Special needs for disinfectants in food-handling establishments

J.T. HOLAH *

Summary: Freedom from microbial and foreign body contamination is essential in food production, and the principal means for controlling the surface route of contamination is sanitation (cleaning and disinfection). After the cleaning phase, disinfection plays a crucial role in further reducing microbial numbers and viability. However, disinfectants for use in the food industry may contaminate the product. Therefore, as well as being effective and suitable for factory use, such disinfectants must also be non-toxic and non-tainting. The author describes the usage criteria and operator safety requirements of disinfectants, together with methods to determine taint potential, toxicity and efficacy. Using these parameters, a limited number of disinfectants are judged suitable for general food industry use and these are compared.


INTRODUCTION

The major limitation on the use of disinfectants in the food industry is the fact that food is destined for either human or animal consumption. While disinfectants have the same role as in other industries (i.e. the reduction of undesirable microorganisms to a safe level), here they are being employed in an environment which will subsequently be used to manufacture edible products. Therefore, suitable disinfectants must primarily be non-toxic and non-tainting. These limitations reduce the selection of biocides to only a few major product types, all of which are less effective in the presence of organic matter. Disinfectants in food-handling establishments must therefore be used as part of a structured sanitation programme, and disinfectant use must be preceded by a cleaning procedure.

Of major importance in food manufacture is the freedom of the finished product from contamination by microbes (spoilage and pathogenic microorganisms) and foreign bodies. Contamination in food products may arise from four main sources: the constituent raw materials, surfaces, people (and animals), and the air. Food may become contaminated as it moves across product contact surfaces or if it comes into contact with food operatives or pests. The air may act both as a source of contamination (i.e. from outside the processing area) and as a transport medium, transferring contamination from people or non-product contact surfaces. If uncontrolled, such contamination may lead to product recalls and the associated loss of sales and profits,

* Head, Food Hygiene Department, Campden Food and Drink Research Association, Chipping Campden, Glos GL55 6LD, United Kingdom.
adverse publicity and subsequent loss of customers. In addition, if regulatory requirements have been infringed, fines, sanctions or ultimately site closure or loss of export licence may result.

Cleaning and disinfection, together referred to as 'sanitation', are the major day-to-day means of controlling the environmental routes of food product contamination. Cleaning and disinfection remove soilage from food-processing surfaces, control personnel hygiene (by hand-washing procedures), help reduce pests (by removing food and habitat sources), and reduce microorganisms in the air (through fogging).

Both this paper and another article by the author on the use of disinfectants in food production areas (12) are concerned solely with the sanitation of 'hard' surfaces (e.g. equipment, utensils and environmental surfaces) and 'open' surfaces (where the food product is not enclosed). Sanitation of 'closed' surfaces by 'clean in-place' (CIP) techniques is a separate procedure, which should be performed and checked only by specifically-trained staff. Consideration of CIP techniques is outside the scope of this article. However, the principles of CIP, especially for the disinfection stage, are very similar to those for the disinfection of open systems.

When correctly implemented, sanitation programmes have been shown to be cost-effective and easy to manage. If diligently applied, such programmes may reduce the risk of microbial or foreign body contamination. In this context, surface sanitation is undertaken with the following aims:

- removing microorganisms, or material conducive to microbial growth; this reduces the chance of contamination by pathogens and, by reducing spoilage organisms, may extend the shelf life of some products;
- improving the appearance and quality of the product by removing food materials remaining on production lines (which may deteriorate and re-enter subsequent production runs);
- removing materials which could lead to foreign body contamination, or provide food or shelter for pests;
- extending the life of and preventing damage to equipment and services; providing a safe and clean working environment for employees, thus boosting morale and productivity;
- increasing process performance in some areas (e.g. by plate and scraped-surface heat exchangers);
- presenting a favourable image to customers and the public; on audit, the initial perception of an 'untidy' or 'dirty' processing area, and hence a 'poorly managed operation', is subsequently difficult to overcome.

In the future, sanitation will undoubtedly feature much more prominently in food manufacture and will be given the same degree of attention as other key processes, due to the desire to seek increased standards of hygiene. This desire has arisen as a result of the following factors:

- realisation of the importance of the three environmental routes of contamination
- pressure from customers and consumers
- trends in food production towards short shelf life and less-preserved products (which intrinsically demand higher standards of hygiene)
- ability to sell products of low microbiological load at a premium
- increased plant size, where a single mistake may cause large financial losses
- increased hygiene legislation.

DISINFECTANT REQUIREMENTS

After a thorough cleaning programme (12), disinfectants have an important role to play within the sanitation programme. To successfully fulfil this role, the disinfectant must satisfy the following criteria:

- suitable for typical food factory applications
- non-toxic in the product
- safe for cleaning operatives
- non-tainting
- effective.

Usage criteria

For ‘hard’ surface cleaning, disinfectants are applied directly to the equipment or environmental surface, or a ‘soak tank’ arrangement is provided, in which utensils to be disinfected are placed in disinfectant solutions for extended time periods. The application of disinfectants to surfaces is normally performed directly by manual means (e.g. using brushes or by mist spraying). This has an implication for the duration of contact between the disinfectant and surface-bound microorganisms. Disinfectants for this type of application must be capable of ensuring a microbicidal effect in 5 min or less, as within this time frame the disinfectant will have run off non-horizontal surfaces. Contact time can be increased by applying the disinfectant as a foam or gel, in which case contact times of 10-15 min (foam) and > 15 min (gel) are possible; for this to work properly, the disinfectants must be compatible with foam and gel technology. Alternatively, surfaces can be re-wetted by manual or mist application, but this is very expensive in terms of operator time and is difficult to manage.

Soak tanks are useful for small utensils or items of dismantled equipment, as contact time is dependent only on the time available for disinfection (i.e. until the utensil or piece of equipment is required for re-use). Soak tanks allow the use of less effective disinfectants (those which require a longer contact time to achieve the same effect) or the use of more effective disinfectants at a lower concentration. However, if disinfectants requiring longer contact times are used, these must not be used for non-soak tank applications.

Disinfectants must be active under the temperature regimes of the food-processing facilities. At the lower end of the scale, this is typically in the region of 5°C (for chill cabinets, chill stores or chill food-production units) and rises to a temperature limited by operative safety, normally taken as approximately 55°C. Higher temperatures may be used in soak tanks. For the majority of operations, disinfectants should offer a recognised performance level at ambient temperature within a contact time of 5 min or less.

When purchased, commercial disinfectants arrive in large quantities which, if used little, may be required to be still active after prolonged storage under a variety of conditions. Assurances from the disinfectant supplier are required for the retention of disinfectant performance under the storage conditions likely to prevail at the point of use. These may include storage under light and dark conditions, repeated freeze/thawing actions and high ambient temperatures.
Disinfectants are most likely to be diluted with potable water, which will contain traces of biocide residuals (usually chlorine) used by the water supply company; therefore, disinfectants must not be inactivated by such residues. Similarly, disinfectants are usually used after a cleaning operation and must therefore be compatible (i.e. not lose performance and not produce unsafe, toxic or tainting reaction products) with the residues of a range of non-ionic, cationic and anionic cleaning agents.

In application, disinfectants are likely to meet a wide range of material types. Such contact should not be deleterious to or cause loss of performance in the material (e.g. due to weight loss, corrosion, pitting, stress cracking, swelling, tarnishing or discoloration). Assurance should be given by disinfectant manufacturers that products have no effect on commonly-occurring material types, including the following:

- types 304 and 316 stainless steel, galvanised mild steel and aluminium (metals)
- polyvinylchloride, polyethylene, polypropylene, nylon, polycarbonate and polymethyl methacrylate (polymers)
- ethylene propylene, silicone, nitrile/butyl and fluoroelastomer (rubbers).

In addition, assurances of no harmful effect on brass, copper and various alloys may also be required.

The recommended in-use disinfectant concentration is a critical point in subsequent performance. Therefore, a simple-to-use and rapid test should be available to assess the concentration of the working solution as part of a quality assessment/quality control procedure and thus give some assurance of the likely performance of the disinfectant. A microbiological assessment of performance is not appropriate, as the time scale for results (> 24 h) is much too long.

**Toxicity**

In some countries and for some food products, it is acceptable to leave disinfectant residues on surfaces without rinsing these off prior to commencement of food production, but in most countries all chemicals must be rinsed off prior to food production. In either scenario, the contamination of food products with disinfectant residues is unavoidable. Disinfectants, even at low concentrations, must therefore present no health risks to the food consumer.

Legislation regarding the demonstration of non-toxicity is likely to vary for each country in which the product is used, and is beyond the scope of this article. Guidance on product acceptability must therefore be sought from the relevant national authorities. A reference standard of minimum acute oral toxicity (with rats) of 2,000 mg/kg bodyweight is usually accepted for the toxicity testing of chemicals.

**Operator safety**

Operator safety aspects of the disinfectant and the form of application are crucial. As with toxicity, national legislation in this domain may vary. A compilation of the different national and international regulations is beyond the scope of this article but, as a general guide, the following information should be available:

- product description and intended use
- physical data (appearance, odour, pH, boiling point, solubility)
- health hazards and first aid treatment (inhalation, eye contact, skin contact, ingestion, special precautions)
- fire hazards
- hazardous reactions with other chemicals
- spillage/leakage procedures and disposal
- transport, storage and handling precautions.

**Taint potential**

The major taints associated with disinfectants are described by sensory scientists as 'antiseptic', 'disinfectant' or 'soapy'. Such taints correspond to approximately 30% of all food taint complaints. While not all 'antiseptic' taints can be attributed to the misuse of disinfectants, this is a major problem, and great care is needed in the selection and use of disinfectant products in the food industry. In view of the ability of chlorophenols and bromophenols to produce taints in foods at extremely low concentrations (ppb), these substances are of particular importance. Products based on these chemicals should clearly not be used in food factories, but care should also be exercised in the use of chlorine or bromine in areas with high phenol concentrations in potable water.

Disinfectant taints can be transferred to food products by aerial routes, especially from unsealed concentrated solutions, or directly from disinfectant residues remaining on food contact surfaces. Test protocols have been developed in the Sensory Science Department at the Campden Food and Drink Research Association, to assess the tainting potential of disinfectant products. The basis of these tests is a triangular taste test (4), where foodstuffs which have and have not been exposed to disinfectants are compared by a trained tasting panel. Four types of food products are tested, high moisture (e.g. melon), high fat (e.g. cream), high protein (e.g. chicken) and low moisture (e.g. biscuit) which, taken together, cover the majority of food products. If a disinfectant does not produce a taint in any of the four food types tested, it is assumed to be safe for use in food manufacture.

In testing for aerial transfer, food products in sealed containers are held above the disinfectant solution or distilled water (as a control) for 24 h. This test is based on a method developed for assessing odour transfer from packaging materials (1). To simulate food contact surfaces, food products are sandwiched between two sheets of glass and left for 24 h. Disinfectants can be sprayed onto the glass sheets and left to simulate 'no rinse' status or can be rinsed off prior to food product contact. Control sheets are rinsed in distilled water only. This test is based on a method developed for assessing taint transfer from food containers (5). After the 24 h contact period, food products which have been subjected to potential disinfectant taint are compared to the controls as described above.

**Efficacy**

Ideally, disinfectants should have the widest possible spectrum of activity against microorganisms (viruses, bacteria, fungi and spores) in a time relevant to application contact times. Food producers should be assured that disinfectants are capable of antimicrobial effects, by means of documented disinfectant tests performed under conditions simulating factory use (18).

The biocidal efficacy of disinfectants has been assessed for many years and, in relation to food hygiene, disinfectants are normally evaluated in suspension tests (3, 13). In practice, however, microorganisms disinfected on food production surfaces are those which remain after cleaning, and are therefore likely to be attached to the surface. The relevance of suspension tests has therefore been questioned. However, some organisms
may be present in suspension after the addition of the disinfectant, and suspension tests are also useful for assessing the effect of environmental parameters in general (e.g. temperature, interfering debris [product soils] and contact time).

Traditional surface-based disinfectant test methodologies are available, though less common, and in each case bacteria are dried onto carrier surfaces (2, 6, 7). The creation of the single European market has provided impetus for both the review of disinfectant testing methodology and European standardisation of test methods; the latter has been facilitated by the formation in 1989 of a European Standards Technical Committee on Chemical Disinfectants and Antiseptics (CEN/TC 216), established to harmonise disinfectant test methods in the medical, veterinary, food and institutional fields.

Disinfectants have been evaluated against biofilms through the use of impediametric techniques (8,13) and more novel techniques, such as the application of in vivo bioluminescence using lux AB recombinant derivatives (22). Impediametric techniques measure microbial growth by detecting electrical changes in the surrounding incubation medium. For instance, the rate of change in conductivity can be related to the number of viable microorganisms present; electrical change can thus be correlated with microbial numbers. The unique advantage of impedance techniques is that they may be employed whether organisms are in suspension or attached to surfaces; provided that the organisms are viable, they can change the electrical properties of the incubation medium. This makes the technique particularly suitable for testing surface disinfectants, as there is no need to remove the organisms from the test coupon prior to enumeration. This leaves the biofilm or attached cells in the same morphological state and does not subject them to removal stresses which may influence the degree of disinfectant efficacy recorded.

The application of in vivo bioluminescence for rapid biocide monitoring has been described for a recombinant derivative of Listeria monocytogenes (20, 21, 22). A correlation between bioluminescence and viability was observed for a range of biocides in suspension and surface tests. As with impediametric techniques, the use of bioluminescence not only measures the total loss of viability of an attached population after disinfection per se, but can also be used to give some idea of biostasis and viability recovery immediately after the biocide application. This may be useful in determining and controlling the growth of microorganisms on food surfaces in the period between disinfectant application and the subsequent start of production. Bioluminescence also offers the ability to monitor biocidal activity very rapidly (10 min), in a time related to sanitation programme control.

A number of authors have shown that bacteria attached to various surfaces are more resistant to biocides than when the organisms are in suspension (8, 9, 13, 14, 16, 17, 19, 23). This has led to doubts over whether food manufacturers are using the correct concentration of disinfectant and, more obviously, whether this concentration should be increased. If this measure were to be adopted, the consequences to food manufacturers would be increased costs, enhanced possibility of food taint, toxicological considerations and environmental pollution. In practice, however, many factors are present in the factory environment which may affect the resistance of bacteria prior to disinfection. These are related to the entire sanitation programme and include the action of detergents, high temperatures, pH and mechanical stress, as well as attachment. The synergistic enhancement of disinfectant performance by manipulation of these factors has been reported (11).

It is therefore important to be aware that bacteria attached to surfaces are more resistant to biocides, and that disinfectant tests do not take account of the level of
microbial stress resulting from the cleaning action. The results of disinfectant testing therefore indicate only whether a disinfectant has antimicrobial properties in suspension or on surfaces, and do not necessarily reflect its activity in practice.

**Suitable disinfectants**

If possible, elevated temperature is used as the disinfectant of choice, as this penetrates into surfaces, is non-corrosive, is non-selective to microbial types, is easily measured and leaves no residue (15). While high temperatures are often used as disinfectants in CIP systems and some soak tank applications, their use on open surfaces is usually uneconomical, hazardous or impossible. In such cases, chemical biocides are employed. Universally-used biocides include biguanides, formaldehyde, glutaraldehyde, ozone, chlorine dioxide, iodophors and bromine. However, the most commonly-used acceptable chemicals are the following:

- chlorine-releasing compounds
- quaternary ammonium compounds
- amphoterics
- peracetic acid.

A range of characteristics for various disinfectant types is shown in Table I. Chlorine is the most widespread and cheapest disinfectant used in the food industry, and is

<table>
<thead>
<tr>
<th>Property</th>
<th>Chlorine</th>
<th>QACs *</th>
<th>Amphoterics</th>
<th>Peracetic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbial control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gram-positive bacteria</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Gram-negative bacteria</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Spores</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Fungi</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Developed microbial resistance</td>
<td>-</td>
<td>+/-</td>
<td>+/-</td>
<td>-</td>
</tr>
<tr>
<td>Inactivation by organic matter</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Inactivation by water hardness</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Detergency</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Surface activity</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Foaming potential</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Rinsability</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Problems with taints</td>
<td>+/-</td>
<td>-</td>
<td>-</td>
<td>+/-</td>
</tr>
<tr>
<td>Stability</td>
<td>+/-</td>
<td>-</td>
<td>-</td>
<td>+/-</td>
</tr>
<tr>
<td>Corrosion</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Safety</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Reactions with other chemicals</td>
<td>+/-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+/-</td>
</tr>
<tr>
<td>Cost</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

*QACs: quaternary ammonium compounds
++ large effect  + effect  +/- potential effect  - no effect
available in fast-acting (e.g. chlorine gas, hypochlorites) or slow-releasing forms (e.g. chloramines, dichlorodimethylhydantoin). Quaternary ammonium compounds (‘quats’ or QACs) are amphipolar, cationic detergents, derived from substituted ammonium salts with a chlorine or bromine anion. Amphoterics are based on the amino acid glycine, often incorporating an imidazole group. Peracetic acid may be used alone or formulated with hydrogen peroxide.

In conclusion, disinfectants play a critical role in some sectors of the food industry, where their use may be one of the major factors in preventing microbial spoilage and food safety problems in the product. However, if incorrectly selected, disinfectants can be ineffective, or they may give rise to product taint, health hazards to sanitation operatives, or toxicity to food product consumers. Therefore, the advice of the disinfectant manufacturer (or another source of expertise) should always be sought if the suitability of the disinfectant is in doubt.

* *

LES BESOINS PARTICULIERS DE DÉSINFECTANTS DANS LES ÉTABLISSEMENTS DE TRAITEMENT DES ALIMENTS. – J.T. Holah.

Résumé : L'absence de contamination par des microbes et par des corps étrangers est essentielle dans l'industrie alimentaire, et le principal moyen permettant de contrôler les voies de contamination externe est l'assainissement (nettoyage et désinfection). Après la phase de nettoyage, la désinfection joue un rôle crucial dans la réduction ultérieure du nombre de microbes et de leur viabilité. Cependant, les désinfectants utilisés dans l'industrie alimentaire peuvent contaminer le produit. C'est pourquoi ils doivent être non seulement efficaces et adaptés à l'utilisation en usine, mais également non-toxiques et non-contaminants. L'auteur décrit les critères d'utilisation et les exigences concernant la sécurité des personnes qui utilisent ces désinfectants, ainsi que les méthodes permettant de déterminer leur pouvoir (de pollution) éventuel, leur toxicité et leur efficacité. A partir de ces paramètres, un nombre limité de désinfectants est jugé propre à une utilisation dans l'industrie alimentaire en général, et l'auteur compare ces désinfectants.


* *

NECESIDADES ESPECÍFICAS DE DESINFECTANTES EN LAS PLANTAS AGROALIMENTARIAS. – J.T. Holah.

Resumen: Evitar la contaminación por microbios u otros cuerpos extraños es fundamental en la industria agroalimentaria, y el principal medio a arbitrar para poder controlar la contaminación externa es el saneamiento (limpieza más desinfección). Tras una primera etapa de limpieza, la desinfección desempeña un papel esencial en la reducción de la cantidad de microbios y de su viabilidad; pero existe el problema de que los desinfectantes en uso en la industria alimentaria pueden contaminar el producto. Por esta razón, debe cuidarse no
solamente que estos desinfectantes sean de probada eficacia y adaptados al uso en la industria, sino también que no sean tóxicos ni colorantes. El autor describe los criterios para el uso de estos desinfectantes y las exigencias respecto de la seguridad de las personas que vayan a usarlos, así como los métodos que permiten determinar su capacidad de coloración, su toxicidad y su eficacia. A partir de tales parámetros, sólo una cantidad limitada de desinfectantes se consideran aptos para ser usados en la industria agroalimentaria en general. El autor concluye el artículo comparando estos últimos productos.


* * *

REFERENCES


