Strategies for Preventing Food Products from Contamination along the Supply Chain

Dr. rer. Nat. Thomas M. A. Gronewold
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Supply Chain – Compliance with national specifications

- Contaminants in foodstuff are unwanted – Independent of any risk assessment
- Transparency creates confidence
Supply Chain – Transparency or Risk

- Missing Hygiene/Equipment
  - Raw Materials
    - No backtracking possible, No control
  - Storage
    - Possible Contamination: Microbiology, Allergens, Foreign Bodies
  - Production
    - Cleaning mistakes / Disinfection; No defined Standard, Certificates not reliable
  - Missing Hygiene/Equipment
    - Errors in Production; Missing Hygiene and Control

- Container not food compatible
- Cleaning mistakes/Disinfection; No DIN check

Strategies for Preventing Food Products from Contamination along the Supply Chain
Supply Chain – Level of Registration of „Suppliers“ and „Producers“

- Raw material: > 99%
- Transport: < 5%
- Production: > 99%
- Cleaning: < 2%

Safety Gaps - Risks are forwarded along the entire Supply Chain

Strategies for Preventing Food Products from Contamination along the Supply Chain
Actual contaminants in food (RASFF)

Rapid Alert System for Food and Feed - Overview 2016 until 07/2017 „Food“
Bulk of produce bears the combined contaminants from every of the involved small farmers:

- Foreign bodies
- Allergens (crop rotation)
- Pesticides (often many different ones in bulk produce)
- Mycotoxins (field: Ergot alkaloids; storage: toxic Aflatoxin, Ochratoxin A, Fusarium toxins)
- Heavy metals (ground, water, human influence)
- Microbiological contamination

Often, a vast number of contaminants is found at low levels in one sample. Single-chemical risk assessment underestimates risks: Coactions of multiple contaminants – addition and synergistic toxicity (esp. at higher exposure concentrations)
Prevention

- Good agricultural practice
- Sufficient drying of crops after harvest
- There is considerable on-going research on methods to prevent pre-harvest contamination of crops. These approaches include developing host resistance through plant breeding and through enhancement of antifungal genes, use of biocontrol agents, and targeting regulatory genes in mycotoxin development
- Mycotoxins cannot be prevented completely, e.g. Zearalenone in maize. The same fungi might grow on other grains. Therefore should wheat not directly follow maize on the same field: Crop rotation
- Microbiological contamination, e.g. with the bacterium *E. coli*, often actually results from human handling at harvest! A non-invasive measure is for example steam sterilisation.
- Veterinary drugs in agro-cultural products result from feeding and from fertilisation with contaminated feces.
Fractionation Column: Refinement of crude oil by fraction distillation:
Heat and catalysts are used to convert the heavier oils into lighter products using three “cracking” methods: fluid catalytic cracking (FCC), hydrocracking (Isomax), and coking (or thermal-cracking).
Mineral oils are enriched in fat. Tested is the food content of saturated mineral oils from C_{10} to C_{56}. Natural occurring hydrocarbons such as waxes etc are not reported.

MOSH = Mineral Oil Saturated Hydrocarbons
POSH = Polyolefin Oligomeric Saturated Hydrocarbons
MOAH = Mineral Oil Aromatic Hydrocarbons

Typically reported: (1) MOSH/POSH; (2) MOAH

C_{5} – C_{10} Gasoline

C_{10} – C_{16} Kerosene

C_{14} – C_{20} Diesel

C_{20} – C_{50} Lubricants

C_{20} – C_{70} Heavy fuel oil

The LOQ depends on the fat content of the sample.
Minimising Mineral Oil Hydrocarbons in foods

Testing methods:
• Direct measurement
• Migration e.g. from cardboard boxes made from the print on recycled paper

✓ Use as little as possible Mineral Oil which might contact the foodstuff. Critical points are planting, harvest, drying (electric pumps), transport (fuel) and storage to processing
✓ Obtain raw materials from reliable and reputable suppliers; ask for certificates
✓ Pack in suited primary package material / with protective barriers; contamination free containers
✓ Only use suited cleaning agents
✓ Reduce lubricant quantity and check lube points
✓ Consider mineral oil hydrocarbons from allowed sources
✓ Take care at sampling / sending samples: Do not introduce traces at sampling, e.g. washed hands and glass containers instead of protective gloves and plastic materials
Typical factors causing moisture inside a container

- **Products**: Major factor inside a container is the moisture content of the product itself. It might vary from ~10% – 35%. Cargo with moisture $\geq$25% becomes problematic.
- **Container Floor**: The moisture content of the wooden floors became higher – based on the quality of the wood being used and/or the floors being cleaned with water and used without sufficient drying.
- **Packaging**: The moisture of wooden pallets is $>20\%$ and also cardboard boxes contain a lot of moisture, which always causes problems for any product. Its moisture which will spread into the cargo or vaporizes into the air.
- **Journey and climate factors**: The conditions during transport are uncontrollable, beginning with the transport time, destination, and most important the climate changes during shipment and at final destination.
Relative Humidity:
The Relative Humidity is the percentage measure of moisture the air currently holds compared to how much it can hold in total.

- Completely dry air has a relative humidity of 0%

Relative humidity [%] = \( \frac{\text{Moisture in air}}{\text{Max. moisture the air can hold}} \)

More moisture evaporates into the warmer air since it can accept a lot more moisture. When the air cools, more water is released as condensation. Within a container, temperatures can change quickly up and down. Even 5 degrees Celsius (day/night) can cause condensation to occur. At moisture content of the air > 100%, condensation rains out.
Warm air can hold more moisture than cold air ↔ At lower temperatures, the air becomes more humid

Air becomes more humid at colder temperatures. At some point, the moisture starts to rain out as condensation (= dew, fog).

Most worldwide transportation relies on containers – in ships, trucks, or airway. Rarely, goods are transported openly.

Containers are closed spaces with an own “climatic system”. Still, they are influenced by outside variations. Although some ships offer temperature controls on an ocean voyage, it is typical that containers are unloaded in-between. Therefore, the temperature inside a container might fluctuate between below freezing, and > 50°C.

Forms of condensation in containers:
• “Container rain” = condensation on the container ceiling which drips down
• “Cargo sweat” = water condenses on the cargo itself which can be even more damaging
The risk for moisture damage increases when the temperature rises inside the container – either at passing a warmer climate, or moisture enters from the outside through ventilation holes.

Rule of thumb:
- At 60% humidity, metals will begin to corrode or discolour
- At > 80%, mould begins to grow. Storage mycotoxins might be formed.
- Moisture in containers causes e.g. growth of mold, fungus, mildew, rust decay, lumping, caking, agglomeration, and decomposition. Moisture can also cause electronics to malfunction.

**Condensation might occur only locally:**
As air moves around inside the container, warm air can move into a colder part of the container, becoming humid and even causing condensation. This results in unusual patterns of damage, such as mould formation in so-called “hot spots”.

Therefore, moisture damage can be invisible at first sight. Mycotoxins might have formed without visible mould growth, electronics might be corroded inside the device.
Prevention of Condensation

✔ Thermal treatment of boxes
Pre-shipment to dry fresh, unused wooden boxes and to prevent pest infestation.

✔ Product
Make sure that the product remains dry all the way throughout its journey. Condensation on the surface of a product evaporates faster. Remaining moisture inside the product might cause growth of moulds and fungi damaging the centre.

✔ Packaging inside the container
Add more units to absorb the extra water molecules. Still, a lot of free air remains between the products.

✔ Lining of the container with Sweat Paper
The Relative Humidity is difficult to control in goods with very high moisture condensation. For their shipment, Sweat paper installed under the ceiling inside a container absorbs moisture in form of container rain.

✔ Do not shrink-wrap pellets
Or make holes so the water molecules won’t get trapped.

✔ Use of Desiccants
Exceeding moisture is absorbed and retained e.g. into silica gels by extracting water vapor present in the air, thus preventing the relative humidity inside the container from reaching dew point and condensing (ventilation holes in the container need to be closed).

**Generally, there is no risk of damage of cargo if the relative humidity in a container stays below 50%.**
Allergens from uncleaned containers, transfer between containers

Allergens enter the food chain
- At production, e.g. based on wrong crop rotation (wheat after maize, peanut)
- From incompletely cleaned containers
- Transfer between containers at transportation
- But mostly at production
Fraud might not even be intentionally!

When the trade is not directly with the farmer, at every trading point adulteration might occur.

Food fraud became a prominent item in the last years since it is so common, e.g.:

- Intermixing with inexpensive foodstuff or even harmful ingredients (Melamine in dried milk products)
- Dyes: Illegal dyes, dyes in general, even dyes harmful to health to enhance coloration or to mimic a product

### Strategies for Preventing Food Products from Contamination along the Supply Chain

<table>
<thead>
<tr>
<th>Topic</th>
<th>Questions</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety / Species</td>
<td>Does the content conforms with the label: Review of claims; verify stated species?</td>
<td>Basmati rice, spices, salmon, honey, goat cheese</td>
</tr>
<tr>
<td>Cultivation / Production</td>
<td>Does the product comply with the certification?</td>
<td>Organic or not? GMO-free</td>
</tr>
<tr>
<td>Manufacturing process</td>
<td>Was the product manufactured as specified? Is it natural or synthetic?</td>
<td>Halal, extra virgin olive oil (cold pressed), vanilla flavour</td>
</tr>
<tr>
<td>Origin / Regional Origin</td>
<td>Is the good derived from the claimed geographical origin? Especially in case of protected geographical indication.</td>
<td>Olive oil, wine, Darjeeling tea, Parma ham</td>
</tr>
<tr>
<td>Variety / Species</td>
<td>Is the product mixed with other varieties / species?</td>
<td>Honey, coffee, spices, rape seed in linseed, hazelnut, chickpea in flour</td>
</tr>
<tr>
<td>Allergens / Impurities</td>
<td>Can allergenic residues or impurities be traced? Are foreign substances contained?</td>
<td>Egg in wine, peanut in spices, gluten in tea, stones, metal</td>
</tr>
<tr>
<td>Substitution</td>
<td>Was the quantity of the product extended, diluted, added or blended for profit maximisation?</td>
<td>Saffron, coffee, olive oil, honey, oregano, Ginkgo biloba</td>
</tr>
<tr>
<td>Illegal additives</td>
<td>Can additives – naturally contained or foreign – be found to artificially enhance quality?</td>
<td>Pepper powder (Sudan red; flour), sugar, water, vitamin C, milk powder (melamine), wine (Glycol),</td>
</tr>
</tbody>
</table>

### Authenticity, food fraud, adulteration

**Fraud might not even be intentionally!**

*When the trade is not directly with the farmer, at every trading point adulteration might occur.*

*Food fraud became a prominent item in the last years since it is so common, e.g.:*

- Intermixing with inexpensive foodstuff or even harmful ingredients (Melamine in dried milk products)
- Dyes: Illegal dyes, dyes in general, even dyes harmful to health to enhance coloration or to mimic a product
Prevention measures are as many as sources for food fraud, but two basics should be considered:

- As little as possible middle-man at trading
- Testings at Critical Control Points
- GMO Testings: Presentation Ulf Rathjens, Eurofins GeneScan
- Follow acknowledged global standards / certificates like IFS Food, BRC, FSCC 22000

*) International Featured Standards, certificates; British Retail Consortium; Food Safety System Certification
## Pesticides and veterinary drugs: Use after harvest

<table>
<thead>
<tr>
<th>Substance (examples)</th>
<th>Application</th>
<th>Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,3-dichloropropene</td>
<td>Preplant fumigant, nematicide in soil; container fumigation</td>
<td>Potato, tobacco (e.g. US)</td>
</tr>
<tr>
<td>Fipronil</td>
<td>Pesticide; misuse for cleaning and sanitising (poultry mite)</td>
<td>Egg-producing hens</td>
</tr>
<tr>
<td>Glyphosate; strobilurin fungicides</td>
<td>Crop desiccation; harvest aid; drying agent when conditions are wet</td>
<td>wheat, oats, edible beans and other crops</td>
</tr>
<tr>
<td>Bromide; formaldehyde; hydrogen Cyanide; Sulfuryl Fluoride; Chlorpyrifos, Dithiocarbamate, Paraquat/Diquat, Chlormequat/Mepiquat, Fotesyl/Phosphonic acid (phosphine)</td>
<td>Pest control: Fumigation eliminates insect pests and eggs in goods like fruits and vegetables, e.g. inside a container. Prevention transfer of exotic organisms as well as pests that inhabit wooden structures, such as woodborers and drywood termites.</td>
<td>Foodstuff in buildings or containers, soil, grain. Actual case Chlorpyrifos in Egyptian spice tested before being sold and after arrival in Germany</td>
</tr>
<tr>
<td>Chlorination</td>
<td>Cleaning, sanitation</td>
<td></td>
</tr>
</tbody>
</table>
Acrylamide (2-propenamide) develops in various starch-containing, thermally processed foods like French fries or potato crisps.

- Commission regulation 2017/2158: Establishing mitigation measures and benchmark levels for acrylamide in food
- Setting of maximum levels in accordance with Reg. (EEC) 315/93
  - New regulation will apply from April 11th 2018.

Acrylamide is formed by thermal procedures >120 °C like baking, roasting, frying and deep-frying from asparagine and reducing sugars like fructose and glucose.

Acrylamide causes cancer within animal testing. In 2015, the European Food Safety Authority (EFSA) confirmed that acrylamide in food potentially increases the risk of developing cancer for consumers in all age groups.

*) The originally for 2018 expected regulation on acrylamide was already approved on 20th November 2017. Commission regulation 2017/2158
## Extract of EU Indicative Values *

<table>
<thead>
<tr>
<th>Indicative Values (EU) [µg/kg]</th>
<th>Indicative Values (EU) [µg/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>French fries (ready-to-eat)</td>
<td>Roast coffee</td>
</tr>
<tr>
<td>Potato crisps from fresh potatoes and from potato dough</td>
<td>Instant (soluble) coffee</td>
</tr>
<tr>
<td>Potato-based crackers</td>
<td></td>
</tr>
<tr>
<td>Other potato products from potato dough</td>
<td></td>
</tr>
<tr>
<td>Soft bread</td>
<td></td>
</tr>
<tr>
<td>a) Wheat based bread</td>
<td>Coffee substitutes</td>
</tr>
<tr>
<td>50</td>
<td>a) Coffee substitutes exclusively from cereals</td>
</tr>
<tr>
<td>100</td>
<td>500</td>
</tr>
<tr>
<td>b) Soft bread other than wheat based bread</td>
<td>b) Coffee substitutes from a mixture of cereals and chicory</td>
</tr>
<tr>
<td>750</td>
<td>4000</td>
</tr>
<tr>
<td>Breakfast cereals (excl. porridge)</td>
<td></td>
</tr>
<tr>
<td>- Bran products and whole grain cereals, puffed grain</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
</tr>
<tr>
<td>- Wheat and rye based products (*)</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
</tr>
<tr>
<td>- Maize, oat, spelt, barley and rice based products (*)</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Biscuits and wafers</td>
<td></td>
</tr>
<tr>
<td>Crisps and wafers</td>
<td></td>
</tr>
<tr>
<td>350</td>
<td>1) Non-whole grain and/or non-bran based cereals. The cereal present in the largest quantity determines the category.</td>
</tr>
<tr>
<td>400</td>
<td>2) The benchmark level to be applied to coffee substitutes from a mixture of cereals and chicory takes into account the relative proportion of these ingredients in the final product.</td>
</tr>
<tr>
<td>350</td>
<td>3) As defined in Regulation (EU) No 609/2013.</td>
</tr>
<tr>
<td>800</td>
<td></td>
</tr>
<tr>
<td>Products similar to the other products in this category</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
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</tbody>
</table>

* For more details see EU Commission Regulation (EU) 2017/2158

Commission regulation 2017/2158
Production: Reduction of Acrylamide levels (mitigation)

- Esp. larger-scale businesses are targeted: Setting of benchmark levels (as low as reasonably achievable), sampling procedures and analytical criteria in application to regulation (EC) 882/2004
- Implementation of hygiene rules / good hygiene practice
- Procedures based on hazard analysis and critical point (HACCP) principles
- Verification of mitigation measures through sampling and analysis
- When Indicative or Signal Values are exceeded, producers are obliged to implement measures to minimise the acrylamide levels within their products. Therefore they may use intervention steps summarised in the Acrylamide Tool Box (FoodDrinkEurope) or the Code of Practice for Acrylamide (Codex Alimentarius).

Commission regulation 2017/2158
Production: Reduction of Acrylamide levels (mitigation)

- Reducing the amount of asparagine levels and follow good agricultural practices on fertilisation [esp. balanced Sulphur levels in soil, nitrogen application]; follow good phytosanitary practices on crop protection to prevent fungal infection

- Substitute or lower amounts (if possible) of ingredients containing reducing sugars (fructose and glucose, ideally ≤1.5%) and asparagine – e.g.
  * selection of potato/sweet potato/prune varieties
  * exchange syrups and honey in bakery goods for glucose
  * exchange rye and other grains with rice or maize
  * exchange coffee beans Robusta for Arabica

- Prevent formation of reducing sugars and control levels (esp. potatoes: harvest, storage, production process; transport all >6°C, damaging, avoid browning of slices)

- Recommend best cooking methods on packaging specifying; time, temperature, quantity, larger sizes and smaller surface areas – and of final product the colour and high moisture content (post frying)

- Prevent or limit usage of ammonium bicarbonate – Lower pH if possible

Commission regulation 2017/2158
Topics depend on matrix – and are subject to change

<table>
<thead>
<tr>
<th>NGOs</th>
<th>BfR</th>
<th>RASFF</th>
<th>EU / EFSA</th>
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</thead>
<tbody>
<tr>
<td>Irradiation</td>
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<tr>
<td>Aluminum, Nickel, other Elements</td>
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<tr>
<td>Plant toxins &amp; Alkaloids (PAs, TAs)</td>
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<tr>
<td>Food Fraud</td>
<td></td>
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<tr>
<td>Organic contaminants (MOSH/MOAH)</td>
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<tr>
<td>Environmental Contaminants (Micro- und Nano plastics in Food)</td>
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<tr>
<td>Perfluoroalkylated substances (PFAS), persistent Industry chemicals</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pharmacologically active substances</td>
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</tbody>
</table>

→ „Identification of food safety priorities using the Delphi technique (publ. 31.03.2016)“

- Allergens in general, Risk analysis – Determination of Allergen Thresholds
- Cocktail Effects for e.g. Pesticides and PAHs, research on interaction of substances
- Food-born viruses (e.g. Hepatitis A, Norovirus in Food)
- Effects through the change of agricultural application modes, use of pesticides, occurrence of mycotoxins
Quality Services along the Value Stream

**Market Studies - Sensory & Consumer Tasting**
- Label Content & Design
- Selection Food Contact Material
- Product Specification
- Risk-oriented Analytical Test-Scheme

**Product Development**
- Supplier Selection
- Product Development and Implementation of Quality Management Systems
- Supplier Qualification
- Supplier Audits in accordance to IFS Global Markets Food, IFS-6, [...] (Eurofins ASM)
- Supplier Certification

**Supplier-Selection**
- Continuous Risk Assessment
- Food Fraud Defense
- Contaminants & Residues Monitoring
- Release Testing (e.g. Microbiology, Mycotoxins)
- Consulting (Eurofins ASM)

**Raw Materials - Semifinished Goods**
- Supplier Audits (Good Manufacturing Practice + Food Defense)
- Monitoring Specification-Compliance
- Release Testing (Microbiology)

**Production**
- Frequent Marketability Checks
- Label Compliance
- Confirmation of Specification Compliance
- Supplier Assessment
- Food Regulatory Assessment

**Finished Product**
- Goods Outbound Quality Check
- Check Temperature Control
- Store Checks + HACCP
- Staff Training

**Logistics & Sales**

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Eurofins support e.g. for upcoming issues, trend parameters or as crisis support.
Differentiation and additional value – Gapless Tracking

Certification Logistics, Organisation, Personal

DIN-control on Food compatibility

Consultancy, Risk analysis, Staff training

Raw Material

Tracking - System
(Products, Allergens, Cleaning, Pre-Loading)

Validation / Certification of Cleaning processes

Auditing / Certification of Cleaning facility according to e.g. ENFIT-HQF-Standard. Defined Cleaning Standards

Consultancy, Risk analysis, Staff training

Storage

Production

Consultancy, Risk analysis, Staff training

Strategies for Preventing Food Products from Contamination along the Supply Chain
Establish a register of ingredients

Carry out audits of suppliers and / or analyses

Ensure that no changes are made by the supplier of such ingredients that increase level of contaminants

Define and control limits at all processes regarding e.g. temperature, humidity in environment, moisture in product, time

Monitor the processes; train staff:

- Sampling: Representative; specify frequency (annually, lots, at any production changes) depending on likelihood to exceed levels

- Analysis: Check for set benchmark levels of contaminants; likelihood to exceed levels; product attributes can be implemented with statistical correlation with set levels, e.g. colour / acrylamide levels

- Mitigation: Levels of contaminants as low as reasonably possible

- Information to competent authorities if required

UPCOMING: Traceability via BlockChain technologies enables to locate the origin and the complete supply chain of a produce within minutes!
If you have questions, please contact

T: +49 40 49294 2906
ThomasGronewold@eurofins.de

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