ROLE OF MICROWAVE IN FISH PROCESSING: A REVIEW

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ABSTRACT

Use of microwaves increased largely in the domestic household in the last few decades due to the convenience of using microwave ovens. Even today, microwave ovens are mainly used for cooking, defrosting, heating and reheating of fish products. Microwaves are electromagnetic waves whose frequency varies within 300 MHz to 300 GHz. The industrial applications using microwaves have seen an expansion in recent years and industrial scale microwave processing units have been developed for drying, precooking of fish, pasteurization of ready meals, and tempering of fish. Modern fish consumers are demanding high quality, minimally processed products, which have led to the development of novel microwave processing technologies for thawing, blanching, baking, pasteurization, and microwave extraction of bioactive compounds. The possibility of using microwave energy in innovative ways and identifying novel applications will remain an exciting research area and ensure an ever-growing field of opportunities.

KEY WORDS: Cooking, Fish Processing, Heating, Microwave

INTRODUCTION

Microwaves are electromagnetic waves within a frequency band of 300 MHz to 300 GHz (Singh and Heldman, 2013). In recent years, microwave has become one of the most popular home appliances for fish processing applications. The consumers have widely accepted the microwave technology due to its wide range of advantages, which helped them to overcome from the fear and taboos that existed in the beginning. Microwave heating is a volumetric heating process, where heat is generated evenly throughout the entire volume of the food material. This is due to the complete interaction between microwave, polar water molecules and charged ions in food. Microwave energy is selectively absorbed by areas of greater moisture, with more uniform temperature and moisture profiles. The microwave technology has emerged as one of the most promising fish processing technology. It has gained popularity due to its considerable advantages over conventional heating methods. It has been applied in various food processing industries such as cooking, pasteurization, sterilization, thawing, baking, blanching and drying of food materials (Decareau, 1985). The reimbursements includes high heating rates, lower processing time, more uniform heating, safe handling, easy operation, low maintenance and energy efficiency. The efficiency of a microwave oven, when defined as the ratio of power converted to heat (in the food) to the power supplied to power supplied to oven, is generally greater than the cooking efficiency of a conventional oven (Hoogenboom *et al.*, 2009). A common misconception is that microwave heating is always more expensive than heating by conventional techniques. This will actually depend on the application and utility costs. However, in some cases, microwaves can be 50 per cent or more efficient than conventional technique, resulting in major savings in energy consumption and cost (Mujumdar, 2006)

Fish processing applications

The current and potential future applications of microwaves in fish processing, which are increasingly being optimized for tempering, vacuum drying, freeze-drying, dehydration, cooking, blanching, baking, roasting, pasteurization, sterilization and extraction (Lidstrom *et al.*, 2001; Lew *et al.*, 2002; Venkatesh and Raghavan, 2004; Krishnaswamy *et al.*, 2013). The major reasons for relatively the slow development and implementation of industrial applications of microwave processing in the fish industry are due to the considerable cost of the microwave equipment, operating costs, and safety issues (to limit microwave leakage) during scaling up (Wray and Ramaswamy, 2015). In order to successfully establish industrial applications of microwave technology in the fish industry, either the process or the manufactured product should possess unique features compared to conventional processing. Some industrial applications of microwaves are presented in the following sub-sections.

1.*Cooking*

Cooking is one of the most familiar applications of microwave oven. Microwave heating is so rapid that it takes the product to the desired temperature in a short time; hence it is possible to do selective and quick cooking (Fito *et al.*, 2005). The microwave oven is well suited for cooking the food in small quantities, especially for households (Juliano, 1985), though not convenient for mass cooking. If the sizes of foods are small and the shape of foods is flat, the uniform heating through overall volume is possible. Microwave cooking has advantage of less loss of moisture contents and the greatest energy savings, and the nutrition of foods will be preserved very well (Puligundla *et al.*, 2013).

Changes in tenderness, unit proteolytic activity, protein denaturation and fatty acid content of trout (*Onchorhyncus mykiss*) cooked in microwave oven for different time-power combinations were studied and the relationship between protein denaturation and textural changes was investigated. Trout was cooked in the microwave oven at 20, 40 and 60 per cent powers for 10, 20, 30 and 40s. As a control uncooked fish was used. Proteolysis was controlled by using microwave energy. Texture degradation due to proteolytic enzymes was reduced as microwave power increased. As cooking time and/ or power of the microwave oven increased, proteolytic activity decreased which was a sign of the increase in enzyme inactivation. Most of the fatty acids were not destroyed during microwave cooking. The optimum cooking conditions in microwave oven were determined as 60 per cent power for 20s of cooking time (Sahin and Sumnu, 2001).

2.*Blanching*

Blanching of vegetal materials is a pretreatment to preserve food quality mainly through inactivation of enzymes, and also to reduce the volume of the material by expelling intracellular trapped air, reduce the microbial load and eliminate undesirable odors and flavors (Binsi *et al.,* 2014). The target enzymes are mainly peroxidase, polyphenol oxidase, and pectinases.

Microwave blanching is recognized as a technology that reduces the time and energy required to achieve the inactivation of enzymes since it is a method that allows high temperature/short time treatment of solid foods through volumetric heating. This is important to preserve thermolabile nutrients, vitamins, and other bioactive compounds. Successful applications of microwave blanching in animal tissue are the improvement of color and texture of catfish fillets, when a combination of microwave blanching and quick chilling was assessed (Binsi *et al.*, 2014).

Microwave blanching imposed minimum changes on fatty acid and mineral composition of fish meat. A marginal increase in fat content was recorded after microwave heating of fish fillets. The microwave-blanched fillets showed minimum cooking loss of 3.2 ml per 100 g meat. A slower increase in spoilage parameters was obtained with microwave-blanched samples compared with unblanched samples. Microwave blanching increased the hardness and chewiness values and decreased the stiffness values of fish fillets. The biochemical and sensory evaluation of microwave-blanched and vacuum-packed sutchi catfish fillets showed extended storage life of 21 days, compared with 12 days for unblanched vacuum-packed samples (Binsi *et al.*, 2014).

The conditions to achieve a successful microwave blanching depend on the particular vegetable, the power of the microwave emitters, and the amount of vegetable material in the microwave oven. Most of the studies utilize 2450 MHz ovens, with a power ranging from 350 to 900 watts, sample weights from 10 to 200 grams, time of microwave treatment from 0.25 to 6 min, and temperature usually ranges from 80 to 100^0C.

3.*Cooking sausage*

The third largest application of microwave processing is sausage cooking. The sausage patty quality could be improved along with better yield by using the microwave process. In sausage cooking also, microwave processing is used to reduce drip loss—loss of water, fat, nutrients, and flavor. Various laboratory-scale systems have been developed for microwave processing of sausage, but not with much commercial success.

4. *Drying*

Drying is one of the oldest methods of food preservation to prolong the storage life of foods. Convective air drying is the most commonly used method of drying in the food industry. Despite the simple operating principles of convective drying systems and low construction cost, there are certain criteria, such as energy inefficiency and undesired product quality which make air-dried food products less desirable. In convective drying, dry air is used to remove the moisture from the product creating a pressure gradient between the inner core and the surface leading to movement of moisture from the inside to the surface. This may lead to case hardening, wherein the outer layer of the product is over dried, preventing the removal of moisture from the less accessible inner core. The equilibrium is reached after an extended time period and with potential overheating of the product surface. Prolonged exposure of the food product to high temperature results in loss of flavor, volatile aromatics, and color, texture deterioration, and it affects the overall quality of the products (Alibas, 2007; Guine and Barroca, 2012; Mayor *et al.,* 2011; Wray and Ramaswamy, 2015).

Duan *et al.* (2011) used combined microwave – hot air drying for tilapia fish fillets at microwave power from 200 to 600 W and air temperature from 40 to 50^0C with constant air velocity of 1.5 m/s. They found that hot air-microwave drying technology can be used for dehydration of fresh tilapia fillets due to decrease in drying time and to improve quality (rehydration ratio). Hot air drying followed by microwave drying can decrease remarkably the drying time for drying fresh tilapia fillets compared with hot air drying.

Tempering and thawing

Frozen foods are either thawed or tempered before further processing. Thawing is the process when the frozen material is allowed to stand at ambient temperature i.e., above 0^0C to become free from ice so that further mechanical processing such as slicing, cutting, molding can take place. At the industrial level, thawing is done by immersing the frozen products in water for extended periods of time (Taher and Farid, 2001) conducted studies on microwave thawing of frozen minced meat, both theoretically and experimentally, and found that the time required for microwave thawing was 20 per cent shorter than that required for conventional thawing. For the tempering process, the temperature of the frozen material is brought to just below freezing to ease the mechanical chopping and handling. Tempering is an initial process of increasing the product's temperature which is continued by complete thawing (Shaheen *et al.,* 2012). Microwave tempering is used to improve the uniformity of temperature distribution with no temperature abuse of the product and reduced drip losses.

Pasteurization and sterilization

Microwave pasteurization and sterilization have been motivated by the fast and effective microwave heating of many foods containing water or salts and better quality of product (Shaheen *et al.,* 2012). Recent focus has been in the microwave pasteurization of packaged food. Microwave pasteurization process produced uniform heating, while reducing the process time by at least one-half compared to water-bath heating. The microwave pasteurization significantly reduced thermal degradation of food product. When using microwave heating for pasteurization, care must be taken to ensure the homogeneity of the thermal process within the product and the target lethal temperature is maintained for a sufficient period of time to provide a safe product (Finot, 1996). Sterilization is a more severe thermal treatment of foods. The sterilization is recognized as a thermal process sufficient to eliminate toxin-producing *C. botulinum* from the food, make the food commercially sterile if adequately packed and stored at room temperature. Microwave sterilization has been studied for potential commercial applications. Microwave sterilization has some problems such as unpredictable and non-uniform energy distribution. Therefore, progress of microwave sterilization at the industrial level has been relatively slow. But continuous studies and researches have overcome this problem (Adarsh and Devaraju, 2017)

Baking

Microwaves are used in baking, mostly in combination with conventional and infrared processing to accelerate the baking process. Since 1950, microwave baking has been under research and there have been many investigations on appropriate formulations with various emulsifiers, gums, starches, fats and enzymes (Sumnu, 2001; Seyhun *et al.,* 2003;

Keskin *et al.,* 2004) and microwave baking resulted in greater drying rates and uniform internal moisture profiles (Ahmad *et al.,* 2001). Microwave baking drastically reduces the baking time compared to traditional oven baking.

Microwaves for microbial inactivation

Absorption of microwave energy in the food involves two primary mechanisms: ionic interaction and dipolar rotation (Rosen, 1972). Ionic polarization occurs when an electrical field is applied to food solutions containing ions; the ions move at an accelerated pace due to their inherent charge and collide with other ions. The resulting collisions cause the conversion of kinetic energy of ionic movement into thermal energy. Water in food is the primary component responsible for dipolar rotation. Due to their dipolar nature, water molecules try to follow the electric field associated with electromagnetic radiation, as it oscillates at microwave frequency (Datta and Davidson, 2000). The absorbed energy from microwaves may raise the temperature of the food high enough to inactivate microorganisms. Even though a large number of studies have proven that the thermal effect is the essential contributor to the destruction of microorganisms, some researchers have attempted to provide an explanation for non thermal effects of microwaves on microbial inactivation.

Microwave extraction

This technique has been reported to enhance the extraction yield of bioactive compounds from various matrices compared to traditional solid-liquid extraction (Kaufmann and Christen, 2002). The mechanism of microwave assisted extraction is through inter- and intra- molecular friction, together with the movement and collision of a very large number of charge ions, causing the rapid heating of the reaction system and resulting in the breakdown of cell walls as well as membranes (Grosso *et al*., 2015). Microwave extraction rates and the quality of the extract depend on the dielectric properties of the sample and solvent, solubility of the interested compounds in the solvent and temperature. Temperature is important in the extraction process as the higher the temperature the higher is the diffusion rate and, therefore, the extraction rate. However, this may be undesirable when extracting heat-sensitive compounds over long extraction periods. Nonetheless, microwave extraction is advantageous over conventional extraction techniques with improved extraction yield, reduced extraction time, rapid and volumetric heating of the absorbing medium, low solvent consumption, higher selectivity of target molecules, and high potential for automation (Pallaroni *et al*., 2002; Wang *et al*., 2010). The use of microwave assisted extraction may degrade bioactive carbohydrates due to the localized high temperature (Routray and Orsat, 2012). There are many reports about extracting bioactive materials from marine organisms using microwave assisted extraction. For example, some researchers have applied a microwave assisted extraction method for fish tissues (Reyes *et al.,* 2009), Oysters (Bhattacharya *et al.,* 2015), and Shrimp (Tsiaka *et al.,* 2015), and microwave assisted acid hydrolysis of proteins for peptide mass mapping and tandem mass spectrometric analysis of peptides has been reported (Zhong *et al.*, 2005).

Packaging for microwave foods

Microwave food product development is possibly the most challenging task the food technologist faces. Much of the reason for this surrounds those peculiarities of microwave heating that are so appealing to consumers: the speed of heating and cool oven operation, i.e., that the air inside the oven remains cool whiles the food becomes hot. There are also unusual temperature profiles, in large part due to the dielectric properties of the food, but also influenced by the size and shape of both the food and the container. As a result, the selection of the proper packaging system is more important with microwavable foods than with most other products. It controls how quickly and uniformly a food heats. In some cases, the package may actually contribute to the heating by providing a heated surface for browning and crisping, or a high-heat steam atmosphere for moisture retention and faster heating (Schiffmann, 2005).

Nutritional effects

According to Ohlsson and Astrom (1982) and Jonsson (1989), the nutritional quality after comparable degrees of conventional and microwave heating. They concluded that the protein quality is retained in microwave heating of animal foods. Minerals and vitamins such as potassium and vitamins B1 and C, are better retained in microwave heating as the cooking is done in a minimum of water - provided excessive heating is avoided. On the other hand, data on the effects on carbohydrates (starch and nutritional fibers) and on fat-soluble vitamins were found to be lacking.

According to Finot and Merabet (1991), the possible effects on racemization of amino acids and isomerization of fatty acids. They concluded on the basis of comprehensive investigations, that there are no such effects of microwave heating that differ from those of conventional heating methods.

CONCLUSION

Microwaves have been successfully used for fish food processes, such as in the cooking, drying, baking and blanching of fish food materials. Microwave-cooked products have the advantages of better retaining taste, colour, quality, and nutritional value compared to those cooked by conventional methods. Faster heating and high energy efficiency are also advantages of microwave processing. At the same time, this technology has been found to be more effective in the destruction of pathogens or in the inactivation of enzymes, largely attributed to the enhanced heating rates, leading to significant enhancement or magnification of thermal effects. Microwave technologies have a wide scope of applications in functional and novel fish processing sectors, sterilization, pasteurization, pretreatment processing, dehydration, and shelf-life extension of fish products. The possibility of using microwave energy in innovative ways and identifying novel applications will remain an exciting research area and ensure an ever-growing field of opportunities.

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