

Food fraud and adulteration: a challenge for the foresight of Veterinary Services

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Summary

Demographic and commercial trends show an increase in production of food of animal origin in the coming decades. Therefore, it is expected that health risks will also intensify in parallel. During recent years, food fraud has emerged as a potential threat to various countries, with direct implications for public health and international trade in livestock commodities. Thus, Veterinary Services need to work together in an integrated manner to make food hygiene a shared responsibility between the state and private sector, to guarantee the right of people to eat safe food. This article analyses why food fraud is an emerging challenge for national Veterinary Services and proposes possible lines of action to mitigate its side effects.

Keywords

Adulteration – Food fraud – Food safety – Food security – Veterinary Services.

Introduction

Demographic and commercial trends show a likely increase in the productivity of foods of animal origin in future years. Therefore, it is expected that the health risks will also intensify in parallel (1). Ensuring food safety has become an element of growing concern for

governments, consumers and international organisations. This has led to the development of a set of binding and enforceable guidelines to ensure public health and establish a more consistent pattern of international trade (2, 3).

The traditional concept of food safety is based on access to nourishment free from hazards. However, current trends could change this concept by including the authenticity of products as a key element to ratify the existence of food safety. From the legal point of view, the adulteration of food constitutes a flagrant violation of the principles of fair trade and caution, while defrauding consumers, who do not receive the product (in quality or quantity) for which they are paying. Under this line of thought, the existence of fraudulent products raises questions and mistrust in consumers regarding quality issues inherent to food hygiene, for several reasons:

- food fraud and adulteration (FFA) hinders food safety by ignoring the composition, origin or side effects of adulterants on consumers' health;
- it prevents the successful implementation by statutory veterinary authorities of collective policies and programmes aimed to ensure public health (4);
- consumers are now more aware of what they eat. From this perspective, ensuring the authenticity of a food item is a critical issue that has a pivotal role in the reliability of a particular food product, livestock sector or type of industry (5, 6).

Food fraud and adulteration is an ancient and an anti-competitive criminal practice (7, 8). However, during the last decade food fraud has emerged as significant threat to various countries owing to the direct implications for public health and the international trade in livestock products. In 2000, the World Health Organization (WHO) adopted a resolution to strengthen its standards on food safety and security, by ensuring actions to promote universal access to a healthy and nutritionally balanced diet, as a means to fight hunger and malnutrition. From this point of view, adulterated foods are a risk to

international standards by jeopardising the health of consumers through several side effects on the human organism (from catalysis of oncogenic processes or the bioaccumulation of toxic compounds to the death of consumers) (9).

The number of cases of FFA is increasing (10). Recent episodes of food adulteration such as the incident of melamine being found in milk in the People's Republic of China (China) or the horsemeat scandal in the European Economic Community (EEC) indicate that fraudulent activities in the food industry are reaching pandemic proportions through the globalisation of economies and markets for commodities derived from livestock inputs. In addition, in most countries the actual proportion of FFA and traffic is unknown or miscalculated, making the adulteration of animal by-products a major public concern in terms of health issues and economic cost. Currently, it is estimated that the global cost of fighting FFA in 2014 alone exceeded \$79 billion dollars (11). This article analyses the characteristics and possible causes of food fraud, the challenge for veterinarians in assuring food security in the context of FFA and possible lines of action to minimise its side effects.

Understanding food fraud and adulteration

Food fraud and adulteration is defined as a dishonest act or omission related to the sale or preparation of food which is intended to generate personal economic benefit or damage to a third party (12). The types of food adulteration described in animal products are defined in Table I.

Insert Table I

Although cases of illegal food product tampering occur with some frequency in the apiarian, dairy and fishing markets (where the replacement of one species or ingredient by another of lower commercial value is common) (18, 19), it is in meat products and by-products – particularly in developing countries – where more cases related to food fraud are reported. This is because meat supplies have

a number of inherent characteristics that make them particularly vulnerable to this type of interference, including the following:

- they have a high economic value in the market for food products, so illegal tampering and adulteration of these products may be highly profitable;
- they are nutritionally essential sources of iron and proteins, which makes them one of the food types most sought and appreciated by consumers;
- the production and processing of animal by-products such as sausages or hams includes later stages of cooking, where meat proteins undergo structural and conformational changes to give them the characteristics properties of smell, taste, texture, colour and flavour of the final product. The use of various additives is common and is aimed at obtaining these food quality attributes. Food additives are usually vegetable proteins (soybean, cassava, potato, yucca or wheat), which are also major sources of allergens. Owing to the physicochemical changes in nutrients and additives during the manufacturing process the addition of an adulterant may go unnoticed and is easily masked (20);
- the demand for meat supplies worldwide (especially in developing countries) has increased. This has caused a significant increase in food prices and transaction costs along the supply chain, a key factor that modifies the purchasing patterns of consumers and is a trigger for FFA. As a result, the high cost of food is a serious economic constraint on the most socially vulnerable stratum; these people are therefore required to replace the traditional sources of animal protein with more accessible foods (21, 22). Thus, economic limitations on access to food may indirectly influence the quality of a specific foodstuff, by making adulterated items inexpensive and affordable (23).

Food fraud and adulteration as a challenge to Veterinary Statutory Authorities

In contrast to other types of emergency related to food safety, FFA is characterised as intentional act that may be a substantial and highly profitable activity; it is carried out by certain unscrupulous individuals who generate significant economic profits by reducing production costs while decreasing the quality of products and placing them illegally in particular markets. The smuggling of fraudulent food products is one of the mechanisms by which illegal organisations can launder the proceeds of other criminal activities. In any case, the trade of products with questionable authenticity and modified profiles, containing unknown ingredients and potentially having harmful effects on consumers, has important and direct public health implications.

Public health and access to safe food as an inherent human right covers four elements:

- consumer protection, achieved by managing the overall quality of the distributed product
- intervention to prevent food fraud
- ensuring food hygiene
- fighting agro-terrorism (24).

The safeguarding of all these aspects, in conjunction with food sovereignty, is a critical factor in ensuring food security and the commercial competitiveness of a country and its inhabitants.

Food quality refers to four elements that are functional characteristics of a product: nutrition, safety, sensory aspects and physicochemical properties. In general, preventive food safety focuses on avoiding the occurrence of chemical, physical and microbiological hazards in food, and is traditionally addressed towards a harmless or hygienic approach. However, an episode of adulteration of food could significantly affect the basic components that define the quality of a product. Therefore, to evaluate and verify the authenticity of an edible

item is vital in ascertaining whether or not it complies with the regulatory standards and the characteristics that identify and differentiate it as a non-fraudulent and innocuous product.

Nowadays, consumers are more aware of what they consume. From this perspective, the consumer perception of food is important in strengthening the reliability and economic competitiveness of the structure of a specific livestock manufacturing and supply chain, at local, regional or international level. For example, the episode of melamine in milk led to a severe blow for the Chinese dairy industry that affected the local economy and exports from this Asiatic country, because of a reduced level of trust in its products shown by consumers worldwide.

Veterinary Services are pivotal for ensuring food safety and security throughout all stages of the agro-productive chain; consequently, their role is catalogued as a global public good. These professionals are key to ensuring the flexibility of animal commodities through their inspection, enforcement and certification processes. Thus, Veterinary Services are tangible and integral elements in the commercial and health systems of any country.

From the veterinary public health (VPH) point of view, the adulteration of livestock products results in a number of risks to consumer health and welfare. Thus, classification and identification of risks associated with FFA episodes are important for developing public health policies aimed at preventing and controlling human fatalities arising from acute or short-term illegal tampering with food, cumulative toxicity associated with addition of a fraudulent compound to a product to which chronic exposure causes specific pathology (oncogenesis, hormonal disruption, etc.), or technical risks linked with mislabelling or inefficient packaging.

Food fraud incidents usually go unnoticed because only the criminal knows the exact nature or kind of adulteration used. Depending on the toxic nature of the additive incorporated, its concentration in the food, the amount ingested and the timing of consumer exposure to the product, the same type of adulteration may have different risk levels.

The severity of food fraud incidents associated with public health is shown in Table II. Additionally, official regulatory bodies are often unable to detect the presence of some adulterants until it is too late, usually when the fraudulent product is already in the hands of consumers (27). Hence, it is necessary that countries establish protocols to ensure access to safe and secure foods and avoid the fraudulent sale of foodstuffs to people. Adulteration of food is a rising challenge for international statutory bodies (the World Organisation for Animal Health [OIE], Food and Agriculture Organization of the United Nations [FAO], WHO) and veterinary agencies for the reasons discussed below.

Insert Table II

Nowadays, most countries have unstructured monitoring systems to detect food fraud. Consequently, protocols for evaluating food quality are not designed to detect new or unconventional adulterants, allowing these incidents often to pass unnoticed, and contributing to the fact that the true prevalence of adulterated products remains unknown.

Although in recent years the adulteration of livestock inputs has become a major problem in public health, most countries do not have clear and well-structured legislation to regulate it.

Food fraud and adulteration represents a deliberate act that allows evasion of international standards on food safety. This represents a latent threat to international commercial standards and the fulfilment of the precautionary and fair trade principles of the Agreement on Sanitary and Phytosanitary Measures (SPS Agreement).

The person committing food fraud has, intrinsically and inherently, an opportunistic nature. Their detection, and intervention to prevent their activity, is often difficult, especially if the acts occur randomly, in isolation and on a small scale. Hence, from an epidemiological perspective, FFA does not have a normal frequency distribution in terms of the number of people affected. Thus, incidents of adulteration of products are not easily predicted by conventional risk analysis, and

require different strategies, a more pragmatic approach and multidisciplinary management interventions.

Recent incidents of adulteration of animal products have shown that there is a lack of standardised diagnostic tests for the detection of some adulterants. Therefore, it is necessary that the signatory members of the SPS Agreement use the principles of harmonisation and equivalence to normalise certain laboratory diagnostic tests and include them in their legislation. The reference organisations that have direct regulatory standards for food hygiene and international trade of livestock products (WHO, OIE, FAO) lack binding norms within their standards to regulate, control or prevent food fraud. In addition, the globalisation of food markets, together with the increasing complexity of food mass production, allows illegal adulteration of a foodstuff that was committed originally in a particular country to have global implications.

Food fraud and adulteration is a clear mechanism used to cheat consumers, who do not receive the product (in terms of quality and/or quantity) for which they are paying. The European cases of food adulteration in 2013 that involved beef patties containing pork and horse meat led to a negative religious and cultural impact and perception in certain ethnic groups. As consumers become more aware of what they eat, the recent incidents of illegal product tampering counter the ability of the regulatory actions carried out by Veterinary Services to ensure food safety along the supply chain and reduce the feasibility of traceability protocols.

Actions to fight against food fraud

The author proposes a series of elements necessary to implement through Statutory Veterinary Services that may have a tangible effect in the fight against adulteration of food derived from animal products.

Development and harmonisation of new laboratory analyses

The establishment and development of standardised laboratory analysis methods that are more specific and effective should include techniques to detect the presence of new adulterants and eliminate ingredient substitution, allowing the confirmation of food integrity. Trial mechanisms should be developed to search out the geographical origin of a foodstuff (28). In order to promote wider distribution of the technologies and their harmonisation, these methods should be inexpensive, easy to use and universally implementable.

Diagnostic methods commonly used to assure the authenticity of animal products include several types of laboratory test, such as immunoassay or enzyme-linked immunosorbent assay (ELISA), polymerase chain reaction (PCR), liquid or gas chromatography and short range infrared spectroscopy (29, 30). The PCR is the most specific and sensitive method for detection of traces of animal proteins or adulterants with a possible degree of allergenicity (e.g. soybeans or wheat) (31). However, this technique has the disadvantages, with liquid or gas chromatography and short range infrared spectroscopy, of being relatively expensive and requiring special laboratory equipment for its implementation. In contrast, the immunoassay or ELISA method is not as expensive and allows the rapid testing of large quantities of products, but it is associated with false-positive reactions due to cross-reaction with other foods with a common molecular structure or phylogenetic association (e.g. proteins found in bovine milk can cross-react with similar nutrients also found in goat, sheep or buffalo milk) (32, 33).

Methods that detect certain types of metal isotope, frequently used to indicate the origin of a product, could also be used in the future as an alternative to evaluate the authenticity of a product, especially for those nourishments categorised as Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI). However, this approach is extremely costly, which limits its large-scale use. Products under the designations PDO or PGI (e.g. certain cheeses originating in

Colombia, Mexico and Costa Rica) (34, 35, 36) have a greater appeal and in some cases a higher consumption rate by consumers, which makes them more likely to be targeted for adulteration.

Implementation of efficient legislation

The fight against adulteration and the assurance of food safety is a shared responsibility between the government sector and the food industry. For example, interdisciplinary actions to ensure the risk management of livestock commodities through the cooperation of different actors is regulated under paragraph 12 of the Protocol of San Salvador. Thus, private industry has an inherent legal responsibility to guarantee that food-processing operations, as well as packaging, transportation and storage of the finished product, are performed hygienically, without health risks for consumers.

There is a primary need for efficient legislation that promotes and facilitates communication and synergy among government agencies at the local level, in order to regulate the importation, exportation and transport of foods and raw materials inside a country, and also to safeguard public health. However, public health legislation often is excessively bureaucratic and inefficient, and constrains small and medium producers who may be unable to comply with the regulatory requirements (37). Therefore, public health legislation must be updated to allow all sectors to fulfil the standards, not only at the level of exportation, but also for domestic consumption and production (38). The strengthening of health legislation should also include FFA as a criminal offence, attributable either as civil or criminal perjury, with penalties appropriate to each of the different types of adulteration.

Strengthening of Statutory Veterinary Services

The promotion and integration of public policies aimed to prevent and control food fraud by international statutory bodies is imperative. Veterinary Services play a crucial role in the execution of the normative rules. Thus, the strengthening of the veterinary authorities should include:

- establishment of tools, processes and laboratory parameters to detect the substitution or dilution of a product, weight adulteration or mislabelling;
- mechanisms to strengthen technical and human resource capacity. In developing countries, the lack or shortage of both elements is a critical factor that has a direct impact on the fight against food fraud by weakening the institutional capacity of the veterinary authorities to address the new challenges that are generated in increasingly complex production chains;
- encouraging the development of new biotechnologies focused on animal production, such as the use of tissue engineering for manufacturing and growing meat *in vitro* as a mechanism to ensure food safety and authenticity;
- establishment of parallel systems to minimise the risk of food fraud at the private industrial level, such as the Threat Assessment Critical Control Point (TACCP) (threat/food defence) or the Vulnerability Assessment and Critical Control Point (VACCP) (vulnerability/food fraud), and integrate them into the Hazard Analysis Critical Control Point (HACCP) protocols (hazard/food safety), in order to foster holistic Food Safety Management Systems (FSMS) (39). This approach is promoted worldwide by the Global Food Safety Initiative (GFSI) as a preventive tool to fight FFA;
- fostering the development of Hazard Analysis and Preventive Controls Based on Risk (HARPC), which is promoted by the United States Food and Drug Administration (FDA) for the modification and actualisation of the Food Safety Modernization Act (FSMA). This approach requires that food processors and manufacturers address as part of their food safety analysis, with both qualitative and quantitative assessment, the probability and significance of hazards that may be intentionally introduced into the agro-food chain;
- implementation of mandatory programmes and mechanisms for tracing animals and their derivatives along the supply chain;

- establishment of more stringent controls on the labelling requirements for imported and locally produced foodstuffs (40).

Veterinary certification

Periodic certification through quality stamps issued by a state agency to food producers or distributors constitutes an important element in ensuring and strengthening consumer confidence in the food they are buying and eating. This presupposes a direct action that the private industrial sector actively fulfils to comply with local and international food safety policies (41). From the perspective of the food industry, this certification not only allows innovation with better and stricter quality controls but also enables improvement of competitiveness in terms of the trading market, thus granting greater flexibility and openness to regional commercial partners (42).

Implementation of food fraud databases

The establish of a database at government level that records cases of local and international food fraud should be used as an important tool to detect different trends and mechanisms of product adulteration, allowing government authorities to develop methodologies and policies to prevent and control food adulteration (27). Among the advantages of FFA databases are:

- identifying which foods are commonly adulterated, to enable assessment of trends in the frequency, susceptibility, risk or vulnerability of a particular product or raw material;
- recognition of the existence of one or more types of adulteration for a specific foodstuff;
- providing valuable information to identify the best analytical and laboratory methods to detect a particular type of adulterant in a specific food group;
- the use of computational models to evaluate and take into account epidemiological, socioeconomic and bioclimatic factors affecting the provision of food or raw materials that potentially could restrict access

to one or more products, which may be used as a preventive tool to avoid further FFA cases (28);

– standardisation of a global food fraud database with free access, or available on subscription, which is interactive and able to provide biosecurity information in real time. This would be an important component in the fight against FFA (43).

Use of emerging biotechnologies in animal production

Research on strategies to improve the quality and hygiene of animal products has received increasing interest within the scientific community. Biotechnology aimed at developing means to differentiate stem cells for veterinary and zootechnical purposes has been shown to have an important application in future food production (44). The cultivation of meat *in vitro* could have a direct impact on food security in the coming decades (45, 46). However, although the development of these technologies is currently very expensive and limited to food produced under laboratory conditions, it also offers considerable advantages, such as:

– food products developed in controlled environments offer major confidence to consumers with regard to their hygiene and authenticity (47);

– they involve no animal abuse or negative effects on livestock commodities derived from physiological stress due to poor animal handling and husbandry, inadequate slaughter procedures or deficient transport practices (48);

– the use of *in vitro* cultures also has a beneficial effect from an environmental perspective, because the utilisation of large amounts of land for free-grazing livestock (especially beef cattle) has an important effect on climate change. Methane emissions produced by ruminant digestive fermentation generate between 15 and 17% of all greenhouse gases released annually into the atmosphere. Hence, food products developed under controlled laboratory conditions are

environmentally friendly and provide sustainable food inputs, thus directly helping to mitigate global warming side effects (49);

– the demand for animal products worldwide is predicted to increase in the next few decades. However, the livestock industry has been under public scrutiny due to recent episodes of food fraud in China and the European Community. Thus, foodstuffs made using biotechnology offer an alternative that may provide safe products with higher acceptance and intake rates by the average consumer (50).

The cost and the specificity of the laboratory equipment required to perform trials of these foods currently inhibits their large-scale application. However, food engineering is an excellent line of research, providing a viable alternative to ensure food security and safety through the production of foods with a recognised, tangible and ascertainable identity.

Conclusions

The increase in world livestock trading, mostly in developing countries, has allowed economic growth and a higher availability of food commodities, but the risk of food-borne diseases has increased concomitantly. Therefore, attention to food safety and security is essential to protect public health, and to promote food trade and the economic development of nations.

Outbreaks of food-borne diseases are one of the major challenges to public health worldwide; they cause high morbidity and mortality rates and have a large impact on the economy of health services. Thus, improved competitiveness and greater access to international markets requires adjustment of food safety policies and requires harmonisation of international agricultural trade standards based on the SPS Agreement and the Agreement on Technical Barriers to Trade.

Public policies aimed at ensuring consumer health and the hygiene of animal products that are processed, produced, packaged, stored and distributed in a given country must have an adequate legal substrate that protects and fosters an effective, robust and coherent regulatory

framework to facilitate their implementation and execution. Thus, access to safe food is a public good sustained by governments. In addition, the assurance of safe food, free of any type of adulterant, is a matter of strategic importance for a country's sustainable development, given the side effects of FFA and its implications for public health, food security, agricultural development, trade competitiveness and access to international markets.

Therefore, given the diversity in the origin and characteristics of food fraud risks, both food safety and the fight against food adulteration require a multidisciplinary and transverse approach. It is imperative to address this issue in an integrated manner during all the steps that comprise the food chain, from pre-production farm stages to retail distribution; the assurance of food safety must be taken as a shared responsibility between the state and civil society.

Given the latent and growing threat of agro-terrorism there is a rising need in both developed and developing countries to review the legal and regulatory food safety framework concerning FFA control and prevention, by improving coordination and risk management with more reliable mechanisms during the entire food manufacturing process. These actions should also include updating of the legislation aimed at controlling new food risks and threats.

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Table I
Typology of food fraud (13)

Typology	Definition	Example	Reference
Adulteration	One or more of the ingredients of the legitimate product differs from the original composition	Melamine in milk	(14)
Diversion	Sale and distribution of products without the legal requirements or certificates	Halal meat fraud	(15)
Mislabelling	Misinformation or complete lack of data on the packaging or label	Mislabelling on fishery products	(16)
Substitution	Consists in replacing a food entirely with a similar and inexpensive product, also called food forgery	Horse meat instead of bovine tissue in beef patties	(17)

Table II
Risk matrix according to food fraud typology

Food fraud typology	Risk level			References
	Low ^(a)	Medium ^(b)	High ^(c)	
Adulteration		•	•	(25, 26)
Diversion		•	•	(25, 26)
Mislabelling	•	•		(25, 26)
Substitution	•			(25, 26)

a) Episodes that do not represent a direct impact on public health, but consumer confidence in the product may be affected owing to alterations in sensory and physicochemical parameters of the food, its labelling or packaging.

b) Refers to the exposure of consumers in the short or medium term to microbiological and chemical hazards present in a particular food; side effects on health cause chronic or acute alterations in body homeostasis without causing fatalities.

c) Indicates an attack and deliberate modification of products. The main motivation is to generate fear in the population or substantial economic loss in a given agricultural sector or country. Has an important impact on public health and may even cause the death of consumers and the imposition of non-tariff trade barriers on the fraudulent products.