Chapter 5
Milk Pasteurization and Characterization Using Mono-Mode Microwave Reactor and Slotted Coaxial Antenna

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ABSTRACT

Mono-mode microwave reactors are usually used to heat substances, especially food. This is because heating using a microwave reactor can sustain the flavor, color, and nutrition of the food. Furthermore, this heating technique is cost-effective and time-saving compared to a conventional heating method. The mono-mode reactor is able to determine the absorption of microwave power accurately on the heated substance versus a multimode reactor. In this chapter, a simple and precise mono-mode microwave reactor is designed and developed especially for research laboratories. The advantage of this reactor is to provide a more accurate calibration process, in order to improve the optimum energy use in the heating process, as well as the temperature of the specimen. The reactor can generate output power from 30 watts to 1500 watts, operating at 2.45±0.03 GHz and capable of accommodating a specimen volume of 780 cm^3. Pure water is used as a heated specimen to demonstrate the performance and efficiency of this reactor.

DOI: 10.4018/978-1-5225-9420-8.ch005

INTRODUCTION

Microwave Reactors

In 1945, the heating effect of microwave energy was accidentally discovered by Percy Spencer when he noticed the melted candy bar while he was objected to the active radar. He decided to test it with popcorn and egg and the food was cooked using microwave. In 1947, the first commercial microwave oven so-called "Radarange" was developed by Raytheon with weight of 340 kg and height of 1.8 meter (Osepchuk, 1984). In 1967, the first domestic (home model) microwave oven was commercialized byAmana (a division of Raytheon).

Microwave heating is characterized by conventional heating being penetrative heating, non-contact which reduces of overheating of material surfaces, short thermal gradients, volumetric heating, energy saving, environmentally friendly, and fast which increases the production rate (Bogdal, 2005; Groisman and Gedanken, 2008).

Recently, the use of microwave reactor is growing rapidly in the process of heating in food stuff factories, such as food dehydration/frozen drying and food pasteurization/sterilization for storage control. The reason is due to the tendency of water to absorb microwave energy and generate the heat within the food. When the raw food is exposed to the microwave, the water molecules in the food will be induced to rotate and produce heat as shown in Figure 1 (You, 2017). Thus, the rate of water removal and the effective used energy are higher than hot-air drying method. Besides, the microwave heating is capable of maintaining original texture structure, nutrition, flavor and color of the food at specify heat temperature compared to conventional oven drying techniques.

The comparison of the efficiency of used energy between various heating techniques is listed in Table 1 (Constellation, 2016).

There are two microwave frequencies allocated by the US Federal Communications Commission (FCC) for industrial, scientific and medical (ISM) use, which are 915 MHz and 2.45 GHz. Normally, most of the microwave heating applications are devoted to 2.45 GHz, since it provides a suitable compromise between power deposition and penetration depth as well as it is an unlicensed operating frequency. Villamiel et al. (1996; 1998) have demonstrated the effectiveness of microwave heating over conventional heating proved that volumetric heating at 2.45GHz produces lower denaturation levels of whey proteins and β-lactoglobulin as compared with conventional pasteurization. In addition, Coronel et al. (2003) used 915 MHz microwave applicator based on continuous-flow and it is shown that milk is heated rapid

Table 1. Comparison of energy efficiency for various heating techniques (Constellation, 2016)

Heating Techniques	Temperature (°C)	Heating Time	Used Energy (kWh)
Electric Oven	350	1 Hour	2.0
Electric Convection Oven	325	45 Minutes	1.39
Gas Oven	350	1 Hour	0.90
Electric Frying Pan	420	1 Hour	0.90
Toaster Oven	425	50 Minutes	0.95
Electric Crockpot	200	7 Hours	0.70
Microwave Oven	High	15 Minutes	0.36