal logging of species of conservation concern in particular.

Products are most vulnerable to fraud where there are large differences in value depending on provenance or attributes (e.g. Australian beef, organic status) and products occur in a form that is difficult to verify the labelling claims (e.g., cuts compared with a whole recognisable item). Product fraud results, as for other criminal activities where opportunities are present, there is a motivation to cheat and when laws and control systems are absent or insufficient to deter fraudulent practices. Australian Food Standards laws and regulations are often not supported by active surveillance and product authentication testing to beat or deter fraudsters.

No process can guarantee that products and their supply chains are not the target of fraudulent activity. Australian Government initiatives, such as mandated country-of-origin labelling and lists of recommended approved fish names, assist, but the only legitimate and legal way to guarantee product authenticity is through analytical testing of the product itself. Powerful analytical techniques are now available but are currently limited to mostly one-off investigations, and Australian food authenticity research is at a low level and does not make a significant contribution to the field.

Despite the recognised utility of genetic-based methods for product authentication and testing globally, there appears to be a general lack of support for coordinated and routine testing from either governments or industry in Australia, which is required to support law enforcement and public confidence. This appears to be driven by insufficient clarity on the return on investment of such an undertaking. Establishing one or more Centres of Excellence would dramatically enhance the development and application of cutting-edge technology, focusing on low-cost, rapid and on-site authentication testing, maximising the value to producers of authentic, high-quality products.

Technologies such as next generation DNA sequencing, DNA chips and lab-on-a-chip technology offer great potential for effective, low-cost, rapid and on-site solutions for a broad range of authenticity testing of products. Next generation sequencing opens the door for food authentication analysis and detection for products including wine, beef, seafood, mixed-species products and herbs and spices. The development of new DNA technologies to enable the authentication of timber products is considered to be a major priority given the uncertain identity and provenance of species involved. The Oxford Nanopore MinION is a small (i.e. mobile phone sized), inexpensive and powerful new DNA sequencing technology that enables on-site and real-time authentication of seafood products. It has recently been successfully applied to seafood species testing in Singapore.

DNA sequencing will progressively revolutionise product fraud research and approaches to authentication testing, especially for processed food products with mixed species and high complexity. Blockchain and other traceability systems are often oversold as a ‘guarantee’ of product authenticity but remain dependent on the quality and accuracy of the data included. It is now widely accepted that vulnerability assessment is an important first step in addressing the product fraud issue. However, while vulnerability assessments and third-party certifications are available to assist companies with developing product fraud mitigation strategies, these do not appear to have been widely applied. A number of case studies of companies successfully tackling food fraud and authentication exist. One such example is Beston Global Food Company, which simultaneously has a reputation for producing premium-quality dairy products and investing in technology that enables customers to authenticate its products.

Based on our analysis of the landscape with respect to product fraud and authentication, we recommend that consideration be given to completing an in-depth and comprehensive review of genetic authenticity testing capability of products in Australia, based on international experience of detecting food fraud. We recommend consideration be given to establishing and funding a Centre of Excellence for product authenticity testing and approved genetic product testing laboratories, both for the development and application of cutting-edge technology, training and product testing Australia-wide. We recommend consideration of a research program to genetically barcode all Australian-grown grape varieties from all major wine grape-growing regions, and to develop and test the latest methods to effectively identify region based on genetic variation.

Finally, we recommend consideration of Australian research into consistent and cost-effective genetic and genomic approaches using international best practice and the urgent undertaking of comprehensive surveys to investigate levels of food and agriculture product adulteration and species substitution in Australian marketplaces and internationally for exported Australian agriculture species.
12.1 Beef and veal

12.1.1 Export volume and value

- In 2018–19, Australia exported 1.2 million tonnes of beef and veal products.
- The value of beef and veal exports in 2018–19 was $9.5 billion.
- Australian live cattle exports were valued at $1.6 billion in 2018–19, with 1.26 million head exported.

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity/Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total: 1.2 kt swt</td>
<td></td>
</tr>
<tr>
<td>Total: $9.48 billion FOB</td>
<td></td>
</tr>
<tr>
<td>Total: $1.6 billion</td>
<td></td>
</tr>
</tbody>
</table>

Source: ABARES 2018–19

- Australia’s top five beef and veal export markets were Japan (25%), the United States (20%), China (19%), the Republic of Korea (16%) and Indonesia (9%).

12.2 Sheep meat

12.1.1 Export volume and value

- In 2018–19, Australian lamb exports totalled 292 kt (shipped weight). Over the same period, 197 kt of Australian mutton was exported and 925,000 live sheep were exported.
- In 2018–19, the gross value of Australian exports of sheep meat (lamb and mutton) was $3.96 billion.

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity/Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilled lamb 26%</td>
<td></td>
</tr>
<tr>
<td>Frozen lamb 36%</td>
<td></td>
</tr>
<tr>
<td>Chilled mutton 2%</td>
<td></td>
</tr>
<tr>
<td>Frozen mutton 36%</td>
<td></td>
</tr>
<tr>
<td>Total: 489 kt swt</td>
<td></td>
</tr>
<tr>
<td>Total: $3.96 billion FOB</td>
<td></td>
</tr>
</tbody>
</table>

Source: ABARES 2018–19

- In 2018–19, lives sheep exports were valued at $121 million.
- Australia’s top five lamb export markets were the United States (30%), the Middle East (23%), China (16%), Japan (4%) and the European Union (23%).
- Australia’s top five mutton export markets were China (35%), the Middle East (19%), the United States (11%), Malaysia (9%) and Singapore (6%).
- The Middle East is by far the largest export market for live sheep (89%).

Value of Lamb Exports - Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>Middle East</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>European Union</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>23%</td>
<td></td>
</tr>
</tbody>
</table>

Source: ABARES 2018–19

Value of Mutton Exports - Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>35%</td>
<td></td>
</tr>
<tr>
<td>Middle East</td>
<td>19%</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>20%</td>
<td></td>
</tr>
</tbody>
</table>

Source: ABARES 2018–19

Value of Live Sheep Exports - Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle East</td>
<td>89%</td>
</tr>
<tr>
<td>Other</td>
<td>11%</td>
</tr>
</tbody>
</table>

Source: ABARES 2018–19
12.3 Pig meat

12.3.1 Export and import volume and value

- Australia imports more pig meat than it exports. In 2018-19, Australia exported 36,180 tonnes of pig meat. Import volume for 2018-19 was 190,525 tonnes.
- In 2018-19, the gross value of Australian pig meat exports was $148 million.
- In 2018-19, the gross value of Australian pig meat imports was $916 million.

Australia's top five pig meat export markets were Singapore (42%), PNG (15%), Hong Kong (11%), New Zealand (10%) and Vietnam (5%).

Australia's top five pig meat import markets were the United States (48%), Denmark (25%), the Netherlands (15%), Ireland (4%) and Canada (4%).

12.4 Chicken meat

12.4.1 Export volume and value

- Australia is a small net exporter of chicken meat. Exports account for less than 5% of domestic chicken meat production.
- In 2018-19 the volume of chicken meat exports was 40.8kt, with an export value of $73 million.
- Around 95% of exports comprise frozen cuts and offal such as feet, kidneys and livers. These attract a higher price in export markets than Australia. The remaining 5% of exports largely comprise frozen whole chickens.
- South Africa, Hong Kong, Singapore and the Philippines are the major export countries.
- There is no significant importing of chicken meat apart from high-value specialised products.
12.5 Dairy products

12.5.1 Export volume and value

- The major export markets for Australian dairy products are as follows:

  **Volume of Cheese Exports - Country**

  - Japan 51%
  - China 12%
  - Rep. of Korea 6%
  - Other 5%

  **Value of Cheese Exports - Country**

  - Japan 49%
  - China 11%
  - Rep. of Korea 6%
  - Other 35%

  **Volume of Skim Milk Powder Exports - Country**

  - China 29%
  - Indonesia 22%
  - Vietnam 6%
  - Other 43%

  **Value of Skim Milk Powder Exports - Country**

  - China 29%
  - Indonesia 22%
  - Vietnam 6%
  - Other 43%

  **Volume of Whole Milk Powder Exports - Country**

  - China 46%
  - Bangladesh 10%
  - Singapore 8%
  - Other 36%

  **Value of Whole Milk Powder Exports - Country**

  - China 46%
  - Bangladesh 10%
  - Singapore 8%
  - Other 36%

  **Volume of Butter Exports - Country**

  - Thailand 24%
  - China 10%
  - Malaysia 9%
  - Other 57%

  **Value of Butter Exports - Country**

  - Thailand 13%
  - China 14%
  - Malaysia 8%
  - Other 65%
12.6 Wheat

12.6.1 Export volume and value

- Australian wheat is a bulk commodity export commodity.
- For the year 2017-18, Australia’s top five export markets were Indonesia (21%), the Middle East (11%), the Philippines (10%), Vietnam (9%) and China (6%).
- In the year 2018-19, wheat exports to China declined significantly from $292.5 million down to only $32.2 million.
- The Philippines was the largest growth market for Australian wheat exports in value terms in 2018-19, increasing from $87.1 million to $529.8 million.

12.7 Coarse grains

12.7.1 Export volume and value

- In 2018-19, the volume of Australian coarse grain exports was 5,476 kt, approximately 50% of domestic production. The value of exports was $2.4 billion.
- Barley was the largest export category with an export volume of 4,684 kt (85% of total coarse grain volume exports) and an estimated export value of $1.8 billion.
- The volume of coarse grain exports in 2018-19 was:
  - Barley - 4,684 kt
  - Oats – 281 kt
  - Sorghum – 242 kt
  - Corn – 62.9 kt
- The value of coarse grain exports in 2018-19 was:
  - Barley – $1,374 million
  - Rice – $297 million
  - Oats – $121 million
  - Sorghum – $96 million
  - Corn – $33 million
- For the year 2018-19, Australia’s top five export markets for barley were China (53%), Japan (16%), Vietnam (8%), Thailand (8%) and the Middle East (4%).
12.8 Wine

12.8.1 Export volume and value

- Australian wine exports grew by 3% in value to $2.96 billion in the year 2018-19.
- Major wine export types are red wine (59%) and white wine (38%).
- The top five export markets by value (2018-19) were China (36%), the United States (15%), the United Kingdom (13%), Canada (7%) and Hong Kong (5%).

12.8.2 Import volume and value

- The volume of wine imports was 101 ML in 2018-19, with an import value of $834 million.
- The top four import markets by value (2018-19) were New Zealand (41%), France (38%), Italy (12%) and Spain (2%).
12.9 Wool

12.9.1 Export volume and value

- In 2018-19, the value of Australian wool exports was $4.15 billion. The five major markets for Australian wool (by value) were China ($3.162 billion), Italy ($261 million), India ($225 million), Czech Republic ($119 million) and the Republic of Korea ($112 million).

<table>
<thead>
<tr>
<th>Country</th>
<th>Volume of Wool Exports (%)</th>
<th>Value of Wool Exports ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>78%</td>
<td>84%</td>
</tr>
<tr>
<td>India</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>Italy</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>Rep. of Korea</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>8%</td>
<td>8%</td>
</tr>
</tbody>
</table>

12.10 Cotton

12.10.1 Export volume and value

- In 2018-19, the value of Australian raw cotton exports was $2.56 billion. The five major markets by value were China ($891 million), Vietnam ($376 million), Bangladesh ($200 million), Indonesia ($73 million) and Thailand ($56 million).

<table>
<thead>
<tr>
<th>Country</th>
<th>Value of Raw Cotton Exports (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>34%</td>
</tr>
<tr>
<td>Vietnam</td>
<td>15%</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>8%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>3%</td>
</tr>
<tr>
<td>Thailand</td>
<td>2%</td>
</tr>
<tr>
<td>Other</td>
<td>38%</td>
</tr>
</tbody>
</table>
12.11 Horticulture\textsuperscript{48,49,50,51}

12.11.1 Export volume and value

- In 2018–19, Australia exported 828,000 tonnes of fresh horticultural products, with an estimated gross value of $2.7 billion.

**Horticulture Product Exports - Volume**

- All fruit 58%
- All vegetables 29%
- All nuts 13%

Total: 828,000 t

**Horticulture Product Exports - Value**

- Fresh fruit 46%
- Fresh vegetables 10%
- Nuts 34%
- Other fresh horticulture 1%
- Processed fruit 6%
- Processed vegetables 3%

Total $2.7 billion

**Australian Horticulture Major Export Products - Volume (tonnes)**

<table>
<thead>
<tr>
<th>Product</th>
<th>Volume (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherries</td>
<td>5,055</td>
</tr>
<tr>
<td>Mandarins</td>
<td>188,056</td>
</tr>
<tr>
<td>Oranges</td>
<td>8,221</td>
</tr>
<tr>
<td>Mangoes</td>
<td>8,371</td>
</tr>
<tr>
<td>Pears</td>
<td>9,190</td>
</tr>
<tr>
<td>Peaches/nectarines</td>
<td>15,645</td>
</tr>
<tr>
<td>Plums</td>
<td>4,693</td>
</tr>
<tr>
<td>Table grapes</td>
<td>6,429</td>
</tr>
<tr>
<td>Broccoli</td>
<td>110,213</td>
</tr>
<tr>
<td>Carrots</td>
<td>5,910</td>
</tr>
<tr>
<td>Celery</td>
<td>47,490</td>
</tr>
<tr>
<td>Onions</td>
<td>45,912</td>
</tr>
<tr>
<td>Potatoes</td>
<td>17,705</td>
</tr>
<tr>
<td>Almonds</td>
<td>88,451</td>
</tr>
<tr>
<td>Macadamias</td>
<td></td>
</tr>
</tbody>
</table>

**Australian Horticulture Major Export Products - Value (A$million)**

<table>
<thead>
<tr>
<th>Product</th>
<th>Value (A$million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherries</td>
<td>80</td>
</tr>
<tr>
<td>Mandarins</td>
<td>139</td>
</tr>
<tr>
<td>Oranges</td>
<td>308</td>
</tr>
<tr>
<td>Mangoes</td>
<td>30</td>
</tr>
<tr>
<td>Pears</td>
<td>37</td>
</tr>
<tr>
<td>Peaches/nectarines</td>
<td>16</td>
</tr>
<tr>
<td>Plums</td>
<td>62</td>
</tr>
<tr>
<td>Table grapes</td>
<td>25</td>
</tr>
<tr>
<td>Broccoli</td>
<td>555</td>
</tr>
<tr>
<td>Carrots</td>
<td>20</td>
</tr>
<tr>
<td>Celery</td>
<td>97</td>
</tr>
<tr>
<td>Onions</td>
<td>39</td>
</tr>
<tr>
<td>Potatoes</td>
<td>31</td>
</tr>
<tr>
<td>Almonds</td>
<td>257</td>
</tr>
<tr>
<td>Macadamias</td>
<td></td>
</tr>
</tbody>
</table>
### 12.11.2 Import volume and value

- In 2018-19, Australia imported 186,000 tonnes of fresh horticultural products, with an estimated gross value of $2.7 billion.

### 12.12 Fisheries

#### 12.12.1 Export volume and value

- The total volume of exports of Australian seafood is 46.6 kt (about $1.5 billion), which compares with 221 kt of seafood imports valued at $2.27 billion.
- The export industries are limited to relatively few, albeit diverse, industries that are dominated by live, fresh, or frozen high-value products, with rock lobsters the principle product ($527 million), making up over 50% by value of all seafood product exports.
- Other significant exports are tuna ($171 million), abalone ($154 million), prawns ($110 million) and salmonids ($111 million).
- The charts below profile the share of Australian edible fisheries exports during 2018-19.
The Australian export value of fish products by country is profiled in the charts below.

**Australian Edible Volume (kt) Fisheries Exports**

<table>
<thead>
<tr>
<th>Product</th>
<th>Volume (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live fish</td>
<td>0.6</td>
</tr>
<tr>
<td>Tuna</td>
<td>11.3</td>
</tr>
<tr>
<td>Salmonids</td>
<td>9.8</td>
</tr>
<tr>
<td>Swordfish</td>
<td>0.3</td>
</tr>
<tr>
<td>Other fish</td>
<td>7.1</td>
</tr>
<tr>
<td>Rock lobster</td>
<td>8.7</td>
</tr>
<tr>
<td>Prawns</td>
<td>4.3</td>
</tr>
<tr>
<td>Abalone</td>
<td>2.1</td>
</tr>
<tr>
<td>Scallops</td>
<td>0.3</td>
</tr>
<tr>
<td>Crabs</td>
<td>0.5</td>
</tr>
<tr>
<td>Other Crustaceans &amp; Molluscs</td>
<td>0.8</td>
</tr>
</tbody>
</table>

**Australian Edible Volume ($m) Fisheries Exports**

<table>
<thead>
<tr>
<th>Product</th>
<th>Value ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live fish</td>
<td>25.8</td>
</tr>
<tr>
<td>Tuna</td>
<td>151.6</td>
</tr>
<tr>
<td>Salmonids</td>
<td>117.9</td>
</tr>
<tr>
<td>Swordfish</td>
<td>3.9</td>
</tr>
<tr>
<td>Other fish</td>
<td>69.3</td>
</tr>
<tr>
<td>Rock lobster</td>
<td>82.6</td>
</tr>
<tr>
<td>Prawns</td>
<td>193.7</td>
</tr>
<tr>
<td>Abalone</td>
<td>9.2</td>
</tr>
<tr>
<td>Scallops</td>
<td>28.7</td>
</tr>
<tr>
<td>Crabs</td>
<td>28.7</td>
</tr>
<tr>
<td>Other Crustaceans &amp; Molluscs</td>
<td>20.7</td>
</tr>
</tbody>
</table>

**Non-Edible Value ($m) Fisheries Exports**

<table>
<thead>
<tr>
<th>Product</th>
<th>Value ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine fats and oils</td>
<td>4.3</td>
</tr>
<tr>
<td>Fish meal</td>
<td>1.6</td>
</tr>
<tr>
<td>Pearls</td>
<td>56.0</td>
</tr>
<tr>
<td>Ornamental fish</td>
<td>2.8</td>
</tr>
<tr>
<td>Other non-edible</td>
<td>20.7</td>
</tr>
</tbody>
</table>

*The Australian export value of fish products by country is profiled in the charts below.*
12.12.2 Import volume and value

- Australia imports 41% of its seafood by value and 48% by volume. If one deducts the volume and value of exported products, then Australians consume 58% by value and 55% by volume of their seafood as imported products.

- Thus, the Australian seafood industry and market is dominated by a small number of high-value industries that export, and a domestic market that is dominated by lower-priced imported seafood species and products. Further, the seafood products imported into Australia represent multiple species and products, from many parts of the world.
12.13 Forestry

12.13.1 Export volume and value

• The value of Australian wood product exports increased for the sixth consecutive year in 2018-19, by 9% to $3.9 billion (from $3.6 billion in 2017-18). Increases in the export value of woodchips, paper and paperboard (in particular packaging and industrial paper), and roundwood contributed most to the overall growth in export value over the year.

• Woodchip products are the largest exports by volume (49%), and by value represent the largest commodity, 43% (two-fifths) of Australia’s total exports.

• The value of woodchip exports grew strongly in 2018-19, reaching a record $1.6 billion, up 18.7% from the previous year.

• The value of paper and paperboard, and roundwood exports also reached record highs in 2018-19. Paper and paperboard exports increased by 8.3% to $1.0 billion, driven by 12.4% growth in the value of packaging and industrial paper exports. Total roundwood exports increased by 3.1% to $664 million, reflecting higher export values of hardwood roundwood (up 2.0%) and softwood roundwood (up 8.8%).

• In value terms, Australia’s top export destinations in 2018-19 were China, Japan and New Zealand. Together these countries accounted for 72% of Australia’s total wood products exports.

• The value of wood products exports to China reached a record high in 2018-19, increasing by 13.4% to $1.9 billion (from $1.7 billion in 2017-18), and represented most of the growth in total wood products exports over the year. In 2018-19, woodchip exports to China grew strongly to $974 million (up 24.3%). In 2018-19 the total value of exports to China ($1.9 billion) exceeded the total value of imports from China ($1.8 billion). By value, exports to China accounted for 49% of Australia’s total wood products exports, 62% of total woodchip exports and 92% of total roundwood exports.

5 Major Export Forestry Products 2018-2019 (kt)

<table>
<thead>
<tr>
<th>Product</th>
<th>2018-19 (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodchips</td>
<td>7328.9</td>
</tr>
<tr>
<td>Paper &amp; Paperboard</td>
<td>1130.6</td>
</tr>
<tr>
<td>Roundwood</td>
<td>4267.9</td>
</tr>
<tr>
<td>Recovered Paper</td>
<td>1092.3</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1121.3</td>
</tr>
</tbody>
</table>

5 Major Export Forestry Products 2018-2019 ($m)

<table>
<thead>
<tr>
<th>Product</th>
<th>2018-19 ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodchips</td>
<td>$1576.50</td>
</tr>
<tr>
<td>Paper &amp; Paperboard</td>
<td>$1042.80</td>
</tr>
<tr>
<td>Roundwood</td>
<td>$663.80</td>
</tr>
<tr>
<td>Recovered Paper</td>
<td>$235.10</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$136.90</td>
</tr>
</tbody>
</table>

Export Value by Country 2018-2019

<table>
<thead>
<tr>
<th>Country</th>
<th>Value of Exports ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>$1800.00</td>
</tr>
<tr>
<td>Japan</td>
<td>$1576.50</td>
</tr>
<tr>
<td>New Zealand</td>
<td>$1400.00</td>
</tr>
<tr>
<td>Rest of World</td>
<td>$1400.00</td>
</tr>
<tr>
<td>Paper &amp; Paperboard</td>
<td>$1200.00</td>
</tr>
<tr>
<td>Roundwood</td>
<td>$1000.00</td>
</tr>
<tr>
<td>Recovered Paper</td>
<td>$800.00</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$600.00</td>
</tr>
</tbody>
</table>


9 Available at http://www.transparency.org/country.


12 Food Fraud Advisors (2020). Food Fraud Risk Database. www.foodfraudadvisors.com


15 Food Adulteration Incidents Registry (FAIR) Database. www.foodshield.org/tools.


