# Review of Microwave Food Processing

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***ABSTRACT:** Microwave heating has a wide range of uses in the food processing industry, including cooking, drying, pasteurization, and food preservation. Various microwave food processing applications, such as microwave cooking, microwave pasteurization, and microwave aided drying, were thoroughly examined in this article. The benefits of microwave cooking of food items have been examined, as well as the variables that influence microwave cooking. The topic of microwave pasteurization of fresh juices, milk, and other foods has been extensively explored. Because of the substantial increase or multiplication of thermal effects, microwave pasteurization may destroy bacteria at temperatures lower than traditional pasteurization. Microwave aided hot air drying, microwave vacuum drying, and microwave freeze drying are all examples of microwave drying applications. Microwave drying, when coupled with other traditional drying techniques, improves the drying properties of microwave drying alone. Modeling of microwave heating of food materials using Maxwell's equations and Lambert's law equations, as well as their applications, have been discussed. The temperature and moisture distributions during microwave heating of food products may be predicted using microwave modeling. The variables that influence food material's dielectric property, as well as the uses of dielectric property measurements, were also addressed. Several solutions were suggested to address non-uniform temperature distribution during microwave heating of food items. More research at the pilot scale level is needed to achieve improved final product characteristics of food ingredients. During microwave heating of food items, it's also important to avoid hot patches or uneven temperature distribution.*

***KEYWORDS:** Cooking, Drying, Modeling, Microwave Heating, Pasteurization.*

## INTRODUCTION

Over the course of many decades, microwave heating has had several uses in the area of food preparation. Microwave heating is used in food processing for a variety of purposes, including drying, pasteurization, sterilization, thawing, tempering, and baking of food components. Microwave cooking has grown in popularity in the food processing industry due to its ability to achieve high heating rates, significantly reduce cooking time, provide more uniform heating, be safe to handle, operate, and maintain [1]. Furthermore, when compared to conventional heating during the cooking or reheating process, microwave heating may change the flavor and nutritional qualities of food to a lesser extent. Microwaves are electromagnetic waves with frequencies ranging from 300 megahertz to 300 giga hertz. Industrial microwave systems use frequencies of 915 MHz and 2.45 GHz, whereas domestic microwave equipment use 2.45 GHz. Section 2 discusses dielectric properties of food materials, measurement techniques, and applications; Section 3 discusses microwave cooking; Section 4 discusses microwave drying; Section 5 discusses microwave pasteurization and sterilization; and Section 6 discusses modeling microwave–food interactions [2]. This study focuses on the most recent advances and present state of microwave food processing research, as well as future research directions. The capacity of materials to absorb microwave radiation and convert it to heat causes microwave heating.

Dipolar and ionic processes are primarily responsible for microwave heating of food items. The dipolar property of water produces dielectric heating in the presence of moisture or water. When water molecules are exposed to an oscillating electric field, the permanently polarized dipolar molecules attempt to realign themselves in the direction of the electric field [3]. This realignment happens at a million times every second because to the high frequency of the electric field, causing internal friction of molecules and volumetric heating of the material. The rhythmic movement of ions in the meal, which produces heat in the presence of a high frequency oscillating electric field, may potentially cause microwave heating [4]. Microwave heating and heat dispersion are influenced by a number of variables, the most significant of which are dielectric characteristics and penetration depth. Knowing a material's dielectric characteristics may help you figure out how well it converts microwave radiation to heat. The actual portion of dielectric property, known as dielectric constant, refers to the capacity to store electric energy, while the imaginary part, known as dielectric loss, refers to the ability to transform electric energy into heat. Pure water's dielectric constant drops somewhat with frequency.

Similarly, the dielectric loss of wet meals rises with increasing frequency. The chemical content and, to a lesser degree, the physical structure of dietary items influence their dielectric characteristics [5]. Food is often made up of a combination of organic material, water, and salt. With the addition of salt, the dielectric loss at a given frequency rises. In the presence of an electromagnetic field, salt solutions behave as conductors, resulting in a reduction in permittivity and an increase in the dielectric loss factor, as discovered by Icier. Water has different dielectric properties depending on whether it is in a free or bound condition. The polar molecules of free water orient more easily than those of bound water in the presence of an electric field. The dielectric characteristics of frozen materials with a high water content may improve as the melting zone temperature rises [6]. Runaway heating of frozen and thawed meals causes non-uniformity problems because the warm portion is quickly heated while there is still some ice remaining in the food substance. The dielectric properties of dietary components may also vary depending on particle size, structure, and density. The apparent density of a granular or particulate material's air–particle combination affects dielectric characteristics as well. The dielectric characteristics of foods like bread, wheat, fruits, and vegetables are mostly determined by their water content. Although the dielectric constant and dielectric loss values for fats and oils are usually modest, a temperature-dependent rise in dielectric loss has been reported.

For solutions containing salt, sugar, and carboxyl methyl cellulose (CMC), the change of dielectric characteristics with temperature and microwave frequencies was studied. Based on the findings, it was determined that CMC has no substantial impact on dielectric characteristics but does have an effect on viscosity [7]. The dielectric constant of sugar solutions rises with temperature and sugar content. Due to the non-polar nature of sugar, the dielectric loss factor reduces with sugar content, but it was also discovered that the dielectric loss factor rises with temperature. Sugar, salt, and CMC, for example, may be used to imitate the dielectric and rheological characteristics of the food product to be processed. For frequencies over 1 GHz, dielectric loss rises with temperature for natural honey with an 18% moisture content [8]. The dielectric characteristics of in-shell and shelled peanuts at different densities, temperatures, and moisture content across a frequency range of 300 to 3000 MHz were found to increase with water content at low frequencies owing to ionic conduction. The dielectric characteristics of low moisture content samples were found to be temperature dependent at microwave frequencies of 915 and 2450MHz.The dielectric characteristics, on the other hand, were shown to be less important on temperatures at greater moisture levels. Various methods, including as the lumped circuit, resonator, transmission line, and free space method, may be used to test dielectric characteristics. For frequencies below 100 MHz, the lumped circuit approach is appropriate, but it is not appropriate for low-loss materials. For frequencies between 50 MHz and 100 GHz, the cavity resonator method may be utilized. This method works at high and low temperatures, as well as for materials with extremely low loss tangents loss tangents in the tens of thousands [9]. The transmission line technique works well for liquids and solids, but not for gases since their permittivity is so low. This technique may be used for frequencies ranging from low to high.

Microwave permittivity is used to determine the ripeness of peaches. Fresh peaches were chosen for their various states of ripeness. The Dixired variety was the first to mature, followed by Red haven, and then Windblown. At 0.2 GHz and 10 GHz, peach permittivity levels are linked to different phases of maturation, which are also depending on variety. The open-ended coaxial line probe and network analyzer were used to test permittivity. At 0.2 GHz, an increase in dielectric constant was seen as maturity progressed, however the dielectric loss was found to be unaffected by maturity stages. At 10 GHz, however, dielectric loss was shown to rise with maturity, while the dielectric constant was found to be unaffected by maturity stages. The permittivity maturity index, which is defined as the ratio of a sample's loss tangent at two distinct frequencies, particularly at lower and higher frequency ranges, may be used to identify the various phases of maturity. vegetables apple, banana, avocado, cantaloupe, carrot, cucumber, grape, orange, and potato at temperatures ranging from 5 °C to 95 °C across a frequency range of 10 MHz to 1.8 GHz. The dielectric loss factor dropped significantly as frequency increased, while the dielectric constant fell little. Similarly, the dielectric loss factor was shown to rise with temperature in most cases. The dielectric constant, on the other hand, was shown to increase with temperature at lower frequencies while decreasing at higher frequencies.

Due to the presence of more water in the tissue sample, the dielectric constant of fruits and vegetables with higher moisture content is typically higher across temperature ranges of 5 °C to 95 °C. The loss factor is affected by the ionic conduction process at low frequencies in the region of 200 MHz to roughly 12 GHz. Between 1 and 2 GHz, the dielectric mechanism changes from ionic conduction to dipole polarization, and beyond 2 GHz, the dielectric loss behavior is dominated by the dipolar relaxation mechanism. Carrot has the greatest magnitude of permittivity values at low frequencies, it was discovered dielectric constant and dielectric loss. Fruits and vegetables with the lowest dielectric constant values were determined to be carrot, avocado, cantaloupe, orange, potato, banana, cucumber, grape, and lastly apple. Carrot, avocado, banana, grape, cantaloupe, potato, orange, cucumber, and apple are in decreasing order in terms of dielectric loss. Although moisture content was not linked to dielectric characteristics, other variables such as density, tissue structure, and the type of water binding to fruit and vegetable components may have influenced dielectric capabilities [10].

## DISCUSSION ON WORKING OF MICROWAVE FOOD PROCESSING

Microwave cooking is one of the most common uses for the device. Different studies on the effects of microwave cooking on quality, flavor, and color retention for various food ingredients are discussed in this section. There have been many reports about utilizing microwaves to bake bread and cook rice and meat. In many instances, a comparison between microwave and conventional cooking is done. Browning and excellent texture are required in the bread baking process at a constant moisture level. Traditional baking with hot air produces the desired color and texture. Microwave baking did not provide enough brown color on the surface of the loaves, nor did it allow for crust development. The air around the food product is cold during microwave cooking, and water evaporating from the food condenses when it comes into touch with the cold air, resulting in a loss of crispness in the food product. Subsectors were put at the bottom of the sample to help the food product develop a crust and brown on the top. Subsectors are microwave-absorbing materials that convert microwave energy to heat and transfer it to weak microwave-absorbing materials through conduction and radiation.

Microwave and jet impingement may produce a crisp crust with a brown hue. Jet impingement baking is done with the assistance of a professional electrical oven and high-speed convection. The air jets were injected at a speed of 10 m/s from top to bottom. Combining high-speed convection heat with microwaves in the same JET oven results in microwave–impingement combo baking. Microwaves were introduced from the top, and air jets were introduced at a speed of 10 m/s from both the top and bottom. Microwave infrared baking combines microwave and infrared heating into one convenient package. Halogen lights were installed at the top oven ceiling and bottom oven floor of the combined oven, as well as a rotating table to enhance sample heating uniformity. The temperature was greater in a microwave–infrared combination, intermediate in a microwave–impingement combination, and lower in a JET oven, according to the findings. When comparing loaves cooked in JET to those prepared in other combination modes, JET breads maintained the most moisture. The temperature at the surface was lower and a lot of moisture had escaped because microwave plus infrared heating did not create a strong, hard outer crust. As a consequence, the ultimate volume of the bread is reduced. Based on these findings, it is determined that microwave baking, either alone or in conjunction with other types of heating (hot air or infrared), does not provide superior final product quality than traditional baking. Microwave-baked loaves had the lowest moisture level of any of the samples.

During microwave heating, a significant amount of heat is produced throughout the sample volume, resulting in the formation of an internal pressure gradient. This causes a flow of quickly departing vapor outward. Microwave-baked samples, among other heating modes, had the greatest hardness, setback viscosities, total mass crystallinity, and retro gradation enthalpies. As a result, staling occurs more quickly in microwave cooked loaves than in traditionally baked breads. The inclusion of specific ingredients, such as xanthan guar mix, and other household appliances, such as an electric rice cooker (ERC) and an LPG (liquid petroleum gas) pressure cooker, may also significantly delay the staleness of breads. For regular, continuous, and regulated cooking, unoaked and pre-soaked rice were used. The rice and water combination was heated to 100 °C in controlled cooking, and then the heating was restarted after a 5-minute power outage. The conversion efficiency of electrical to microwave and microwave to thermal energy were determined. The theoretical efficiency was calculated as the ratio of the minimal energy required for cooking to the total energy input. The absorption efficiency was calculated by dividing the thermal energy produced by the electrical energy input. The results of different cooking techniques for regular cooking of unoaked and presoaked rice in terms of specific energy consumption. Despite the fact that microwave cooking of rice took less time than other techniques, the electric rice cooker was determined to be the most energy efficient. The moisture content of rice cooked in an electric oven was found to be low at the top and bottom and high in the middle. Surface evaporation produces a reduction in moisture content at the top, while the moisture level was low at the bottom owing to the presence of the heat source. The moisture content was almost uniform in microwave cooking owing to volumetric heating, except at the top, where the moisture level was somewhat lower due to surface evaporation.

Even though microwave rice cooking has a shorter cooking time and greater moisture distribution uniformity, the energy efficiency of microwave rice cooking must be improved to compete with an electric rice cooker. In a single-mode microwave vibrio-fluidized bed drier, unfrozen and frozen cooked rice is dried. The dried cooked rice should have a suitable porosity structure to produce instant rice with excellent rehydration capacity. Furthermore, for a professional look, the whiteness must be maintained. Rice becomes gelatinized after cooking as a result of water absorption. When it comes to microwave heating, water in a bound form has a low dielectric constant. To produce rice that was separated with a certain texture, a conventional cooking method of two-step soaking and steaming was used. Hot air was fed from the bottom to a bed of cooked rice supported on a vibrating perforated plate during drying, and microwave energy was irradiated to the fluidizing cooked rice at the same time. For the calculation of the effective moisture diffusivity and activation energy, mathematical models with exponential and linear temporal changes were suggested. Whiteness, microstructure, bulk density, and rehydration capacity were all evaluated as quality criteria. Based on the findings, it was determined that no pre-freezing treatment was needed and that drying at 160°C was sufficient to guarantee whiteness, porous structure, low bulk density, and excellent rehydration capacity. The quality of the product was influenced more by process factors such as power output and cooking time than by product parameters such as bacon type and chemical composition. When compared to back bacon, streaky bacon exhibited more uniform heating due to its greater fat content. Fats were not evenly distributed in back bacon, with a smaller quantity of fat towards the margins.

As a result, a lower power output and a longer cooking time for back bacon may result in a more consistent and acceptable product. It was also discovered that the presence of containers impacted the strength of the microwave field, as well as the weight loss and processing time. Due to consistency in magnetron location and material movement through the microwave system, cooking in an industrial microwave was more uniform than in a home microwave oven. By minimizing weight loss, cooking time, and ensuring uniform cooking, the industrial microwave oven produced a superior and more cost-effective product. In a home microwave oven, the most efficient setting for cooking streaky bacon was 1000 W for 3 minutes with the sample maintained 43 mm above the turn table. The most effective operation condition for back bacon was 500 W for 5 minutes at the same height. When kept in a vacuum at 0 °C to 4 °C, these goods have a minimum shelf life of 11 days. The impact of different fat levels on microwave cooked goat meat patties (5, 10, 15, and 20%). Because the dielectric constant and loss factor decrease as fat content increases, each burger was cooked in the microwave. A sample with a high fat content may also have a reduced specific heat capacity, resulting in a slower heating rate. Because of the substantial overall cooking loss, the product yield (i.e. the ratio of cooked weight to raw weight) was found to be considerably lower for the 20% fat level. It's important to note that the cooking loss refers to the weight lost as a result of the cooking process. The cooking loss during microwave heating may be minimized by seasoning the beef patties with salt or sodium.

Furthermore, cooking 20 percent fat patties resulted in a greater fat percentage retention than cooking other fat patties. Because of the increased lubrication of the shear force apparatus, the shear force values of cooked patties with 20% fat content were determined to be the lowest. Visual color assessments showed that the greatest redness value was discovered in the 5% fat level, while the highest yellowness was found in the 20% fat level. Furthermore, sensory research showed that patties with low fat levels had less taste and juice than those with high fat levels. I cooked at 100°C in water, (ii) fried at 180°C in refined sunflower oil, (iii) canned using a normal canning method, and (iv) microwaved for 10, 15, and 20 seconds. The loss of health-promoting PUFA was shown to be I little when cooking or boiling, (ii) 70–85% when frying, (iii) 100% when canning, and (iv) 20–55 percent when microwave heating.

## CONCLUSION AND IMPLICATION

Microwaves have been effectively utilized in a variety of food operations, including cooking, drying, and pasteurization. Experiments on different microwave aided food processing methods and modeling of microwave heating of food components were discussed in this paper. When constructing a microwave oven, understanding dielectric characteristics is very beneficial. The shape, size, and location of a food item were discovered to influence non-uniform temperature distribution during microwave cooking. In general, hot spots were more prevalent in the middle of a food substance than in other areas. Moisture and fat levels in food items have an impact on microwave cooking. Microwave cooked foods have the benefit of maintaining more flavor, color, quality, and nutritional content than those prepared using other techniques. Because of the substantial amplification or multiplication of heat effects, microwave pasteurization was discovered to be more efficient in the eradication of germs or the inactivation of enzymes. When microwave drying was coupled with additional drying techniques such as air drying, infrared drying, vacuum drying, or freeze drying, the drying properties were better than when microwave drying was used alone. Microwave heating of food items was modeled using a combination of electromagnetic equations (Maxwell's equations or Lambert's law equations) as well as heat and mass transport equations to predict temperature and moisture distribution during microwave heating. Microwave heating of food items with supports and microwave heating of porous medium are among the uses. Although microwave radiation has a broad range of applications and uses in different culinary processes, further study is needed in some areas. Methods for obtaining final food items with improved sensory and nutritional characteristics, in particular, must be investigated. Other potentially difficult areas include increasing energy efficiency in rice cooking and producing a high-quality result in bread baking. Microwave processing of food ingredients should be done on a pilot scale rather than in a lab setting if the findings are to be relevant for industrial applications. Despite the fact that microwave–food interactions are complicated, additional study is needed to get a better knowledge of the process.

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