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A TUTORIAL AND COMPREHENSIVE BIBLIOGRAPHY ON THE IDENTIFICATION OF FOREIGN BODIES FOUND IN FOOD

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Abstract
The paper presents a philosophical approach to the investigation of foreign body incidents in food. The suggested procedure has similarities with "key" procedures used for taxonomy. However, the wide diversity of materials encountered and the need to determine something of the history of the offending item demands modifications to this process. The categorisation may be made on instinct or experience, and appropriate confirmatory tests will be applied in the light of the initial categorisation. Cardinal rules are proposed: firstly, the receipt of the items should be well documented; and secondly, the initial observations should be as non-destructive as possible. The stereo microscope is the major instrument used to reveal clues as to origin of foreign substances. Other microscopy and analytical techniques are used to supplement the stereo microscope. The paper includes suggested categories for foreign materials; lists of possible origins of foreign contamination; examples of specific recurrent foreign materials associated with foods and a bibliography of helpful sources of information.

Key Words: Foreign bodies in food, stereo light microscope, X-ray microanalysis, Fourier-transform infrared (FTIR) microscopy, direct probe mass spectrometry, product defects, polarised light microscopy, solubility tests, glass, insects.

Introduction
The examination of foreign matter found in foods is a complex operation which does not fit easily into a single discipline. Various terms have been used to describe this activity but none of them has gained wide acceptance.

The food industry makes very considerable efforts to prevent the ingress of foreign objects into food and to detect those that are present. However, the scale of many food processing operations, and the fact that many steps in distribution and use of the product are difficult to control, means that some complaints will inevitably result. These complaints need to be investigated in order to prevent recurrence in those cases where the system has failed. Obviously, foreign body complaints are bad for business since foreign bodies are a cause of consumer dissatisfaction.

Foreign bodies can also lead to prosecutions and in the United Kingdom about half of the annual number of food related prosecutions are connected to foreign bodies. In recent years, considerable publicity has been given to malicious tampering of food in order to embarrass particular companies or to extort financial gain. The result of this publicity has been to heighten public awareness of the problem of food contamination and inevitably this leads to a greater need to carry out thorough investigations into complaints.

The most common complaint relates to metal contamination, with insect complaints being fairly close behind. Glass and animal excreta are normally high on the list of complaints which lead to prosecutions. Some foods are more susceptible to foreign bodies than others and there is also a pre-disposition towards particular foreign bodies being found in certain foods. An example is milk which is often delivered to the door in returnable bottles (in the U.K.). This makes the product vulnerable to glass, slugs, snails and paper (notes to the milkman!) complaints. Bread and cake are fairly susceptible to metal and insect complaints whilst chewy sweets create a number of complaints relating to dental materials.

In the early 1980's, the Analytical Methods Panel of Leatherhead Food Research Institute (LFRA) commissioned an investigation aimed at producing a Scheme for
the Examination of Foreign Material Contaminants in Foods (Smith, 1983). The scope of this scheme was to produce a guide to the steps to be taken in investigating complaints. It is not possible to provide a universal key to foreign bodies in the same way as a botanical or entomological key might be conceived and the final scheme represents a practically based but essentially philosophical approach to identifying foreign bodies. In other words, it describes the thought processes to be undertaken in an investigation and as such is a unique publication and underlies all of the foreign body studies carried out at LFRA. This paper summarises the scheme and uses examples of microscopical approaches to illustrate its use.

Microscopy is probably the single most useful approach to aid the identification of foreign objects. There are few, if any, cases where an examination with a stereo microscope operating at between 10x to 40x magnification will not reveal significant clues as to the origin of a sample. This examination can be totally non-destructive and should form the initial phase of virtually all investigations.

General Approach

Documentation and records

It is essential to have an adequate system for recording and identifying foreign body samples. The precise nature of this system depends on the number of samples handled and on the extent to which formal proceedings may result from the samples but should cover the following points:

a) Each sample should be identified with a unique code number.

b) The source of each sample along with the date of receipt and the method of delivery should be recorded.

c) A description of the complaint sample and the product in which it was allegedly found, should be recorded.

d) The progress of the investigation in terms of its examination, and preliminary and final reports should be available.

It is now possible to computerise many of these records and this will often allow a rapid, selected recovery of information to be extracted. However, a sample record book kept near to the telephone is invaluable when customers are enquiring about the progress of their samples.

Preliminary examination and classification

The cardinal rule in the early stages of an examination of a sample is to cause as little damage as possible to the sample. For this reason, examination in a stereo microscope and, if necessary, photography of the sample are essential considerations. If the offending item is still embedded in the product, then as much information as possible about its relationship with the product should be obtained before removing the foreign body. In these cases, it is generally wise to photograph the sample before removal.

Key observations to make at this stage are the size of the object(s), paying particular attention to the size of the mesh or aperture that the object might have passed through. If there are several objects of the same general nature, then it is worth seeing if they will fit together to form a single item, in this case the size of the largest and smallest pieces along with the size of the assembled pieces should be recorded. A close examination of the surfaces of the sample should be made; if any of the original surfaces remain, these may give information regarding the method of manufacture and the shape of the original item. The presence of any debris on the surfaces should be noted, if there is a large amount of debris, then some may be removed at this stage and examined in a compound microscope using polarised light and microchemical tests as appropriate.

Signs of wear in the form of chips and scratches should be noted, as should the presence of any metal flecks on the surfaces. The position of debris, wear marks and metal flecks can be significant. In particular, if all the signs of wear and debris are on the original surfaces with none on broken or fractured surfaces, then it is reasonable to conclude that the wear was not produced during the food processing operation whilst if the wear is evenly distributed over all the surfaces then this indicates that damage has occurred after the object was broken. Some objects attract wear at particular points, for example, drinking glasses and small bowls are often scored around the top rim, mixing bowls attract metal flecks around the base and sides, and casserole dishes are often scratched around the base.

Colour, opacity, shape, and signs of melting or heat damage are all features to be noted during this preliminary examination.

At this stage, the item should still be intact and undamaged, but will have yielded a bit of information about itself and the microscopist should have started to form some view as to the nature of the sample and its possible history. Some sort of classification will have been made. A key feature of the Scheme proposed by Peter Smith is that it gives a formalisation of this classification (Smith, 1983). In essence, the process is one of placing the object into increasingly well-defined categories until the final category is achieved. At this point, it is appropriate to apply confirmatory tests. If these agree with the categorisation, then the object can be considered to be identified. If not, then the new information gained from the test can be used to reassess the
categorisation and possibly place the item into a new
category and apply another confirmatory test, if appro-
priate. The process continues until:

a) The item is confirmed in a category,
b) The specimen has been consumed by repeated
negative confirmation tests,
c) All imaginable categories have been tried to no
avail.

It should be noted that results b) and b) are unusual
although the degree of specificity obtained within the
categorisation may not always be as great as one would
wish.

The Scheme suggests eleven primary categories into
which an item can be placed. In order of increasing
uncertainty and desperation, the list is as follows:

1. Recognisable objects: These are items which
are immediately identifiable, such as nuts and bolts,
pins, staples, match-sticks, etc. In this case, the chal-
lenge is not so much to identify the object as to deter-
mine its history, especially in relation to the time and
place that it entered the product. Some key observations
will involve the interaction of the item with the product
and the process. For example, an acid product will
often affect the surface of metal items, plastic items may
melt at particular temperatures, fat will be absorbed into
some materials and, of course, the size of certain items
will preclude some routes of entry.

2. Metal items: Whilst the precise identity of the
object may not be immediately apparent, it may be quite
obvious that the item is metallic. The characteristics,
which lead to this conclusion, include hardness, colour,
brightness, etc., and these will have been noted during
the initial examination. Testing with a magnet is a good
non-destructive test which can be applied here to distin-
guish ferromagnetic materials. Clearly, similar observa-
tions on the type and distribution of wear and surface
characteristics to those, which apply to recognisable ob-
jects, will be of value in determining the history of the
complaint. The composition of the metal can easily be
determined by X-ray microanalysis, or other modern
analytical techniques, if these are available. Spot tests
are also possible and many of these will be adaptable for
use on a microscope slide which will decrease the
amount of sample needed for each test. References to
some of these spot tests are given in "Vogel's Qualita-
tive Inorganic Analysis" (1987), "Feigl's Spot Tests in
Organic Analysis" (1958), and similar publications.

3. Metal/non-metal composites: In some cases,
part of the object will be clearly metallic whilst other
parts will be non-metallic. Examples of this type in-
clude: tooth/amalgam, insulated wiring, reinforced tub-
ing and plastic/foil packaging. In this case, it will be
useful to identify each component in order to check
against known materials. The metal component can be
approached as with Metal items, the non-metallic com-
ponents may be identifiable by X-ray microanalysis
(e.g., ceramics or tooth fragments) or simple solubility
tests carried out on a microscope slide (e.g., nylon
film). Instrumental techniques, such as Fourier trans-
form infrared (FTIR) microscopy or direct probe mass
spectrometry, may also give a great deal of composi-
tional information and require very little material to
work with.

4. Biological materials - animal: This is a diverse
grouping including hair, droppings, whole insects or
their parts, and even, at times, whole rodents. Clearly,
no simple scheme will be able to easily sub-divide this
category. Classical morphological procedures will be
helpful in cases where a substantial part of the animal is
available. Insects are probably the single most important
animal contaminant and a number of good guides to both
food related and other insects are available. Deducing
the processing history of an animal specimen is impor-
tant and tests based on residual enzyme levels are one
approach that can be used. Alkaline phosphatase has
been used as a marker and in many cases this gives a
good guide to whether a material has been cooked or
not. However, the results should be treated with some
certainty since it is prone to both false positive (e.g., if
mould growth has occurred) and false negative results
(e.g., soaking in acid media). Some insects have natu-
really low levels of alkaline phosphatase and it is a good
idea to carry out acid and alkaline phosphatase tests
alongside each other. The test has been used to claim a
precise cooking treatment. In general, this is not possi-
ble and claims to this effect should be regarded with
some skepticism.

5. Biological materials - vegetables: As with an-
imal specimens, vegetable-based foreign bodies can en-
compase a wide range of objects: seed pods, seeds,
starch clumps, peel, and wood splinters all would be
classified under this heading. Microbiological contami-
ants represent a science in their own right. However,
where the problem is a visible one, such as mould pelli-
cle (which can often be reported as rubber or paper), or
a bacterial, or yeast haze, or sediment, then the sample
may be received as a foreign body. Sometimes, the
only diagnosis needed is that the contamination is of
microbiological origin. Where a more detailed appraisal
of the origin of the sample is required, the sample
should be passed on to specialist microbiologists. More
conventional vegetable foreign bodies are generally iden-
tified by their morphology and by comparison with de-
scriptions given in reference works or, preferably, by
comparison with known samples.

It is generally reasonably easy to determine whether
an item is of animal or plant origin. In some cases, an object initially appears biological but is damaged to an extent where it is not immediately obvious whether it is of plant or animal origin. Then, some simple staining reactions for cellulose, starch, lignin, and proteins will often clarify the matter.

6. Crystalline materials: These are generally recognised by their geometric forms with flat faces and well-defined edges with consistent angles. They may be quite large and easily separated from the matrix in which they are found, or they may be in the form of a haze, where the individual crystals are only apparent on microscopical examination. In the latter case, the examination may involve filtration or centrifugation to isolate the crystals. Most crystals are birefringent and can be recognised using polarised light microscopy. Exceptions to this general rule are the crystals with cubic packing which are isotropic; the most common of these are sodium chloride crystals. Several approaches are available to assist with the identification of crystals and the choice of these will depend on the available equipment and expertise. Melting point determination and simple solubility tests can be carried out on a microscope slide and will give a general indication as to the type of substance involved. It may be possible to measure the principal refractive indices, birefringence or other optical parameters of the crystals and compare them with data such as those contained in the Particle Atlas (McCrone and Delly, 1973), or Winchell (1987), or Winchell and Winchell (1989). Instrumental techniques such as X-ray microanalysis, FTIR microscopy, and mass spectrometry can also give rapid and useful information where they are available.

7. Fibrous materials: Essentially, this category covers all those items with a filamentous structure. Obviously, there will be some overlap with the plant and animal categories (since many fibres are of biological origin) and some crystalline materials (e.g., asbestos) could be classified as fibrous. There are many references on hairs and fibres, although these are sometimes contradictory especially as far as hairs are concerned; a varied supply of known hairs is a good idea if precise identification is required. Where the investigation only requires a general indication of the fibre type, it is generally fairly straightforward to distinguish animal hairs, plant fibres, and synthetic fibres from each other based on morphological features. Solubility, melting point, optical properties, and specific staining tests can be useful in distinguishing synthetic fibres from each other. The instrumental approaches mentioned for crystalline materials may be used in some cases. Many fibres are susceptible to processing damage which may give clues to the point of entry into the system.

8. Laminar materials: This term essentially applies to materials in thin sheet form. The most common source of this type of material as foreign matter in food are packaging materials. Polyethylene film is widely used in the protection of primary raw materials as well as for intermediate and finished products. Generally, these materials can be recognised on sight by the operatives, who regularly handle them, but it may sometimes be necessary to identify or compare samples. In this case, similar tests to those used for synthetic fibres will be useful. Other sources of laminates include paints and coatings and some biological materials such as finger nails may be placed in this category.

9. Amorphous materials - hard: This category covers those items which cannot be classified into the morphological groups described above but are generally hard materials. Glass is the main sub-division in this category. The appearance of original surfaces, optical properties, physical properties, and X-ray microanalysis spectra are all useful in tracing the source of glass fragments. A detailed account of glass analysis is given in Lewis (1984, 1986), and has been updated by Auty and Lewis (unpublished). Minerals such as stones and coal may be categorised as hard as may some plastics and dried or charred food deposits. An examination with a compound light microscope coupled with some basic staining and solubility tests will generally allow further characterisation. Where available, X-ray microanalysis will be especially useful.

10. Amorphous materials - soft: The category covers those items without a well-defined shape and more especially those which deform easily. Oily and greasy deposits are the main items in this category; these will sometimes present themselves as dark featureless marks on the product or may appear as discrete attachments to the product. If they can be dissected from the product, then the mineral oil element can be identified by chemical techniques. Many lubricating oils are fluorescent and examination of discoloured areas with an ultraviolet (UV) lamp can be helpful. However, animal urine marks will also fluoresce in UV light. Grease will generally include particulate inclusions which can be seen in a compound microscope. The inclusions are often metallic and are present as a result of wear; determining the composition of the metal will generally give a clue to the source of the contamination. The metallic particles can be isolated by centrifugation, filtration, or with a magnet after dissolving the hydrocarbon component. After isolation, the composition can be determined by X-ray microanalysis or spot test as described for metals. Additives, such as graphite and molybdenum disulphide, may also be isolated and recognised by these procedures. Discoloured patches may also be due to
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metallic contamination; sometimes small iron particles are found in components of icings and when these are wet, the iron disperses to give a poorly defined yellowish brown patch. Earthy deposits, build-up of food particles and squashed food may also be placed in the soft (amorphous) category.

11. Composite materials: Some foreign bodies reveal a combination of morphological characteristics and at the initial stage of an investigation it may not be possible to place them into any of the above categories. Examples are glass-reinforced plastics (amorphous hard material with fibrous inclusions), conveyor belting (laminar material with fibrous inclusions), and cement (amorphous hard material with crystalline inclusions).

The above categories are suggested as useful ones although each investigator may prefer to use his/her own set of categories depending on the type of problems encountered. The concept, as described of trying to place the object into increasingly specific classes, is a sound one. This probably represents the mental process employed by most analysts even if it is not carried out as a conscious process. Some objects may well be placed in more than one of the primary categories and some cross referencing to allow the possibility of reaching the same conclusion by different routes is a wise feature of any scheme. Check lists are a useful part of this process and some of the more common foreign body sources are given below. Again, individuals will want to add to these lists or produce their own lists to meet their needs.

Possible Origins of Foreign Contamination

The integrity of a product is always at risk from objects and materials in the environment. These may be displaced only a small distance to reach the product and cause a foreign body incident. The factory environment is, in theory, under total control of the management, but this discounts human errors, accidents, breakages, malicious acts, etc., and the sporadic intervention of outside contractors, engaged to maintain the building fabric or to service the plant.

The lists below show some of the many possible sources of contamination, grouped according to type of contaminant. Much more comprehensive lists could be compiled by someone with intimate knowledge of a specific factory and such an exercise has two main benefits to recommend it. It provides a 'prompt' when searching for the origin of a contaminant after its type has been identified and, more importantly, the thought put into the exercise raises the level of awareness on hygiene and may well reveal immediate precautions which could be taken to prevent some forms of contamination.

List of Sources of Foreign Bodies in Food (Smith, 1983)

Metal
Nuts, bolts, washers, rivets, and roves etc. from machines or maintenance activity.
Welding spelter, welding scale, welding rod from maintenance activity.
Filing and swarf due to maintenance activity or machinery wear.
Rust flakes.
Detached flakes of chrome plating.
Fragments broken from machines, especially cutter blades and stirrers.
Trunking and fittings.
Tools and implements.
Thermocouple wires and probes.
Sieve wires.
Flexible metal hose and metal-reinforced rubber/plastic hose.
Wire brush bristles.
Braided wire-covered hose or electrical cable.
Wire wool scourers.
Carton staples, metal reinforcements and banding.
Nails and screws, grub-screws.
Tramp metal from raw materials.
Caps, lids, and other closures.
Fragments from can opening.
Can pull-rings.
Solder from cans or maintenance activity.
Essence and flavour containers.
Meat tags and pins.
Fish hooks in salmon.
Lead shot in game.
Metal foil and foil/plastic laminates.
Process instrument parts.
Light fittings.
Electrical wiring, fuses.
Piping and conduit.
Mercury from switchgear and thermometers.
Noodles, pins, and safety pins.
Clothing buttons, button stalks, hooks and eyes, popper fasteners, zips.
Hair clips and slides.
Jewellery, necklaces, rings, ear-rings, bracelets, wrist and neck chains, etc.
Spectacle fittings e.g., hinge pins or screws.
Wrist watch and cigarette lighter parts.
Coins.
Badges and identity tags.
Pen and pencil parts.
Keys.
Dental fillings, white amalgam or gold.
Dental screws and parts of dental braces.
Paper clips, spring clips, and staples.
Drawing pins.

**Wood**

- Fragments from boxes, pallets etc.
- Cutting and chopping work surfaces.
- Stirring paddles.
- Twigs, stalks, bark and general extraneous vegetable matter in raw materials.
- Doors, door-frames and general structural wood.
- Tables, chairs, cupboards, shelves etc.
- Duck-boards.
- Handles of brushes, brooms, knives, spatulas, scrapers etc.
- Wooden spoons.
- Transport vehicle bodywork.
- Miscellaneous sticks for stirring, prodding and poking.
- Pencils.
- Baskets.
- Punnets and chips.
- Match-sticks and match boxes.
- Material from maintenance activity.

**Glass**

- Fragments from jars and bottles broken in process.
- Fragments from imperfect jars and bottles (blisters etc.).
- Light bulbs and fluorescent tubes.
- Sight tubes and protective plate glasses.
- Inspection ports.
- Gauge dial glasses.
- Instrument case glazed doors.
- Glazed cupboard doors.
- Windows, external and in partitions, and doors.
- First aid bottles.
- Milk, beer, lemonade bottles, etc. used for refreshment.
- Glass thermometers.
- Containers used for sampling.
- Spectacle lenses and contact lenses.
- Watch dial glasses.
- Necklaces and ring stones.
- Refractometers and other optical test equipment.
- Glass-fibre insulation.
- Glass-reinforced plastics.

**Rubber and Plastics**

- Packaging films and bags, including metallised plastics.
- Plastic spoons and working implements.
- Flashings from the moulding of plastic containers.
- Plastic containers, trays, cups and tubs, liners and seals etc.
- Brushes with synthetic bristles and also plastic stocks.
- Stoppers, caps and other closures.
- Moulded plastic separators from cartons.
- Rubber or plastic moulds.
- Plastic work surfaces.
- Scraper blades on stirring plant.
- Conveyor belts.
- Hermetic seals on plant and control instruments.
- Hose, plain or corrugates, rubber or plastic, with or without metal/textile reinforcement.
- Tool handles.
- 'Squeegee' blades.
- Protective gloves, rubber or plastic.
- Rubber finger stalls and wound plasters.
- Sack ties.
- Cable insulation.
- Light diffusers and shades, light switches and fittings.
- Plastic electrical conduits and fittings.
- Safety glasses, face shields etc.
- Ear plugs and ear protectors.
- Spectacle frames and plastic contact lenses.
- Synthetic fibre clothing.
- Clothing buttons.
- Hair combs and fasteners, hair-nets etc.
- Finger nails, natural or artificial.
- Erasers and eraser-tipped pencils.
- Pens and propelling pencils.
- Chewing gum.
- Rubber footwear.
- Rubber or plastic protective clothing.
- Gaskets and seals, washers on taps and ballcocks.
- Elastic bands.
- Rubber or plastic mats.
- Composition flooring.
- Foamed plastic, soft or rigid, for insulation.
- Plastic ceiling and wall tiles.
- Plastic-cased instruments.
- Clear plastic windows in instruments.
- Instrument and control panel switches and knobs etc.
- Protective plastic sheeting and covers.
- Drive belts.
- Synthetic strings and ropes.
- Plastic tags, labels, Dymo tapes.
- Clear plastic safety guards, spray hoods, etc., on machines.
- Cellulose tape, insulating tape.
- Synthetic filter fabrics.
- Synthetic fibre cloths and swabs.
- Synthetic foam sponges.
- Paint flakes.

**Hair, fibres, etc.**

- Human hairs.
- Meat animal hairs in meat products.
- Rodent infestation hairs.
- Wild animal hairs in field crops.
- Feathers and feather barbules in fowl products and as a contaminant of field crops.
- Fine fish bones in fish products.
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Brush bristles, synthetic or natural.
Natural bristles, (squirrel, badger, etc.) may be mistaken for rodent contamination.
Filter cloths and mats, filter aids.
Reinforcement fabrics in conveyor belts, drive belts, hoses etc.
Fabric-backed plastic sheets.
Fabric-lined rubber/plastic gloves, boots etc.
Rope, string, cotton and thread, natural or synthetic.
Sacking, natural or synthetic.
Clothing, natural or synthetic.
Cloths and swabs.
Paper and packaging materials of laid fibre construction.
Wound dressings.
Braided covers on flexible wiring and hoses.
Mould growths.
False eye-lashes, hair pieces etc.

Extraneous vegetable matter

Twigs.
Stalks.
Leaves.
Calices.
Fruit stones and pips.
Nut shells.
Husks and bran.
Bark.
Peel and skin.
Bird, rodent, and insect nests.
Foreign vegetable species, e.g., grass, straw, leaves, weeds, and general cross-contamination.
Cigarette ends and constituent parts (tobacco, cigarette paper, filter, and cork tip).

Animals, insects, etc.

Contamination by animals, insects, etc., can occur at any point along the route to the consumer. The entry points can be resolved into six main areas:
(a) raw materials, contaminated before delivery to the factory;
(b) raw materials store in the factory;
(c) factory processing area;
(d) finished product store in the factory;
(e) wholesale/retail selling chain;
(f) consumer’s premises.

The risk of contamination is generally highest for raw materials. Most are derived from living material produced outdoors, often in foreign countries, where they are subject not only to parasitic pests but also to adventitious animal contamination. Further opportunity for entry of foreign animal matter can occur during bulk handling and the transport of raw materials. The risk is lower when the materials reach the planned, protective environment of the food factory. The main risk here is from well-recognised storage pests, against which continuous sanitary measures are taken. The chance of contamination decreases as material passes along the factory line to the product-packaging stage. Infection in the selling chain and the consumer’s premises depends on the degree of care exercised and certainly cannot be ruled out.

The contaminating foreign matter derives from three main sources:
(a) parasites which use the raw material or products as host;
(b) predatory animal forms which seek the raw material or product as food;
(c) animal forms which co-exist in the environment and cause accidental contamination.

Foreign Materials and Quasi Foreign Materials Associated with Specific Products

Some products are particularly prone to specific defects which give rise to consumer complaints. In some cases, the cause of complaint is not a true foreign material but a normal constituent of the product which has become obtrusive by crystallising. In other cases, it is a real foreign material closely linked with methods of handling or with one of the ingredients.

A few examples of each type are given below:

Baked goods
Sliced bread: Saw-blade fragments; contaminants.

Dairy products
Cheese products: Glass-like crystals of calcium phosphate; granules of lipoprotein; normal constituents.
Condensed milk and ice cream: Lactose crystals; normal constituents.

Fruit and vegetable products

Fruit products and preserves: Crystals of flavanone glycosides (e.g., hesperidin; see Smith, 1953); crystals of sugars, usually D-glucose; normal constituents.
Grapefruit pulp: Crystalline aggregates or naringin (see Smith, 1953), often considerable amounts at bottoms of barrels; normal constituents.

Vegetable products: Calcium oxalate crystals, normal constituents.

Pickled onions: Yellow crystals of quercetin (see Morpeth, 1948; Fernandez and Vega, 1981); normal constituent.

Canned strawberries: Sand; contaminants.
Tree exudate gums: Sand and bark; contaminants.

Black currants: Snails of similar size and colour; contaminants.

Vine fruits: Sand and siliceous matter;
contaminants.

**Tea:** Wood fragments and nails from cases; contaminants.

**Meat and fish products**

**Canned fish:** Glass-like crystals of struvite (magnesium ammonium phosphate); normal constituents.

**Crab paste:** Calcium carbonate crystals, normal constituents.

**Meat products:** Natural contaminants such as bone chips, tufts of hide and hair, pieces of neck ligament (Ligamentum nuchae) of grazing animals (see Tinker and Tappel, 1982) which resembles wood when dry.

**Handling contaminant:** Polythene film fragments embedded in frozen meat blocks, fragments of Hydroflaker or guillotine blades in frozen meat, blue-dyed meat from inspector's stamp, manilla labels and metal staples used by inspectors, metal or plastic meat tags.

**Product defects:** Phosphate crystals from polyphosphate treatment, black metal sulphide stains against can seams.

**Corned beef:** Blue crystals in meat adjacent to can wall, which darken on exposure to air. Probably a compound of iron and phosphate, caused by interaction between product and can; product defects.

Illustrations of the Use of the Scheme

**Beetles**

Figure 1 shows foreign bodies which might be found in food. The process of identification might go like this. They would fairly clearly be placed in the Biological materials - animal category and counting their legs would suggest the insect class. The presence of hard wing cases (elytra) would place them in the Beetle order (Coleoptera). Most people would probably reach this stage without thinking of the mental processes involved, in other words, they would simply look at them and say "Oh they're beetles". Noting that the antennae are beaded, that the elytra cover the abdomen, that they are less than 11 mm long and that they are darkly coloured and not blue/green might lead to the conclusion that they belong to the Tenebrionidae family (Darkling/Pineate Beetles). A closer look at the body shape and the lack of hairs on the dorsal surface coupled with the size and number of tarsals on each of the legs and inspecting the site of insertion of the antennae leads to placing the beetles in the Genus Tribolium. Finally, a close inspection of the shape and size of the eyes and the shape of the apical antennal segment leads to the conclusion that the objects are Tribolium castaneum or red flour beetle. The significance of the precise identification in this case is that this particular species can only survive permanently in heated buildings in the U.K. and this can obviously be helpful in tracing the source of the contamination.

In this identification the criteria for identification have been entirely morphological. This kind of classification is well known to biologists and is the basis of most taxonomy. In one sense, the proposed scheme for identifying foreign matter attempts to extend this concept outside the biological area.

**Crystals**

Figure 2 shows a sample (of 2 from) some milky white crystals. They could readily be placed into the primary category of Crystalline materials based on the regular angles and shapes. Most of the crystals were bipyramidal in shape. Some "twinning" of the crystals was noted. They were found in a mixed fruit and dairy product. This gives a possibility that the crystals could be salts of organic acids, and two possibilities would be potassium tartrate or calcium oxalate-based crystals. Using fragments of the crystals, it was possible to obtain patterns of solubility in different solvents. The crystals were soluble in most acids but not in acetic acid and recrystallisation of needle-like crystals occurred in dilute sulphuric acid strongly suggesting calcium sulphate as a positive test for calcium. The crystals also dissolved slowly in 20% sodium hydroxide but were insoluble in ethanol, ethyl acetate and hexane. In acidified potassium permanganate (acidified with sulphuric acid), the crystals dissolved with some evolution of gas and decolourised the potassium permanganate in their vicinity. Recrystallisation of needle-like crystals was also seen. Figure 3 shows the reaction of these crystals in acidified permanganate.

From the solubility profile, it is possible to deduce that calcium oxalate is the most likely identification and the presence of calcium, carbon, and oxygen as the main elements was easily made by X-ray microanalysis. Consulting Winchell (1987) indicated that the di- or trihydrate form of calcium oxalate will give tetragonal crystals with a bipyramidal shape. The size and shape of the crystals suggests that they were formed relatively slowly and were not directly extracted from plant cells, hence their formation was probably due to a high level of free oxalate in the fruit component reacting with calcium in the dairy product. In this case, morphology has been used along with some fairly simply solubility and chemical tests which could be carried out on a microscope slide with a minimum of material. Added confirmation can be obtained by X-ray microanalysis.

Another crystal-based problem was encountered with anchovy paste. An unsightly white deposit was present and microscopical examination showed this to be of a crystalline nature. Some initial thoughts were that the
crystals could be phosphates, fat, or soaps of fatty acids. They were soluble in acid and alkali but not especially so in organic solvents. X-ray microanalysis did not show the expected phosphorus peak or any common cations but only carbon and oxygen. At this point, the three initial possibilities seemed unlikely and some crystals were washed, dried, and placed in probe tubes for direct probe mass spectrometry which showed a large amount of tyrosine.

At first, this was thought to be a contaminant due to inadequate washing of the crystals but in fact it proved to be the major constituent of the crystals. There was some embarrassment on searching the literature which revealed that Food Research Reports No. 1 published by...
Leatherhead Food RA in 1926 dealt with the "Spotting of Anchovy Paste" and had concluded that the problem was caused by tyrosine! The only consolation was that using the conventional techniques available in 1926 it had taken many months to reach that conclusion as opposed to a few days with the use of the mass spectrometer, and that in the report, the investigators had tried the same initial categorisation as we had. Similar problems with amino acid precipitation can be encountered in soy sauce and meat products.

Glass

Figure 4 shows some glass fragments. The original complaint concerned two of the pieces which had been found in a frozen dessert product. In this case, the categorisation through the "Amorphous materials - hard" category to glass was straightforward. The shape of the piece suggested the rim of a drinking glass or small bowl. The curvature was estimated from interference fringes and found to be about 7-9 cm diameter. X-ray microanalysis of the glass showed it to be similar in analysis to many kitchen/tableware objects. Hence the report concluded that the glass had derived from a drinking glass or small bowl and the inference was that the contamination was most likely from the complainant's kitchen.

The local regulatory authorities were involved in this case and were initially reluctant to accept the conclusion that this was a domestic accident. However, after several weeks, they agreed to inspect the complainant's kitchen and on searching a cupboard found two or more pieces of glass. These were received in the laboratory and were found not only to be a good analytical match with the previous pieces but all four pieces could be fitted together. Hence the original conclusion was confirmed and the company, who manufactured the product was shown not to be at fault in any way. The incident raises a couple of interesting points. First, the batch of the frozen product had been on hold for around ten weeks before being cleared for sale. This obviously involves some expense to the company. The other point is that the second two pieces of glass had clearly lain in the cupboard for over two months without being discovered. Clearly, the original breakage may have been many months before the initial complaint and had probably been totally forgotten by the complainant.

Conclusions

The study of foreign matter in foods is a varied and fascinating subject but one which is not immediately amenable to a rigid systematic approach. Many of the disciplines involved in foreign body identification do have well defined approaches to classification and a consideration of the philosophies underlying these approaches can be applied in a general sense to foreign body identification. The aim of this paper has been to present the overall approaches to the subject and to illustrate this with some examples as well as to provide a list of useful reference works and check lists to aid the investigator. The paper is heavily based on the Leatherhead Food Research Association publication "A Scheme for the Examination of Foreign Material Contaminants in Food" (Smith, 1983) which gives a more detailed explanation of the various methods available.

References: Cited in the Paper


Related Literature

A list of reference material used at the Leatherhead Food RA to aid in the identification of foreign matter in foods, arranged in categories, is provided below. References listed above are repeated below also. This sections has been categorized under: General/Miscellaneous; Insects and other invertebrates; Hairs, Fibres and Plastics; Glass, Minerals, Metals; and Plant related.

General/Miscellaneous


Insects and other invertebrates


Hairs, fibres, plastics


Beadle JD (ed.) (1971). Fabricating Plastics. The
Foreign Bodies in Food


Doring U, Bielig HJ (1978b). Differential staining of hairs and feathers in foods. Gordian 78, 244-246.


Glass, minerals, metals


Plant related


Discussion with Reviewers

M Kalab: The manufacturer of the frozen dessert, described in the last example, was lucky that matching glass fragments were found in the consumer’s cupboard. A question would raise from this incident: Do consumers permit searching of their cupboards by representatives of the manufacturers if there is a suggestion that the contamination took place at the consumer’s place?

Author: Indeed the manufacturer had some good fortune in this case. The incident concerned a relative of the local chief environmental health officer so the circumstances were unusual. However, many diligent environmental health officers will visit the home of complainants and will carry out an initial inspection of the kitchen before deciding on what action to take. There are several other examples where the contamination has been traced to the kitchen.

W.C. McCrone: Light microscopists would emphasize the use of polarised light microscopy for the identification of particulate food contaminants. This is because no other microanalytical tool yields so much useful characterisation data [e.g., homogeneity, size, shape, colour, opacity, refractive index (or indices), retardation, birefringence, extinction, and interference figures, as well as melting points, microcrystal tests, solubility, etc.]. Should not these procedures be more emphasized in your paper?

Author: My experience indicates that most foreign bodies are identified by morphological features. In food studies polarised light microscopy is used mainly to obtain contrast and as a qualitative indicator of birefringence. More sophisticated measurements are difficult within a food matrix. It is certainly true that solubility is a most useful test when carried out on a microscope slide and the calcium oxalate example was included to illustrate that point. I agree that melting point determination is under represented in the paper. It is certainly useful for aiding identification and can be crucial in determining whether objects are likely to have survived heat processes. However, in many cases the material is contaminated/infiltrated with food material which can make accurate melting point determination very difficult; so it must be used with some caution.

W.C. McCrone: Since many, if not most, laboratories today have a scanning electron microscope (SEM) with the energy dispersive (EDS) X-ray microanalysis option, and an FTIR often with the microscope option, would it not be reasonable to discuss these tools rather than mass spectrometry as supplements to the light microscope for the identification of food contaminants.

Author: I do not consider that mass spectrometry has been given more prominence than X-ray microanalysis in this paper. The examples given relate to practice at LFRA where no FTIR facilities are available. The aim of the paper was to present an overall view of foreign body identification concentrating mainly on readily available equipment such as might be found in a food quality control laboratory. Few food quality control laboratories have SEM-EDS, FTIR-microscopy or mass spectrometry facilities. The reference to more sophisticated techniques was included to demonstrate the sort of techniques which might be used when simple approaches fail or which might be quicker than manual manipulation.