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Effect of radio frequency heat treatment on protein profile and functional properties of maize grain

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ABSTRACT

The study was aimed at investigating the effect of radio frequency (RF) heating at different temperatures on the protein profile and functional properties of maize grains. Maize grains with 14% moisture content exposed to the radio frequency energy at 300 W for different temperatures 50, 55 and 60 °C, respectively. The results indicated that radio frequency heating had no effect on the protein profile of maize. The molecular weight distribution of protein remained in the range of 20–25 kDa after RF heating. On the other hand, the functional properties in term of oil holding capacity and emulsifying properties of maize were improved after RF heating. According to these finding, it can be concluded that radio frequency heating improves the functional properties of maize flour. Thus, RF may provide a potential as an effective emerging technology for improving the quality characteristics of maize grains.

1. Introduction

Worldwide, maize (*Zea mays* L.) is considered as the most important cereal crop and it is ranked first in 2016 with an annual production of 1.06 billion tons followed by wheat and rice (FAOSTAT, http://www.fao.org/faostat/en/#data/QC accessed on 26/6/2018). The consumption of maize is varied from country to country. It is consumed for various purposes, according to Ranum et al. (2014), about 75% of maize production used for human and animal feeding and the rest (25%) used for corn ethanol and other different industrial purposes. In addition, it is considered as an important source of energy (62% starch), protein (8.7% protein), fat (4%) (Nuss & Tanumihardjo, 2010; Rehman, 2006; Singh, Singh, Kaur, Sodhi, & Gill, 2003), and minerals (Gu et al., 2015).

In the post-harvest stage, like other agricultural products, maize grains attacked by numerous varieties of stored-product pests. These infestations negatively effect on the quantity as well as the quality of maize (Alavi, Htenas, Kopicki, Shepherd, & Clarete, 2012; Kaminski & Christiaensen, 2014). Chemical fumigants such as Chlorpyrifos, Malathion and Aluminum phosphide (Satya et al., 2016), are commonly used for controlling the store pests, however, extensive application of these pesticides negatively influences both environment and human health (Cherry, Abalo, & Hell, 2005; Nicolopoulou-Stamati, Maipas, Kotampasi, Stamatis, & Hens, 2016). Thus, several physical alternative methods have been recommended for postharvest pest control. Among these alternative methods radio frequency heating has advantages in eliminating store pests and enhanced the shelf life of stored products (Hou, Johnson, & Wang, 2016; Marra, Zhang, & Lyng, 2009; Nelson, 1996).

Radio frequency is non-ionizing electromagnetic waves with the frequency range between 1 and 300 MHz and wavelength of up to 11 m. Radio frequency wave can penetrate deep into the dielectric materials such as food and produce heat volumetrically through dipole rotation and/or ionic polarization (Hou et al., 2016; Marra et al., 2009). However, the success of the application of radio frequency in food industry depends on several factors. Some of these factors are associated with the nature of the dielectric material including structure and moisture content, while others are related to the condition when dielectric heating applied such as frequency, density, temperature, and other factors. However, most of these studies confirmed that the moisture content of materials is the most significant factor affecting the dielectric properties and improve the heating uniformity during the RF heat treatment (Guo, Tiwari, Tang, & Wang 2008; Sacilik & Colak 2010).

Furthermore, using radio frequency as a heating source in the drying process of food is advantageous because it offers a potential for fast and constant heating rate compared to common heating methods

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(Marra et al., 2009). These advantages reduce the drying times and enhance the quality of the foodstuffs (Marra et al., 2009; Wang & Tang, 2001).

Recently, several researchers conducted the potential ability of radio frequency for controlling store pests and drying of agricultural products (Guo, Wu, Zhu, & Wang, 2011; Hou, Hou, Li, Johnson, & Wang, 2015; Marra et al., 2009; Yang et al., 2018; Zheng, Zhang, & Wang, 2017; Zhou & Wang, 2016a,b). In a study conducted by Gao, Tang, Wang, Powers, and Wang (2010) to investigate the effect of radio frequency heating on the quality of almond. They reported that the quality characteristics of almond were positively improved after radio frequency treatment. Similarly, Li, Kou, Cheng, Zheng, and Wang (2017) stated that almond quality was not changed by the RF treatments even after the storing for 20 days. Additionally, Hassan, Pawelzik, and von Hoersten (2016) investigated the nutritive value of radio frequency treated-corn. They stated that radio frequency heating enhanced the nutritive value of corn flour and increased its protein solubility, particularly at a temperature up to 55 °C.

On the other hand, during the application of radio frequency, the polar group in protein molecule are capable to absorb heating more waves and generate free radicals, which might lead to aggregation and unfolding of the protein. The interactions of these free radicals among the protein molecules may cause modifications in the protein formation and its functional properties (Cerny & Hobza, 2007). However, most of the studies investigating the effect of radio frequency on the structure and functional properties of the protein imparted the advantageous of radio frequency heat treatment. Guo et al. (2017) show that treatment of soy protein isolates with radio frequency waves under different temperature up 90 °C did not change the primary structure of the protein. Furthermore, Boreddy, Thippareddi, Froning, and Subbiah. (2016) show that combines radio frequency heating with conventional heating at 60 °C for different times effectively improves the functional properties of egg white.

Despite a number of researchers describe the effect of the electromagnetic wave on food quality, still, little information is presented on the effect of radio frequency heat treatment on the protein structure and functionality. To improve the utilization of radio frequency in the food industry, further studies in this field are needed. Therefore, this study was aimed to assess the effects of radio frequency on the protein structure and functional properties of defatted maize flour.

2. Materials and methods

2.1. Materials

Maize (*Zea mays* L.) cultivar "Amadeo" with 11.2% initial moisture content received from KWS SAAT AG; Einbeck, Germany was used in this study. Molecular weight markers and Ethylene Diamine Tetra Acetic acid (EDTA) were obtained from Sangon Biotech. Co. Ltd. (Shanghai, China). All other chemicals were of analytical grade.

2.2. Characteristics of the radio frequency (RF) system

A pilot-scale RF system (Sairem, S.A.S, 1511) with 27.12 MHz and maximum power of 3 kW was used for heating maize samples. An exhaustive description of the RF systems found in Hassan et al. (2016). The dielectric material (maize grain) was placed between the top and ground electrodes and the power is transmitted to the product through the top electrode. A balance is attached to the system to measure the mass of products during the heat treatment. Three sensors were used to measure the temperature of maize grain during RF heat treatment. The radio frequency system is also associated with the control panel to display the measured data, temperature, electrode height, output power, reflected power, application time and the mass weight, every 3 s.

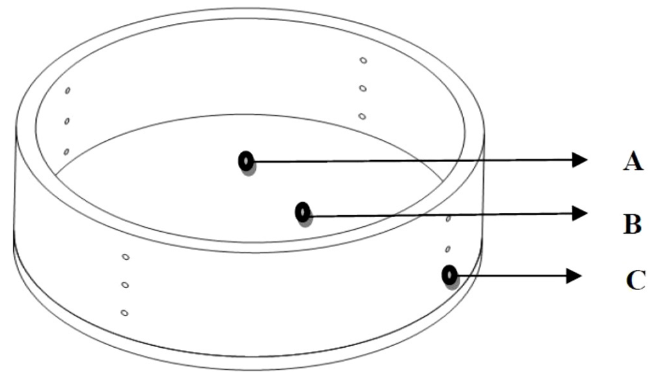

Fig. 1A. The schematic view of Teflon container used in radio frequency treatments. The inset circle in the figure show the locations of the fiber optics thermometer at the depth of 0 cm (A), 2 cm (B) and 4 cm (C).

2.3. Samples treatments and preparation

About 275 g of maize grain was located in a Teflon cylindrical container with a diameter of 11 cm and 4 cm height (Fig. 1A). The radio frequency power was set at 300 W to heat up the grains to the target temperature. Based on our preliminary experiments, the distance of 6 cm between the electrodes was stabled to fulfil proper heating rate (13 °C/min). According to the thermal death kinetics of the maize weevil's adults in maize after radio frequency heating (unpublished data), the target temperatures 50, 55 and 60 °C were selected. Fiber optic sensors placed in three different locations and depth monitored the grain temperature, during the RF treatments. As shown in Fig. 1A, fiber optic (A) measure the temperature of the grains on the top, fiber optic thermometers (B) measured the surface temperature of grain in the depth of 2 cm and (C) were placed in the bottom of the container (depth of 4 cm). The RF power was switched off when the average temperature of the three -fiber optics thermometers displayed in the control panel reached the desired processing temperature (Fig. 1B). Directly after RF processing maize grain was cooled down at ambient condition following the procedure of Gao et al. (2010). Control and RF-treated maize grains were then ground to fine flours using a laboratory mill then packaged in a polyethylene bag and kept in climate chamber until used for analysis.

2.4. Defatting of maize flour

Defatting of maize flour was done following the cold extraction method. About 50 g of maize flour was mixed with petroleum ether (1:10 W/V) and shaken for 24 h at room temperature. The solvent was then removed from the oil using a rotary evaporator. The defatted

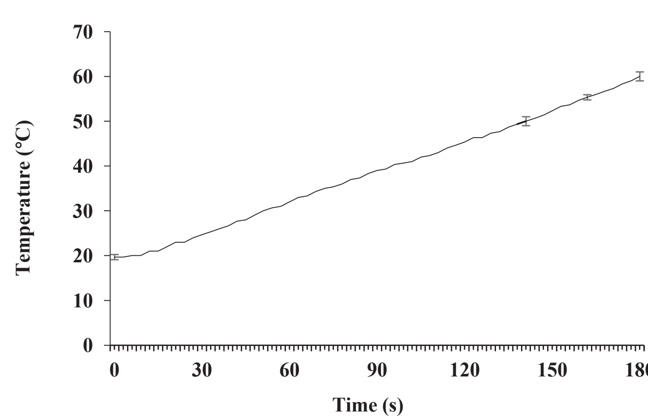

Fig. 1B. Surface temperature of maize grains during Radio frequency treatments. Data represent the mean ± SD (n = 3).