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Global Food Fraud Trends and Their Mitigation Strategies: The Case of Some Dairy Products: A Review

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Abstract
This review was initiated with the objective of assessing global food fraud trends and their mitigation strategies with special emphasis on some dairy products. Different aspects of food fraud such as the types of food fraud (adulteration, tampering, counterfeiting, artificial enhancement, use of non-declared, unapproved, or banned biocides, misrepresentation of nutritional content, fraudulent labeling claims and removal of authentic constituents etc), global food fraud trends, why is food fraud a growing concern, incidents of food fraud, top ten food fraud vulnerable food ingredients and milk and milk based products fraud and their mitigation strategies to address food fraud were discussed. The increasing trend in food fraud practices led to food safety concerns; which led companies to build brands on reputable basis for safety and quality. In the meantime markets grew from local to global. This led to complexity of supply chains and this has aggravated food fraud. Based on this, it was concluded that fighting food fraud and adulteration remains a race between the criminals committing food fraud and the scientists developing new methods to uncover food fraud, frequent analysis and quality control measures are essential to create awareness among the public about malpractices in food supply chains, consumers must be aware about the kind of food they consume, the regulatory authorities should realize and practice frequent inspection of the market to check whether food products meets the minimum legal standards. It is also recommended that academic institutions should shift from intervention and respond to prevention, define the value of technology and enforcement of food laws and education in behavioral sciences and criminology. The industry's food fraud prevention focus has to be holistic and has to build consumer confidence, industry has to engage governments in request for comments and risk assessment. The governments has to focus broadly on product fraud not just adulterants, define food fraud in laws not just in regulations or guidance documents, create and engage public private partnership forum and risk assessment.
Keywords: Global, Food, Fraud, mitigation, safety, dairy, products

1. Introduction

At present there is no statutory definition of food fraud/EMA (Economically Motivated Adulteration). A comprehensive definition generally used by different bodies is from the Food Fraud Initiative of Michigan State University (Anza, 2017). Food fraud is a collective term that encompasses 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. A more specific type of fraud is the fraudulent addition of non-authentic substances or removal or replacement of authentic substances without the purchaser's knowledge for economic gain of the seller (Renee, 2014).

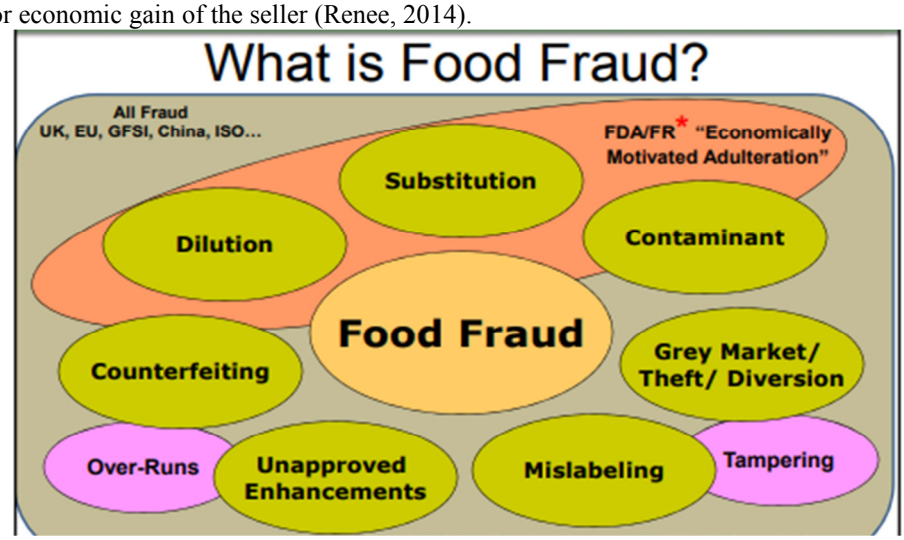

Figure 1. Complexity of food fraud in the food chain (Anza, 2017)

Food fraud is a broader term than either the economically motivated adulteration (EMA) defined by the Food and Drug Administration (FDA) or the more specific general concept of food counterfeiting. Economically motivated adulteration refers to incidents of food adulteration that are intentional and motivated by malicious

intentions (e.g. bioterrorism) or by financial motives (Everstine et al., 2013). The economic motivation behind food fraud is distinctly different from those for food safety, food defense and food quality. The cause of an event might be food fraud, but if a public health threat becomes involved, the effect is an adulterated product and a food safety incident (John and Douglas, 2011).

In recent years, new and challenging risks related to food frauds have emerged and have become a major concern within the food sector as food supply chains have become increasingly more global and complex (Sarpong, 2014; Manning and Smith, 2015).

Food fraud has often been considered to be fore most an economic issue, but recent cases have highlighted that this detrimental practice affects indeed economies and businesses, but also consumer confidence. Food fraud can be commercially devastating since it is usually followed by loss of sales. Although there is no exact data about how widespread food fraud is worldwide, the Grocery Manufacturers Association (GMA) estimated that fraud may cost to the global food industry between $10 billion to $15 billion per year, affecting approximately 10% of all commercially sold food products (Johnson, 2014). However, most researchers acknowledge that the full scale of food fraud "may be unknown" since the number of documented incidents is "most likely a fraction of the true number of incidents because the goal of adulteration for economic gain is not to be detected (Johnson, 2014). Moreover, food fraud can have a detrimental impact on consumer trust and it entails product recalls and damage to reputations (Lotta and Bogue, 2015). The incidences have raised crucial questions about the security of food supply chains and waves of criticism were prompted (Manning and Smith, 2015). Currently, reputable companies have not find yet a solution to this detrimental practice. Consequently, consumer trust has diminished and food security has become a central issue in the food chain (Grunert, 2005; Verbeke, 2005). Consumers occupy a crucial position in food chains and are active market participants; therefore it is necessary to maintain high levels of confidence (Lotta and Bogue, 2015). Consumers demands for safe and wholesome food. This provides the biggest driving force for the creation of a variety of information systems such as traceability and quality assurance schemes which can help in fighting food fraud (Leat *et al*., 1998; Gellynck and Verbeke, 2001). Food fraud undermines product authenticity, origin, quality and biological characteristics. It has annoyed consumers, manufacturers, retailers, importers throughout history (Spink *et al*, 2016). For instance, the melamine incidents in 2007 and 2008 and the horsemeat scandal in 2013 have sparked the attention of both the media and consumers about the problem of food fraud, revealing the large impact on consumer confidence and on the reputation and finances of food businesses (Lotta and Bogue, 2015).

An integrated, systems-based approach to food protection that encompasses both food safety and food defense is imperative for ensuring the integrity of food supply (Karen, 2013). To mitigate food fraud, knowledge on why and how food fraud is happening is vital. Furthermore, technical and managerial control measures are needed in fraud vulnerable situations (Van Ruth, 2017).

In the food chains consumers occupy crucial position and are active market participants. They demand for safe and wholesome foods. Therefore, it is necessary to maintain high levels of consumer confidence (Lotta and Bogue, 2015). This provides the biggest driving force for evidences on traceability and quality assurance schemes (Leat et al., 1998; Gellynck and Verbeke, 2001). So, food supply chain has to follow integrated, system based approach to food protection and encompass food safety and food defense (Karen, 2013). To mitigate food fraud, knowledge on why and how food fraud is happening is vital. Moreover, technical and managerial control measures are crucial for most fraud vulnerable food items such as milk and milk based products (Ruth, 2017; Lara, 2017; Sasika, 2017). Without the capability to differentiate fake high quality food products from truly high quality ones, consumers could suffer from consuming adulterated products. Food fraud is a significant and growing concern, driven by globalization of supply chains, economic opportunity, and in many cases by the low probability and severity of punishment. Therefore, now more than in the past, food fraud requires a clear strategy of mitigation, detection and elimination (Lara, 2017). Therefore, investing in traceability and dispersion to mitigate EMA risk is vital. Hence, this seminar was initiated with the objective of reviewing global food fraud trends and their mitigation strategies with emphasis on some dairy products.

2. Global food fraud trends

Before discussing global food fraud trends, it is necessary to clarify food safety, food defense and food protection. "Food safety" refers to the reliability of the food system in terms of reducing exposure to expected and unintentional hazards. "Food defense" refers to the resilience of the food system to intentional attacks (Busta and Kennedy, 2011). These attacks may be motivated by the desire to inflict physical or economic harm, or the desire for economic gain (Dalziel, 2009). Intentional attacks on the food supply may involve the use of known food safety hazards, recognized biological, chemical, or radiological terrorism agents, or novel agents (Lee, 2003; CDC, 2010: CDC, 2011). "Food protection" broadly covers both the safety and defense of the food supply. A comprehensive food protection plan relies on integrated food safety and food defense control (Dalziel, 2009).

Food fraud or the act of defrauding buyers of food or ingredients for economic gain whether they are consumers, food manufacturers, retailers or importers has annoyed the food industry throughout history. Food

fraud, including the subcategory of economically motivated adulteration, is of growing concern (Spink et al, 2016). Food fraud originated as a money-making opportunity, a way to extend a food's primary ingredients for added profit. As early as the 17th century, governments started to introduce food purity laws to address abuses that included watered-down milk and the use of chalk as filler in bread. Generally, the food supply system is vulnerable to various types of contamination and adulteration (Renée, 2014). The vulnerability of the food system to unintentional contamination is well known and has been repeatedly demonstrated by large-scale foodborne outbreaks such as *E. coli* O104:H4 contamination of sprouts that infected thousands of people in multiple European countries in 2011 (Karch et al., 2012).

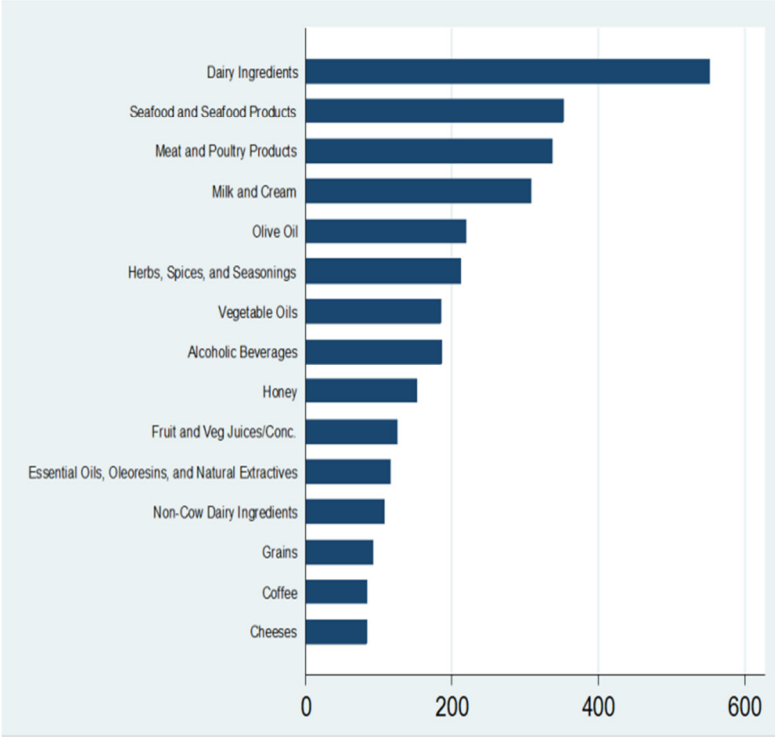

Figure 2: Food fraud data trends (Ingredient groups). Source: USP Food Fraud Database

2.1. Types of food fraud

1. Adulteration /dilution/ replacement: Substitution with an alternate ingredient (this can include misrepresentation of geographic, botanical, varietal, or animal origin; or the additional of a non-food grade substance). A component of the finished product is fraudulent. For instance, melamine in milk, changing product's country of origin, species adulteration of goat/buffalo milk in cow milk (Abrantes, 2014). Clouding agents or food processing aids to enhance the appeal or utility of a food or food component, such as palm oil and other allowed food ingredients, are often used in fruit juices, jams, and other foods. Of particular concern is the fraudulent replacement or addition of the plasticizer Di (2-ethylhexyl) phthalate (DEHP) and other related phthalates, as a substitute for other ingredients. DEHP may also be used in food contact materials, such as seals and packaging. DEHP is associated with public health risks, including cancer and reproductive concerns (Spink and Moyer, 2013).

2. Counterfeiting/Concealment: To give a deceptive appearance of authenticity in whole or in part, of substances those are different in quality and quantity. Counterfeiting of middle range foods, rather than luxury foods is another emerging trend. Most well-known examples of food counterfeiting in past years have been linked to premium brands and luxury goods such as expensive wines, whiskeys, truffles, saffron and caviar. However there are increasing reports of mid-range goods being 'faked', with condiments, sauces, chocolate bars and beverage mixes all having been fraudulently counterfeited in recent times (Food fraud training, 2017).

3. Artificial enhancement: Substitution of perceived quality with substances that increase apparent protein content enhances color, or increase organoleptic qualities.

4. Use of non-declared, unapproved, or banned biocides: Example antibiotics, preservatives, or anti-fungal agents.

5. Misrepresentation of nutritional content: Includes formulation of fraudulent products.

6. Fraudulent labeling claims: Example sale of inorganic foods as organic, selling non-halal meat products as halal, selling caged birds as cage free.

7. Removal of authentic constituents: Removal of non-polar constituents from paprika (lipids and flavor

compounds) to produce paprika derived flavoring extracts (Anza, 2017).t

2.2. Why is food fraud a growing concern?

The challenges involved in combatting fraud are complicated by the many opportunities for food adulteration and the complexities of today's global and multi-tiered supply chains. These conditions create a perfect storm for those wanting to commit fraud. As a result, while awareness of food fraud continues to rise among consumers and the industry, major challenges impair companies' ability to detect and reduce the risk of fraud (Julia, 2016).

Figure: 3. Greed for money is the motivator for food fraud (Ric, 2016)

1. Lack of upstream supply chain visibility

While knowledge of tier suppliers may be known, visibility to tier vendors and beyond is often blurred. Sourcing practices of tier suppliers are often not assessed or understood.

2. Poor supply chain risk management practices

Financial risk assessments and operational audits may be common, but a broad approach to supply chain risk management is rare.

3. Difficulty in detecting food fraud

It can be difficult to effectively identify instances of food fraud. Strong food fraud programs have reliable testing and analysis, integrate seamlessly with broader supply chain operations and facilitate rapid incident reporting and response.

4. Complex and constrained regulatory framework

In the US alone, multiple agencies are involved in preventing food fraud. But a 2012 US government accountability office review identified overlapping challenges between agencies. With limited foreign-facility inspections due to limited federal resources, many companies feel the need to embark on their own endeavors (Julia, 2016).

2.3. Impacts of food fraud

Declining consumer trust, loss of sales and crisis management are the most important impacts of food fraud on businesses while, most cases of food fraud are not harmful to the consumers but there are some notable exceptions. Food fraud is a global problem and is a growing phenomenon and as a result 10% of produced food is suffering from food fraud phenomena (Everstine *et al*., 2013). Information on food fraud are available within minutes, there is heightened media attention, there are improved detection systems, there are also more whistle blowers who spread the food fraud incidents, there is better traceability due to advancing test methods, the number of incidents of food fraud are increasing and there are growing google searches (Anza, 2017). Large-scale foodborne outbreaks and economically motivated adulteration incidents cost society millions in medical care, lost wages and loss in industry profit (Spink and Moyer, 2011a). They also illustrate vulnerabilities in the food supply system that could potentially be exploited by people's intent on causing widespread illness, death, or economic damage. A successful attack on the food supply chain could result in significant morbidity and mortality, economic and trade consequences, a strain on public health systems and political instability (Spink and Moyer, 2011a). Manufacturers and retailers directly engaged with food fraud or not suffer consequences through sourcing and supply challenges, drops in market share, escalating consumer distrust and respects of years of brand rebuilding (Everstine *et al*., 2013). A successful attack on the food supply could also result in significant morbidity, mortality, economic and trade consequences, a strain on public health systems and political instability (Spink and Moyer, 2011a).

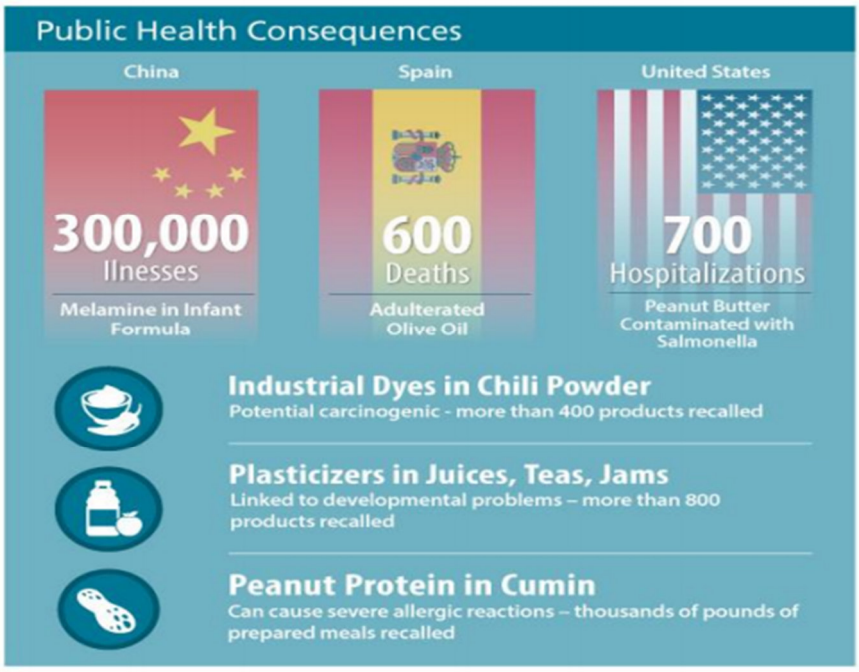

Figure 4. Food fraud public health impact Source: USP Food Fraud Database

2.4. Incidents of intentional adulteration in the world

The vast majority of fraud incidents do not pose a public health risk, but some cases have resulted in actual or potential public health risks. Incidents of intentional adulteration of the food supply with intent to cause harm were Salmonella Typhimurium adulteration of restaurant salad bars in Portland Oregon by a religious cult in 1984 in an effort to affect voter turnout, which caused illness in over 700 people *(*Torok *et al*., 1997*)*; and *Shigella dysenteriae* adulteration of food items in a work place by a displeased laboratory worker in Texas in 1996, which caused illness in 12 people *(*Kolavic et al., 1997*)*. In 2004, trace amounts of ricin were detected in two jars of brand-name baby food but the offender was not identified (Mohtadi andMurshid, 2005). Perhaps the most high-profile case has involved the addition of melamine to high-protein feed and milk-based products to artificially inflate protein values in products that may have been diluted. In 2004, UK food safety professionals warned of the number of serious food offences being carried out by organized criminals including the introduction into the food-chain of meat unfit for human consumption, such as reprocessed chicken sludge, that had been bleached and treated to resemble something palatable (Declan, 2017). Besides, the horsemeat scandal represents only a small segment of a much larger crisis that encompasses the bulking-up, watering-down, substitution, mis labeling and misrepresentation of the contents of the food we eat. It's equally unsettling that tampering with the food chain likely has occurred, either undetected or unreported over many years (Declan, 2017). Because, criminals worldwide have identified opportunities for significant financial gain by exploiting complicated, largely hidden system of food supply and distribution networks. This has led to questions relating to the integrity and sustainability of the food-supply chain in the UK (Pointing and Teinaz, 2004). In 2007, pet food adulterated with melamine reportedly killed a large number of dogs and cats in the United States, followed by reports that melamine-contaminated baby formula had sickened thousands of Chinese children in 2008. Fraud was also a motive behind Peanut Corporation of America's actions in connection with the *Salmonella* outbreak in 2009, which killed 9 people and sickened 700. Reports also indicate that fish and seafood fraud is widespread, consisting mostly of a lower valued species, which may be associated with some types of food poisoning or allergens, mislabeled as a higher-value species (Karen, 2013). Other instances of economically motivated adulteration such as authentic pappercorns adulterated by 25 % papaya seeds, cumin adulterated by 20% Peanut shells, (Alissa, 2017).

2.5. Top ten fraud vulnerable food ingredients

The United States Pharmacopeia Convention (USP) which has set up a global database, added almost 800 new records, based on information published in scholarly journals and through the media in 2011 and 2012 (Moore et al, 2012). This database has been analyzed by Moore et al (2012) to determine the food ingredients which are most prone to fraud worldwide. Some of the earliest reported cases of food fraud, dating back thousands of years, involved olive oil, tea, wine and spices (Renée, 2014). Other types of foods associated with fraud include honey,

meat, milk, grain-based foods, fruit juices, organic foods, coffee and some highly processed foods. These products continue to be associated with fraud, along with some other foods (Renee, 2014). According to Moore et al. (2012) olive oil, milk, honey, saffron, orange juice and coffee seem to be the most common targets for adulteration. Milk contributes 14% of all records from 1980 to 2010 and is the second most common adulterated ingredients, after olive oil which scores 16% (Moore et al., 2012; Spink, 2014; European Commission, 2016). By major food ingredient, oils (24%), milk (14%), and spices (11%) account for nearly 50% of all reported cases (Food Chemical Codex, 2014).

Figure 5: Top ten products that are most at risk of food fraud (Anza, 2017)

2.5.1. Olive Oil

Olive oil is often substituted with a lower cost alternative, whether it is regular olive oil instead of higher priced extra virgin olive oil or a less expensive variety from Greece or Turkey, instead of from Italy as the label claims. In such cases the fraud was associated with efforts to defraud the European Union's farm support program, which subsidizes olive oil, as part of the Common Agricultural Policy (CAP). In some cases an alternate seed or nut oil may be sold as or thinned out with hazelnut, soybean, corn, peanut, sunflower, safflower, walnut, vegetable, canola, or palm oil, and lard. Some combinations contained no olive oil. The use of nut or legume oils could pose a problem for those with certain food allergies. In rare cases, non-food-grade oil such as rape seed may be added (Busta and Kennedy, 2011). Olive oil diluted with hazelnut oil is a common form of economically motivated adulteration (Jeffrey, 2016).

2.5.2. Fish and seafood

Some higher-value fish and seafood are replaced with cheaper, more abundant fish. Fish samples purchased at grocery stores, restaurants, and sushi bars in major cities were often mislabeled, including red snapper (tilefish); white tuna and butterfish (escolar); wild Alaskan salmon
(farmed Atlantic salmon); caviar (catfish roe); and monkfish (puffer fish). Some substitutions have involved fish or seafood associated with certain types of fish poisoning or allergens. Other substitutions are intended to evade import and other restrictions (Anza, 2017).

2.5.3. Honey, maple syrup, and other natural sweeteners

Honey might have added sugar syrup, corn syrup, fructose, glucose, high-fructose corn syrup, and beet sugar, without being disclosed on the label. Honey from a "non-authentic geographic origin" is also common, such as cases where honey from China is transshipped through another Asian country and falsely sold as honey from the second country usually to avoid higher customs duties and tariffs that would be imposed on honey from China. Some of this honey might also contain unapproved antibiotics or other additives and heavy metals. Maple syrup is sometimes thinned out with sugar or corn syrup (Gallagher and Thomas, 2010).

2.5.4. Fruit Juice

Juices might be watered down, or a more expensive juice (such as from pomegranates or other "super" fruit) might be cut with a cheaper juice (such as apple or grape juice). Some juice may be only water, dye, and sugary flavorings, although fruit is the listed ingredient on the label. Orange juice has been shown to sometimes contain added unlisted lemon juice, mandarin juice, grapefruit juice, high fructose corn syrup, paprika extract, and beet sugar. Apple juice has been shown to have added unlisted grape juice, high fructose corn syrup, pear juice, pineapple juice, raisin sweetener, fig juice, fructose, and malic acid (GFSI. 2014).

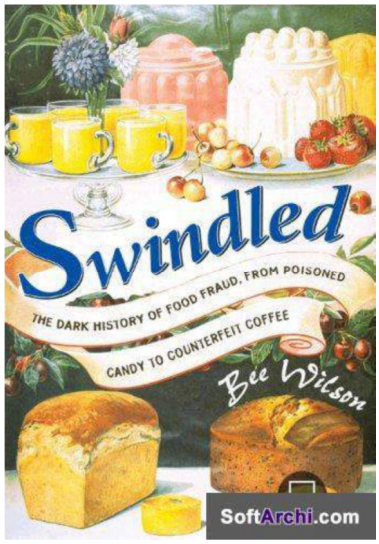

Figure 6. The dark history of food fraud/swindle (GFSI, 2014)

2.5.5. Coffee and Tea

Ground coffee might be cut with leaves and twigs, as well as roasted corn, ground roasted barley, and roasted ground parchment. Instant coffee may include chicory, cereals, caramel, more parchment, starch, malt, and figs. Tea may contain leaves from other plants, color additives, and colored saw dust (Food fraud training, 2017).

2.5.6. Meat fraud

Halal fraud appears to be on the rise, with developing countries such as Indonesia and Malaysia at high risk. Halal meat is often indistinguishable from its non-halal counterpart which means that everyday consumers are not able to verify food sellers' claims about halal status. Falsely claiming halal for a food item is an easy fraud to perpetrate, especially during the retail sale of un-packaged food in restaurants and takeaway stores (Food fraud training, 2017). Halal fraud can be as sophisticated as forgery of certification documents accompanying bulk shipments of food or as simple as dishonest signage in a takeaway store. There have been a number of incidences of halal fraud in the news lately and these are almost certainly the tip of the iceberg. Indonesia and Malaysia are some of the world's biggest markets for halal food. Both countries have variable and sometimes chaotic food supply chains accompanied by uneven regulatory enforcement. Halal forgery also happens in the developed world, with a recent prosecution in the United Kingdom in which the fraudster is alleged to have netted a quarter of a million pounds. With this kind of money up for grabs, you can expect halal fraud to continue (Sarah, 2013).

Figure 7. Leading Food Categories with reported cases of food fraud (www.foodfraudadvisors.com)

2.5.7. Spices

Saffron is the world's most expensive spice, and has been found to have added glycerin, sandalwood dust, tartrazine (a yellow dye), barium sulfate, and borax. Ground black pepper has been shown to have added starch, papaya seeds, buckwheat, flour, twigs, and millet. Vanilla extract, turmeric, star anise, paprika, and chili powder are other spices prone to fraud. Sudan red dyes have been used to color paprika, chili powders and curries, but are also known carcinogens and are banned for use in foods (Dalziel, 2009). Wheat extended with urea, turmeric extended with lead chromate is also some forms of economically motivated adulteration (Jeffrey, 2016).

2.5.8. Organic Foods and Products

Using fraudulent certification to market, label, or sell non-organic (conventionally produced) agricultural products as USDA-certified "organic" is a violation of U.S. law and federal National Organic Program (NOP) regulations. Products fraudulently labeled as "organic" have been detected by USDA for a range of foods and food ingredients from both domestic and international suppliers (Dalziel, 2009).

2.5.9. Wine fraud

Many of the great wines of the world have been subject to claims of substitution or counterfeiting, damaging the reputation of the affected brands and countries of origin. Wine fraud also involves mislabeling, alteration or sale of stolen goods (Eric et al, 2016).

2.5.10. Milk and milk based products fraud

Milk fraud has annoyed through history and continues to be a serious global issue (Johnson, 2014). Milk a raw material for all other dairy products has historically been one of the most adulterated foods and one of the earliest frauds was to dilute it with water, an easy way to dilute milk simply sold on a weight or volume basis for illegal profits (Food Chemical Codex, 2014). Milk is a high risk commodity of concern for fraudulent activities and perpetrators may diminish nutritional quality through intentional adulteration and/or malpractices under poor hygiene conditions, lack of preservation, or without cooling facilities (Handford et al., 2016). Milk adulteration contributes 14% of all records from 1980 – 2010. Milk is the 2nd most commonly adulterated food ingredients after olive oil (16%) (Moore et al., 2012; Food Chemical Codex, 2014).

Milk from bovine cows is being adulterated with milk from other species of animals, such as sheep, buffalo, and goats, antelopes. but also adulterated with reconstituted milk powder, urea, and rennet, among other products (oil, detergent, sugar, salt, and skim milk powder). Adulterated milk may also be watered down and then supplemented with melamine to artificially raise the apparent protein content and hide dilution. Melamine, an organic base chemical, is widely used in plastics, adhesives, and other consumer products, and is known to pose a public health threat (Maryam and Mohtadi, 2017). Adulterated milk might also be added into infant formula and other milk-based products. Baby formula is a common target for retail theft, often by tampering with the sell-by codes to move expired product (Maryam and Mohtadi, 2017).

In developing countries, milk is adulterated with formaldehyde (formalin), rice flour, sucrose salt, glucose, water, soap, hydrogen peroxide, Coal tar dyes, turmeric, whey, cane sugar, neutralizers (caustic soda, caustic potash, sodium carbonate, sodium bicarbonate and lime water), sodium and potassium nitrates (Mohammed and Shuming , 2017; Borin *et al*., 2012; Mohit et al, 2014). 20-25% powdered milk products in Brazil are adulterated with starch, whey, sucrose, urea, soap and other hazardous chemicals (Venkateswar, 2001; Mohammed and Shuming, 2017). In the US, 'Wood in cheese' media frenzy spotlights fraud, revealed the adulteration of cheese by saw dust (Alyssa, 2016). In China, 64 tonnes of raw dairy materials were contaminated with melamine (BBC news, 9 Jul. 2010).

In India, ghee is adulterated with animal depot fats and cheaper vegetable fats. Ghee is considered as the sacred holy food in India. But, the unscrupulous traders are not only robbing the people of their money, but also playing with the religious sentiments, especially of the vegetarian section of the society, besides adversely affecting their health (Anil et al., 2015).

Several news reported that wood pulp may be included in grated parmesan cheese available for purchase at various retailers. Bloomberg Business reports that it hired an independent laboratory to test store-bought grated cheese for wood pulp content. A small amount 2 to 4 percent is allowed in grated cheese as an additive to keep the product from clumping and is listed on ingredient labels as cellulose. Cellulose is recognized as safe by FDA and is used in a wide variety of packaged food products (Alyssa, 2016).

Table 2. Positive results of inhibitory substances, preservatives, commercial additives and heat treatment in raw buffalo milk in Egypt

Items	Dairy shops		Street vendors		Farmer's houses	
	+ve/25	%	+ve/30	%	+ve/30	%
a- Inhibitory sub .&preservatives: 1–General test	25	100	15	50	14	46.6
2–Formalin	15	60	3	10	9	30
3-Salicylic acid	—	—	—	—	—	—
4–Hydrogen peroxide	—	—	1	3.4	—	—
5–Boric acid & Borax	10	40	9	30	5	16.7

+ve = number of samples Source: Eman et al., 2015

Table 3. Overview of milk fraud in India

Aim of the study	Results	Remarks	Reference
To detect presence of harmful adulterants in milk	Presence of, detergents, urea and veg. oil were detected Headaches, Eyesight problems, diarrhoea were reported in children in all age group	Adulterated milk is shown to have a lower or higher pH than normal milk depending on the adulterants used. Urban areas were highly affected than rural areas.	
To identify the commonly used adulterants	Approx. 68% samples failed to meet FSSAI standards.	Water is the most common Adulterant, powdered milk is reconstituted to meet the milk supply and demands The presence of detergents suggests a lack of hygiene and sanitation in milk production.	Bhatt et al (2008) FSSAI (2012)
To expose adulterants in milk samples collected from various institutions.	The level of adulteration ranged greatly with neutralizers, sodium chloride, urea, detergent etc.	A large number of samples did not meet to the legal standards set by the FSSAI. -The investigations shows that the adulterants were added during the production or processing of milk.	Singuluri and Sukumaran (2014)

Table 4. Causes of milk adulteration in India

Cause	Reason
Demand and supply Gap	Demand and supply Gap is large due to large population
Financial greed	passion for more profit
Physical nature of milk	Aqueous and opaque nature of milk can accommodate many adulterants.[14]
Perishable nature of milk	The unscrupulous producers / vendors use preservatives neutralizers etc. to prolong the shelf life of milk
Low purchasing power power of consumer	Encourages the supplier to adulterate milk and sell at cheaper rate
Informal supply chain Industry	Most of the milk is procured and traded by unorganized dairies, which freely adulterate the milk
Lack of vigilance	Lack of organized food defense
Inadequate test methods technology support	Lack of user-friendly and low cost technology for testing, analysis, storage, transportation etc.

Source: Bhamare et al., 2016

Table 4. Extraneous substances added to milk and milk products in Boditti town and its surrounding, Ethiopia

S.N.		Kebeles				
	ubstances added	Boditti Qorke	Boditti Hagaza	Fate	Hagaza Doge	Over all %
1	Vegetable oil/girl ghee	76.6	69.93	86.6	89.91	80.8
2	Water	89.91	93.24	36.63	16.7	59.12
3	Defatted milk	53.3	50	10	6.7	30
4	Banana	6.7	10	43.3	46.62	26.7
5	Preservatives/spices/herbs	13.32	16.7	26.64	33.3	22.5

Source: Asrat and Zelalem, 2014

Milk has a heavier weight or density, the specific gravity of normal milk ranges from 1.026–1.032 g/ml at 200c compared to water (1.000 g/ml). When milk is adulterated with water or other solids are added, the density either decreases if water is added or increases if solids are added. If milk fat or cream is added to milk, the density/specific gravity decreases (O'Connor, 1994; Lore, et al 2006). Another normal milk specific gravity standard set by the European Union is from 1.027 -1.035 g per ml with a mean value of 1.032 g per ml (Tamime, 2009).

Table 5. Physical properties of raw and pasteurized milk in Addis Ababa, Oromia, Southern region and Amhara regional states, Ethiopia

Variable	Average result	Standard /range
Specific gravity (g/ml)	1. 021	1.026-1.032 (East Africa) 1.027-1.035 (EU)
Milk temperature (0C)	20.67^{o}c	4^{o}c
Freezing point (0C)	0.026^{0}c	-0.525 to -0.550 0C (ESA) -0.512 to -0.550 0C (US)
Water added/ adulteration (%)	2.45 (0.06±0.40 to 25.65±1.20)	

Source: Alganesh *et al*., 2018

Table 6. Food fraud alerts in cheese curds

Date	Issue	Company	Country of origin	Notified by
09/02/2017	Undeclared mustard and undeclared wheat found in cheese curd	Bright cheese and butter manufacturing company Limited, 816503 County Rd 22, Bright, ON, Canada	Canada	Canada

Source: Alyssa, 2016

The great American cheese scandal

In the late 1990s, an unscrupulous dairy brokerage Wilfran agricultural industries (Malvern, Pennsylvania) – started sellingAn illegally misbranded product labeled "Low Heat Non-Fat Dry Milk." But the bag's original label claimed: "Spray Dried Milk Protein Concentrate – Product of France" (Pete, 2010).

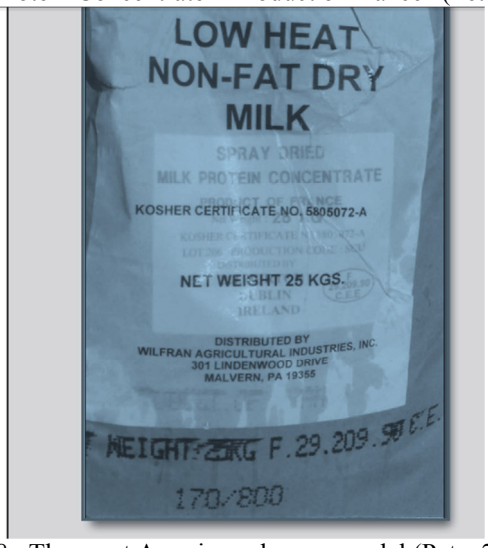

Figure 8: The great American cheese scandal (Pete, 2016).

2.6. Food fraud mitigation strategies

Food fraud is a problem that must be tackled by all major stakeholders and consumers under pinned by good investigative techniques, sound methods of detection, sufficient enforcement powers and adequate resources (Gallagher and Thomas, 2010). Vulnerability assessment refers to identification and assessment of vulnerable ingredients and supply chains. There are nine contributing factors for fraud mitigation strategies illustrated as follows:

1. Supply chain: What is the degree of vertical integration in the supply chain for a particular ingredient, or are purchases made on the open market?

2. Audit strategy: Is there a robust, onsite audit strategy with antifraud measures, or a less mature audit strategy without targeted anti-fraud measures?

3. Supplier relationship: Is the supplier relationship established and trusted?

4. History of regulatory, quality, or safety issues with a supplier:

5. Susceptibility of quality assurance methods and specifications: Are quality assurance methods and specifications specific and effective for a range of potential adulterants?

6. Testing frequency: Is every lot tested by the buyer, is testing conducted intermittently, or is there reliance only on certificates of analysis?

7. Geopolitical considerations: Is the ingredient sourced from, or does it travel through, a geographic area with political, food safety, or food security concerns?

8. Fraud history: Is there a high volume of known and documented food fraud incidents in the ingredient?

9. Economic anomalies: Are there supply pressures, pricing discrepancies, or other economic factors that may increase the incentive for fraud in the ingredient?

Food fraud detection methods

a. Biological methods: ElISA, PCR, DNA sequencing

b. Physicochemical methods: Conventional methods, spectroscopic methods, high resolution Mass Spectroscopy, non-targeted approach, combination of lab-based methods with statistical soft wares to determine if sample falls within expected parameter ranges. The technical control measures include analytical tests which need to be improved and updated all the time since fraudsters always try to catch up and circumvent these methods. In the past, analytical methods were primarily focused on the detection of single compounds, e.g., protein or fat content in milk. Later on, multiple compounds or ratios of compounds were considered. In the past decade, we have seen an increase in methods which consider a full spectrum or full chromatogram as an analytical fingerprint of a food. Due to the complexity of the data, comparison of these fingerprints requires more advanced statistical modelling techniques (Saskia and Daniel, 2017). Although there used to be the tendency to aim for the detection of individual adulterants, a trend of assuring the general authenticity of a product is emerging. In this case, authentic material is separated from any unusual material to allow rapid confirmation of the authenticity, which is also called broad anomaly testing. This more general screening for the good and the bad is also seen with the miniaturization of instruments. Portable, handheld devices are very suitable for a first impression of a food product and for red/green traffic light approaches. Although fraud detection will not prevent fraud, fraud detection is an inseparable part of fraud mitigation (Saskia and Daniel, 2017).

3. Conclusion and Recommendations

- Fighting food fraud and adulteration remains a race between the criminals committing food fraud and the scientists developing new methods to uncover food fraud
- Frequent analysis and quality control measures are essential to create awareness among the public about malpractices in food supply chains
- Consumers must be aware about the kind of food he/she consumes
- The authorities should realize and practice frequent inspection of the market to check whether food products meets the minimum legal standards

Academic Institutions

- Shift from intervention and response to prevention
- Define the value of technology and countermeasures in terms of the impact on prevention
- Lead with the behavioral sciences and criminology

Industry

- Food fraud prevention focus has to be holistic and has to build consumer confidence
- Industry has to engage governments in request for comments on risk assessment or vulnerability frames

Government

- Focus broadly on product fraud not just adulterants
- Define food fraud in laws not just in regulations or guidance documents
- Create and engage public private partnership forum
- Risk assessment

Regional states and Organizations

- Awareness creation on food safety and quality assurance schemes at all levels
- Collaborate to define risk and science based approach
- Evaluate food inspectors

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