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Chemical risks from an industrial perspective

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I – Introduction

Food safety and, in particular, the occurrence of chemicals in food, are of great concern from many points of view: (i) *consumers* are demanding high quality food products with the confidence that they are safe and that no adverse health effects will be expected at short and long term; (ii) *authorities* have to set up and applied the legal requirements to guarantee and control the safety of food and the health of consumers; and (iii) *food industry* should comply with all legal requirements and produce safe food in order not to suffer economic loses. This lecture is focused mainly on the industrial perspective of chemical risks; however both the consumers' and authorities' perspectives have a lot of influence on how food industry faces these types of risks.

Many definitions of the term risk have been developed and usually they try to differentiate it from the term hazard. For example, the Codex Alimentarius (FAO/WHO, 2004) has adopted the following definitions:

Hazard: A biological, chemical or physical **agent** in, or condition of, food with the **potential to cause an adverse health effect**.

Risk: A function of the **probability** of an adverse health effect and the severity of that effect, consequential to a hazard(s) in food.

As part of the project for the Harmonization of Approaches to the Assessment of Risk from Exposure to Chemicals, the International Programme on Chemical Safety (IPCS, 2004) has developed slight different definitions:

Hazard: Inherent property of an **agent** or situation having the **potential to cause adverse effects** when an organism, system or (sub)population is exposed to that agent.

Risk: The **probability** of an adverse effect in an organism, system or (sub)population caused under specified circumstances by exposure to an agent.

As it can be seen in both definitions the term risk is associated with the probability of occurring an adverse effect whereas hazard is related to the agent/property/condition causing that adverse effect. In general, chemicals and food are two words that people do not want to see together. Chemicals are bad considered and they usually cause more concern than microbiological contamination because the exposure to them is considered to be beyond consumers' control (Kher *et al.*, 2011). Moreover, fears are expressed regarding their capacity to cause long term effects. However, chemicals are commonly needed in everyday life and also contribute with beneficial effects when used in a proper way. Regarding food industry many chemicals are used as additives to improve the quality (color, flavor, odour, shelf life…) and safety (antimicrobials, functional ingredients…) of food products.

II – Chemicals in the food industry

Several steps are needed to get food from the farm or fisheries to our table. This process includes the primary production, processing, distributing, retailing, consumption and at the end, the disposal of waste. In each step many chemicals can enter in contact with food, thus residues might occur in the final product and consumers' might be exposed to them. Next some examples of chemical in each step are presented:

1. Production

The continuous increase in the world population has brought up the need of the enhancement of agricultural activities, fisheries and stockbreeding. In order to secure enough food to satisfy the global demand, an improvement of production is needed. In this sense, chemicals can be of great help to improve production efficiencies and avoid the attack of pests or the appearance of animal illnesses. In the case of agriculture, fertilizers and phytosanitary products such as herbicides or pesticides are used to provide good protection against a range of pests that may decrease production causing important economic losses. Regarding aquaculture and stockbreeding veterinary products are used to maintain the health of animals. All these substances are intentionally added by producers and should be done following Good Manufacturing Practices (GMP). Unfortunately, due to different causes (e.g., excessive use/misuse, environmental pollution, and especially physical properties, such as chemicals solubility and stability), food products can contain residual amounts of a range of chemical substances.

Apart from intentionally added substances another source of chemical substances is the environmental pollution. Ecosystems are suffering the direct emission of hazardous chemical substances to the environment coming from the expanded industrial activity and the increasing population which generates a negative pressure on the sustainability of the environment and leads to the occurrence of residues in food products. Even if GMPs are applied, food production is subject to be contaminated by toxic substances. Mercury is one example of this environmental contaminant. Hg is found in various forms (elemental, inorganic and organic), all with different toxicological properties. The most toxic to humans is the organic form, being methyl mercury (MeHg) the predominant form in fishery products. MeHg is largely produced from the methylation of inorganic Hg by microbial activity, particularly in marine and freshwater sediments (EPA, 2011). As Fig. 1 shows, MeHg is widespread distributed all around the world.

Several food safety agencies (EPA, EFSA, national agencies) have established dietary recommendations after performing a risk assessment. Certain vulnerable groups have been defined: women who might become pregnant, women who are pregnant, nursing mothers, young children; who are prone to exceed the maximum tolerable intake of this substance.

As a consequence of bad practices or environmental contamination hazardous substances might be present in our food stuff. Food producers might be aware of this fact and establish the necessary controls to guarantee safe products to consumers.

2. Processing

Some processing steps require the use of various chemical products such as extraction, solubilisation, deionization or other separation techniques. In the end, these chemicals should be removed and controlled in order to check that their concentration levels do not reach a limit to be considered as a risk. Also, cleaning operations constitute another source of chemicals (detergents, antimicrobials, acids, bases…) as strict hygiene requirements applied to food industry.

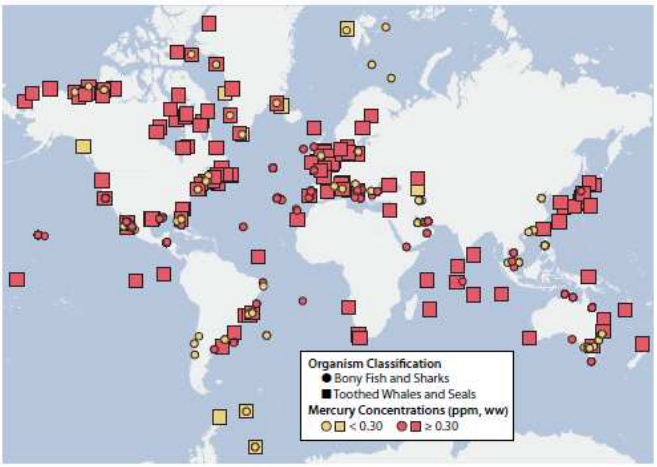

Fig. 1. The global distribution of average mercury concentrations (ppm, wet weight) in sharks and rays, ony fish, seals, and toothed whales from muscle tissue. Most samples exceed 0.3 ppm, the U.S. EPA human health criterion. Map from Biodiversity Research Institute, Gorham, ME, based on data summarized from published literature.

Apart from these steps, other chemicals are intentionally added to perform certain technological functions, for example to colour, to sweeten or to help preserve foods. These substances are called Food Additives, they should be identified and included in the ingredients list of foods; and must be authorized before they can be used in foods (in Europe safety assessment is carried out by EFSA).

During processing there can also occurred unwanted contamination by migration of chemicals from surfaces in contact with food (equipments, packaging…) and the generation of toxic by-products such as:

(i) Acrylamide. It has been found in certain foods, with especially high levels in potato chips, French fries, and other food products produced by high-temperature cooking. At high concentrations is known to be a risk for several types of cancer in animals.

(ii) Furan. It can be formed in a variety of heat-treated commercial foods and has been shown to be carcinogenic in animal experiments.

(iii) Ethyl carbamate. It is a known genotoxic and carcinogen in animals and probably carcinogenic in human beings. It can occur naturally in fermented food and beverages, such as spirits, wine, beer, bread, soy sauce and yoghourt.

(iv) Polycyclic aromatic hydrocarbons (PAHs). The can be formed as a consequence of thermal treatments of varying severity in food preparations and manufacture (e.g., drying), accidental contamination during food processing, addition of food additives such as liquid smoke flavourings, and cooking procedures.

Food scares where these substances were involved have been reported during the last decades such as the elevated levels of benzo[a]pyrene found in olive pomace oils coming from Spain or the acrylamide present in crisps an coffee. Consequently, this process creates a short-term negative impact upon consumer consumption/purchase behaviour as well as negatively impact upon the producer, manufacturer or retailer (Knowles *et al*., 2007).

3. Distributing and retailing

These steps involve the storage, transport, distribution and sale of food products in supermarkets and other food establishments such as street-food vendors and market stalls. Also, it is important to mention these steps associated to the supply of materials to be in contact with food that should be done following safety measures to prevent chemical contamination. Usually, the challenge is to maintain proper refrigeration temperatures and to keep the "cold-chain" from breaking. This will ensure that the food products will reach consumers at the best conditions possible, avoiding the proliferation of specific spoilage microorganisms. However, chemicals can also contact food during these procedures resulting in contaminated food products.

The migration of chemicals from pallets or packaging is one important source of exposure to chemicals as well as the cleaning and sanitizing operations. Moreover there are other factors that can result in the supply of unsafe products. This is especially important when different kind of products are transported or stored nearby. Cross-contamination may occur and a risk can be generated. In this sense, the case of food contamination with allergens can be highlighted. The estimated prevalence of the food allergies is about 2% in adults and 4-7% in children, thus affecting more than 20,000,000 people in the European Union, and its incidence seems to be increasing in the developed countries, causing an important sanitary expense, and severely affecting the life quality of affected persons. It is important that this is taken into consideration when assembling pallets, staging or storing in addition to how allergens containing foods are located in a distribution center.

Cross-contamination with non-food products should be also avoided and since the terrorist attacks of 2011 in the US terrorism has become another issue that requires special provisions with regard to the food products control. Possible threats should be examined and actions should be taken to prevent any intentional attack on the food supply.

Food industry should ensure the supply of safe food products to consumers, but when a risk is identified procedures for the immediate recall of adulterated products from trade and consumer channels (this applies to processors, transporters, and wholesale and retail distributors).

Relevant chemical contamination incidents can be found regarding storing, distributing and retailing. For instance, the presence of toxic substances in baby food that comes from packaging is of great concern as infants are a very vulnerable population and special preventive measures should be taken. Other cases of using contaminated containers or cans can be mentioned: vinegar contaminated with antifreeze products was distributed in China and cause a food poisoning outbreak; and the Coca Cola incident of 1999. In the latter incident the absence of relevant concentrations of hazardous substances made difficult to identify this fact as the main reason for the observed symptoms in students. Nevertheless, this incident resulted in substantial financial costs to The Coca-Cola Company and in considerable damage to its global image and reputation.

4. Consumers

Food industry should also consider consumers as an important factor when planning the control of the safety of their products. Foods are stored in different conditions (chilling, freezing, room temperature) and risks coming from cross-contamination with other food or non-food products can also occur.

Culinary treatments play a key role in the bioavailability of chemical contaminants. On the one hand, steaming, grilling or frying affect the structure of foods and can make contaminants more available for absorption due to the breakdown of the interaction of contaminants with the food matrix. On the other hand, chemicals can undergo degradation process under high temperatures that lead to metabolites which in some cases might be even more toxic than the

parent compound. Figure 2 shows the bioavailability of cadmium and mercury under different culinary treatments.

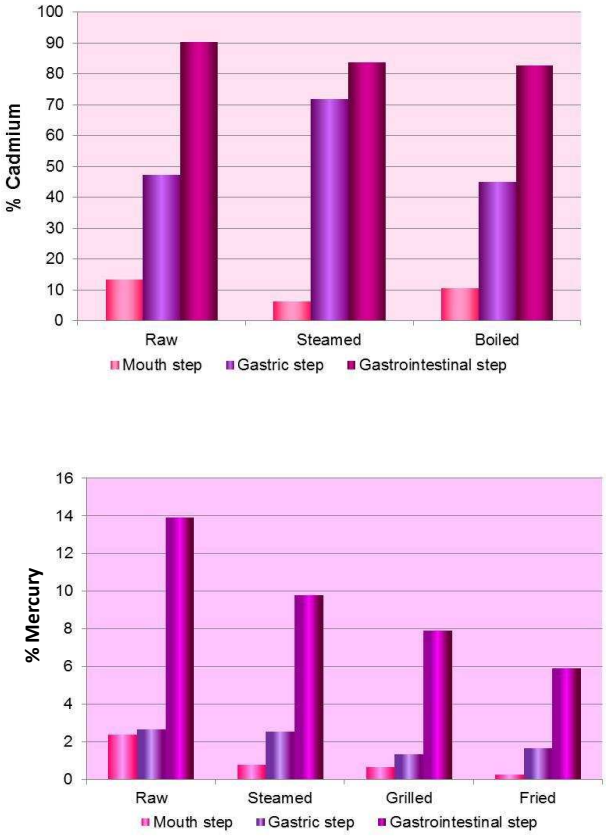

Fig. 2. Biavailability of cadmium from edible crab and mercury from blackscabbard fish. Source: Maulvault *et al.*, 2011.

While cadmium is slightly affected by culinary treatments and high bioavailability (80-90%) is achieved, less than 10% of mercury is available after treatments. This information is important for risk assessment and for establishing preventive measures.

III – Food policy

In the last decades food safety issues have been gaining significant political, scientific and societal concern. In this context, food scares and incidents have alerted and informed consumers about hazardous substances present in our foods and the potential risk involved. Nowadays, consumers have a lot of information available and we chose food products according to our perception of risks. Social media, consumers associations, NGO and of course, scientists, have played an important role in the dissemination of all this information. In Table 1 a summary of main food scares in Europe are shown.

As a consequence, EU food policy has put emphasis on consumers in order to guarantee public health through the availability of safe foods. In this sense, the European Food Safety Agency

(EFSA) was created as well as many other national agencies and a lot of work has been done in the harmonization of risk assessment and testing methodologies in order to unify a regulatory framework within Europe. One of the most important characteristic of this framework is the "precautionary principle". In those cases where scientific data do not permit a complete evaluation of the risk, recourse to this principle may, for example, be used to stop distribution or order withdrawal from the market of products likely to be hazardous.

Table 1. Summary of main food scares (1996-2006). Data from Knowles *et al.,* 2007

Year	Contaminant
1989	Alar pesticide (EU)
	Sewage contamination of fresh meat (Fr)
1990	Benzene in Perrier bottled water (EU)
1999	Dioxins in animal feeds (EU)
	Fungicide/poor carbon dioxide in Coca-Cola (EU)
2001	Olive oil contamination (Sp/UK)
2002	Nitrofuran in prawns (UK)
	Nitrofen in wheat (EU)
	Acrylamide (EU)
2003	Mercury poisoning in swordfish (UK)
	Sudan I (EU)
2004	Lasalocid in eggs (UK)
	PCBs and Dioxins in salmon (UK)
	Sudan I (EU)
2005	Sudan I (EU)
	Para Red (EU)
2006	Benzene in soft drinks (Fr/UK)
	Dioxins in animal feeds (Be/Ne)

Regarding chemical contaminants many families of substances are under controlled: veterinary products, phytosanitary products, food contact materials, residues of contaminants, flavourings and additives. There are list of approved substances that can be used for food production and also maximum residue (MRLs) limits have been set up taking into account the toxicity and dietary exposure among other information.

As in Europe other countries have established their own agency and regulatory framework. In the USA the Federal and Drug Administration (FDA) serve an important role in these activities. In this case food safety policy and decision making incorporates precaution and science-based risk analyses too (IFT, 2009). Also residue limits have been established and there are lists of approved substances. However, a new term has been defined: GRAS (Generally Recognized As Safe). Under this definition are lots of substances that are exempted from food additive status and therefore free form the usual regulatory requirements. These decisions are based on generally available data and information; it does not require the same quantity or quality of scientific evidence needed for food additive approval and can be done by the food industry itself who can voluntary inform the FDA. Nevertheless, FDA can perform complete studies of these substances (373 substances have been already reviewed) (FDA, 2014).

IV – Food industry perspective

Food industry is facing numerous pressures coming from the consumer, the economic situation, new policies, accidents, attacks, competitors and the new information provided by the science. These factors force the food industry to be in continuous innovation, looking for solutions not to

lose competitiveness and demand a high responsibility to ensure the supply of safe food to the market. Therefore, these factors might be seen as a threat because imply new investments; increasing the cost of production and the need to be continuously aware of possible new inputs from these factors. However, it can also be an opportunity to developed new strategies of production or new products to gain the confidence of the consumers.

Food safety and chemical risks are a big challenge for food industry. New and lower residue limits are usually being established and new substances are included in the regulatory framework. In the end, a lot of substances have to be controlled and sometimes at very low concentration levels. With this purpose, new rapid, cheap and easy detection systems are highly demanded. Moreover, this analytical effort is usually performed out of the industries' facilities because the recommended measurement techniques are based on complex instruments that only can work in a laboratory environment. That means that the results are not available in rapid way, so the fabrication process should be adapted. The economic cost is greater in the case of SMEs due to their smaller production. Another challenge is the satisfaction of consumers' demands for new and safe food requiring a high adaptation and more costs for the food industry. Furthermore, food industry should be looking to be better than competitors and flexible enough to adapt to new situations in a rapid manner.

Apart from the regulated chemicals there are also unknown and emerging risks that all agents involved in the food production chain should be aware of. In this context, scientific community has to work on providing the necessary information in order to be able to define new risks and how to deal with them.

These challenges can also be transformed into opportunities for the implementation of new technologies to improve quality, safety and production efficiency. This modernization will bring new products, specialized products (for a certain group of population) to satisfy the consumers' demand. The involvement of all agents in the food production chain will bring also new opportunities. In this sense, several contaminant-free products can be found in the market. Packaging industry has moved on to the development of new products not using hazardous substances (BPA-free) and improving the capabilities of their products. There are also food producers certifying the absence of contaminants.

V – Conclusions

Food industry views food safety as one priority and make a lot of effort to produce safe food. However, the food production chain is complex and cooperation among producers, ingredient suppliers, food scientists, processors and other food technologists, distributors, and authorities is critical in ensuring the safety of the global food supply and maintaining consumer trust and confidence.

The mere presence of a chemical in a food does not mean that the substance necessarily poses a risk to health. However, new procedures and technologies are needed to analyse the scope of the issue and determine an appropriate type of response. There will be always chemicals in our foods but risk-benefit analysis should be performed in order to guarantee public health.

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