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Retort Cooling Water Bacteriological Load and Possible Mitigation Strategies for Microbial Buildup in Cooling Water

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ABSTRACT

There has been a concern that *Clostridium botulinum* might enter a defective can of low-acid food through a microleak after thermal processing and during the cooling process. This paper reviews most current surveys on bacteriological quality of cannery cooling water, bacteriological testing methods in cannery cooling water, disinfection of container cooling water in canning systems, and common types and methods of disinfection. The Grocery Manufacturers Association (GMA) survey of cooling water systems currently used in industry showed a high percentage of routine microbial testing and chemical treatments. Published reports on the microbiological conditions of the retort cooling water indicated that containers may be sufficiently protected against leaker spoilage only if the aerobic plate count (APC) of the cooling water is less then 100 CFU per ml. Disinfection of all cooling water systems, including single pass systems, is recommended when APC loads exceed 100 CFU/ml. Microbial testing and cooling water treatments may be included in an operational or standard operation procedure to control microbial buildup in retort cooling water and reduce the possibility of post-process contamination.

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INTRODUCTION

A recent case of *Clostridium botulinum* contamination in a canned vegetable product has prompted the Food and Drug Administration (FDA) to take a closer look at retort cooling water systems *(6)*. The FDA noted the recovery of *C. botulinum* spores in well water used in the processor's one-pass cooling water system as a major concern. An event such as this serves as a reminder that food canners should pay close attention to controlling bacteriological levels in cooling water. There is always concern that water used in the cooling of thermally processed containers may provide an opportunity for waterborne microorganisms to enter the sterilized container through seam or seal leaks and become a health hazard *(7, 29)*. Odlaug and Pflug *(19)* modeled the probability of a botulism health hazard from post-processing contamination and concluded that the likelihood of post-processing contamination from *C. botulinum* in canned foods is between 10^{-7} and 10^{-10}. When the possibility of *C. botulinum* growing in canned foods and the likelihood of a consumer eating spoiled product are considered, the probability of human botulism from leakage decreases to approximately 10^{-9}

TABLE 1. Cannery cooling surveys: anaerobic spore content[1]

Samples	Anaerobic spores/ml			Cooling system	Reference
	Median	Range	% Positive		
59	< 0.03	< 0.03–9.3	15.2	SP and R	*(7)*
210	NR	< 1.0–4.0	4.0	SP and R	*(11)*
171	< 0.1	< 0.1–5.9	NR	NR	*(19)*
274	< 0.03	< 0.03–4.6	10	R	*(29)*

[1]Adopted from Thompson and Griffith *(29)*

SP, single-pass; R, recycled

NR, not reported

to 10^{-12}. The former National Food Processors Association (currently the Grocery Manufacturers Association) and the Can Manufacturers Institute (NFPA/CMI) Container Integrity Task Force *(17)* calculated that between 1940 and 1982, 1.3×10^{12} cans of low-acid foods were consumed. Over the same period there were five botulinal incidents in which container leakage was observed as the source of contamination. Thus, the Task Force estimated the probability of botulism from container leakage as 3.8×10^{-12}, or one chance in every 260 billion cans of foods consumed.

Several surveys on bacteriological quality of cannery cooling water have been conducted to determine the aerobic plate count (APC) and the incidence of spores from mesophilic anaerobic sporeformers. The conditions that permit a buildup of mesophilic anaerobic sporeformers would be favorable for *C. botulinum.* The objectives of this paper are: (1) to provide a review of the available literature on bacteriological quality of cooling water used in thermal processing plants, and (2) to make recommendations on adequate testing and control of microbial population build up in retort cooling water to reduce the possibility of post-process contamination.

SURVEYS ON BACTERIOLOGICAL QUALITY OF CANNERY COOLING WATER

Few reports on the microbiological quality of cooling water used in food canning facilities have been published. The bulk of studies that are available were conducted two or more decades ago. Kibler et al. *(12)* conducted a survey in nine canneries, located across the United States, for mesophilic anaerobic spores, including *C. botulinum.* Numbers of positive samples in cannery water out of the total 60 samples cultured for mesophilic anaerobic spores were 7 for cooling canals and 17 for cooling towers. None of the samples contained *C. botulinum*. Most of the water was treated with chlorine, but sometimes pond water was used for the cooling process. Pond water was pumped into the plant when needed, treated with an iodophor, used in the cooling process and then returned to the pond. The authors concluded that because of the presence of numerous mesophilic anaerobic bacteria in the cooling water, good manufacturing procedures should be followed, good sanitation procedures enforced, container defects minimized and post-processing equipment regularly cleaned and sanitized.

Lake et al. *(13)* conducted another survey in three low-acid food canneries (Cannery A, Cannery B and Cannery C) on enumeration and isolation of mesophilic anaerobic sporeformers from cannery post-processing equipments and cooling water. The authors reported that a significant number of these spores were isolated from various pieces of equipment. In one instance a depalletizer turntable (in Cannery C) had a population of 3.5×10^3 CFU/in^2. Spores were also isolated from the can cooling water in two of the canneries (Cannery B and Cannery C). The highest number of anaerobic spores was found in Cannery C (20 CFU/in^2). The isolates from cooling water were identified as *C. sporogenes, C. pasteurianum*, *C. beijerinkii* (Cannery B) and *C. acetobutylicum* (Cannery C). The retorting methods used in these two canneries were continuous rotary cookers (Cannery B) and hydrostatic cookers (Cannery C). Anaerobic spores were not detected in cooling water in the cannery that used still cookers (Cannery A). The low total aerobic plate counts found in the still retort system and high counts in hydrostatic type cookers were consistent with the cooling water counts reported by Graves et al. *(7)* and Odlaug and Pflug *(18)*. No correlation was noted between mesophilic anaerobic spore counts and total aerobic counts. *C. botulinum* was not isolated from any of the survey samples. The authors concluded that post-process can handling equipment in these plants was the main source of anaerobic spores. In this particular study, can cooling water appeared to be an additional source, but of lesser significance.

Mesophilic anaerobic sporeformers were cultured from recycled cannery cooling water by Thompson and Griffith *(29)*. Chlorinated, recycled water for cooling of containers in still retorts was sampled over a 27-month period at one food processing plant. Of 274 samples taken, 28 contained mesophilic anaerbic spores. The isolates were characterized as *Clostridium* spp., with *C. butyricum* and *C. barati* representing 55% of the isolates. The authors summarized the total anaerobic spore count data and compared them with results of others (Table 1).

TABLE 2. Microorganisms found in cannery cooling water

Microorganisms	Source of cooling water and/or type of cooling system	Sanitizers used	References
Flavobacterium, Bacillus and *Corynebacterium*	Can cooling water and/or post - process can handling equipment	Chlorine	*(2)*
Streptococcus, *Staphylococcus aureus, Bacillus* spores and clostridial spores	Well water	Chlorine	*(20)*
Klebsiella sp., *Pseudomonas aeruginosa* and clostridial spores	Surface water	Chlorine	*(20)*
Coliforms, enterococci and putrefactive anaerobic spores	Cooling canals or tanks for continuous and hydrostatic retorts	Chlorine or iodine Residual chlorine up to 8 ppm (mg/l) Residual chlorine up to 5 ppm	*(7, 11)*
Mesophilic, thermophilic and anaerobic spores	Cooling canals for hydrostatic retorts	Chlorine or iodine. Residual chlorine up to 3 ppm Residual iodine up to 4 ppm	*(19)*
Mesophilic anaerobic sporeformers – *C. perfringens*, *C. durum*, *C. butyricum* and *C. beijerinkii*	Cannery cooling water	Free available chlorine 0.02 – 0.75 ppm, pH = 7.2	*(29)*

Can cooling water studies were conducted in 1976 by the former National Canners Association (currently the Grocery Manufacturers Association) (unpublished data). The cooling systems in 17 canneries were surveyed and 203 cooling water samples were analyzed. The aerobic plate counts (APC) for 64% of the samples were in the range of less than 1 to 100 CFU/ml. Spores of aerobic mesophilic bacteria were present in 20% of the samples, and the maximum count did not exceed 20 CFU/ml. Spores of anaerobic mesophilic bacteria were recovered, but in low numbers and from only 5% of the samples. In general, anaerobic sporeformers showed a gradual increase when the APC population counts exceeded 100 CFU/ml *(17).*

OVERALL MICROBIOLOGY OF COOLING AND WELL WATERS

Table 2 indicates that a variety of microorganisms may be present in cannery cooling water, including spores of mesophilic anaerobes and aerobes. These organisms are usually present in low numbers, and their presence is dependent on the source of the cooling water, the type of cooling water systems used and the amount of effective germicide present. However, the APC populations in some instances were high (> 2.1×10^4 CFU/ml) and for this reason some of the microbial examinations were extended to include indicator organisms and bacteria associated with food poisoning *(7)*.

Most of the microorganisms isolated from the sanitized cooling water were obligate anaerobic mesophilic sporeforming rods that produced volatile fatty acids and displayed fermentation patterns typical for the genus *Clostridium (19, 29)*. *Clostridium perfringens*, which is both proteolytic and saccharolytic, and saccharolytic *C. durum, C. butyricum* and *C. beijerinckii* were isolated *(29)*. Put et al. *(20)* found *Streptococcus, Staphylococcus aureus, Bacillus* spores and clostridial spores in the chlorinated well water. The canneries using chlorinated surface waters contained higher numbers as well as a greater variety, of microorganisms including *Klebsiella* sp., *Pseudomonas aeruginosa* and clostridial spores *(20)*. Graves et al. *(7)* noted a relationship between APC and the inci-

TABLE 3. Relation of can abuse and microbial count on double seam areas[1] to rate of spoilage (cans taken at caser)[2]

Severe Can Abuse		Minimum Can Abuse	
Microorganisms Per Can	Spoilage Rate (Cans/1,000)	Microorganisms Per Can	Spoilage Rate (Cans/1,000)
23,000	18	1,000	0
32,000	30	1,600	0
35,000	23	25,000	< 1
69,000	22	52,000	< 1
73,000	24	209,000	< 1
130,000	25	900,000*	< 1
327,000	25	1,790,000*	< 1

[1]Seams inoculated with *Aerobacter aerogenes*

[2]From Weddig, L. M. et al. *(24, 28)* * Seams inoculated with *Aerobacter aerogenes*

dence of total coliforms and enterococci in cooling water. The results showed a trend in which the frequency of coliform detection increased as the APC counts increased. Enterococci were also recovered with greater frequency at the higher APC levels, but no significant trend was noted. The study showed the frequency of aerobic spore detection increased as the APC counts increased. Odlaug and Pflug *(19)* reported that the anaerobic spore means were 0.5 CFU/ml for hydrostatic retorts and 0.4 CFU/ml for the cooling canal. The number of *C. botulinum* spores in the cooling water was not directly measured, but it was assumed that the number was very low, since it would be only a fraction of the total anaerobic spores in the water *(19)*.

BACTERIOLOGICAL TESTING METHODS FOR MONITORING BACTERIAL COUNTS IN CANNERY COOLING WATER

Recontamination of thermally processed cans during the cooling process is the most common cause of microbial spoilage in canned food products *(7)*. Recontamination is dependent upon the condition of the container seam, the condition of the container handling system and the condition of the water *(21)*. Incidences of spoilage are correlated to the number of bacteria in container cooling water *(20)*. As the count in the water increases, the probability of spoilage organisms entering the can also increases. In most cases, water from municipal supplies and deep wells is low in bacterial counts and surface waters are frequently high in bacterial counts. Bacteria multiply rapidly in reused cooling water that is not chlorinated *(16)*.

Although determination of free residual chlorine can be used as a guideline for water quality, counting of bacteria is the most reliable and direct procedure for monitoring the purity of can cooling water *(16)*. Aerobic plate counts (APC) are sufficient indicators of the bacterial content of can cooling water. For testing a city water supply, well water, single pass continuous coolers and cooling canals, where the water is not reused, an appropriate sample should be taken from the source and 1, 0.1 and 0.01 ml tested in duplicate. For water from continuous coolers and cooling canals, an appropriate sample should be taken and the following dilutions tested: 0.1, 0.01, 0.001 and 0.0001 ml. Each dilution should be plated at least in duplicate and incubated at 48 ± 2 h at 35°C *(1, 14)*. If the water has been chlorinated, the chlorine should be neutralized by addition of 1.5% sodium thiosulfate solution *(16)*. The American Water Works Association and Water Environment Federation recommend the heterotrophic plate count (HPC), formerly known as the standard plate count, be used *(4)*. Three different methods, such as a pour plate method, a spread plate method and a membrane filter method, may be used to determine the HPC. In the pour plate method, submerged bacterial colonies in agar medium may be exposed to heat shock from the transient exposure of the sample to 45°C agar. The spread plate method causes no heat shock, and all colonies are on the agar surface, where they can be distinguished readily from particles and bubbles. The membrane filter method permits testing large volumes of low-turbidity water and is the method of choice for low-colony waters (< 1 to 10 CFU/ml). This method produces no shock but adds the expense of the membrane filter *(4)*.

Many thermal processing plants do not have the facilities and trained workforce required for aseptic microbial testing. Simplified and rapid microbial testing methods might be the solution for this situation. Currently, there are several modified methods of conventional microbiological testing that can be used for monitoring bacteria in canning plants. This includes the use of 3M Petrifilm™, which uses disposable cardboard disks containing dehydrated media, designated for enumerating specific bacteria. This test eliminates the need for preparing media and agar plates, economizes storage and incubation

space, and also simplifies disposal of materials after analysis. The Iso-Grid™ uses special hydrophobic grid membrane filters that can handle larger cell densities. This reduces the number of dilutions needed prior to filtration. These rapid test kits are approved by AOAC and provide performance equivalence to standard cultural methods such as those contained in the FDA Bacteriological Analytical Manual *(14)*.

DISINFECTION OF CONTAINER COOLING WATER IN CANNING SYSTEMS

Leaker spoilage, also known as post-process contamination, frequently occurs from seam/seal defects and mechanical damage to containers. It may occur in warehouses or retail stores if seams or seals are stressed or damaged, or if containers are punctured or otherwise compromised. Post-process contamination most often occurs during direct water cooling of the container *(8)*.

During the cooling process, in the case of cans or glass containers, containers transition from being pressurized units with the ends/lids extended, to having an internal vacuum. While these changes in container configuration are occurring, or if the seam/seal were to be damaged, the container may allow entry of trace amounts of cooling water. Vacuum, by definition, exerts less pressure than the surrounding atmosphere and water or air could be drawn in from the environment if the container seal is compromised *(15)*. Even high quality seam/seals can draw in small amounts of water before the sealing compounds have set. If the water contains bacteria and organic materials (e.g., product) and environmental conditions are favorable, the bacteria will grow, resulting in possible spoilage. Such spoilage may or may not result in gas production that distends the container *(8)*.

Less than optimum seams/seals or poor operation of processing systems resulting in container abuse only compounds potential problems, as poor quality seams or seals are more prone to leakage. Uncontrolled pressure fluctuations during retorting and cooling operations may also stress the seam, resulting in poor seam/seal integrity and subsequent leaker spoilage. Table 3 illustrates the profound difference in spoilage for cans subject to severe abuse versus those subject to minimum abuse.

For these reasons, the bacterial condition of cooling water is very important. As the concentration of microorganisms increases in the cooling water, less contaminated water would be needed to be drawn into the container to cause spoilage. Even the ingress of a single droplet of water containing a single bacterium capable of growing in the product could cause leaker spoilage to occur. Consequently, even low numbers of microbes may tax the ability of even the best closure seals/seams to keep out microbial contamination. For example, a can immersed in cooling water containing an evenly dispersed population of 100 bacteria/ml would have to draw in only 1/100 milliliter (0.01 ml) of water to allow entry of a single bacterium, which may be capable of causing spoilage. If cooling water disinfection is not properly managed, and the microbial population of the water is allowed to reach 10,000 bacteria/ml, then only 1/10,000 milliliter (0.0001 ml) would have to be drawn into the can to create a potential spoilage situation *(27)*. Or, the same 0.01 ml of water could draw in 100 microorganisms, which is likely to result in spoilage. The size of the pathway which allows entry of microorganisms into a container depends upon the microbial quality of the environment *(3, 22)*. In the period from 1948 to 1964, six outbreaks of typhoid fever, including an outbreak in Aberdeen, Scotland, occurred in the U.K. Stersky et al. *(25)* attributed them to post-process contamination of canned corned beef. The Aberdeen incident was thoroughly investigated and researchers determined that *Salmonella* Typhimurium gained entry into a can from unchlorinated river water used for cooling after thermal processing. Investigations at the Argentina manufacturing plant showed that cooling water chlorination equipment had been out of use for 14 months. The unchlorinated river water was obtained downstream from Rosario, Argentina, a city of 600,000, which discharged raw sewage into the river.

Odlaug and Pflug *(18)* indicated that the public health hazard from post-process leakage of *C. botulinum* spores into thermally processed low-acid food containers should be extremely small if the cooling water is properly treated and the addition of soil or any other outside source of *C. botulinum* spores is eliminated. *C. botulinum* will not likely multiply in cooling water that is properly treated with disinfectants. Therefore, only the introduction of large numbers of *C. botulinum* spores into improperly treated cooling water could lead to a public health hazard if those spores were to germinate, grow and yield viable vegetative cells of *C. botulinum* subsequent to entering a container of food.

In their 1980 paper, Ito and Seeger *(10)* reviewed various publications on the re-contamination of previously processed commercially sterile containers. They summarized that all of those investigations found that the application of a germicide was beneficial in obtaining good quality (containing low bacterial numbers) cooling water. In recirculated systems, careful attention must be given to ensure adequate germicidal applications.

Proper disinfection of container cooling water requires an active management process. Without a disinfection program, recycling of water could result in the buildup of contaminants. Disinfection of recycled water can be critical to minimizing the potential amplification of microbial contamination. Changes in product volume, quality of incoming water, or temperature of the water can require adjustments of the disinfection system *(8)*. Ito and Seeger *(10)* stated that a regular schedule of monitoring applied germicides at appropriate locations in cooling water systems should be established. Processors should manage cooling water so that it contains as low a microbial population as practical.

In the Aberdeen case described by Stersky et al. *(25)*, contaminated single-pass (one-use), non-recirculated water was a causative factor in the *Salmonella* Typhimurium spoilage, showing that single-pass water is not exempt from microbial contamination. Processors should have disinfection management-programs even if they employ single-pass cooling water; water from these systems should be monitored for microbial quality. Results from bacterial analyses may dictate the need to appropriately apply disinfectants in order to maintain bacterial counts below a desired set-point (e.g., 100 CFU/ml).

TABLE 4. GMA survey results from canning facilities

Topic	Yes	Types
Facilities using a treated water source	90%	City water treated, well water treated
Facilities further treating source water	60%	Chlorine, chlorine dioxide, bromine, sodium bromide, lime, filters
Microbial testing of cooling water	80%	APC[1] in all cases
Microbial testing of source water	70%	APC[1] monthly/quarterly, potable water test
Single pass systems	53%[2]	
Recirculating systems	47%[2]	

Responses are from 10 processing facilities. Some facilities reported multiple source and water treatment systems

[1]APC: Aerobic Plate Count

[2]Based on 15 cooling water systems

COMMON TYPES AND METHODS OF DISINFECTION

While prevention of leaker spoilage may involve several factors, microbes are the agents responsible for post-process contamination, regardless of how they get into the container. Various canning regulations (21 CFR 113.60 (b), 9 CFR 381.305 (h) (2 and 3), 9 CFR 318.305 (h) (2 and 3)) require chlorination, or other methods of sanitation, for cooling canals and recirculated cooling water. While there are many other ways of cooling containers, these two examples are distinctly addressed in the regulations cited here.

Hypochlorites, either sodium or calcium, or gaseous chlorine can be used for chlorine disinfection. Chlorine disinfection is dependent on pH, temperature and the level of organic content of the water *(7, 8, 10)*. If systems using hypochlorite and chlorine gas injection do not maintain the proper pH, the chlorine may not be in the chemical form of hypochlorous acid, which is the active disinfectant commonly measured as free available chlorine. Elevated pH values will yield hypochlorite, a poor sanitizer, and there will be little disinfectant activity, or free available chlorine *(8)*. Odlaug and Pflug *(18)* concluded that when chlorine compounds are added to water with a properly controlled pH to yield free available chlorine, the solution can be both bactericidal and sporicidal. The literature has suggested that calcium hypochlorite, sodium hypochlorite, and chlorine gas, when added to water with the proper conditions (e.g., proper pH control) to yield free available chlorine, are all equally effective in delivering a 4 log (99.99%) reduction in numbers of viable spores of *C. botulinum* Types A, B, and E *(18, 19)*. According to Graves et al. *(7),* chlorination at a level of 0.5 mg/l is satisfactory where water is used once to cool containers and then discarded. However, where water is subject to organic contamination or to fluctuation in pH and temperature, management must provide proper mitigations to control the microbial levels in the cooling water. One such mitigation is maintenance of a higher chlorine (disinfectant) residual.

Chlorine dioxide does not react as chlorine does with organic matter, ammonia, or phenolics. Therefore, in water with high organic loads it can be more effective than hypochlorous acid. However, chlorine dioxide is highly reactive and unstable, and it cannot be effectively stored. Therefore, it must be generated on-site. Unlike chlorine, chlorine dioxide appears to be more effective in destroying aerobic spore formers than in destroying anaerobic sporeformers *(10, 23)*. When chlorine dioxide is used, the anti-microbial activity is not as dependent on pH; it has similar effectiveness between pH 6 and 10 *(10, 23)*.

Control of pH is also crucial in bromine disinfection, although hypobromous acid is present at a higher pH than hypochlorous acid *(8)*. Bromine dissolves in water three times more effectively than chlorine. No dangerous gasses are required for bromine production. It should be noted that bromine is very reactive and thus its activity in water is short lived. Even though low residuals may be quite effective, depending on individual situations, to maintain adequate disinfection, the amount of bromine that must be added may be high *(8)*.

Iodophors are complexes of iodine and certain surface active agents, which slowly release free iodine when diluted with water. They are effective at destroying vegetative bacteria and yeasts. However, iodophors have limited effectiveness against spore-formers, both anaerobic and aerobic. In these cases, high levels of iodophors are required to get population reductions in a relatively short amount of time *(10)*.

Over the past several years, computer controlled systems have emerged that can control water disinfection automatically. Chlorine, ozone, bromine and iodine are all oxidizers, and oxidation involves the transfer of electrons. This flow of electrons creates an electrical potential or current, and this current can be measured as the oxidation-reduction potential (ORP) of the water. ORP monitoring provides a rapid and single value assessment of the disinfection potential of the water. In tandem with pH sensors, ORP sensors can create an automated management system to provide demand-based injection of oxidizer and/or acid *(26)*. Computerized systems can also provide real-time web access to data and enhance recordkeeping.

Water supplies vary from place to place; some supplies are more corrosive than others, and pH values vary, as does mineral content (soft vs. hard water). Therefore, the disinfectant level necessary to achieve and maintain recommended minimum residual concentration and the maximum level that can be tolerated (e.g., to maximize employee safety and minimize corrosivity) must be determined for each individual system. Whatever verification system is employed should include monitoring the bacterial quality of the water. Simply targeting for a residual disinfectant level alone may not be adequate.

GMA SURVEY

Results of a survey by GMA, conducted in the summer of 2008, requesting specific cooling water system information from low-acid canned food facilities are summarized in Table 4. Respondents represent small to large canning companies with various system approaches. A total of 10 facilities, representing 15 separate systems, responded to the survey. Some of these facilities used multiple water sources (city water treated/untreated and well water treated/untreated) and cooling water systems (single pass and recirculating systems). Most of the respondents (90%) indicated that source water is treated (with disinfectants) prior to entering the facility, and 60% of the facilities further treat incoming water regardless of the source. Routine microbial testing on the source water was performed on 70% of the cooling water systems. Additional microbial testing of cooling water systems was performed in 80% of the facilities responding to the survey. More than half (53%) of the systems reported are single-pass systems with recirculating systems making up the balance. For recirculating systems, all plants indicated replenishment with fresh water, chemical treatment, and testing for chemical residual. One facility noted the use of carbon filters and oil skimming. Half (50%) of all respondents treating their systems checked for chemical residuals of disinfectants at the cooling water or retort discharge. Respondents indicated that chemical residuals were predominantly checked at cooling water sumps and can discharge locations, and in one instance a respondent indicated checking the cooling water feed to retorts. Residual disinfectant levels reported ranged from 0.1 to 1.5 ppm; however, the chemical type was not specified, making the differentiation between various forms of chlorine, bromine, or other disinfectants impossible. A number of processors noted the use of alarms, and one reported the use of an automated chemical injection system (with a manual check backup). Three of the respondents reported a product hold and review process following a chemical residual alarm.

RECOMMENDATIONS

Many factors ultimately contribute to the assurance of bacteriological quality in food plant cooling water systems. As seen from surveys of cannery cooling water systems, bacteriological loads can be significant. While container integrity plays an important role in the final spoilage rate for the end product, it is important to understand and control as many risk factors as possible to insure against rare events, such as suboptimal seams/seals. For the purposes of this paper, adequate seam/seal integrity will be assumed relative to any cooling water system recommendations.

As discussed earlier, APCs have been shown to be significant indicators of specific spoilage organisms and rates of product contamination. Several sources have suggested that containers may be sufficiently protected against leaker spoilage only if the bacterial count (APC) of the cooling water is < 100 CFU/ml *(5, 7, 8, 9, 20, 30)*. Put et al. *(20)* found that reinfection of containers could be minimized if cooling water had less than 100 bacteria/ml and if the number of bacteria in the water on the double seam at the end of container handling was less than 10,000/ml. Herbert *(9)* reported that there was little or no recontamination of cans at the cooling stage when cooling water counts were less than 100 bacteria per ml. Williams *(30)* considered 100 bacteria per ml to be an acceptable contamination level for cooling water. Consequently, it is a good practice to monitor the bacterial level of cooling water on a periodic basis. This includes both the microbial quality of incoming water, and the microbial quality of the cooling water system.

Disinfection of all cooling water, regardless of source, is a dependable means of maintaining microbial counts of cooling water at low levels. As mentioned above, various canning regulations require chlorination, or other methods of sanitation, for cooling canals and recirculated cooling water and stipulate a measurable residual level of sanitizer at the discharge point of the container cooler section. When single pass systems have APC loads of 100 CFU/ml or above as the water enters the cooling system, these systems should be monitored and treated in the same manner as recirculating systems.

As seen from the GMA survey (above), chemical residual levels may vary by chemical and by facility. It is important for each facility to document and maintain chemical treatment protocols that are sufficient for their product, container and historical incidence of spoilage. It is recommended that processors take advantage of the expertise and services of water treatment professionals in the food industry and/or their local area.

Combining microbial testing and cooling water treatment into an operational protocol, or standard operational procedure, would allow the processor to better evaluate and control risks associated with the cooling of thermally processed food containers in their facilities. In view of the fact that there is no one solution that works for every producer, it is important that companies include basic testing, monitoring and treatment protocols in their cooling water systems in a structured and documented program, such as an Standard Operating Procedure (SOP), with clear plans of corrective actions and verification procedures should non-optimal conditions exist.

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