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Effects of hot air-assisted radio frequency roasting on quality and antioxidant activity of cashew nut kernels

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ABSTRACT

This study investigated hot air-assisted radio frequency (HA-RF) roasting effects on physicochemical properties, sensory quality, and antioxidant activity of cashew nut kernels. Raw cashew nut kernels placed inside polypropylene cuboid containers with different sample thickness (7 cm and 5 cm) were roasted by HA-RF treatments. Uniformity of roasted sample moisture content and color, sensory attributes (9-point hedonic scale), and antioxidant activity (TEAC and DPPH radical scavenging capacity) were evaluated. Roasting temperature of 120–130 °C and sample thickness of 5 cm were selected based on sample uniformity. For kernels with initial moisture content of 6.2 g/100 g (d. b.), HA-RF roasting reduced moisture content to 1.5 g/100 g within 30 min. Peroxide value and acid value of HA-RF roasted samples were significantly ($p < 0.05$) lower than those roasted by conventional hot air at 140 °C for 30 min, indicating better physicochemical quality of samples roasted by HA-RF heating. Both sensory attributes and antioxidant activity of the kernels roasted by HA-RF were in well-acceptable range, and had no significant difference ($p > 0.05$) compared with the samples roasted by conventional hot air method. This study demonstrated that HA-RF roasting holds great potential for roasting cashew nut kernels in a more efficient and environmental-friendly pattern.

1. Introduction

Cashew nut (*Anacardium occidentale* L.) is one of the most important tree nuts. The cashew nut kernels are rich in lipids (43 g/100 g), proteins (20 g/100 g) and inorganic constituents (Nascimento, Naozuka, & Oliveira, 2010), contain various health-beneficial constituents, including unsaturated fatty acids, vitamins, minerals and polyphenol compounds (Brufau, Boatella, & Rafecas, 2006), and have pleasant taste and flavor (Irtwange & Oshodi, 2009). Cashew nut kernels are usually consumed as snacks in roasted and fried forms to achieve better texture and flavor (Neto, Narain, Silva, & Bora, 2001).

Cashew nut kernels roasted in hot air is generally more preferable than fried because of the lower oil content in final product (Wanlapa & Jindal, 2006). However, conventional hot air roasting requires cashew nut kernels to be spread in a single layer on a stainless steel wire mesh tray (Wanlapa & Jindal, 2006), resulting in low efficiency and high energy consumption. Therefore, it is necessary to investigate advanced roasting technologies to improve roasting efficiency without sacrificing the quality of the products.

Recently, several new technologies have been evaluated in nuts roasting. Kosoko et al. (2014) studied the application of halogen-oven in roasting of cashew nut kernels and indicated that the halogen-oven is a better option for producing nutritious and wholesome roasted kernels with acceptable sensory quality. Yang et al. (2010) investigated the application of infrared heating in dry-roasting and pasteurization of almonds. Bagheri, Kashaninejad, Ziaiifar, and Aalami (2016) demonstrated that combination of infrared and hot air roasting can produce high quality roasted peanuts with lower energy cost. Agila and Barringer (2012) found that almonds roasted by microwave heating have the strongest aroma and are mostly preferred comparing with oven and oil roasting. Milczarek, Avena-Bustillos, Peretto, and Mchugh (2014) further optimized microwave roasting conditions (time and applied microwave power) to achieve similar quality attributes with those roasted by hot air and indicated that microwave roasting is a promising alternative method for almonds. However, both infrared and microwave heating has shallow penetration depth, thus limiting their application for roasting of bulk materials.

Radio frequency (RF) heating is a fast and volumetric heating method with frequency range of 3 kHz–300 MHz. The heat is produced by molecules friction inside foods because of ionic conduction and

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dipole rotation. Compared with microwave, RF has a longer wavelength, thus deeper penetration depth, which is suitable to treat bulk and thick materials (Jiao, Zhu, Deng, & Zhao, 2016; Pan, Jiao, Gautz, Tu, & Wang, 2012). Many studies have investigated the application of RF energy in process and preservation of agricultural and food products, such as killing pests in walnuts and coffee beans (Mitcham et al., 2004; Wang et al., 2001), pasteurization of in-shell almonds (Gao, Tang, Wang, Powers, & Wang, 2010), post-drying of partially baked cookies (Palazoğlu, Coşkun, Kocadağ, li, & Gökmen, 2012), and thawing frozen meats (Farag, Lyng, Morgan, & Cronin, 2011).

Several studies have shown that forced hot air combined with RF heating can enhance heating uniformity and drying efficiency (Gao, Tang, Villa-Rojas, Wang, & Wang, 2011; Pan et al., 2012; Wang, Zhang, Gao, Tang, & Wang, 2014). Hot air-assisted radio frequency (HA-RF) heating has been applied in drying in-shell macadamia nuts resulting in rapid and uniform heating and acceptable quality of nuts (Wang, Zhang, Johnson, et al., 2014). Our recent study indicated that HA-RF technology is an effective roasting method of peanuts (Jiao et al., 2016). Therefore, the objectives of the present study were to investigate the influence of different HA-RF treatments on uniformity of roasted cashew nut kernels; and to compare the effect of HA-RF roasting and traditional hot air roasting on physicochemical properties, sensory quality, and antioxidant activity of the roasted cashew nut kernels. The results from this study will provide new insight in producing roasted cashew nut kernels with an efficient and environmental friendly method.

2. Materials and methods

2.1. Materials

Raw cashew nut kernels were obtained from a processing plant in Vietnam. The original moisture content was about 6.2 g/100 g (d. b.). The raw kernels were sealed in light-tight and air-tight plastic bags and stored at a 4 °C refrigerator till use. Before testing or roasting, the samples were removed from the refrigerator and allowed to reach room temperature.

2.2. HA-RF heating system

A 12 kW, 27.12 MHz pilot scale free-running RF system (310 × 100 × 165 cm^3) with parallel electrodes and a built-in hot air system (GJD-6A-27-JY, Huashi Jiyuan Co. Ltd., Hebei, China) was applied in this study. There are small holes distributed uniformly on the bottom electrode for allowing hot air to get into RF cavity. The temperature of hot air in the system was set to a range of 20–80 °C according to the demand of different treatments. The position of top electrode (75.0 × 55.0 cm^2) was adjusted to obtain different RF heating rates. Fiber optic sensors (ThermAgile-RD Optsensor, Xi'an Heqiguangdian Co. Ltd., Shanxi, China) connected with a computer were used to record the real time temperature changes during RF heating. More information related to RF system can be found from Wang, Tiwari, Jiao, Johnson, and Tang (2010). Two uncovered polypropylene (PP) cuboid containers of different sizes (13.0 L × 8.5 W × 6.0 H cm^3; 11.0 L × 11.0 W × 7.5 H cm^3) with small holes on the side and bottom were used to hold samples for HA-RF roasting. Four fiber optic sensors were placed at four typical positions inside the sample container (Fig. 1).

2.3. HA-RF roasting treatment

Raw cashew nut kernels were put in the container, which was placed on the bottom electrode and subjected to HA-RF roasting. Based on our preliminary study, electrode gaps of 8.0, 9.0, and 10.0 cm for 7.0 cm of sample thickness and 8.0, 8.1, 8.2 cm for 5.0 cm of sample thickness were selected and compared to obtain an appropriate heating rate. Hot air system was turned on when sample temperature rose to 80 °C and hot air temperature inside RF cavity was controlled to 70 °C. Three roasting temperature ranges (110–120 °C, 120–130 °C and 130–140 °C) were chosen and compared for heating uniformity and quality of roasted samples. The roasting process was stopped when moisture content of nut kernels decreased to about 1.5 g/100 g. After roasting, samples were taken out immediately and cooled in a single layer by forced ambient air for 5 min. Samples were then collected for further analysis.

2.4. Conventional hot air roasting treatment

Cashew nut kernels were spread on a stainless steel wire mesh tray in single layer, and then the tray was placed in a hot air oven. Kernels were roasted at 140 °C for 30 min, which was the optimum roasting condition for cashew nut kernels based on Wanlapa and Jindal (2006). After roasting, samples were taken out immediately and cooled by forced ambient air on the stainless steel wire mesh tray for 5 min. Samples were then collected for further analysis.

2.5. Roasting uniformity

To measure the uniformity of cashew nut kernels roasted by different HA-RF treatments, samples processed by the same parameters were manually classified into three grades (light, medium, dark) based on the lightness of kernels. The moisture content and total color difference of each grade were calculated as well as the standard deviation among three grades.

Moisture content of the cashew nut kernels was measured using vacuum drying method (Jiao et al., 2016). Briefly, cashew nut kernels were ground using a grinder (FW135, Taisite Co. Ltd., Tianjin, China). About 2 g of ground samples were placed in an aluminum dish, and dried in a vacuum oven (DZF-6020, Yihengkeji Co. Ltd.,Shanghai, China) at 60 °C for 4 h.

The color of raw and roasted samples was measured using a colorimeter (LabScan XE, Hunter Associates Laboratory, Inc., USA). About 10 g ground cashew nut kernels were placed in a plastic petri dish (5 cm diameter), and color values of CIE L (darkness), a (green–red), and b (blue–yellow) were recorded. The total color difference (ΔE) was calculated as (Yang et al., 2013):

$$\Delta E = \sqrt{(L_f - L_0)^2 + (a_f - a_0)^2 + (b_f - b_0)^2} \quad (1)$$

where the subscripts *0* and *f* denoted raw and roasted cashew nut kernels.

The acid and peroxide values were determined after oil extraction. The kernel samples were ground using a grinder firstly. Petroleum ether was added in the ground kernels (1:3, *mL:mL*), and agitated with a magnetic stirrer for 30 min at ambient temperature. After standing for 12 h, the mixture was filtrated through a funnel filled with anhydrous sodium sulfate. The cashew kernel oil was obtained by evaporating the petroleum ether completely using a vacuum rotary evaporator.

2.6. Quality evaluation

To evaluate the quality of cashew nut kernels, the physicochemical properties (water activity, peroxide value and acid value), sensory quality, and antioxidant activity (Trolox equivalent antioxidant capacity (TEAC) and 1,1-Diphenyl-2-picrylhydrazyl (DPPH) radical scavenging capacity) were determined in this study.

2.6.1. Physicochemical properties

Water activity was measured by a water activity meter (FA-st lab, GBX Instrumentation Scientifique, France). Peroxide value was determined according to the method described by Yang et al. (2013). Extracted oil (2.0–3.0 g) was placed in a 250 mL conical flask followed