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Microwave Processing of Foods: Applications and Future Perspectives

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Abstract

This paper introduces microwave-assisted processing of foods, fundamental principles and future perspectives provides a comprehensive exploration of the evolving landscape of microwave technology in the food processing. Despite widespread use in households, the industrial application of microwave processing remains relatively untapped. The narrative delves into specific applications, such as blanching, baking, pre-cooking, thawing and tempering, pasteurization, sterilization, microwave-assisted frying, rapid extraction, drying and inactivation of microorganisms, emphasizing the rapid temperature rise achievable in materials of low thermal conductivity. As the evolution of microwave technology continues, the emerging trends and future prospects, offering a forward-looking perspective on its potential contributions to sustainable and efficient food production is discussed. However, it underscores the wide scope of microwave technologies in functional and novel food processing sectors, emphasizing ongoing research opportunities for microwave energy applications and innovative approaches. This paper serves as a comprehensive guide for researchers and food industry professionals interested in harnessing the full potential of microwave processing for the advancement of culinary science and the creation of innovative, high-quality food products. Furthermore, by exploring the synergy between microwave technology and food processing, this paper illuminates avenues for enhanced nutritional retention and flavor preservation. It also highlights the importance of optimizing microwave parameters for specific food matrices to achieve desired outcomes efficiently. As the field continues to evolve, interdisciplinary collaborations and advancements in microwave engineering promise to revolutionize food production, ensuring both sustainability and consumer satisfaction. This paper thus presents a roadmap for unlocking the untapped potential of microwave-assisted food processing.

Keywords: Microwave Processing, Food processing, Non-thermal technology

INTRODUCTION

As an innovative method that has gained prominence in recent years, microwave processing of food materials has gained significant attention due to the shorter processing time and energy consumption compared to conventional processing methods. The word "microwave" describes a range of frequencies that are used, as well as the techniques and ideas that are applied. Microwaves, or simply MWs, are electromagnetic (EM) waves that fall between 300 MHz and 300 GHz in frequency. In the EM spectrum they are embedded between the radiofrequency (RF) range at lower frequencies and infrared (IR) and visible light at higher frequencies [1–4]. MWs are classified as non-ionizing radiation as a result. Radar transmissions and cell phones, among other telecommunications uses, also employ the MW frequency range. Despite widespread use in households, the industrial application of microwave processing remains relatively untapped.

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Certain frequency bands are set aside for industrial, scientific, and medical (ISM) uses in order to reduce interference problems. A certain radiation level must not be exceeded by communication devices. In the range of MWs. the ISM bands are to be found at 433, 915, and 2450 MHz. The former is rarely used, whereas the latter is typically prohibited in European countries [5–7].

Outside the acceptable frequency range, leakage is forbidden. The 915 MHz frequency has some considerable advantages for industrial applications while MW ovens at home use 2450 MHz. Figure 1. Depicts electromagnetic spectrum.

Application of Microwaves in Food Processing

The applications of microwaves in food processing include pasteurization and sterilization of pre-packaged foods, cooking of meat products, tempering of frozen meat and poultry products, drying of various foods, baking of bread, biscuits, and confectionery products, thawing of frozen products, and blanching of vegetables [8]

Pasteurization

Pasteurization is a heating process that uses relatively mild heat treatment for foods to kill key pathogens and inactivate vegetative spoilage bacteria and enzymes to make food safe for consumption and increase shelf life. Microwave pasteurization systems typically take 1.5 to 2 min to raise product temperatures to 70°C. This is considered sufficient to control *L. monocytogenes* (≥6 log reduction) for a shelf life of 7 days under refrigeration. For a shelf life of ≈9 weeks, heating at 90°C, for a minimum of 10 min in the coldest spot, is required to control nonproteolytic *C. botulinum* [9].

Microwave pasteurization is a process that is a viable alternative for liquid food products where temperature homogeneity is easily achieved. However, with solid products, the most important limiting factor is the nonuniform temperature distribution, which is responsible for hot and cold spots in pasteurized products [10]. The presence of a cold spot could lead to survival of pathogenic microorganisms, which could be a major obstacle to the widespread development of industrial microwave pasteurization systems especially for solid food products [23]

Sterilization

Sterilization of food by heating has been designed to achieve commercial sterility (i.e., non-refrigerated shelf stability) of products. The magnitude of thermal treatment is a function of pH which is interrelated with the thermal resistance of certain bacterial sporeformers. Foods with high pH (low-acid foods, pH >4.6) support the growth of *C. botulinum* which produces a potentially lethal neurotoxin when it is allowed to grow. For a low-acid food, a thermal process sufficient to eliminate toxin-producing *C. botulinum* spores makes it commercially sterile in conjunction with packaging in a hermetically sealed container [11–13].

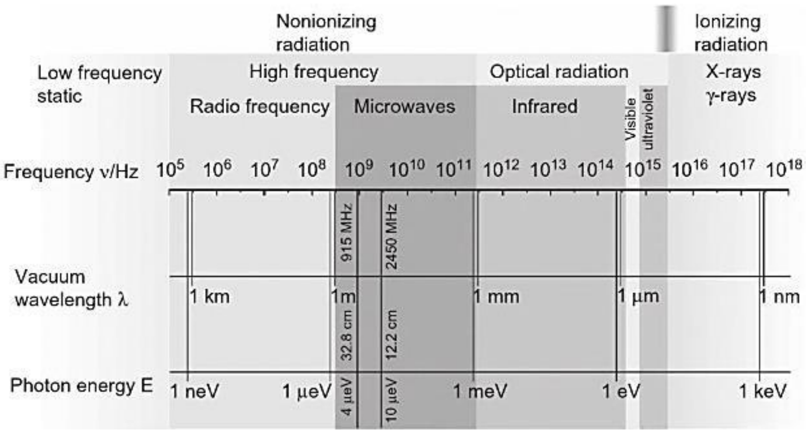

Figure 1. Electromagnetic spectrum [16].

The commercialization of microwave sterilization has faced many obstacles, including the requirement for reliable methods to monitor product temperatures and inconsistent and sometimes unpredictable electromagnetic fields within multimode microwave enclosures. Additionally, there is a dearth of packaging materials that are both highly protective and microwave-transparent.

Moreover, microwaves at 2450 MHz are only effective for processing food items with shallow thicknesses because they have limited penetration capabilities into food. Recently, scientist published an extensive literature review in which he described the development of a 915 MHz single-mode microwave-assisted thermal sterilization (MATS) technology which has received regulatory acceptance [14].

Cooking

The application of microwave heating for microbial inactivation in meat and poultry products has been the subject of numerous investigations. Nonetheless, a number of studies have reported cases when microbes were not completely eliminated when cooking in microwaves.

Uneven temperature distribution inside the food specimen is usually associated with incomplete inactivation. Researchers found, for example, that when chicken was cooked in a microwave, the internal and external temperatures varied by 3 to 11°C. The possibility of germs surviving in contaminated food items is increased when there is an uneven distribution of temperature across cooked product. These results emphasize how crucial it is to adhere to suggested procedures when figuring out when food that has been microwaved is done. To make sure the microorganisms are exposed to high temperatures for the appropriate amount of time, this involves utilizing a thermometer and giving enough standing time for temperature equalization.

Baking

Baking is a multi-step process that includes several physical, chemical, and biological changes in addition to the simultaneous transfer of mass and heat. A number of significant changes occur, such as the denaturation of proteins, the release of carbon dioxide from leavening agents, the expansion of volume, the evaporation of water, the creation of crust, and browning processes. Heat enters the product during traditional baking in three ways: (1) convection from the heating medium, (2) radiation from the oven walls to the product's surface, and (3) conduction towards the center. The main variables that impact quality are the amount and pace of heat delivered, the humidity inside the baking oven, and the baking time.

In microwave (MW) baking, food is exposed to ambient air, and heat is generated by MWs interacting with particles and molecules. This rapid heat speeds up baking but may leave some reactions incomplete. Proper baking time and temperature are essential for achieving quality outcomes, ensuring complete starch gelatinization and browning reactions. MW baking saves time, preserves nutritional content, and requires less space for equipment. However, MWs can penetrate dough, affecting enzymes and causing stickiness in the crumb

Drying

Food is preserved by the traditional method of drying, which lowers the food's moisture level.

A drying curve can be divided into three stages. There is a constant drying rate per unit of surface area during the first stage. There is a constant drying rate per unit of surface area during the first stage. Temperature, humidity, and velocity are among the air condition-related parameters that influence and limit the drying rate during the constant rate phase.

MWs can be used in a drying process in different ways such as continuous application, intermittent, or temperature controlled. When using continuous application, a certain quantity of power is used without taking temperature, weight, or time into account, as long as the process's desired outcomes are met. Microwaves used in intermittent application are turned on at regular intervals. These pulses can have a fixed frequency or fluctuate. Intermittent MW drying has been applied to red pepper. Temperature controlled systems adjust the power of the MWs based on the surface temperature of the food material.

Microwave Blanching

Blanching is a pretreatment method to maintain food quality through inactivation of enzymes. Blanching decreases the volume of the food by driving out intracellular trapped air, decreasing the microbial load, and removing adverse odors and flavors [14]. The target enzymes are predominantly peroxidase, polyphenol oxidase, and pectinases. Conventional techniques using steam, hot solutions, or hot water inactivate enzymes, however, cause leaching of vitamins and other soluble components to the water/solutions [15].

MW blanching, using high temperature/short time treatment, preserves heat-sensitive nutrients and bioactive compounds in solid foods through volumetric heating. Its advantages include speed, energy efficiency, precise control, and quick startup/shutdown. With no need for additional water, MW blanching minimizes leaching of vitamins, reduces waste water, and swiftly denatures enzymes in fruits and vegetables. However, drawbacks include temperature unevenness, especially in scaling up, but this can be mitigated by using rotating devices in the MW cabinet [17].

Nutritional and Sensory Quality of Foods Processed in Microwave

MW systems make heat right away to various degrees in multiple phases of heterogeneous foods. If the anticipated changes in the food are time-dependent, the rapid nature of MW heating may be challenging. Foods transport heat through conduction, and the pace at which this happens depends on a number of variables, including the food's composition (high water content and aeration), shape, and homogeneity. Ultimately, whether microwave heating is considered an appropriate approach will depend on the specific heat-induced effects needed to attain the desired quality features of a dish [18].

The heat-generated effects favourable in foods include the following:

- Breakup of leavening agents by heating to produce and expand gases in cakes and dough systems
- textural development in yeast doughs and meringues as a result of gas expanding with rising temperature.
- texture created when starch in a variety of foods, including breads, cakes, potatoes, corn, and navy beans, gelatinizes.
- Texture generation via protein denaturation (meat, egg white)
- Texture fixation because of protein denaturation/starch gelatinization after gases' expansion due to heat in baked goods
- Texture generation through steam generation from water in popcorn
- Maillard reaction browning resulting in surface dehydration of protein/reducing sugar containing foods such as baked goods and meat
- Caramelization due to sugar dehydration
- Thickening occurs as a result of water evaporation in jams, jellies, and candy.
- Cookies and pizza get their crispy texture from evaporating water and having a higher surface temperature.
- The denaturation of proteins in fruits and vegetables meant for freezing, which results in the inactivation of enzymes.

Simulation of Microwave Processes

Failure to understand anticipated payback from MW processing is mostly a consequence of insufficient communication among researchers, materials engineers, process designers, and MW engineers. The basic hardware, such as power supply, generators, and applicators, required for microwave processing applications is widely accessible in the commercial market. However, the process of integrating the system, which involves system design, custom applicator design, quick equipment prototyping, and process control, is insufficient. It must be known that foods cannot be heated efficiently and consistently if just held in a MW oven without concern of specific MW/materials relations

The Dielectric properties (dielectric constant and dielectric loss factor), Thermal properties (specific heat capacity and thermal conductivity), Physical properties (size, shape, density, and location in the package) influence the degree of food component interaction with MW energy and are significant to reflect on optimizing food design to attain consistent heating [19]. MW food product development is laborious and expensive. Nevertheless, use of the computer simulation tool can hasten the product development cycle and decrease the cost of production. Methods adopted at present for designing of foods for MW heating are mostly based on trial and error. Computer simulation of MW heating of foods make possible appropriate designing of foods to guarantee microbial safety [20].

The challenge for researchers is to become skilled at and implement the modelling theory and technology in a simple and holistic way to create a progress in MW food products and processes [21]. Regardless of the modern advances in coupled simulation techniques and the quick rate of commercial software coming out with enhanced features, it is tough to create a model for coupled Multiphysics problems. The capability to take lead of recent development in coupled problems relies on the overall knowledge-based skills and proficiency of the model developer [22].

Future Perspectives

Microwave drying consumes less energy and enhances sensory attributes compared to conventional drying, though it may result in a more porous food structure. Increased microwave power during heating causes shrinkage, dehydration, and rehydration rates to rise while decreasing water content and recovery rate. Microwave cooking preserves antioxidant activity, retains bioactive components in vegetables, and improves protein digestibility by reducing anti-nutritional factors. However, cooking with excessive water can lead to significant nutrient losses. In addition to providing clear benefits in terms of processing efficiency, microwave technology can effectively overcome the drawbacks of conventional procedures when paired with them. Therefore, research efforts in the future might focus on developing novel combination processing techniques to increase productivity while maintaining product quality and safety. In addition, the continuous discussion about whether non-thermal effects occur during microwave sterilization raises the possibility that more investigation is necessary to clear up any lingering questions and offer new insights.

CONCLUSION

Despite the technological advancements in the 21st century, extensive research is still necessary to broaden the application of microwave (MW) technologies in the food processing industry. Challenges such as high initial costs, process optimization, operational expenses, and safety concerns related to food products hinder widespread industrial use of MWs. Precise equipment design, adherence to safety protocols regarding radiation, and trained personnel for proper maintenance and operation are crucial. MW technologies hold significant potential in various areas like functional and novel food processing, sterilization, pasteurization, pretreatment processing, dehydration, and extending the shelf life of food products. Exploring innovative uses of MW energy and identifying new applications present exciting research opportunities, ensuring a continually expanding field.

REFERENCES

1. Apostolou, I., Papadopoulou, C., Levidiotou, S., & Ioannides, K. (2005). The effect of short-time microwave exposures on Escherichia coli O157: H7 inoculated onto chicken meat portions and whole chickens. *International Journal of Food Microbiology*, *101*(1), 105–110.
2. Esturk, O., (2012). Intermittent and continuous microwave-convective air-drying characteristics of sage (Salvia officinalis) leaves. Food Bioprocess Technol. 5 (5), 16641673.
3. Giese, J. (1992). Advances in microwave food processing. *Food Technology (Chicago)*, *46*(9),

118–123.
4. Hamoud-Agha, M. M., Curet, S., Simonin, H., & Boillereaux, L. (2013). Microwave inactivation of Escherichia coli K12 CIP 54.117 in a gel medium: Experimental and numerical study. *Journal of Food Engineering*, *116*(2), 315–323.
5. Javadi, A. (2011). Effect of roasting, boiling and microwaving cooking method on doxycline residues in edible tissues of poultry by microbial method. *Afr. J. Pharm. Pharmacol*, *5*(8), 1034–1037.
6. Jiang, H., Liu, Z., Wang, S. (2017). Microwave processing: effects and impacts on food components. Crit. Rev. Food Sci. Nutr. 1–14.
7. Kasiviswanathan M. and Gabriela J. S. (2019), Chapter 16-Microwave Processing of Foods, Handbook of Farm, Dairy and Food Machinery Engineering (Third Edition), Academic Press, Pages 417-438, ISBN 9780128148037, https://doi.org/10.1016/B978-0-12-814803-7.00016-6.
8. Knoerzer, K., Regier, M., Schubert, H. (2008). A computational model for calculating temperature distributions in microwave food applications. Innov. Food Sci. Emerg. Technol. 9 (3), 374-384.
9. Kumar, C., Karim, M.A. (2017). Microwave-convective drying of food materials: a critical review. Crit. Rev. Food Sci. Nutr. 1–16.
10. Pitchai, K., Chen, J., Birla, S., Gonzalez, R., Jones, D., Subbiah, J. (2014). A microwave heat transfer model for a rotating multi-component meal in a domestic oven: development and validation. J. Food Eng. 128, 60–71.
11. Pucciarelli, A. B., & Benassi, F. O. (2005). Inactivation of Salmonella enteritidis on raw poultry using microwave heating. *Brazilian archives of biology and technology*, *48*, 939–945.
12. Rahman, M. S. (Ed.). (2007). *Handbook of food preservation*. CRC press.
13. Ranjan, S., Dasgupta, N., Walia, N., Thara Chand, C., Ramalingam, C. (2017). Microwave blanching: an emerging trend in food engineering and its effects on Capsicum annuum L. J. Food Process Eng. 40 (2), e12411.
14. Regier, M., & Schubert, H. (2005). Introducing microwave processing of food: principles and technologies. *The microwave processing of foods*, 3-21.
15. Regier, M., Knoerzer, K., & Schubert, H. (2017). Introducing microwave-assisted processing of food: Fundamentals of the technology. In *The Microwave Processing of Foods* (pp. 1–22). Woodhead Publishing.
16. Regier, M., Knoerzer, K., Schubert, H. (2016). The Microwave Processing of Foods. Woodhead Publishing.
17. Soysal, Y., Arslan, M., Keskin, M. (2009a). Intermittent microwave-convective air drying of oregano. Food Sci. Technol. Int. 15 (4), 397–406.
18. Soysal, Y., Ayhan, Z., E¸sturk, O., Arıkan, M.F. (2009b). Intermittent microwave convective drying of red pepper: drying kinetics, physical (colour and texture) and sensory quality. Biosyst. Eng. 103 (4), 455–463.
19. Soysal, Y., Oztekin, S., Eren, O. (2006). Microwave drying of parsley: modelling, kinetics, and energy aspects. Biosyst. Eng. 93 (4), 403–413.
20. Sumnu, G. (2001). A review on microwave baking of foods. *International journal of food science & technology*, *36*(2), 117–127.
21. Tang, J. (2015). Unlocking potentials of microwaves for food safety and quality. *Journal of food science*, *80*(8), E1776-E1793.
22. Vadivambal, R., & Jayas, D. S. (2010). Non-uniform temperature distribution during microwave heating of food materials—A review. *Food and bioprocess technology*, *3*, 161–171.
23. Zhao, D., An, K., Ding, S., Liu, L., Xu, Z., Wang, Z. (2014). Two-stage intermittent microwave coupled with hot-air drying of carrot slices: drying kinetics and physical quality. Food Bioprocess Technol. 7 (8), 23082318.

