Taint Resolution in the Food Industry

Introduction

Taint in food is a significant cause of consumer rejection of food. Even if the food is safe in both the chemical and microbiological aspects, consumers will usually reject a food product that "doesn't smell right" or "tastes off". This can result in lost production, lost sales, lost consumer confidence, damaged brand names, damaged commercial relationships between supplier, manufacturer and retailer, and even expensive litigation. In addition, identifying the source of the taint can be time consuming and expensive, but is essential in preventing recurrences of the taint.

The ISO definition of taint is a "taste or odour foreign to the product". The term "taint" is normally reserved for unpleasant odours or flavours imparted to the food through external sources, whereas an "off-flavour" is usually used to describe unpleasant odours or flavours imparted to the food through internal deteriorative processes. It is important to emphasise that a taint or off-flavour exists if it is perceived by the human senses and no amount of chemical analysis, assurances by producers or denial statements will make it go away.

Taint Identification

Consumers are usually very good at detecting taints, but are notoriously inaccurate in describing them. Thus, the first step for an investigator is accurate identification of the chemical compound(s) responsible for the taint. Often these are highly odorous compounds present at very low levels; mg/kg (parts per billion) or ng/kg (parts per trillion). High sensitivity analysis is usually required to detect taint compounds in the complex food matrix - in some cases this can be like trying to find the proverbial needle in a haystack.

Fortunately a variety of techniques are available to selectively isolate taint chemicals from the complex food matrix. These include solvent extraction, headspace analysis, steam distillation, purge & trap, closed loop stripping, thermal desorption, vapour phase extraction and supercritical fluid extraction. The preferred method of final analysis for organic compounds is gas chromatography - mass spectrometry (GC-MS) which not only separates compounds but also identifies them by their mass spectral fingerprint. Sometimes the chemical or physical nature of the taint compound precludes the use of GC-MS, so alternative techniques (e.g. HPLC, SEM, TLC, ICP, etc.) must be applied.

Sources of Taint

Identification of the chemical compound responsible for the taint is the first step in taint resolution. The next step is to uncover the source of the taint; this requires knowledge of the chemical and physical properties of the taint compound, the food, raw materials and packaging, as well as a good understanding of the manufacturing process and transportation method. The successful investigator will take all of these parameters into account and, by a combination of science and detective work, ultimately identify the source of the taint.

Some common sources of taint are listed below.

- Solvent residues
- Plasticisers
- Process Chemicals
- Contaminated raw materials

- Contaminated water
- Thermal degradation products
- Chemical degradation products
- Microbiological metabolites

In its simplest form, tainting occurs by contamination of the food with a single chemical compound from a single source (eg solvent vapours from printing inks on the packaging). These cases are relatively easy to solve. However, in some cases the source of taint appears nebulous because the taint compound was formed by a series of chemical reactions involving non-tainting chemicals from a variety of sources. In these cases the taint compound cannot be attributed to a single sourc e and the investigator needs to determine the sources of the precursor compounds and to establish the chain of events which led to the formation of the taint compound.

Mechanisms for Taint Migration

Food will only become tainted if the taint compound is actually present in the food. The mechanism by which the taint compound (or in some cases its precursor) moves into the food is called migration. There are many forms of migration, some of which are listed below. The variety of chemical and physical properties of tainting compounds means that some compounds have preferred migration routes, and conversely some taints can be prevented by blocking the migration mechanism. However, the preferred method of taint resolution will always be the elimination of the taint compound at its source.

The most common mechanisms for migration are:

Leaching (liquid phase transfer) from packaging

- Aqueous phase - internal can coatings, wine corks, bottle cap liners
- Non-aqueous phase - fatty foods eg pizza, chips.
- Osmosis

Vapour phase transfer from packaging

Solvent/Ink residues - hydrocarbons, ketones, alcohols

- Residual monomers - styrene, vinyl chloride.
- Plasticisers - phthalates, adipates.

Process aids (antioxidants, slip additives, biocides, water treatment chemicals, etc.)

Transfer/diffusion of external contaminants through packaging

- Mainly air contaminants
- Sources
- Traffic fumes - nitrous fumes, hydrocarbons
- Industrial fumes - odours from nearby factories
- Volatile emissions from other products stored nearby shipping containers - residues from previous cargo, residues or reaction products from cleaning chemicals
- Ship's holds - incubator effect

Microbiological activity

- Direct metabolites - sulphur compounds
- Indirect metabolites - reaction with food - aldehydes
- Indirect metabolites - reaction with packaging - butyric acid

Thermal degradation of packaging
- Release of volatiles
- Breakdown of non-volatile compounds to release volatiles or leachables

Thermal degradation of food
- Accelerated microbiological activity
- Direct breakdown of food chemicals releasing volatiles or leachables

Food/packaging chemical reactions
- Degradation of food by reaction with a chemical in the packaging
- Degradation of packaging by reaction with a food component
- Degradation of food or packaging by an external chemical

Case Study - The Case of the "Parmesan Cheese" Paper
This case shows how a complex set of events led to the evolution of a highly odorous compound from imported paperboard destined for take-away pizza boxes in Australia.

A shipment of around 500 tonnes of paperboard was shipped from Finland to Australia via the hold of a cargo ship. An initial inspection revealed no defects so the shipment was accepted. However as the rolls were unwound to convert them into corrugated pizza boxes, the corrugator operator noticed an intense odour reminiscent of parmesan cheese. It was discovered that the odour was indeed emanating from the paperboard.

Laboratory investigations using headspace gas chromatography - mass spectrometry identified the offending compound as butyric acid at levels of around 0.2 mg/kg. Butyric acid has a very intense odour which closely matched the parmesan cheese odour in the paperboard. Butyric acid is not normally detected in the volatile emissions from paperboard.

Literature searching uncovered the Clostridia family of bacteria which are commonly known as "butyric acid bacteria". Clostridia also emit acetic acid in a fixed ratio to butyric acid. Further examination of the analytical data revealed that acetic acid was present in direct proportion the butyric acid, thus providing further evidence for Clostridia being the source of the taint. Clostridia is a spore-forming anaerobicbacteria which germinates under warm anaerobic conditions. It feeds on carbohydrates with the major metabolite products being butyric acid and acetic acid.

It was finally traced to the water system of the paper mill in Finland where a new water treatment plant had been installed. In response to environmental pressure to reduce wastewater emissions, the mill had closed up their water system and installed a new anaerobic water treatment plant. It was in this anaerobic system that the bacteria originally bred through many generations resulting in both free bacteria and spores being present in the mill's process water.

The manufacture of paper is a continuous process involving filtering of a dilute slurry of pulp fibres, followed by pressing and drying. The heat of the driers on a paper machine operate at temperatures in excess of 150OC and are normally extremely good at sterilising the paper. However the microscopic spores of Clostridia are resistant to heat and survived the drying process. The spores by this stage were well interred within the tightly wound rolls of paperboard, but did not germinate to form the free bacteria.

No cases of butyric acid contamination were reported from Finland or its local market, Europe, presumably because the climatic conditions were not conducive to the germination of the spores. However, transporting the rolls in the hold of a ship for a six week voyage to Australia did provide suitable conditions for germination of the spores.

Within the tightly wound rolls the temperature and moisture reached levels which activated the spores and conditions quickly became anaerobic. The newly formed bacteria began feeding on the carbohydrates (cellulose and starch) in the paperboard forming butyric acid as a metabolite product. This only occurred deep in the roll as the outer layers remained aerobic due to diffusion of air through the pores in the paper, explaining why the problem was not observed until the rolls were unwound. Final resolution to prevent recurrence of the "Parmesan Cheese" paper involved communication with the Finnish paper mill who altered their process to eliminate the presence of Clostridia in their process system.

Conclusion

The resolution of taint issues is more than just identifying the taint compound It involves identification of the taint compound, its source/formation, the mechanism of migration and finally a proposal for preventing recurrence of the problem. The taint investigator will need to draw on a variety of investigative techniques including consumer interviews, analytical chemistry, process analysis and literature reviews.