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Shelf-life of infrared dry-roasted almonds

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ABSTRACT

Infrared heating was recently used to develop a more efficient roasting technology than traditional hot air roasting. Therefore, in this study, we evaluated the shelf-life of almonds roasted with three different approaches, namely infrared (IR), sequential infrared and hot air (SIRHA) and regular hot air (HA). Nine medium roasted almond samples produced by the aforementioned heating methods were processed at three different temperatures (130, 140 and 150 °C), packed in paper bags and then stored at 37 °C for three, six or eight months. Shelf-life of the roasted almonds was determined by measuring the changes in colour, peroxide value, moisture content, water activity, volatile components and sensory quality. No significant difference was observed in moisture content and water activity among the almond samples processed with different roasting methods and stored under the same conditions. GC/MS analysis showed that aldehydes, alcohols, and pyrazines were the main volatile components of almonds. Aliphatic aldehydes such as hexanal, (*E*)-2-octenal, and nonanal were produced as off-odours during storage. Although the overall quality of roasted almonds produced with SIRHA and HA heating was similar during the first three months of storage, their peroxide value and concentration of aliphatic aldehydes differed significantly for different roasting methods and increased significantly in all roasted samples during storage. We postulate that hexanal and nonanal might be better indicators of the shelf life of roasted almonds than the current standard, peroxide value.

1. Introduction

Roasting is one of the most popular ways to process almonds (The Nut Factory, 2010). However, traditional hot air roasting involves a relatively long processing time (Almond Board of California, 2007; Anon, 2007a; Centrella, 2007; Issacs et al., 2005) and does not meet the minimum 4-log reduction of *Salmonella* Enteritidis phage type 30 (*SE* PT 30) for pasteurisation of almond products mandated by the Almond Board of California and the U.S. Department of Agriculture (Anon, 2007b). Yang et al. (2010) recently developed two new roasting methods for almonds, infrared (IR) roasting and sequential infrared and hot air (SIRHA) roasting. Compared with traditional hot air (HA) roasting, SIRHA heating can produce roasted almonds with up to 30–70% reductions in processing time and meet pasteurisation requirements for producing medium degree roasted almonds at 130, 140, and 150 °C.

Almonds are a high oil yield seed containing around 50% lipids (Ahrens, Venkatachalam, Mistry, Lapsley, & Sathe, 2005; Harris, Westcott, & Henick, 1972; Miraliakbari & Shahidi, 2008; Sathe, Seeram, Kshirsagar, Heber, & Lapsley, 2008). Two unsaturated fatty acids, oleic (C18:1) and linoleic acid (C18:2) account for over 90% of the total soluble lipids (Pićurić-Jovanović & Milovanović, 1993; Sathe et al., 2008). In general, foods with a higher content of unsaturated fatty acids are more susceptible to the development of rancidity and have a shorter shelf life. García-Pascual, Mateos, Carbonell, and Salazar (2003) explained that rancidity originates from the reaction of unsaturated fatty acids with oxygen followed by the degradation of fatty acid peroxides to produce off-flavor compounds.

Roasting of whole cashew nuts improved the oxidative stability of the resulting nut oils (Chandrasekara & Shahidi, 2011a). The effect may have been due to the formation of Maillard reaction products (MRP) which are known to exhibit antioxidative effects. Chandrasekara and Shahidi (2011b) studied the effect of roasting on the content of phenolic compounds and antioxidant activities of cashew nuts and testa. High temperature treated (130 °C for 33 min) cashew nuts and testa showed higher phenolic content and antioxidant activity than low temperature treated (70 °C for 6 h) samples. Similarly, roasting enhanced the antioxidant activity

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of cashew phenolic extracts compared to their raw counterparts when evaluated for their potential in inhibiting accelerated oxidation of commercial stripped corn oil at 100 °C (Chandrasekara & Shahidi, 2011c).

Most of the previous studies on roasted almond storage investigated the influence of various factors (i.e., packaging materials, moisture content, water activity, temperature, time, light or irradiation) on several physical, sensory and chemical parameters of the seeds (Abegaz, Kerr, & Koehler, 2004; Buranasompob et al., 2007; García-Pascual et al., 2003; Sattar, Mohammad, Saleem, Jan, & Ahmad, 1990; Wambura, Yang, Williams, Feng, & Rababah, 2007; Zacheo, Cappello, Gallo, Santino, & Cappello, 2000). Moisture and water activity are important criteria for the evaluation and control of food safety and quality. According to the Grocery Manufacturers Association's recent survey (2010), industry moisture specifications of 3.5–5.5% for raw almonds and 1.5–2.5% for roasted almonds, and a water activity in the range of 0.2–0.3 represent the optimal moisture content and yield the maximum shelf life. Colour is regarded as one of the most important quality attributes of roasted nuts (Francis, 1995; Wall & Gentry, 2007; Warmund, Elmore, Adhikari, & McGraw, 2009; Yang et al., 2010; Özdemir & Devres, 2000), as it affects consumer acceptability. Colour is also used in industry to specify the desired degree of roasting.

The oxidation of fats and the rate of rancidity development are highly dependent on the storage temperature. Commonly, the shelf life of nuts is inversely proportional to storage temperature. Thus, high temperatures can be used to accelerate ageing reaction rates. However, Mattei (1969) observed that almond quality was different when storage temperatures exceeded 43 °C compared with accelerated temperature tests at lower temperatures. Due to this observation and the desire to simulate summer temperatures, storage temperatures of 35–38 °C were selected by researchers performing accelerated shelf life tests (Budin & Breene, 1993; Fritsch, Hofland, & Vickers, 1997; García-Pascual et al., 2003; Harris et al., 1972; Wambura et al., 2007).

Peroxide value is frequently used to measure the progress of oxidative rancidity and as an index to evaluate shelf-life (Chun, Lee, & Eitenmiller 2005; Fritsch et al., 1997; Sánchez-Bel, Martínez-Madrid, Egea, & Romojaro, 2005; Wambura et al., 2007). Moreover, roasting and storage produce different changes in nuts (e.g., volatile compounds) as a result of different heating methods (El-Kayati, Fadel, Abdel Mageed, & Farghal, 1998; García-Pascual et al., 2003; Takei, Shimada, Watanabe, & Yamanishi, 1974; Takei & Yamanishi, 1974; Uysal, Sumnu, & Sahin, 2009). Pyrazines have been reported to be some of the most important flavor compounds in roasted nuts (El-Kayati et al., 1998; Kinlin, Muralidhara, Pittet, Sanderson, & Walradt, 1972; Walradt, Pittet, Kinlin, Muralidhara, & Sanderson, 1971), whereas aldehydes are responsible for dominating off-flavors produced during storage. The concentration of these flavor constituents varies with different roasting and storage conditions.

Krishnamurthy, Khurana, Jun, Irudayaraj, and Demirci (2008) stated that the investigation of the quality and sensory changes occurring during IR heat treatment is critical for its commercial success. Several researchers have studied the quality and sensory changes of food materials during IR heating. The results substantiated that IR heating itself does not significantly change the quality attributes of foods such as vitamins, protein, antioxidant activities and sensory quality (Chua & Chou, 2005; Huang, 2004; Khan & Vandermey, 1985; Meeso, Nathakaranakule, Madhiyanon, & Soponronnarit, 2004; Tanaka et al., 2007). Kouzeh, van Zuilichem, Roozen, and Pilnik (1982) found that full-fat flour made from IR heat-treated soybeans maintained freshness similar to fresh flour for one year. To the best of our knowledge further studies on the shelf life of products processed by IR roasting have not been reported.

The goal of our study was to test the shelf-life of medium roasted almonds produced at different temperatures with three roasting methods, namely IR, SIRHA and conventional HA, and to provide a science-based approach for processing and storage of roasted almonds.

2. Materials and methods

2.1. Almonds

Raw almonds of the Nonpareil variety with size 27/30 CPO (counts per ounce) were provided by the Almond Board of California (Modesto, CA, USA). Almonds were sorted to remove any damaged kernels and then stored in plastic bags at 4 °C. The initial moisture content of raw almonds was 4.6% (w.b.). The average weight of raw almond was 1.04 ± 0.07 g and their dimensions were 7.8 ± 0.4, 12.3 ± 0.3, and 22.2 ± 1.2 mm in thickness, width, and length, respectively.

Raw almonds were roasted to medium degree with three different methods, IR, SIRHA, and HA. The roasting time for IR heating was 11, 6, and 4 min, for SIRHA heating was 21, 11, and 5 min and for HA heating was 34, 18, and 13 min at 130, 140 and 150 °C, respectively. Three replicate samples were processed separately for each roasting condition. The methods of almond roasting were previously described in detail (Yang et al., 2010).

2.2. Temperature-accelerated shelf life test

Nine roasted almond samples processed with different methods were packed individually in paper bags and stored at 37 ± 0.5 °C with 7–8% relative humidity in a Model 70D incubator (Precision Scientific Inc., Winchester, IL, USA). Storage behaviours were determined by measuring changes in colour, peroxide value, moisture content, and water activity each month during six months of storage. The experiment was done in triplicate.

2.2.1. Colour

The colour of raw and roasted samples was measured using a colorimeter (Minolta Chroma meter CR-200, Minolta Corporation, now Konica Minolta Sensing Americas, Inc., Ramsey, NJ, USA). At least thirty randomly selected roasted almond kernels were ground in a blender (Waring Commercial Heavy-Duty Blender 38BL 19 CB10, Waring Laboratory & Science, Torrington, CT, USA) for 5 s. The ground sample (8 g) was placed in a plastic Petri dish (5 cm diameter) for measurement. The total colour difference, ΔE, was calculated using the following equation:

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

The subscripts 0 and f denote raw and roasted almonds, respectively, at a given time during storage.

2.2.2. Peroxide value

A sample of ground almonds (30 g) was combined with 75 mL of hexane and extracted for 1 min using a Sonifier model S-450 ultrasonic processor (Branson Ultrasonics Corporation, Danbury, CT, USA). The mixture was filtered through a Whatman No. 50 filter paper with vacuum using a Büchner funnel. The solvent was removed using a rotary evaporator (Büchi Rotavapor® R-205, BÜCHI Labortechnik AG, Flawil, Switzerland) at 30 °C. The peroxide value was determined according to Commission Regulation (E C) No. 2568/91 (1991) methods (García-Pascual et al., 2003). The lipid sample (2–5 g) was placed in a flask with 10 mL of chloroform, 15 mL of glacial acetic acid and 1 mL of water solution saturated with potassium iodide. It was left in the dark for 5 min, after which