microwave & radio frequency

Microwave debacterization of black peppercorns

1. Introduction

Food powders and grains (such as spices, milk powder, flour…) are largely used in food industry as ingredients or end products. It's estimated that in this sector 80% of the ingredients used are in dehydrated form.
Like all natural products, flour, herbs and spices are susceptible to microbial contamination. It has been shown that a spice that thrives near or on contact soil (basil, black pepper, thyme …) has a much greater microbial load compared to distant spices soil (cloves, nutmeg blossom, etc.).
Processed powders such as dehydrated milk, egg powder or ingredient may experience microbial contamination through the manufacturing process (Den uijl, 1992 ; Völker et al., 1998).
These low-moisture foods were generally considered safe because their water activities are lower than 0.75. However, depending on the process operating conditions, powdered foods are also subjected to potential contaminations with deadly pathogens (Novales et al., 2003). These microorganisms are unable to develop in dry conditions and thus most food powders are generally commercialized without any preservation treatment. However powder rehydration (as ingredient incorporation or for final use) will allow the development of pathogenic bacteria. Several common powdered foods (infant formula powder, powdered egg, tea and coffee powder, fruit and vegetable powders, rice flour related powder and culinary powder) are especially concerned by these serious outbreaks.
The geographical location of the production areas and the low water activity of food powders cause most germs present are thermotolerant and xerophilic, which makes it even harder to eliminate them. Indeed, the microorganisms present in the powders undergo a first osmotic stress which has the consequence of increasing their thermotolerance (Agab et al., 1992 ; Jørgensen et al., 1995 ; Mañas et al., 2011).

The presence of microorganism pathogens in low-moisture foods is an increasing concern. For example, black pepper contaminated with Salmonella has been reported to be the cause of several outbreaks (Centers for Disease Control and Prevention, 2010) and numerous recalls (Dey et al., 2013) which not only causes food safety issues, but also results in enormous economic losses.

Current decontamination methods, thermal (steam, joule effect…) and athermal (such as ozone treatment, fumigation by ethylene oxide, irradiation with gamma rays…) have been developed to reduce microbial load in black pepper, but these methods come with limitations.
Ozone treatment has been reported to reduce the microbial load in ground black pepper by 3–4 log CFU/g, but resulted in graying of some powders (Muraz et al., 1985) and a loss of essential oils resulting in poor organoleptic quality (Zhao and Cranston, 1995). Moreover, the use of this gas requires the implementation of drastic safety rules. Ethylene oxide has been shown to significantly reduce microbial load in black pepper (Leistritz, 1997; Toofanian, 1986). However, this chemical has been banned in the European Union (Uijl, 1992) because of the production of mutagenic and carcinogenic compounds (ethylene glycol, 2-chloroethanol, epichlorohydrin …). Some of these toxic compounds persist for 6 months depending on the nature of the spice (Minet et al., 1990 ; Fiess, 1994). Despite its effectiveness, gamma ray irradiation is not well-accepted by consumers (Song et al., 2014). The consumers see only a complicated and abstract technique involving nuclear energy. Confronted with this psychological barrier and the labeling obligation (decree 2001-1097), manufacturers of powdered foods, in particular of spices and aromatics, preferred to opt for other techniques (Den uijl, 1992 ; Rahman, 1999). Steam treatment is commonly applied to black pepper as a decontamination method in the European spice industry (Schweiggert et al., 2007), but it has been reported to cause increased moisture levels which affect the shelf life of black pepper and modification of organoleptic and sensory qualities (Schneider, 1993; Waje et al., 2008).

Therefore, development of an innovative technology has become necessary for decontamination of black pepper while maintaining product quality.

Microwave treatment is a new heat treatment method based on the dissipation of electromagnetic energy within the targeted product. The heating process is generated by the quick polarity reversal of the electromagnetic field which creates vibration and rotation of the polarized molecules inside the material. This phenomenon is made possible thanks to the dielectric loss properties of materials. With a traditional heating solution heat is transferred by conduction from the outside to the center of the product. Microwave and radio frequency technologies heat the product uniformly: this is called volumetric heating. Heat generation is almost instantaneous and allows for a perfectly controlled process thanks to rapid, uniform heating. Moreover, almost all the energy is transferred to the treated product, drastically reducing energy losses. (Boreddy et al., 2016; Boreddy and Subbiah, 2016; Chen et al., 2017, 2013)

2. Materials and methods

2.1 Materials

One batch of no steam-sterilized black peppercorns was obtained from a spice producer and stored at room temperature (20°C). The contamination flora are the natural microorganisms present when the products are harvested.

2.2. MW heating system

Microwave heating was conducted in a 2 x 6 kW, 2450 MHz pilot-scale system (Labotron FL12000, SAIREM, France) with a hot air system. The sample was placed inside the microwave heating chamber at the center. To ensure the homogeneity of the process, microwaves will be combined with a hot air system. A schematic view of the pilot-scale system can be found in figure 1. To achieve a stable air temperature for sample surface heating, hot air was circulated in the empty cavity for 1 h prior to the combined MW and hot air treatment.

Figure 1 - Labotron FL12000 (SAIREM)

2.3. Temperature measurement
One fiber optic temperature probe (Neoptix, Inc., Quebec City, Quebec, Canada) with an accuracy of ± 0.8 °C was inserted into the container. The sensor was directly inserted 2 cm inside the core and perimeter of the treated sample and the temperature was automatically recorded every 3 seconds. Since the fiber optic sensor consists of electric insulating material, it does not interfere with the temperature profile of the treated sample (Wang et al., 2003)

2.4. Microbial enumeration
Enumeration of mesophilic total flora at 30 °C/72h by an external laboratory following the ISO standard (NF EN ISO 4833-1)

3. Results

3.1 Selected Kinetic heating of black peppercorns
The relationship between forward power and temperature increase during treatment with 2450 MHz MW energy are shown in Fig. 2. For example at 1000 Watts of microwave power the average temperatures of core samples obtained from optic temperature probes after 75, 100 and 125 seconds microwaves heating were 85.1, 105.3 and 120.1 °C respectively.

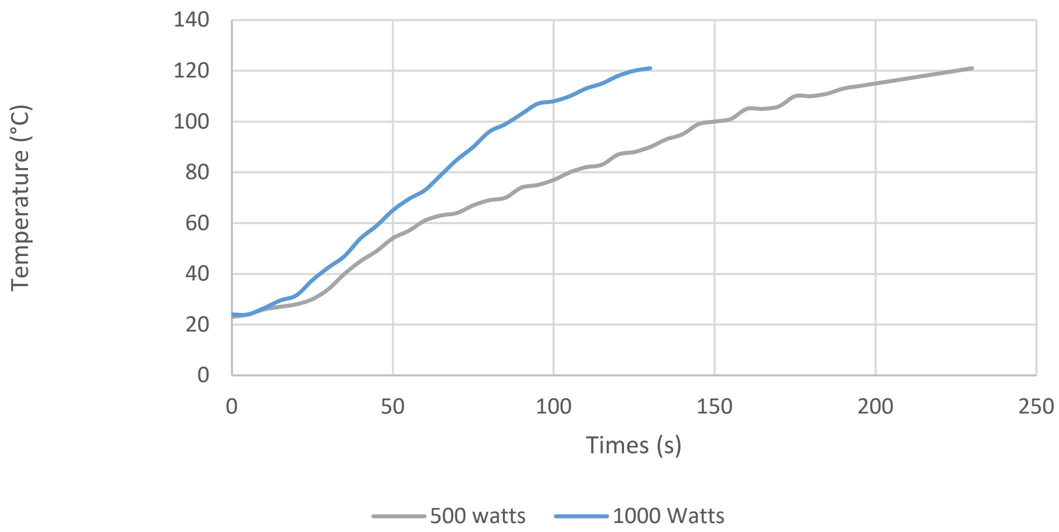

Fig 2. Temperature–time histories of core of black peppercorns when subjected to 2450 GHz MW energy for two power

For forward power of 500 and 1000 Watts the heating rate of black peppercorns was 0.68°C/min, and 1.50°C/min, respectively. To achieve a fast heating rate of more than 1°C/min, the forward power 1000 Watts was selected for the pasteurization test. The heating rate is a very important parameter which makes it possible to preserve the organoleptic and nutritional qualities of the products.

The objective is to increase quickly and homogeneously the temperature and then to maintain the temperature reached with the hot air. The temperatures selected for the pasteurization treatments are 85, 105 and 120 °C which are obtained for microwave residence times of 75, 100, and 125 seconds respectively at 1000 Watts. The holding times chosen for this study are 0, 7 and 14 minutes.

3.2 Pasteurization of black peppercorns

Thanks to the previous results, the processing parameters of the peppercorns can be determined. 3 processing temperatures will be tested: 85, 105 and 120 °C. 3 holding times, which are 0, 7 and 14 minutes, will also be tested.
We therefore have a total of 9 treatment modalities for this study.

The survival of total microorganism in peppercorns during micro wave treatment is shown in Fig 3.

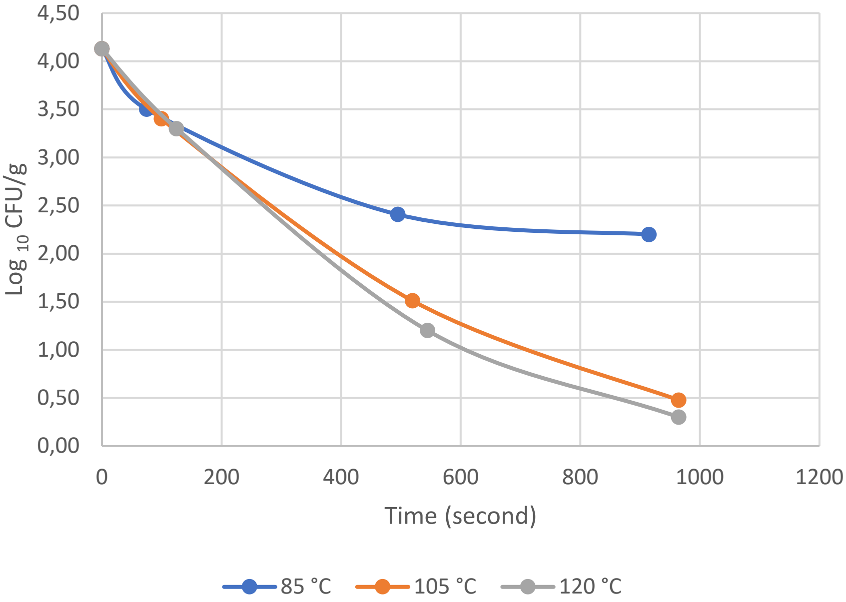

Fig 3 : Logarithmic reduction of the total flora for the different treatment conditions when subjected to 2450 MHz MW energy

The survival of total microorganisms in peppercorns treated during 75, 100 and 125 seconds (no holding time) are 3.5, 3.4 and 3.3 log respectively. The level of microbiological reduction log (no holding time) are 0.63, 0.73 and 0.83 for treatment times of 75, 100 and 125 seconds respectively.
There were significant reductions in microbial levels for 7 and 14 minutes holding times compared to the control and no holding time. Holding time is therefore a very important concept to improve microbial reduction levels.
For a holding time of 7 minutes, microbial logarithmic reduction 1.72, 2.62 and 2.93 (compared to the control) is observed for treatment times of 85, 105 and 120° C. After 14 minutes of holding the microbial logarithmic reduction compared to the control are 1.93, 3.65 and 3.83 for treatment temperatures of 85, 105 and 120° C respectively. We can't show a greater reduction because the initial level of contamination is only 4.30 log. Important results are that after 14 minutes of treatment we reach a very low microbiological contamination level of 0.48 and 0.43 log for treatment temperatures of 105 and 120 ° C respectively.

4. Conclusion

By using the volumetric heating properties of the microwaves, heat is generated within the material and throughout its mass. This can significantly increase heating rates and reduce heating time (Tang and Wang, 2007). Thermal process based on MW energy has great potential as a food pasteurization. In this study, MW heating was shown to effectively disactivate black pepper and provided 3.83 log CFU/g reduction. Further investigations are required to validate this data in other products and against a larger number of spore-former microorganisms, and with artificially contaminated products (pathogens) to be able to show greater reduction.

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