GENERAL INTEREST PAPER

Reducing Food Recalls with Microbial Fumigation of Food Processing Facilities

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SUMMARY

Foodborne illnesses are making headlines almost every day. Food can become contaminated anywhere along the food chain during growing, harvesting, post-harvest handling, transport, processing, distribution, storage and packaging, as well as during final preparation at home or in a restaurant. Typical cleaning and sanitization techniques do not eliminate all of the organisms, leaving some to reproduce. This is how "re-contaminations" occur. Modern fumigation methods, such as use of gaseous chlorine dioxide, can completely eliminate all of the organisms and thereby "reset" a facility.

INTRODUCTION

Every few weeks there seems to be another major food recall. Is food getting more contaminated, or are detection techniques just getting better? Either way, food contamination is a matter of concern because of the large costs associated with foodborne illnesses due to contaminated food; such illnesses cost an estimated $152 billion each year in health-related expenses *(6)*. The Centers for Disease Control and Prevention (CDC) estimates that each year, roughly 1 out of 6 Americans (48 million people) are affected, 128,000 are hospitalized, and 3,000 die from foodborne diseases *(1)*. Another factor contributing to increases is that the United States is importing more food, much of which is coming from nations where sanitary standards might not be on par with those in the U.S.

Food can become contaminated anywhere along the food chain, during growing, harvesting, post-harvest handling, transport, processing, distribution, storage and packaging, as well as during final preparation at home or in a restaurant. Contamination of produce can occur at the farm from infected seeds, irrigation water, runoff, or aspects of the harvesting process. An additional major issue is cross-contamination, which can occur whenever batches of food contact potentially contaminated surfaces. These surfaces include those of transport trucks, storage bins, processing equipment, processing bins, and the actual processing facility where organisms can hide in conveyors, under equipment, on roof supports, and electrical conduits, etc. Because of the nearly constant stream of food products passing through these facilities, defining a clear production break is difficult. Consequently, contamination is detected, the question of how far back to recall is difficult, especially if the current decontamination process is not 100% effective.

Some of the major known pathogens involved in contaminations, foodborne illness outbreaks, and food recalls are *Salmonella, Listeria monocytogenes, and Escherichia coli* O157:H7. With new tools such as improved detection methods and product tracking methods, the Food and Drug Administration has begun an aggressive sampling program, the result of which is an increase in the recall of products that are contaminated or have the potential of being contaminated. The Amendments Act of 2007 *(7)* and the Food Protection Plan of 2007 *(8)* require food manufacturers to report when an instance occurs and to prove that their product is safe in the event that an expensive recall is necessary. Recently some well-known food contamination outbreaks and product recalls have occurred. For example, between July and October of 2011, 146 people in 28 different states were infected by *L. monocytogenes* as the result of eating contaminated cantaloupes from Jensen Farms, out of Granada, Colorado *(2)*. As a result of this outbreak, which resulted in 142 hospitalizations, 30 deaths and 1 miscarriage *(2)*, Carol's Cuts LLC out of Kansas had to recall 594 pounds of cantaloupe, and Fruit Fresh Up, Inc., recalled 4,800 individual packages of fresh cut cantaloupe *(2)*.

A devastating outbreak in the summer of 2011 was the *E. coli* O104:H4 (STEC) outbreak that started in Germany and France and that was due to raw sprouts *(3, 5)*. In this outbreak, 3,126 people were infected, 852 developed hemolytic uremic syndrome (HUS), and there were 32 deaths *(3, 5)*. A total of 6 cases, with one death occurred within the United States *(3, 5)*. As a result of this outbreak, the farm in

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Germany where the outbreak started has been shut down, even though the true source of the contamination is believed to be fenugreek seeds that were imported from Egypt *(3)*.

Another outbreak that occurred in the summer of 2011, which involved ground turkey, resulted in a total of 136 persons being infected with *Salmonella* Heidelberg in 34 states. Thirty-seven hospitalizations and 1 death occurred as a result of this outbreak *(4)*. On August 3, 2011, Cargill Meat Solutions Corporation, in Springdale, Arkansas, recalled approximately 36 million pounds of ground turkey products that may have been contaminated with a multi-drug resistant strain of *Salmonella* Heidelberg, and on September 11, 2011, Cargill Meat Solutions Corporation recalled another 185,000 pounds of ground turkey products after product samples at the plant tested positive for the outbreak strain of S. Heidelberg *(4)*.

The impact of contaminated food has many repercussions. In addition to the obvious and impactful harm to those who become sick from eating it, there are reduced revenues to growers and producers of that product because of reduced demand, even those that were not the cause of the outbreak. There is disruption of the food supply caused by the recall; and there is the cost to the company that caused, or at least did not prevent, the actual contamination. While a recall is always costly, it can be devastating to small and mid-size companies. There is a high probability that they would be forced to go into bankruptcy, destroying the company itself and forcing it to lay off its workforce. Because of this impact, many facilities have been increasing their sampling tactics to better detect contamination occurrences before they can become major issues. Companies are also improving their Contamination Prevention Activities (CPA's), increasing the frequency of wash-downs and surface cleanings, and investigating new liquid solutions. They are also looking into fumigation methods that can reach into all crevices from floor to ceiling. All decontamination methods can provide kill of organisms in ideal locations if chosen and used properly. To work in a realistic setting and eliminate organisms from floor to ceiling, there must be (1) complete distribution, (2) thorough penetration, and (3) a sufficient contact time and (4) a proper concentration with a sterilant. Only fumigation methods have a chance of being able to achieve these goals. Some methods that are being investigated include fogging with liquid disinfectants, fogging with hydrogen peroxide vapor, or fumigating with gasses such as formaldehyde, ozone, or chlorine dioxide. Fogging is quickly discounted because of its physical properties, because typical fog droplets are larger than 5 to 15 microns, which is significantly larger than the organisms (1 or 2 microns) they are trying to reach, the fog cannot get into crevices where the organisms can be hiding. The droplets are also much heavier than air and tend to settle, so that they do not reach high surfaces or beneath equipment. Also, in order for most liquids to produce the highest level of sporicidal kill, surfaces must be kept wet for at least 10 hours, which is not very realistic. Vapor phase hydrogen peroxide (VPHP) is also discounted, because it has a boiling point of 109°C, condensing at room temperatures before it can reach all surfaces, which limits its distribution too much for it to be effective. Ozone, a nice, simple technology, can work well in small areas, but it breaks down too quickly to be used for large areas. It decomposes before it can reach areas distant from the generation point at high enough concentrations to be effective. The only two effective gaseous decontamination methods available are use of formaldehyde and chlorine dioxide (CD), but only CD is registered with the EPA as a sterilant process (EPA registration #80802-1). The formaldehyde process requires the heating of paraformaldehyde to release the gas, long contact times (usually 6–12 hours) and high concentrations (10,000 ppm) to achieve a sporicidal outcome. Also, the residues left by formaldehyde and its carcinogenic properties make it an unattractive choice for use in areas where food is processed *(9)*.

Chlorine dioxide (CD), ozone, and VHP are oxidizers *(Table 1)*, but CD is a less aggressive oxidizer (oxidation potential data) than chlorine, ozone, peracetic acid, hydrogen peroxide, or bleach and is non-corrosive to common construction materials, as well as electronics and other sensitive materials. Gaseous chlorine dioxide has none of the mentioned drawbacks associated with the other decontamination methods; it can

TABLE 1. Key properties of oxidizing biocidal agents (9)

BIOCIDAL AGENT	OXIDATION POTENTIAL (VOLTS)	OXIDATION CAPACITY (ELECTRONS)
O_3 (Ozone)	2.07	$2e^-$
CH_3COOOH (peracetic acid)	1.81	$2e^-$
H_2O_2 (peroxide)	1.78	$2e^-$
NaOCl (sodium hypochlorite)	1.49	$2e^-$
ClO_2 (cholrine dioxide)	0.95	$5e^-$

handle large areas and is compatible with components, equipment, and finishings commonly associated with food production facilities. It is a true gas at room temperature and thus is evenly distributed by gaseous diffusion throughout the area being decontaminated. Gaseous chlorine dioxide can penetrate through water, allowing for decontamination of the water and of the surfaces that the water covers. This is helpful because it saves the time otherwise required to completely dry everything after a facility wash-down or cleaning. Chlorine dioxide gas also has very quick cycle and aeration times, allowing for processing facilities to become fully functional and decontaminated in a shorter period, which saves both time and money.

A microbial fumigation of a facility can be completed in 1 to 3 days depending on the facility's size and configuration. The setup would consist of sealing all of the possible leaks in an area such as around windows, doors, vents, pipe ways, holes, etc. Also, the building exhaust system or HVAC system would need to be controlled in order to contain the CD gas within the facility and/or to exhaust the CD gas at the end of the decontamination cycle. Biological indicators, or spore stripes containing a known value of bacterial spores, can be placed in critical areas to document the effectiveness of the process. Sample and injection tubing is run to many different points throughout the area to achieve representative concentration sampling and even distribution of the gas during the decontamination event. A UV-VIS spectrophotometer continuously and accurately reads the CD concentration throughout the area to ensure that the process parameters are met prior to the cycle being completed. Once the cycle ends and the gas is aerated, the area can be immediately turned back over to production for use.

Food facilities typically either use steam or wash as many surfaces as possible with an anti-microbial solution in an attempt to kill as many contaminating microorganisms as possible. Some microorganisms typically survive the process, either because the agent did not reach them at the proper concentration for the correct amount of time or because of mechanisms that they develop to cope with some sanitizers, cleaning agents and temperatures. Other dry facilities perform no routine actions to eliminate organisms, which if not being completely removed, can slowly increase in number and spread over larger areas, greatly increasing the chances of contamination. By using gaseous CD, which will completely eradicate the microorganisms, frequently and routinely for decontaminating a facility before an issue arises, the chance of a contamination and/or a recall declines drastically, potentially saving money, disruptions to business, and perhaps lives.

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