Ozone as an Antimicrobial Agent in Food Extraction Processes

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Abstract

With the FDA and USDA acceptance of the 2001 EPRI Food Additive Petition that allows the use of ozone as a contact antimicrobial agent in food processing, numerous food processing studies utilizing both gaseous and aqueous ozone were undertaken. The study herein traces the evolution of the use of ozone in food processing and presents how this evolution led to the emergence of the use of ozone as an antimicrobial agent in the extraction of food grade proteins, spices and essential oils.

Extraction processes traditionally utilized chemical solvents such as hexane, acetone and ethylene dichloride that selectively dissolved biological components in food products. Once the desired components were dissolved, they were reclaimed through solvent removal processes. These chemical extraction processes are being replaced by more gentle processes that utilize solvents such as carbon dioxide, ethanol and water for extraction. Today many proteins are extracted using cool water. Extractions at higher temperatures render the final products unusable. These cool water extractions can result in environments highly suitable for microbial growth. To control microbial growth, processors utilize Best Manufacturing Practices (BMP's) and HACCP programs that strive to ensure product environments that are not conducive to microbial growth.

The BMP's utilized are raw product cleanliness, avoidance of cross contamination and equipment cleanliness. HACCP programs consist of procedures that ensure minimum exposure of raw products, intermediate products and final products to potential microbial contamination. Storage temperatures are monitored and antimicrobial treatments of storage areas are common. To supplement BMP's and HACCP, ozone treatments are being investigated and adopted. These practices include raw product washes with ozonated water as well as employing gaseous ozone treatments. Whenever possible, in-process treatments with aqueous and gaseous ozone are utilized. Final products and product storage areas are often treated with gaseous ozone.

Because ozone does not leave harmful residues on processing equipment, it is being tested as a clean-in-place (CIP) treatment for many processes. These CIP treatments are used both as cleaning techniques prior to shutting down process lines and intermediate cleaning during facility down-times. Preliminary results indicate that ozone CIP coupled with chlorine rinses can provide excellent microbial control. Residual chlorine can be removed with a quick ozone rinse prior to start-up. Ozone use in extraction processes and the utilizing of CIP procedures in extraction plants are very promising uses of ozone technologies.

Key Words: Ozone; Extraction; Distillation; Food Processing; Food Additive Petition; Antimicrobial; Ultra Violet; Advanced Oxidation; Fermentation; Crown Extractors; Density Gradients; Clean in Place

Background and Literature

With the FDA and USDA acceptance of the 2001 EPRI Food Additive Petition (FAP) that allows the use of ozone as a contact antimicrobial agent in food processing, numerous food processing studies utilizing both gaseous and aqueous ozone were undertaken. The study herein traces the evolution of the use of ozone in food processing and presents how this evolution is leading to the emergence of the use of ozone as an antimicrobial agent in the extraction of food grade products, spices and edible oils.

Early use of ozone on food products is explored in the FAP as presented to the FDA and USDA. This petition which was delivered to the FDA on August 15, 2001 is roughly 2000 pages and covers all ozone studies relative to foods that could be found by the EPRI petition preparers. The petition is available from the FDA under the Freedom of Information Act. Due to the length of the petition, copying fees can be costly. A CD of the FAP is available through the International Ozone Association.

(Sopher, Graham and Rice, 2001) prepared an EPRI document on the use of Ozone as an antimicrobial agent. This document provides a 44 page review of the use of ozone in food processing. A listing of the references cited in the FAP is attached as an Appendix.

After the FAP was accepted by the FDA and USDA, research and practical applications on the use of ozone on fresh foods as well as in food processing facilities evolved using both aqueous and gaseous ozone technologies. Several of these studies were summarized by (Sopher, Parmenter and Arzbaecher, 2004) in an Ozone Handbook.

Recent applications utilizing ozone in Food Processing can be found in *Ozone Science and Engineering*. These articles are readily available through the IOA website http://www.ozonescieng.com. Recent reports on the IOA website include: (Steffen, Zumstein and Rice, 2010); (Steffen and Rice, 2010); (Karaca, 2010); (Steffen, Duerst and Rice, 2010); (Sopher, Battles and Johnson, 2009); (Strickland et al., 2010). Many of these studies utilize combined Ozone, UV and Advance Oxidation treatments.

Technology Adoption

Even though the beneficial effects of ozone as an antimicrobial agent are well established and the need for better Food Safety tools is ever increasing, the utilization of ozone in fresh and processed foods seems at times to move forward and then languish for periods. This lack of acceptance can be attributed to:

1. Lack of understanding of the technology
2. Sporadic results
3. Safety concerns from ozone off-gassing
4. High capital investments in other Food Safety technologies
5. Perceived competition with other technologies such as UV and Advanced Oxidation
6. Real competition with chemical Food Safety treatments
7. Lack of residual food protection
8. Ozone equipment suppliers that often do not understand food processes and the measures used in Food Safety
9. Food processors with a lack of understanding of ozone technology and generation
10. 2009-2010 economic conditions that have stifled research, development and demonstrations in ozone use for Food Safety

As Food Safety concerns increase, technologies that will provide answers to the previous reasons for lack of acceptance will also develop. Off-gassing and the problems of sporadic results will be overcome. Technology transfer will be utilized to provide a full understanding of the use of ozone and will further enhance acceptance of the use of non-thermal antimicrobial treatments.

Until recently, ozone has not been utilized to any extent as an antimicrobial agent in food extraction processes. This lack of use of ozone in these processes is understandable in that in the past most of the extraction processes utilized heat somewhere in the process. This heat tended to provide sterilization or at least pasteurization of the final products. Today many extraction processes do not utilize heat; thus, high microbial levels may become a problem.

To understand the need for ozone and other non-thermal antimicrobial treatments the following brief overview of extraction processes is presented. This overview is not exhaustive and is a summary of the authors' experience with the processes and extraction technologies.

Extraction Technologies

The technologies usually utilized to extract a product from a raw agriculture product can involve chemical extraction with a solvent, extraction of oil components utilizing pressure and distillation.

Chemical Extraction

Many of the original extraction processes were developed for oil extraction from oil seed crops such as soybeans, corn, and sunflowers. The process consisted of grinding the seed of oil crops and extracting edible or nutritious oils and other components using solvents such as hexane. Once the solvent dissolves the extractable product(s) it is removed and recovered through solvent removal processes. The remaining product or what is commonly called "cake" is washed and pelletized for animal feed.

Chemical extractors generally are either batch extractors or flow-through extractors (often called counter-flow extractors). For batch extraction, materials are placed in a vessel and solvent is added. The solvent may be added with or without agitation. Once the solvent and the material being extracted have reached equilibrium, the solvent is removed. The extracted products are separated from the solvent. This technology works well on smaller batches of product and is often used to extract spice and flower crops for concentrated flavors and colors. Examples of these extractions are chili pepper extraction which results in pepper oleoresins with capsaicin levels many times higher than the original pepper and paprika extracted for red color and used to enhance the color in food products.

Today there are many types of extracted spice and botanicals products in the food trade. Although batch extractors have their place in food extraction processes, static or batch processes are not favored in manufacturing processes because they do not result in a continuous flow of final product. Figure 1 is a laboratory example of a batch extractor.

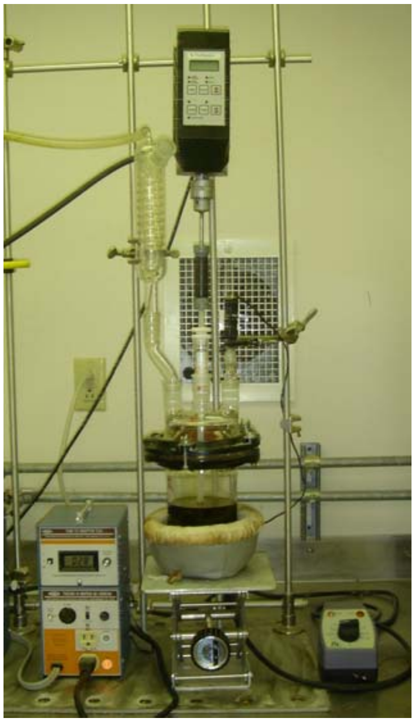

Figure 1: Laboratory Extractor for batch operations. (Photo supplied by Avoca Inc.)

Figure 2: Batch Extractors (Photo supplied by Avoca Inc.)

The batch extraction technique shown in Figure 2 grew from the laboratory extractor shown in Figure 1. There are many batch extractors and the one used will depend on the amount of material to be extracted.

Flow through or counter-flow extractors have become more popular. Figure 3 is an example of a counter flow extractor commonly called a rotocell. It is a circular extractor with various compartments that are filled with feed stock and then solvent is moved through the compartments. After the solvent is moved through the compartments the first compartment filled is then treated with fresh solvent and given one more extraction. The extracted (spent) material is removed and the compartment refilled. The process is continuous with fresh solvent being the final treatment for each compartment.

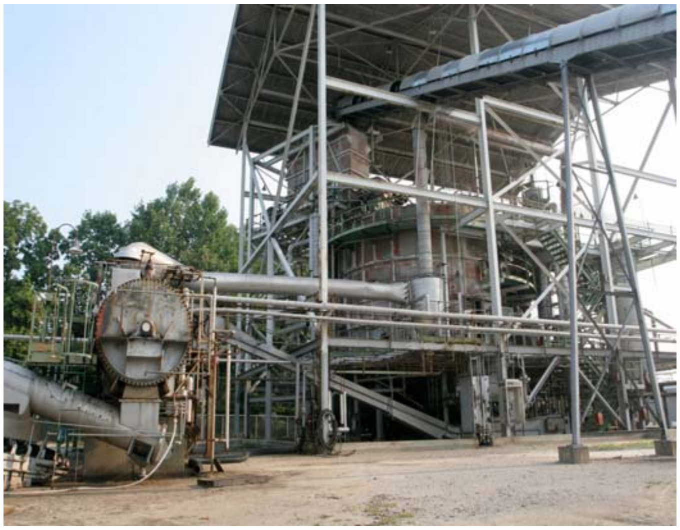

Figure 3: The Avoca Rotocell (Photo supplied by Avoca Inc.)

The equipment in Figure 3 was patterned after soybean extractors in the 1950s and 1960s and is capable of being utilized for such extraction today. The Avoca unit was never used for oil crop extractions. It has a long history of extracting sclareol from clary sage (S*alvia sclarea*). Components from clary sage are utilized in the food, cosmetics and tobacco industry.

Today there are several extractors on the market. Crown Iron Works Company at: Http://www.crowniron.com/ is one of the oldest companies and it is suggested their website be visited for further information on extractor types. Figure 4 and Figure 5 depict Crown Extractors utilized for food extraction purposes.

The extractors shown in Figures 2-5 are provided to demonstrate the size of extraction units that are available. Large extractors can extract massive amounts of material per day. The infrastructure in roads, water supplies, electrical needs, waste treatment and transportation can be massive. Also, the extractors shown in Figures 2-5 are not necessarily dependent on using strong solvents such as hexane and acetone. Many extractions are made using ethyl acetate, isobutyl acetate, alcohols and or water as a solvent. Instead of oils being extracted, many processes extract proteins. These proteins are often very temperature sensitive and extraction temperatures are critical.

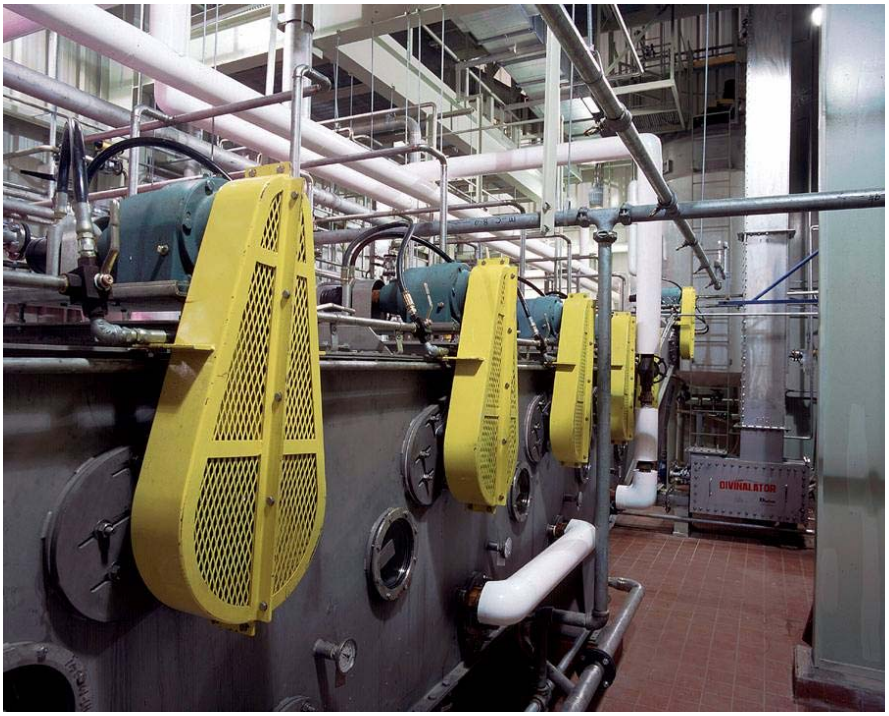

Figure 4: Crown Extractor (Photo Supplied by Avoca Inc.)

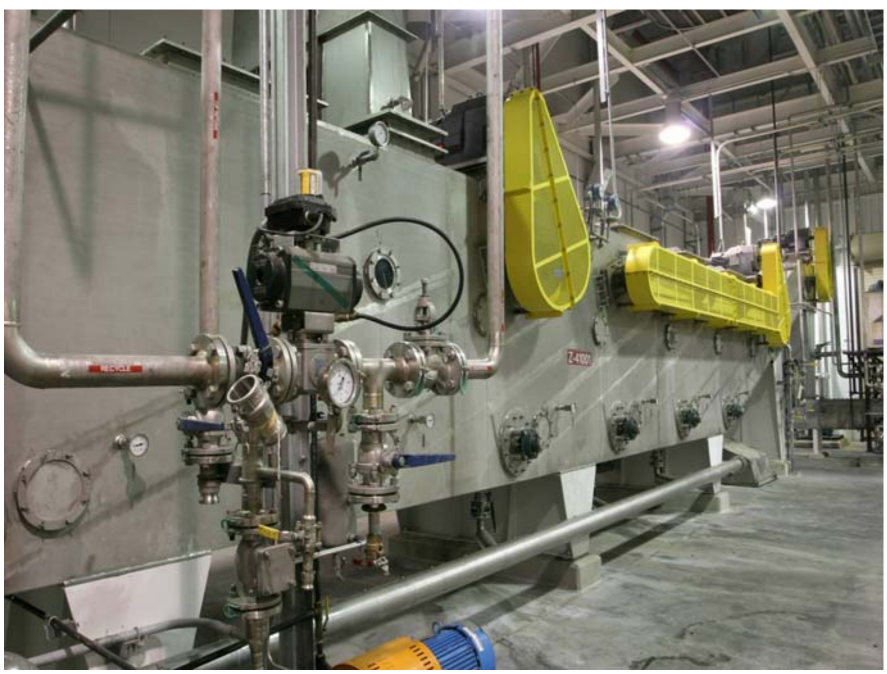

Figure 5: Crown Extractor (Photo supplied by Avoca Inc.)

Pressure Extractions

Oil seed crop extractions can also be accomplished by pressing the crop under medium pressures and simply squeezing the oil from the crop. This technique is often favored for food grade oil so the stigma associated with commercial solvents can be avoided. This technology was and still is very successful but total removal of essential oils cannot be attained and residual oils usually remain in the final product.

Column Chromatography

This extraction technique is fairly complicated but can be very gentle when separating liquid fractions into various components. The procedure is mentioned to acknowledge the technique and recognize the possible need to protect the extracted product with an antimicrobial agent.

Distillation of Extractable Products

Often many products are extracted using simple distillation technologies. These technologies include controlled heat to liquids and live steam for extracting oils and flavors. Alcohols are often separated by controlled heat. Basil and dill oils are examples of products collected by steam extraction.

The Importance of Ozone Treatments in Extraction Processes

The processes discussed under various types of extraction technologies and equipment are important in ozone and non-thermal antimicrobial technologies because all of the processes have the following needs:

- All of the processes are used to some extent for food grade products and Food Safety is paramount.
- All of the processes use raw products that can often benefit from antimicrobial treatments before they are extracted
- Once extracted, the final products must be controlled such that microbial populations do not multiply and cause food-borne illnesses
- Lastly but probably the most important consideration is that all extraction equipment must be cleaned on a very regular basis. Because these extraction facilities are very large, the cleaning process can be expensive. Extreme care must be take to ensure absolute cleanliness

Drivers

The drivers to utilize ozone in food extraction are process dependent. In processes utilizing heat, there is often little need to use ozone. In extraction processes where heat above ambient temperatures can result in changed or altered amino acid profiles or other product alterations, there is often a need for non-thermal cleaning and microbial control.

Three technologies that can provide such cleaning and antimicrobial control are ozone, ultra violet light and advanced oxidation. Although the primary goal of this discussion is to present potential uses of ozone in food extraction processes, there are many applications where UV and advanced oxidation can be coupled with ozone to provide a high degree of microbial control as well as process safety.

The drivers for the use of ozone are:

- High energy costs to produce heat and or steam for clean in place (CIP) procedures
- Need for low or zero heat in the process
- Zero chemical residues in extracted products
- The potential for lower BOD and COD levels in waste water
- Lower process water use

Conclusions

In the future there will be considerable interest in the food extraction industry working with the ozone industry as well as other non thermal industries to provide:

- Clean incoming raw product streams
- Utilize ozone as an antimicrobial agent in final products
- Development of CIP procedures that reduce energy, water and wastewater costs

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