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Dry decontamination techniques – What are the emerging options?

Wet decontamination techniques have been traditionally used to remove microorganisms from foods and surfaces. Although efficient, these technologies are not suitable for all types of products and surfaces: they may damage some foods or some surfaces, and require environmental control (provision of clean water, reuse and disposal). Their use may not be suited to all applications.

Dry decontamination techniques can offer benefits compared to wet techniques. The main benefit is that dry decontamination techniques do not require water. This reduces water use and potential chemical disposal. These both act to reduce costs. Dry decontamination of food or food contact surfaces helps assure safety and quality, and extend the shelf life of the final food product.

Dry decontamination techniques can be advantageous for the treatment of dry foods, delicate fresh foods, work surfaces and packaging.

- Dry foods have been traditionally considered as low risk products. In recent years, there have been several foodborne illness outbreaks where they were identified as the source. Following this, there has been an increased awareness in the food industry of the need to decontaminate dry foods.
- The increased consumption of fresh fruit and vegetables, often in their raw state, means that it is essential to provide a safe product, particularly where further cooking will not be performed.

This white paper aims to help food businesses assess the potential advantages of switching from wet to dry decontamination technologies. It summarises the technologies and applications of decontamination technologies against the background of recent outbreaks of food borne illnesses. The benefits of dry decontamination technologies are then explained, and some example technologies are described: pulsed light, ultraviolet (UV) light and cold plasma.

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FOODS AND DRY DECONTAMINATION

Dry Foods

It had been assumed that dry food and ingredients, by virtue of their low water activity, carried relatively little risk with regards to food borne pathogens. It has become clear, however, that whilst pathogens are unlikely to grow in dry products, they can often survive. Recent outbreaks have raised awareness of the potential of pathogens to grow in some low moisture foods, especially when conditions are right, e.g. addition of the dry food to a wet matrix. According to the US Food and Drug Administration (FDA) and the Centers for Disease Control and Prevention (CDC), a wide variety of dry products have been involved in food poisoning outbreaks, including:

- Almond purée (*Clostridium botulinum* toxin type A outbreak in France and Norway, 2013)
- Dried organic Chlorella algae (*Salmonella* Rissen outbreak in Sweden, 2013)
- Seeds (Hepatitis A outbreak on pomegranate seed mix in the USA, 2013, *Salmonella* outbreak on Sprouted Chia Seed Powder in the USA, 2014),
- Frozen food snacks (*Escherichia coli* O121 outbreak in the USA, 2013),
- Nuts (*Salmonella* Enteritidis outbreak in pine nuts in the USA, 2011),
- Spices (*Bacillus cereus* outbreak in a couscous spice blend in France, 2007),
- Dry pet food (*Salmonella* Infantis outbreak in the USA, 2012),
- Cookie dough (*Escherichia coli* O157:H7 outbreak in the USA, 2009),
- Puffed cereals (*Salmonella* agona outbreak in the USA, 2008).

The decontamination of low moisture foods is challenging as dry heat tends to be relatively inefficient and can cause scorching. Moist heat treatments are more effective but can result in moisture pick up, requiring a subsequent drying phase.

There are many methods used to decontaminate dry ingredients such as nuts, seeds and cereals. Examples include thermal methods, which may involve the incorporation of hot water, steam, dry heat or hot air, roasting and electrical heating. Non thermal methods include the use of chemicals, irradiation or, potentially, emerging technologies such as pulsed light, UV light and cold plasma.

Fruit and vegetables

Fruit and vegetables play an important role in the human diet. They provide vitamins, minerals and fibre essential for health. They can also be a source of food borne illnesses, especially if consumed raw and without washing. Contamination may occur at various stages of production. During growth, they may be contaminated by excessive chemical treatments, animals or pests. During harvest, contamination may be from workers and the containers. They may also be contaminated in the factory before packing. In the last few years, there have been several instances of food borne outbreaks from fresh produce, according to the CDC and FDA.

- Frozen berry mix (Hepatitis A outbreak in Germany and Italy, 2013)
- Cucumbers (*Salmonella* Saintpaul outbreak in the USA, 2013),
- Frozen strawberries (Norovirus outbreak in United Kingdom, Canada, Russia, Denmark, Iceland, Netherlands, 2013)
- Melons (*Salmonella* Panama and *Listeria monocytogenes* outbreaks in the USA, 2011)
- Mangoes (*Salmonella* Braenderup outbreaks in the USA, 2012)
- Salad mix (*Cyclospora cayetanensis* outbreak in the USA, 2013)
- Clover sprouts (Shiga toxin-producing *Escherichia coli* O121 outbreak in the USA, 2014)

Various methods are available for the decontamination of fruit and vegetables. They include the use of heat or pressurised water, ozone decontamination and ionising or non-ionising radiation. The use of warm or pressurised water may cause damage and so accelerate spoilage of the food. There is the additional requirement to use clean water and pay for effluent charge or build in-factory water treatment facilities. Chlorine may be used to disinfect recirculated filtered water to reduce the volume of water used, although it is not permitted for use on foods in some countries. Dry technologies including ozone, irradiation, UV light, pulsed light and potentially cold plasma could be used.

Food contact surfaces and packaging

During harvesting, transportation and processing, foods come into contact with various surfaces. If these surfaces are contaminated with pathogens, the microorganisms may transfer onto the surface of the food product. If the product is to be consumed raw, without further disinfection, it may cause a food borne illness. Disinfecting surfaces that come into contact with the product can reduce the chances of cross contamination with pathogens.

After processing, the food is packaged (bottles, punnets, bags, pots, etc.). If the food is not to receive further pasteurisation after packing, any pathogens present on the packaging may be transferred onto the food. Disinfection of the food packaging may be used to prevent this.

The strategies used for cleaning food contact surfaces are mainly chemical disinfection (quaternary ammonium compounds, 70% alcohol, chlorine, etc.). Hydrogen peroxide is usually used for decontamination of packaging. Some emerging methods for disinfection include pulsed light and UV light and potentially cold plasma.

ADVANTAGES OF DRY DECONTAMINATION

Advantages of using dry decontamination technologies

Wet decontamination has limitations; these are outlined in Figure 1, together with the rationale for how dry decontamination could solve them.

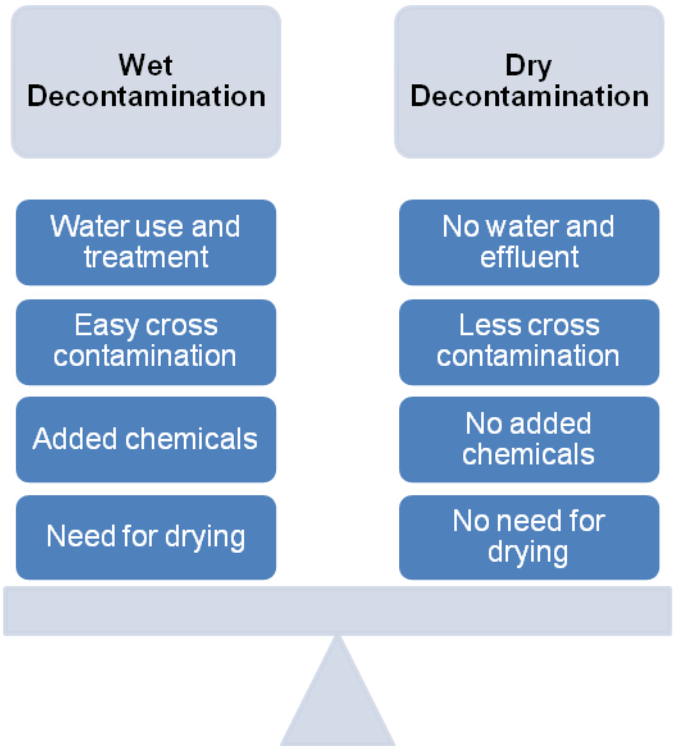

Figure 1: The advantages of dry decontamination

Wet decontamination requires the use of water to wash the product, either in its pure form or with the addition of chemicals (chlorine for example). The process needs large amounts of water. The waste water may contain a large amount of dissolved and suspended solids with a large biological and chemical oxidation demand (BOD and COD). This means that the company bears the cost of effluent disposal or water treatment facilities. If dry decontamination techniques are used, no water is required. There may be the need to remove soiling from some products before the disinfection step.

Water may act as a vector to spread microbial contamination through a batch. This can be mitigated by using antimicrobial agents such as chlorine. This might, however, give rise to chemical residues or otherwise impact on product quality. After washing, the product must be dried before packing. With dry decontamination techniques, there would be no added chemicals. No water is introduced during the process, so there is no need to dry the product before packing.

Reasons for using dry decontamination technologies

Food producers may want to use dry decontamination technologies for various reasons:

- Improve product safety
- Improve product quality
- Product not suitable for wet decontamination
- Increase production rate
- Reduce cost:
    - Reduce effluent production
    - Reduce water use and need for reuse.
    - Potential energy reduction if water requires heating

DRY DECONTAMINATION OPTIONS

Pulsed light

Pulsed light is a dry decontamination method for surfaces. The material is subjected to very short pulses (milliseconds) of broad-spectrum white light. The spectrum of light is typically between 200 and 1100 nm and includes UV, visible and infrared components. The UV component is believed to have the strongest antimicrobial effect. The product is typically exposed to 1-20 pulses having an energy density in the range of 0.01 to 50J/cm^2 at the surface. For instance, the pulsed light system at Campden BRI typically delivers 0.2 to 1.8 J/cm^2.

Campden BRI conducted tests with pulsed light (R&D report 281). Using only a single 300 µs pulse, up to a six log reduction in vegetative organisms was achieved on stainless steel that had been inoculated with *Staphylococcus aureus*. However, inactivation levels of *S. aureus* were found to be lower on PET (up to 4 logs). Microbial reduction on the surface of foods (meat, cheese and fruit) was found to range from 0.9 to 2.4 logs.

Industrial applications for pulsed light in the food industry include the decontamination of packaging surfaces such as bottles, pots and caps. Applications for food are likely to include surface treatment of relatively short shelf-life products that are susceptible to mould growth, such as baked goods, and transmissive materials such as water. A relatively modest reduction in microbial numbers could offer a significant shelf-life extension for very short-shelf life products.

We have a Claranor pulsed light system on site for research and contract services. Figure 2 shows the inside of the system. We have used pulsed light for increasing the shelf life of food products and for decontaminating surfaces for research projects.

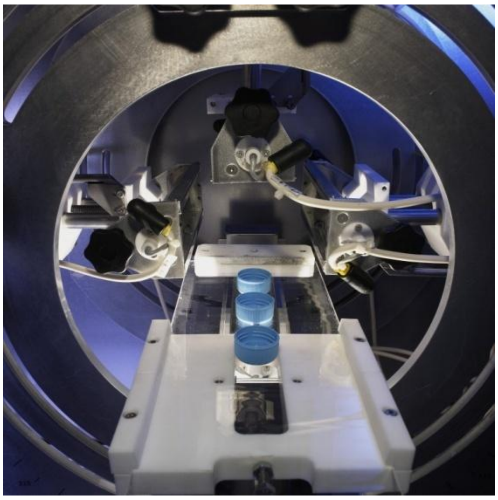

Figure 2: Pulsed light system at Campden BRI

Ultraviolet light (UV light)

UV light treatment is a non-thermal, non-chemical technology used to inactivate microorganisms. It has been used to disinfect water/air systems and for surface decontamination (packaging/work surface). The wavelength of UV light lies in the range 100 - 400 nm. It can be subdivided into three categories: UV-A from 315 to 400 nm, UV-B from 280 to 315 nm and UV-C from 100 to 280 nm. Although all UV wavelengths cause some photochemical effects, wavelengths in the UV-C range are particularly damaging to cells because they are absorbed by proteins, RNA, and DNA. Germicidal efficiency reaches a peak at about 254 nm.

The degree of inactivation by UV radiation is directly related to the UV dosage applied to the food products. Treatment with ultraviolet energy offers several advantages to food processors as it does not leave a residue, and does not require extensive safety equipment. It is also easy to use and is relatively low on equipment, energy and maintenance costs.

Ultraviolet light is applied worldwide for the disinfection of drinking water, wastewater, process water and industrial effluent and is gaining more interest across the whole spectrum of food and beverage industries. Current industrial applications include the treatment of conveying lines, packaging, containers, as well as wine and surfaces of products such as fruits or vegetables.

We recently acquired a UV light tunnel system for research and innovative applications (Figure 3). The system consist 16 x 95Whigh-output UV-C emitters, where the product can be treated from both above and below.

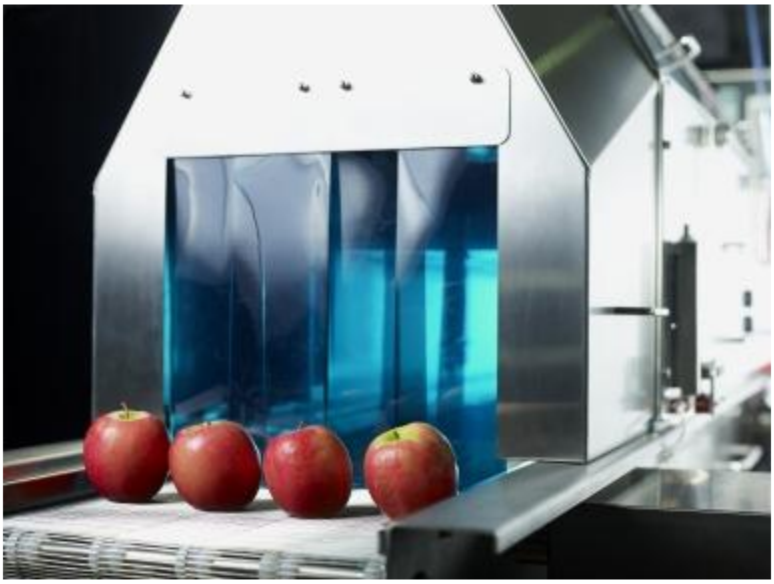

Figure 3: UV light tunnel system

Cold atmospheric plasma

Cold plasma is sometimes referred to as the fourth state of matter. Stars are examples of natural hot plasmas, but man-made plasma can be generated at low temperatures, typically by applying a voltage to a gas (atmospheric air or gas supply). The electric field generated from the applied voltage can accelerate any free electrons in the gas. Accelerated electrons collide with gas atoms to excite or ionise them. Ionisation of gas atoms releases more electrons. This cascaded reaction can generate a rich abundance of highly reactive chemical species (ozone, reactive oxygen and nitrogen species, ions and electrons), as well as UV light. The dominating reactive plasma species can be influenced/ tailored by the gas composition, the power supply, the electrodes and the way the power is supplied to the electrodes. The reactive species generated are capable of inactivating a wide range of microorganisms, including food-borne pathogens and spoilage organisms. The diffuse reactive species return to their neutral ground state once the applied voltage is removed.

We conducted a feasibility study in collaboration with the University of Liverpool on cold plasma for food and work surface disinfection (R&D report 377). More than 3 log reductions were achieved for plasma treatments of 2 minutes with *Escherichia coli*, *Salmonella* Typhimurium and *Listeria monocytogenes* inoculated separately onto stainless steel surfaces. Trials were also conducted on strawberries. The results indicated that a 2 min plasma treatment could extend the shelf-life of strawberries by about 3 days. Further research has focused on the potential for cold atmospheric pressure plasma for inactivating pathogens and spoilage organisms on the surface of food products. To date varying log reductions have been achieved on the surfaces of melons, mangoes, apples, strawberries, tomatoes, lettuce, potatoes, cheese, almonds, nuts, seeds egg shells, ready-to-eat meats, bacon, chicken and pork.

Cold plasma technology is not yet fully developed for the food industry but this technology offers potential applications that could have significant benefits. The most noticeable application is the disinfection of surfaces, in particular equipment, packaging, food contact surfaces or even food itself. Compatibility with food products could allow shelf-life extension or online disinfection of processing equipment to reduce cross-contamination and the establishment of biofilms on equipment.

We have a continuous cold plasma conveyor system developed and funded through the EPSRC Impact Acceleration Account Scheme in collaboration with the University of Liverpool (Figure 4). It is an air based system that doesn't require external gases for plasma generation. This equipment is currently being assessed for continuous decontamination of conveyor belts.

Figure 4: Cold plasma conveyor system

CONCLUSION

Several food borne outbreaks caused by dry and fresh foods have been recorded in recent years. This has increased the awareness in the food industry of the importance of effectively decontaminating dry and fresh foods.

Food can be decontaminated by dry or wet means. Wet decontamination is, however, not suitable for all products and may be costly. Dry decontamination is worth considering for food businesses as it can save money and improve product quality, shelf life and safety. We have a range of dry decontamination equipment, including pilot scale units for cold plasma, pulsed light and UV. The cold plasma and UV systems are both continuous units, and all are available on a research or contract basis for independently evaluating and validating the technologies for fitness for purpose.

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