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# Effects of radio frequency assisted blanching on polyphenol oxidase, weight loss, texture, color and microstructure of potato

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ABSTRACT

This paper is focused on the effects of radio frequency (RF) heating on the relative activity of polyphenol oxidase (PPO), weight loss, texture, color, and microstructure of potatoes. The results showed that pure mushroom PPO was almost completely inactivated at 80 °C by RF heating. The relative activity of potato PPO reduced to less than 10% with increasing temperature (25–85 °C). Enzyme extract showed the lowest PPO relative activity at 85 °C after RF treatment, followed by the potato cuboids and mashed potato, about 0.19 ± 0.017%, 3.24 ± 0.19%, and 3.54 ± 0.04%, respectively. Circular dichroism analysis indicated that RF heating changed the secondary structure of PPO, as α-helix content decreased. Both electrode gap and temperature had significant effect ($P < .05$) on weight loss, color, and texture of the potato cuboids. Microstructure analysis showed the changes of potato cell and starch during RF heating.

## 1. Introduction

Potatoes are widely cultivated all over the world, especially in many developing countries. It is commonly processed into potato flours, purees, and chips, which are favored by consumers. However, enzymatic activity in the potato can result in a series of deterioration reactions including undesirable color and texture, off-flavors, bad odor, and loss of nutrients. Polyphenol oxidase (PPO) is a copper-containing enzyme contributing to enzymatic browning of vegetables and fruits. PPO can be divided into two categories: laccase (EC 1.10.3.2) and catechol oxidase (EC 1.10.3.1). Catechol oxidase is referred to as phenolase, polyphenol oxidase, tyrosinase, catecholase or cresolase, which is clearly distinguished from laccase. Catechol oxidase can catalyze two distinct reactions: (1) the insertion of oxygen in a position ortho to an existing hydroxyl group, usually followed by oxidation of the diphenol to the corresponding quinone, which is referred to as cresolase activity; (2) the oxidation of o-diphenol with hydrogen abstraction, which is referred to as catecholase activity (Mayer & Harel, 1979). Quinones subsequently undergo nonenzymatic reactions resulting in the formation of dark-colored melanins (Duangmal & Apenten, 1999; Kuijpers et al., 2014; Tribst, Júnior, Oliveira, & Cristianini, 2016). Therefore, the inhibition of enzyme activity plays an important role in the food industry. Blanching is a crucial step that is carried out prior to food processes such as frying, drying, freezing, and storing because it can inactivate enzymes, destroy microorganisms, and eliminate air in the potato (Wang et al., 2017).

The methods of inactivation of PPO have been widely studied. The activity of PPO can be inhibited by using chemical reagents, such as sulphites, ascorbic acid, and amino acids, which have been applied in potato (Ali, El-Gizawy, El-Bassiouny, & Saleh, 2016), lettuce (Altunkaya & Gokmen, 2008), and blueberry (Siddiq & Dolan, 2017). However, the residual chemical agents pose a threat to human health. It is necessary to develop novel technologies and to reduce the use of chemical food additives. Thermal treatment is the most common and effective technique to control enzymatic browning in the food industry. A number of studies have been explored to overcome enzymatic browning to improve the quality of products by thermal processes. The methods include hot water, hot and boiling solutions containing acids and/or salts, steam heating, microwave, infrared, ohmic heating, and radio frequency heating (Castro et al., 2008; Icier, Yildiz, & Baysal, 2006; Manzocco, Anese, & Nicoli, 2008; Mukherjee & Chattopadhyay, 2007; Sotome et al., 2009; Vishwanathan, Giwari, & Hebbar, 2013; Wang et al., 2017).

Radio frequency (RF) heating utilizes electromagnetic energy at a frequency range of 3 kHz to 300 MHz and initiates volumetric heating due to frictional interaction between molecules. The advantages of RF heating include higher penetration depth and higher heating rate. Therefore, it can save processing time and improve food quality. RF heating has been studied on drying nuts, thawing meats, post-baking cookies, pasteurization, and controlling insects (Farag, Lyng, Morgan, & Cronin, 2011; Palazoglu, Coskun, Kocadagli, & Gokmen, 2012; Wang et al., 2014; Zhou & Wang, 2016). However, the study about the effect

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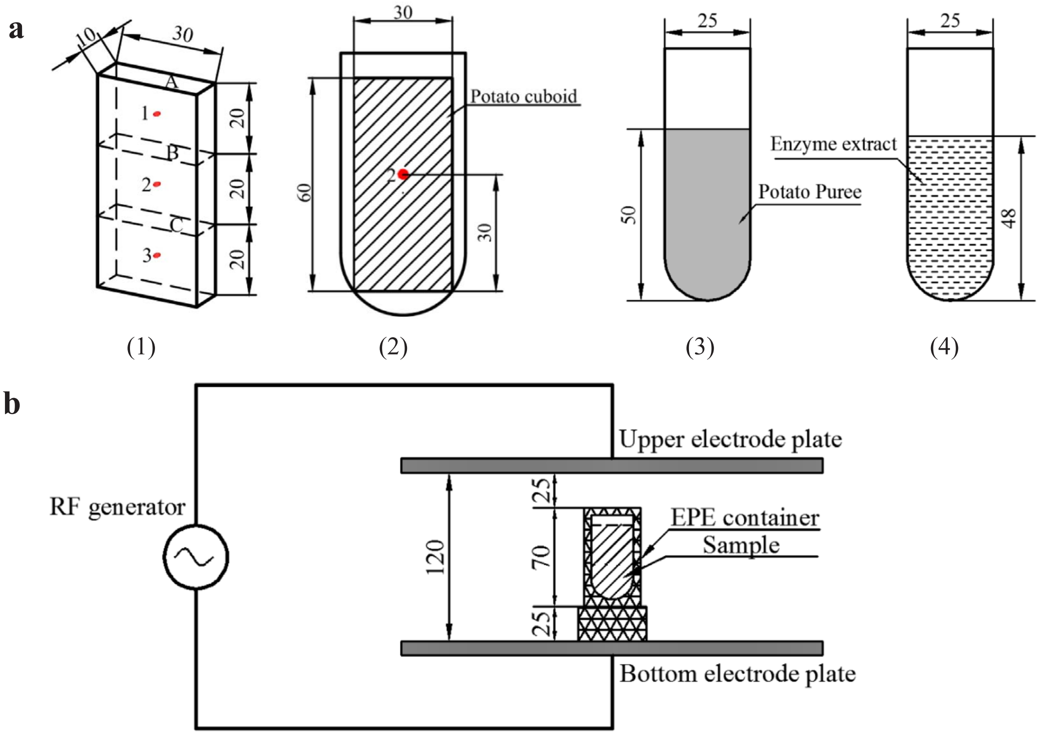


**Fig. 1.** Schematic of the sample in the centrifuge tube (a) and schematic of the potato sample placed in the RF heating system (b). (1) The position in the cuboid for measuring temperature and analyzing texture, (2) potato cuboid, (3) potato puree, and (4) enzyme extract (all dimensions are in mm).

of RF heating on the activity of enzymes in vegetables is still limited so far. It has been reported that RF heating could efficiently inactivated PPO and lipoxygenase (LOX), particularly PPO was more sensitive to an increase in the RF electric field (Manzocco et al., 2008). It showed that RF heating retained a higher sweetness and produced highly appreciated vegetable derivatives than the conventional blanching. Moreover, RF treatment can not only saves time, water, and energy, but also reduces the cost of waste treatment. Orsat, Gariépy, Raghavan, and Lyew (2001) compared the quality of vacuum-packaged carrot sticks treated with RF heating, chlorinated water dipping or hot water dipping, showing that the color and taste were better, and the vacuum of packages were greater of samples in RF treatment than that in chlorinated water or hot water. Lopez and Baganis (1971) also reported that peroxidase, polyphenolase, pectinesterase, catalase, and α-amylase were partially or totally inactivated by RF heating at 70 °C. These results indicated that RF heating has the potential in blanching fruits and vegetables. The main purpose of blanching is to inactivate enzymes which are related to the browning of food. Color, weight loss, and texture were used as indicator to evaluate the food quality during blanching. However, the changes of texture are attributed to the altering of microstructure during blanching (Araya et al., 2007). Therefore, the microstructure of food should be investigated to provide sufficient knowledge of blanching.

In addition should be very interesting to add new information on the effect of RF heating to the secondary structure of proteins. The secondary structure of the protein is a stable conformation of the local peptides in the peptide chain of the protein. Enzymes are proteins which have some active sites. Heat, ultrasound, pulsed electric field, etc., can disturb the delicate balance of covalent and non-covalent interactions that maintain the native structure, which can result in a loss of enzyme activity (Baltacıoğlu, Bayındırlı, & Severcan, 2017). Nevertheless, the reasons of enzyme inactivation whether were due to changes in the active site or the changes of secondary structure need to be studied. Although some researchers have studied the changes in secondary structure of peroxidase (POD) and PPO treated by PEF (Kikani & Singh, 2015; Zhong et al., 2007), to the best of our knowledge, there is no published data so far regarding the conformation changes of enzyme during RF heating.

The objectives of this study were: (1) to investigate the effects of RF heating on model enzyme (mushroom PPO) inactivation and the changes of enzyme secondary structure, (2) to analyze the effects of RF heating on the inhibition of PPO of potato, (3) to evaluate the changes of weight loss, texture, color, and microstructure of potato after RF heating.

## 2. Materials and methods

### 2.1. Materials and preparation of samples

The potato (*Solanum tuberosum* L.) numbering 15–7 was provided by the Potato Molecular Genetics and Breeding Lab of the College of Agriculture at Northwest A & F University in China and stored in a refrigerator at 4 °C. Before the experiments, the samples were taken out and equilibrated to room temperature (25 °C) overnight. Potatoes were washed, hand-peeled, and cut into cuboid with the dimension (length × width × height) of 30 × 10 × 60 $mm^3$ having an average weight of 20 g. The mashed potato was obtained by crushing 20 g potato tubers using an electrical hand blender (Multiquick 7 MQ705, 4199, De'Longhi Braun Household Gmbh, Germany) at room temperature. The method to prepare enzyme extract was described in the section 2.3.

Mushroom PPO (98% purity) as model enzyme (E.C. 1.14.18.1), catechol (≥99% purity) were purchased from Sigma (Shanghai, China) and Aladdin (Shanghai, China), respectively. Other chemicals used in this study were of analytical grade.

### 2.2. RF heating system

RF assisted blanching treatments were performed by a 6 kW, 27.12 MHz pilot-scale free running oscillator RF system (GJG-2.1-10A-