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Microorganism control and product quality improvement of Twice-cooked pork dish using ZnO nanoparticles combined radio frequency pasteurization

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ABSTRACT

ZnO nanoparticles combined radio frequency (ZNCRF) is a novel and effective method of pasteurization. This study was designed to evaluate microorganism control and product quality improvement (sensory, texture, thiobarbituric acid reactive substances (TBARS), flavor and GC-MS determination) of Twice-cooked pork dish using ZNCRF pasteurization. The results showed that the combined pasteurization effect of ZNCRF treatments was superior to conventional high pressure steam (HPS) sterilization. ZNCRF pasteurization preserved the heating uniformity and reduced the loss of sensory, texture and flavor of Twice-cooked pork dish at the same time scale and met China's national standard (GB29921-2013). In order to explain the above changes in principle, volatile organic compounds of Twice-cooked pork dish samples were measured on GC-MS. The measurement result of GC-MS indicated that aldehydes (a typical flavor of Twice-cooked pork dish) decreased from 71.56% to 62.51% with the increase of germicidal strength. Therefore, the experimental results of ZNCRF pasteurization could be helpful for food processing industries to produce high quality sterilized Twice-cooked pork dish.

1. Introduction

Twice-cooked pork dish ranks one of top dishes in China and is also popular in Chinese restaurants overseas. More than half of participants in one public opinion poll voted the dish as most representative of Sichuan cuisine (China Today, 2013). Many studies have showed that Twice-cooked pork dish is rich in high quality protein, essential fatty acids, calcium, phosphorus, iron, thiamine, riboflavin and niacin, which play a role in prevention of anemia (Jiang, Tang, Xue, Lin, & Xiong, 2017; Lee et al., 2007; Ma et al., 2016). Traditionally, Twice-cooked pork dish sold in supermarket is sterilized using conventional high pressure steam (HPS, 121 °C, 30 min). High pressure and temperature cause negatively changes in the quality of the dishes including sensory, flavor and nutrition (Butz, Bognar, Dieterich, & Tauscher, 2007; Dasan, Boyaci, & Mutlu, 2016). Hence, it is necessary to develop new and mild pasteurization technology in order to better preserve the nutritional and sensorial (flavor, texture) characteristics of Twice-cooked pork dish.

ZnO nanoparticles (size between 1 and 100 nm) have a positive antimicrobial property by damaging the membrane wall of the bacteria due to the electrostatic forces (Liu, Zhang, Fang, & Rong, 2014; Zhang et al., 2009). Zinc is an essential trace element in the human body. China's diet habits have caused a downward trend in zinc intake (Thavarajah, Thavarajah, Sarker, & Vandenberg, 2009). People's daily intake of zinc is below the safety limit standards. So adding a certain amount of ZnO nanoparticles in the food is benefits to the food products. By expanding the research, ZnO nanoparticles can be more widely applied as food antibacterial compounds and therefore there is a lower possibility of food safety problems (Sawai, 2003; Espitia et al., 2012). Li et al. (2011) investigated a synthesized Nano packaging which coated polyvinyl chloride (PVC) film with nano-ZnO powder and its effects on the preservation quality of fresh-cut 'Fuji' apple. The results showed that nano-ZnO active packaging could improve the shelf-life properties of 'Fuji' apples as a fresh-cut product.

Radio frequency irradiation (RF) is an electromagnetic wave with a frequency range of 300 kHz to 300 MHz. The application of RF accelerates the pasteurization process owing to its thermal and non-thermal effects on microorganism. These effects can denature the microbial protein and cause their death (Marra, Zhang, & Lyng, 2009; Wang, Wig, Tang, & Hallberg, 2003). RF irradiation uses electromagnetic effect to

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heat materials, relies less on conduction mode of heat transfer due to which the temperature distribution within the material becomes more uniform and the heating time become shorter. Although the mechanism of generation of thermal energy in RF and microwave is similar, the RF heating has greater penetration depth, better uniformity of heating, more stable temperature control compared to microwave heating (Guan, Cheng, Wang, & Tang, 2004; Lassen, Johansen, & Grün, 2006). The effectiveness of heating by RF depends on the moisture content, dimension and shape of the material being heated. The position of sample and the spacing of plate within RF cavity also greatly affect the heating uniformity in materials (Gao, Tang, Johnson, & Wang, 2012; Guo, Tiwari, Tang, & Wang, 2008). Recently, particular attention has been paid to the use of RF-assisted pasteurization in food. Uemura, Takahashi, and Kobayashi (2012) developed an electric pasteurizer utilizing RF heating to inactivate *Lactobacillus brevis* in liquid egg white. The results showed that the RF heating could achieve a 4.3 logarithm reduction of *Lactobacillus brevis* at 60 °C in 2.4 s which were more effective than the conventional thermal sterilization.

Combining zinc nanoparticles with RF heating treatment can have a synergistic effect and reduce the treatment conditions of each of these processes. Thus, ZNCRF pasteurization could be a novel and innovative method of pasteurization. The objective of this study was to evaluate the effectiveness and suitability of ZNCRF to pasteurize Twice-cooked pork. The shortening of pasteurization time and minimizing the damage to the texture, lipid oxidation and flavor properties were the expected outcome of this study.

2. Materials and methods

2.1. Raw materials

ZnO nanoparticles were purchased from Shanghai Yongfu Nano Technology Co., Ltd. Pork, green pepper and mushroom were purchased from the Xuelang market in Wuxi, China. Choose 160 g of pork, 20 g green pepper, and 20 g of mushrooms, according to the menu cleaning and cutting. Thinly slice the pork and add a dash of peanut oil to a hot pan. Then, put in the pork slice, green pepper, and mushrooms, heat and stir fry the materials till pork slices curl at the edges. Add appropriate amount of bean sauce, edible salt, spices, chili and other accessories. After cooling, the samples were added with 10 mL ZnO nanoparticle suspension solution (0.04 g/kg) and vacuum packed in retort pouch and kept in a fridge (0–4 °C) prior to further tests.

2.2. Pasteurization of Twice-cooked pork dish using ZNCRF

A 6 kW, 27 MHz RF processor (Model SO6B, Strayfield Co. Ltd., Berkshire, UK) was used to pasteurize the Twice-cooked pork dish samples. Pasteurization of Twice-cooked pork dish samples was carried out using RF processor at three different time sets: 10 min, 20 min, and 30 min using 20 mm plate spacing. The Twice-cooked pork dish samples were also sterilized using HPS (121 °C, 30 min) and used control without pasteurization for comparison. Total bacterial count, sensory, texture and flavor test were conducted in at least eight repeats. Volatile organic compounds and thiobarbituric acid reactive substances (TBARS) experiments were conducted in at least three repeats.

2.3. Measurements and analyses

2.3.1. Measurement of temperature

An infrared thermal imaging camera (IRI 4010 Multipurpose Imager, IRISYS, Northampton, UK) was used to measure the temperature of samples during ZNCRF pasteurization (Xu, Zhang, & Bhandari, 2014). The samples were taken out of the RF chamber at 10, 20 and 30 min after RF pasteurization, and the temperature was measured immediately by positioning 0.8 m far from the lens of the imaging camera. The entire measurement process was completed within 3 s. The image data was processed by the software associated with the infrared camera.

2.3.2. Microbiological analyse

The total bacterial count of colony forming units (CFU) of pasteurized and unpasteurized Twice-cooked pork dish samples was determined using aerobic plate count method prescribed by national food safety standards of China (GB/T 4789.2–2010). About 25 g of Twice-cooked pork dish samples were cut into pieces and put into 225 mL sterile saline solution (Kinghunt, Nantong Kinghunt Biology Technological Development Co. Ltd., Nantong, China) to achieve 10-fold dilution and then homogenized (SH-IIM, Anke Biotechnology Co. Ltd., Shanghai, China) for 1 min. The homogenized samples were further diluted as required using sterile saline. The inoculum plates were incubated in inverted position for 48 h at 37 °C. The total numbers of reported CFUs are average values of eight measurements.

2.3.3. Sensory evaluation

The sensory assessment team consisted of 20 experienced meat sensory panelists. They were trained before evaluation of the actual Twice-cooked pork dish samples. The scoring standard for appearance (30 points), flavor (30 points) and taste (40 points) were used as shown in Table 1. The cumulative scores were taken as the final score for the assessment.

2.3.4. Measurement of texture parameters

Texture parameters of Twice-cooked pork dish were measured by using texture profile analyser (TA-XT2i, Stable Microsystems Ltd., Surry, UK) using the texture profile analysis (TPA) method as suggested by Ben Slima et al. (2017). A P5 probe was used and the tests were conducted in compression mode. The surface of lean meat was wiped dry with paper napkins before compression. The pretest, test, posttest speeds, and trigger force were 2.00 mm/s, 1 mm/s, 2.00 mm/s, and 5.0 g respectively. The samples deformation ratio was set at 50%. Each sample was compressed twice in each test. The force–deformation curves data was recorded and analyzed using Exponent32™ software associated with the hardware. The peak compressive force (N) was used as the hardness. The ratio of the time that the second compression reaches the peak to the time that the first compression reaches the peak was used as the springiness. The ratio of the peak area obtained by the second compression to the peak area obtained by the first compression was used as cohesiveness. Chewiness means the work required to chew a solid food to achieve swallowability. Resilience refers to the ratio of the elastic energy released during the first compression cycle to the energy consumed by the probe. Eight replicate tests conducted the averaged data are reported for each parameter.

Table 1
The standard of sensory evaluation of Twice-cooked pork dish.

Appearance	Flavor	Taste	Total points
Color red, no charred ingredients. (20–30 points)	Special aroma of Twice-cooked pork dish, no coke flavor. (20–30 points)	Fat is not greasy, lean meat is not hard. (30–40 points)	70–100
Color red, a small amount of charred ingredients. (10–20 points)	Special aroma of Twice-cooked pork dish, a small amount of coke flavor. (10–20 points)	Fat is not greasy, lean meat dry. (15–30 points)	35–70
Color was dark red, a large number of charred ingredients. (0–10 points)	No special aroma of Twice-cooked pork dish, a huge amount of coke flavor. (0–10 points)	Lean meat is very hard, bitter taste. (0–15 points)	0–35