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Novel hybridized infrared-hot air method for roasting of peanut kernels

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ABSTRACT

Roasting is an important step in the processing of peanut kernels. In this study the combination of infrared (IR) and hot-air was explored for roasting of peanut kernels and the effects of processing conditions including hot air temperature (100 and 120 °C), infrared power (130 W, 165 W and 200 W) and roasting time (10, 20, 30 min) on different characteristics of kernels (moisture content, color, textural characteristics, chemical properties, specific energy consumption and sensory properties) were investigated. The results showed that increasing the roasting air temperature, infrared power and roasting time decreased the moisture content, fracture force, hardness, apparent modulus of elasticity, compressive energy, pH and solid soluble content and increased the browning index, total phenolic compounds, and total acceptance of peanuts kernels. The total color difference (ΔE) varied from 2.87 to 19.33. After roasting, hardness of the peanut kernels reduced from initial 91.31 to 33.86 N and total phenolic compounds value were 2.71 mg GAE/g, all in the acceptable limit for good quality of roasted peanuts. The lowest value of specific energy consumed in roasting peanut kernels was observed at 100 °C and 200 W for 10 min (5.06 kWh/kg) and the highest value was at 120 °C and 130 W for 30 min (23.20 kWh/kg). This study demonstrated that combination of infrared and hot-air roasting can produce high-quality roasted peanuts with lower energy cost and time roasting; therefore it could be considered as a new technology for the peanut roasting industry.

Industrial relevance: Infrared radiation could be considered as a promising technique for roasting of soybeans due to lower energy cost.

1. Introduction

The peanut (*Arachis hypogaea* L.) is a fruit or pod of the Leguminosae family (Adebiyi, Adeyemi, & Olorunda, 2002) and the second most harvested legume in the world behind soybeans and provides an important nutrient source to human (Jiao, Zhu, Deng, & Zhao, 2015). Although commonly thought of as nuts, peanuts are legumes. It contains 47–50% oil, 25–30% protein and is an essential source of minerals and vitamins; thus it makes a substantial contribution to human nutrition (Adebiyi et al., 2002). Except for making oil, peanuts have been processed into snack foods because of its unique flavor and abundant nutrients (Jiao et al., 2015). Peanuts are readily acceptable as a cheap protein source and popular snack item that can be eaten alone or combined with other foods (Adebiyi et al., 2002). Recently, peanuts have gained much attention as functional food (Francisco & Resurreccion, 2008).

Roasted peanuts is one of the most popular snack foods, in which roasting is a key step in the process and directly impacts the quality (crispness, taste, and flavor) and shelf-life of the final product (Chen, Kang, Chen, Chen, & Lin, 2010). In other word one of the most widely consumed nuts in the world is roasted peanuts.

Roasting is one of the processing steps involved in the nut industry to improve the flavor, color, texture and overall acceptability of the product (Ozdemir & Devres, 2000; Pittia, DallaRosa, & Lerici, 2001). Understanding of the roasting process is of interest because roasting is a critical processing step not only for peanuts, but for many other food products such as coffee, cocoa, grains and other tree nuts. Roasting is critical to the development of color, flavor and textural through chemical reactions, heat transfer and drying which occur during roasting (Saklar, Katnas, & Ungan, 2001).

Hot air, coal-fired furnace and electric furnace are commonly applied methods for roasting of food products. These roasting technologies are time consuming, have high energy cost and lower production rate (Yang et al., 2010). Among the mentioned methods, hot air roasting is one of the simplest methods with low investment and operating costs. However, it uses a large amount of thermal energy (RuizCelma, Rojas, & Lopez-Rodriguez, 2008) and usually requires a long period of roasting time, resulting in undesirable changes in the final product. To overcome the drawbacks of the hot air roasting, new methods such as infrared radiation has potential to be integrated with it.

IR power is energy in the form of electromagnetic wave and lies in the wavelength range between 0.7 and 1000 μm (Ranjan, Irudayaraj, & Jun, 2002). The FIR wavelength is in the wavelength range between 3 and 1000 μm and can be applied for different heating

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treatments such as baking, drying, roasting, thawing and pasteurization (Rastogi, 2012).

Infrared roasting has gained popularity as an alternative roasting method for beans and nuts. The use of infrared roasting has several advantages in comparison with traditional convective roasting methods. Low roasting time, heat efficiency, high diffusion coefficient and compact equipment are advantages of this method (Wu et al., 2014).

Combined infrared and hot air method has been widely applied for processing (mainly drying) of various foodstuffs including carrots, potatoes (Hebbar, Vishwanthan, & Ramesh, 2004), pineapple rings (Ponkham, Meeso, Soponronnarit, & Siriamornpun, 2012), whole longans (Nuthong, Acharyaviriya, Namsanguan, & Achariyaviriya, 2011), murta berries (Puent-Diaz, Ah-Hen, Vega-Galvez, Lemus-Mondaca, & Scala, 2013) and onion slices (Kumar, Hebbar, & Ramesh, 2006). The combined technique was found to accelerate heat and mass transfer, leading to a shorter processing time (Jaturonglumlert & Kiatsiriroat, 2010) and lower energy consumption (Siriamornpun, Kaisoon, & Meeso, 2012) compared to hot air method.

Chen et al. (2010) have applied far infrared energy to roast peanuts and found that the quality was well maintained under the optimized roasting conditions. Their results showed that during roasting, the acid and peroxide values increased slowly in salty and crispy peanut, but did not affect significantly on quality of kernels under the optimized far-infrared roasting conditions. Reducing sugars and free amino acids decreased during roasting because of Maillard reaction, which was beneficial for flavor of peanuts. Activities of lipoxygenase (LOX) and the anti-nutritional factors such as trypsin inhibitor also declined in peanut kernels during roasting. LOX activity was completely inactivated when salty and crispy peanuts roasted at 130 °C for 0.5 h.

Yang et al. (2010) developed two new roasting methods for almonds, infrared roasting and sequential infrared and hot air roasting (SIRHA). Compared to traditional hot air roasting, SIRHA heating can produce roasted almonds with up to 30–70% reduction in processing time and meets pasteurization requirements for producing medium degree roasted almonds at 130, 140, and 150 °C. In this study no significant difference ($P > 0.05$) was observed in sensory quality of medium roasted almonds processed with different roasting methods. They pointed out that the SIRHA roasting is a promising new method for the production of dry-roasted pasteurized almonds.

The effect of infrared roasting on the formation of sesamol and quality of defatted flours from sesame seed investigated by Kumar, Rao, and Singh (2009) and showed that the conversion efficiency of sesamolin to sesamol increased by 31% after infrared roasting of seeds compared to electric drum roasting. This can be used industrially to obtain roasted oil with greater oxidative stability.

However, to our knowledge, there is no study available for combined infrared-hot air heating technology for roasting of peanuts. Therefore, combined infrared-hot air heating was explored in this study as a new roasting method for peanuts. The main objectives of this study were (1) to develop treatment protocol of combined infrared-hot air roasting for salted peanuts; (2) to evaluate the quality characteristics of product after processing.

2. Materials and methods

2.1. Sample preparation

Dried Goli peanuts were supplied from Agricultural Research Institute of Minodasht (Minodasht, Iran) in 2015 and stored at 4 °C until processing. The weight ratio of kernel was averagely obtained as 73 g/100 g of split sample. The average moisture content of peanut kernels was measured as 5.1% (d.b.). Kernels were sorted manually to get the uniform sizes for roasting. 100 g peanut kernels were soaked in 500 mL of 25% salt solution for 30 min. After soaking, the salt solution was drained using a strainer and the excess water was removed by a cloth filter. After soaking, the moisture content of soaked peanut kernels increased to 8.27% (d.b.).

2.2. Combined infrared-hot air roasting of kernels

Roasting was performed in a combined infrared-hot air roaster (Fig. 1) equipped with a controller to adjust the air temperature and IR power of roasting. The apparatus consisted of heating elements (4 electrical elements with power 750 watts), Scale, Pitot unit, a centrifugal fan, Infrared radiator (Far infrared lamp, 1500 W) and a roasting chamber. For roasting, two air temperatures (100 and 120 °C), three IR power (130, 165 and 200 W) and three times (10, 20 and 30 min) and constant air velocity (1 m/s) were applied. After roasting, the whole kernels were allowed to cool at room temperature (23 ± 2 °C). Roasting process was performed in 3 replications.

2.3. Moisture determination

Moisture content of peanut kernels was measured in triplicate using oven drying method (130 ± 2 °C) until a constant weight was reached (McDaniel, White, Dean, Sanders, & Davis, 2012).

2.4. Color analysis

The color of peanut kernel was measured using of a flat scanner system (Jpeg format) with resolution of 600 dip (dots per inch). The L*, a* and b* values are three dimensions of a measured color which gives specific color value of the material. The L value represents light-dark spectrum with a range from 0 (black) to 100 (white). The a* value represents green-red spectrum with the range from −60 (green) to +60 (red). The b value represents blue-yellow spectrum with the range from −60 (blue) to +60 (yellow). The L*, a* and b* values for each sample were converted into ΔE and BI values according to the following equations (Eqs. (1) and (2)):

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

$$BI = \frac{(x-0.31)}{0.17} \times 100$$
$$x = \frac{a* + 1.75L*}{5.645L* + a* - 3.012b*} \quad (2)$$

The ΔE value, calculated using Eq. (1), indicates the total color difference. In this study, ΔE values were calculated in relation to the raw peanut kernel. The last color parameter is BI which was calculated using the Eq. (2). It indicates the purity of brown color and is reported as an

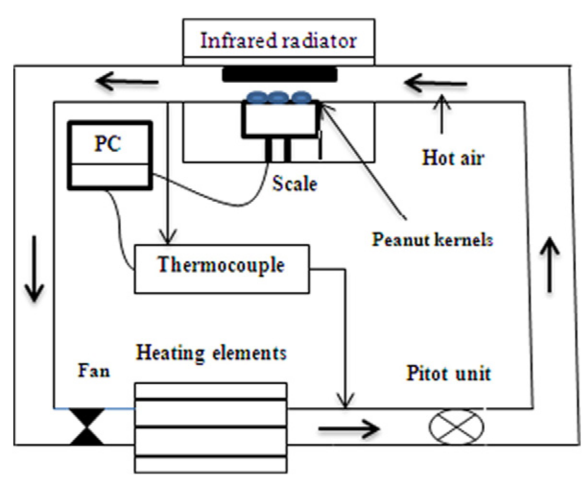

Fig. 1. Diagram of combined infrared-hot air roaster.