# Inactivating Pathogenic Micro-organisms Through Microwave Sterilization Technology

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***Abstract*—Microwave heating as a means of inactivating pathogenic micro-organisms in commercially produced food products in sterilization and pasteurization processes is discussed in this paper. The physics of a microwave heating system was explored and compared to the more widely used retorting processes. Existing and developing microwave sterilization processes were researched and are discussed here.**

***Index Terms*— Microwave oven, food technology, microwave technology, dielectric materials.**

## I. INTRODUCTION

A Microwave oven's ability to heat food is a result of an interaction between polar moisture molecules and charged ions in a rapidly alternating electromagnetic field. Exploiting the use of microwaves as a method of sterilizing food products can be highly advantageous when compared to conventional retorting processes.

## II. PRINCIPLES OF OPERATION

When food is placed inside a microwave oven, the dipolar moisture molecules contained within the product react to the alternating electromagnetic field with which it is illuminated. These water molecules will attempt to track the charged ions in the electromagnetic waves and will cause friction, which in turn results in a rise in temperature [1]. Microwave ovens operate on either the 915 MHz or 2450 MHz frequency bands (as allocated by the Federal Communications Commission (FCC)), the former being implemented exclusively in industrial heating systems.

In these type of systems, the product to be sterilized is placed in a microwave oven where heat is generated directly inside the product, creating the potential for increased uniformity in the heating pattern and greater control over the overall product temperature.

On the other hand, conventional retorting systems rely on a high pressure stream of hot water to inactivate degenerative micro-organisms such as bacteria. In contrast, these systems function by transferring heat to the surface of the material under test by means of convection, conduction or infrared radiation. The heat is then displaced to the interior by thermal conduction.

## III. ADVANTAGES OF MICROWAVE STERILIZATION

Sterilization with microwave technology holds key advantages over conventional retorting. The most prominent being a greatly reduced processing time; this is especially beneficial since a prolonged exposure to an elevated temperature environment causes a decline in sensory attributes of food products, reducing value as well as shelf life [2].

Due to the nature of conventional retort heating, the processing time for a standard packaged meal is at least 45 minutes, which is excessive when compared to a processing time of under 10 minutes observed in microwave systems. This is a direct result of the difference between the two technologies; where the manner in which heat is generated in the material as well as the fact that microwave power can be activated and deactivated instantly raises questions regarding the efficacy of conventional sterilization processes.

The nature of microwave processing also eliminates the need for refrigeration in certain products, which can reduce refrigeration and storage costs astronomically.

## IV. LIMITATIONS AND CHALLENGES

Designing a microwave sterilization system is not without its challenges and designers are persistently exploring new techniques and technologies to identify cold spots caused non-uniform radiation and standing-wave patterns inside the oven, determine optimal packaging solutions and dealing with varying dielectric properties. Perhaps the most prominent difficulty designers are faced with lies with dielectric properties of food products; which differ depending on the type of product, their current temperature and also the frequency at which they are being radiated.

Predicting and controlling the heating applied by a microwave system and locating cold spots inside the material becomes increasingly difficult when these parameters are considered.

All of these complications contribute to an overall increase in cost of a microwave sterilization system, which at the moment greatly exceeds that of a conventional processing system.

An important consideration is that advances in the field will depend on adapting microwave heating equipment to the sterilization process, instead of adapting processes to currently available microwave systems – utilizing frequencies in the THz range being one example.

## V. RESEARCH FOCUS

Research conducted by the Biological Systems Engineering Department at the Washington State University is primarily focused on obtaining widespread approval by the Food and Drug Association for their pilot 915 MHz sterilization process. This system consists of a single-mode microwave oven operating in the aforementioned frequency band. Radiating dielectric materials at this frequency is advantageous in food processing because of the increased penetration depth associated with the lower frequency (compared to current generation domestic microwaves which operate on 2450 MHz). This stems from the dependence that penetration depth displays on frequency and temperature. However, microbiological safety of foods processed at this frequency cannot be entirely validated.

Fiber-optic sensors have been developed into the test facilities at the Washington State University as a suitable means to measure temperatures in short-term processes. This is absolutely necessary in developing the sterilization process, since one of the key difficulties lie in monitoring process history which is necessary to determine microbiological safety. These sensors are particularly suited for short duration processes; due to their small size, which leads to a reduction in response time as well as the fact that they do not interact with microwaves.

Another series of experiments that compare and evaluate alternative packaging materials have been extensively conducted in the laboratories at the National Aeronautics and Space Administration. The results of these experiments – which are focused on determining the optimal packaging solution for long term space missions – are directly relevant to commercial microwave processing of food products.

The most suitable solution thus far consists of thin films engineered from ethylene vinyl alcohol; these films have good resistance to temperatures of approximately 130 °C, display satisfactory barrier properties that enhance shelf life and they are also the least problematic when regarding solid waste disposal. This solution has limitations of its own, such as a high moisture absorption rate in high humidity conditions.

Despite these advances in packaging and process technology, the optimal sterilization solution lies with utilizing a combination of microwave and retort heating, or combination heating as it is recognized as in the literature. It has been shown [4] that the use of microwave-circulated water combination technology has respectable potential in sterilization of packaged foods.

As briefly mentioned earlier, exploitation of the advances in THz spectroscopy in medical and nutritional applications also hold merit in food processing. Research conducted in [6] provide encouraging results with regards to the efficiency of THz spectroscopy. It is clear that the ability to record real-time and non-invasive measurements are extremely valuable in food processing, enhancing the ability to accurately measure the behavior of microwave sterilization systems.

## VI. STANDARDIZED INDUSTRIAL USAGE

As mentioned earlier, as a result of more stringent approval criteria by the FCC in the United States; microwave sterilization processes are not implemented industrially there. A fairly low amount of products have been cleared for this type of processing thus far [5], therefore limiting its value in most food processing facilities.

However, TopsFoods Olen NW in Belgium utilizes this technology for a wide array of products (as do the Otsuka Chemical Co. in Japan); the continued implementation by these companies is a verification of the commercial value and potential that it offers.

## VII. PRACTICAL AND ECONOMIC CONSIDERATIONS

There are a number of practical and economic factors that influence the implementation of dielectric heating and sterilization systems. In a tightly controlled environment, combination heating methods can achieve acceptable temperature distribution, which in turn will improve overall product quality. The process in itself is also quite flexible and is thus well suited for automated heating lines.

However, as soon as foods that are nonhomogeneous in composition and temperature or irregularly shaped items are heated, a substantial uncertainty is introduced in the nature of the heating pattern which leads to largely uncontrolled heating.

Ensuring this high level of quality and control, causes equipment cost to increase along with the overall complexity of the system, which in turn limits the exportability to developing nations.

## VIII. CONCLUSION

Various aspects concerning microwave sterilization and pasteurization technology were investigated and discussed. It is clear that further developments in process technology is required in order to apply the technology to an acceptable range of food products; but the potential shown in economic viability and increased product quality have resulted in continual research and development focus in the field.

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