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A flavour of omics approaches for the detection of food fraud

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Food fraud has been identified as an increasing problem on a global scale with wide-ranging economic, social, health and environmental impacts. Omics and their related techniques, approaches, and bioanalytical platforms incorporate a significant number of scientific areas which have the potential to be applied to and significantly reduce food fraud and its negative impacts. In this overview we consider a selected number of very recent studies where omics techniques were applied to detect food authenticity and could be implemented to ensure food integrity. We postulate that significant reductions in food fraud, with the assistance of omics technologies and other approaches, will result in less food waste, decreases in energy use as well as greenhouse gas emissions, and as a direct consequence of this, increases in quality, productivity, yields, and the ability of food systems to be more resilient and able to withstand future food shocks.

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Introduction

In the spring of 2016 the latest report from Operation Opson (Opson V) was released detailing the largest ever seizures of hazardous fake food and drink ever recorded [1]. This joint international Interpol/Europol operation originally began in 2011 and initially included 10 European countries, with it now expanding to include 57 countries across the world. Perhaps not surprisingly the release of the report led to a slew of media headlines involving terms such as monkey meat, copper sulfate painted olives, fertiliser contaminated sugar, and tonnes of locusts and caterpillars seized, to name but a few; alarmist headlines perhaps, but all of them true (see Table 1 for a summary of Opson V seizures). It should also be pointed out that these large-scale and *record seizures* of fake and counterfeit foods and beverages, carried out at shops, markets, industrial estates, air- and seaports, all occurred during a relatively short period from November 2015 to February 2016, and are only a snapshot of the severity of the problem. The news of Opson V appeared to coincide with the release of the first report [2] from the UK's newly formed National Food Crime Unit (NFCU) which covered the period November 2014 to July 2015. Whilst informative, the only seizures mentioned within the NFCU report involved counterfeit and adulterated alcohol, including 35 000 bottles of counterfeit vodka originating from Ukraine, and 8 000 litres of vodka from Lithuania with forged duty stamps. More worryingly, these seizures also included 20 000 counterfeit branded vodka bottles and material suggesting adulteration with anti-freeze, as well as 130 000 litres of potentially toxic spirits alongside bottling and labelling materials from another raid [2]. More recently, reports of organised international food fraud involved seven countries and thousands of tonnes of wheat, corn, soybeans, rapeseed and sunflower seed imported from multiple non-EU countries, mislabelled as organic and shipped to EU countries via Malta or Italy [3]. These reports readily illustrate and reinforce the fact that food fraud can be international in scope, with no country being immune from its reach and impacts, and that this transboundary criminal activity can be both opportunistic, as well as highly organised. Here though, as analytical scientists, we are primarily concerned with the single greatest, or what could be termed *grand challenge* of food adulteration; its unequivocal detection. Therefore, we have selected a very small number of recently reported omics and related technologies that are being developed to enable the detection of food authenticity and integrity.

Omics technologies

During the past two decades molecular-based technologies have rightly proven themselves as an invaluable option for the detection of food authenticity and integrity [4]. Such DNA-based methodologies generally rely on specific DNA sequences (markers) that can be used for detection of food adulterants and/or approving the authenticity (i.e. quality and origin) of raw ingredients [5].

Table 1

A summary of seizures of fake food and drink undertaken between November 2015 and February 2016 from Opson V

Country	Summary of seizures
Australia	450 kg of honey found to be blended or adulterated. Peanuts repackaged and relabeled as pine nuts.
Belgium	Several kilos of monkey meat found at Zaventem airport.
Bolivia	Warehouse containing thousands of cans of sardines, and fake labels from a famous Peruvian brand of sardines.
Burundi	36 000 liters of illicit alcohol seized during the operation, as well as nine Kalashnikov rifles, ammunition, and three grenades
France	11 kg of locusts and 20 kg of caterpillars seized and destroyed.
Greece	Three illicit factories producing counterfeit alcohol. Equipment, fake labels, caps, empty bottles and 7 400 bottles of fake alcohol seized.
Hungary	Counterfeit non-alcoholic sparkling wine, chocolates, sweets.*
India	See Thailand below.
Indonesia	70 tonnes of chicken intestines preserved in formalin seized. 310 000 illegal food products found behind piles of tiles in a warehouse and believed to be smuggled from Malaysia.
Italy	85 tonnes of olives seized, painted with copper sulfate solution to enhance colour. Counterfeit non-alcoholic sparkling wine, chocolates, sweets.*
Lithuania	Counterfeit non-alcoholic sparkling wine, chocolates, sweets.*
Malaysia	See Indonesia above.
Romania	Counterfeit non-alcoholic sparkling wine, chocolates, sweets.*
South Korea	Arrest made associated with the online sale of fake dietary supplements/weight loss products estimated to have generated US$170 000 in a 10 month period.
Sudan	9 tonnes of counterfeit sugar contaminated with fertilizer.
Thailand	Four tonnes of meat smuggled by one individual from India. Further investigation led to discovery of illicit network operating across 10 provinces. Recovery and destruction of more than 30 tonnes of illegal beef and buffalo meat, unfit for human consumption and destined for sale in supermarkets.
Togo	24 tonnes of imported tilapia.
United Kingdom	10 000 litres of fake or adulterated alcohol, including wine, whisky and vodka.
Zambia	1 300 bottles of fake whisky in original packaging. Over 3 200 cartons of diet powder drinks with modified expiration dates.

* Aimed at children and destined for export to West Africa.

DNA-barcoding, named due to this technique using a specific region of the genome described as the DNA-barcode, is considered as one the most common identification systems for taxonomic discrimination [5]. However, the successful application of this approach for the separation of food and foodstuffs relies on the availability of comprehensive reference sequence libraries, such as the barcode of life database (www.barcodeoflife.org).

DNA-barcoding is of particular interest when it comes to authentication of seafood products [6]. This interest is mainly due to the presence of a wide-range of species, morphological similarities between species, as well as a loss of the structural and visible characteristics of the raw material during different food processing procedures (i.e. heat treatment, or cooking). Several studies have successfully applied this approach for seafood authenticity testing, such as those by Cutarelli and co-workers, who reported the application of mitochondrial cytochrome b (Cytb) and cytochrome oxidase subunit I (COI) genes as DNA markers for the identification of 58 Mediterranean marine fish samples sold on the Italian market. Whilst Pereira *et al.* demonstrated the efficacy of barcode methodology (*COI* gene), for the highly accurate (99.2%) identification of 254 species of freshwater fish samples, Kim and co-workers picked up the metaphorical baton, taking this approach a step further by employing a combination of DNA-barcoding and stable isotope analysis for the identification and verification of the origin of Hairtail fish and shrimp. This strategy also allowed these authors to differentiate between natural and farmed shrimp [7], an important and significant area for fish authenticity and traceability, which was only possible as the stable isotope analyses allowed the phenotype of the organism to be measured.

As might be expected, DNA-based methodologies have been applied to the authentication and traceability of a wide-range of food products, including the detection of the mislabelling or cross-contamination of halal meat [8] and the detection of species such as horse in ground meats [9]. With one very recent article of significant interest involving the development of a real-time PCR approach for the relative quantitation of horse DNA in raw beef mixtures [10••]. Other studies have involved labelled milk and milk products, such as yogurt and cheese, which were traced through a production chain via DNA tags, in this case silica particles with encapsulated DNA (SPED) [11], with the applicability of synthetic and naturally occurring DNA sequences demonstrated. Identifying species specific differences in herbal medicines [12], chilli adulteration of traded black pepper powder down to 0.5% adulteration [13], and tracing/tagging of edible oils (e.g. olive oil) using encapsulated DNA in heat-resistant and inert magnetic particles [14] have also been reported. However, the application of DNA-barcoding