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Influence of roasting conditions on health-related compounds in different nuts

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ABSTRACT

Due to their health-beneficial ingredients the consumption of nuts can contribute to a healthy diet. The composition of hazelnuts, almonds, macadamia nuts, pistachios and walnuts regarding health-promoting and potentially harmful compounds was examined before and after roasting under different time and temperature conditions. Fatty acid compositions were not affected by roasting. Malondialdehyde increased with higher roasting temperatures (17-fold in walnuts). Levels of tocopherol isomers were reduced after roasting (α-T: 38%, β-T: 40%, γ-T: 70%) and hydrophilic antioxidant capacity decreased significantly in hazelnuts (1.4-fold), macadamia nuts (1.7-fold) and walnuts (3.7-fold). Increasing roasting temperatures supported the formation of significant amounts of acrylamide only in almonds (1220 μg kg^{-1}). In general, nuts roasted at low/middle temperatures (120–160 °C) exhibited best sensory properties. Therefore, desired sensory quality along with a favourable healthy nut composition may be achieved by roasting over a low to medium temperature range.

1. Introduction

Due to their health-beneficial constituents, which comprise essential macro- and micro-nutrients, such as unsaturated fatty acids, vitamins (vitamin E, folic acid, niacin) and minerals (phosphorus, copper) as well as polyphenols (Alasalvar & Shahidi, 2009), nut consumption can contribute to a healthy diet. On the other hand, nuts contain high amounts of fat and are therefore often considered unfavourable for health by the broad public. Several studies showed that, despite the high fat content, moderate consumption of nuts does not result in the gain of weight (Vadivel, Kunyanga, & Biesalski, 2012), and consequently up to 40 g nuts are recommended for daily intake (USDA, 2009). In addition, the unique lipid profile of nuts, comprising high contents of monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs), is responsible for several health-promoting effects, such as reduced levels of blood LDL-cholesterol, improved blood lipid profile and protection from cardiovascular diseases (Banel & Hu, 2009; Sabate, Oda, & Ros, 2010). Nut consumption also contributes to a reduced mortality risk, as shown by the recent SUN project (Fernandez-Montero et al., 2014). Another health-promoting nut ingredient is dietary fibre. A portion of 30 g of nuts can provide up to 12% of the daily recommended dietary fibre intake (Alasalvar & Shahidi, 2009; Ros, 2010), and nuts therefore influence gut health. The EPIC study, for example, showed that nut consumption is inversely correlated with colon cancer risk in women (Jenab et al., 2004). Nuts are also an important source of vitamin E isomers as antioxidant active compounds, although the contents of distinct vitamin E isomers vary between different types of nuts (Robbins, Shin, Shewfelt, Eitenmiller, & Pegg, 2011).

Many nuts are predominantly consumed roasted. Roasting is responsible for the development of the typical taste and aroma as well as the crunchy texture of nuts. The roasting process involves microstructural and chemical changes, like the decrease in moisture content, lipid modifications and changes in colour as well as the formation of compounds responsible for the typical roasted nut flavour, mainly due to Maillard reactions (Alamprese,

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Ratti, & Rossi, 2009; Amaral, Casal, Seabra, & Oliveira, 2006; Saklar, Katnas, & Ungan, 2001). However, microstructural and lipid modifications might lead to an enhanced susceptibility to lipid oxidation of roasted nuts (Alamprese et al., 2009) compared to raw nuts. Also changes in the content of metabolites (e.g., antioxidants) may occur due to roasting (Amaral et al., 2006). Therefore, the roasting process may influence both the formation of health-promoting nut components and those with potentially adverse health effects. Until now, only a few studies elucidated the influence of the roasting process on the composition of nuts regarding health-promoting or potential harmful properties. In the present comprehensive study, we examined the composition of macadamia nuts, hazelnuts, almonds, pistachios and walnuts before and after roasting under different conditions regarding the content of constitutional (fatty acids, FA; vitamin E isomers) or potential harmful (thiobarbituric acid reactive substances, TBARS; acrylamide) nut components and antioxidant capacity. We also compared laboratory and industrial roasting and considered sensory properties.

2. Methods

2.1. Characterisation of nuts

Macadamia nuts (South Africa), pistachios (California) and walnuts (California) were delivered by the Southern African Subtropical Growers' Association, Paramount Farms and the California Walnut Association, respectively. Hazelnuts (Turkey) and almonds (California) were obtained from Viba Sweets GmbH (Floh-Seligenthal, Germany). All nuts were mature and harvested in 2012. After the roasting experiments (see Section 2.2) nuts were hermetically sealed and stored at 4 °C until use. To enable the different analytical determinations, in each case 50 g of nuts were randomly sampled from a 10 kg charge. Freshly ground nuts were used for all experiments.

2.1.1. Quantification of main constituents in raw nuts

Water, protein (basis 160 mg N per g protein) and fat (petroleum ether extract) contents were determined in the ground nut samples (2, 0.3 and 1 g, respectively) according to the Official German Methods for Food Surveillance (BVL, 2014). The total dietary fibre content of the different nut varieties (10 g ground nuts) was determined according to a certified protocol (AOAC 991.43) (AOAC International, 2005).

2.1.2. Quantification of micronutrients in raw nuts

For the analysis of micronutrients matrix disintegration was made *via* pressure digestion of 0.5 g lyophilised ground samples mixed with 3 mL concentrated nitric acid and 1 mL hydrogen peroxide. Ca, K, Mg, Na, P, Fe, Zn, Cu and Mn were detected by inductively coupled plasma atomic emission spectrometry (ICP-AES, Optima 3000, Perkin Elmer Inc., Waltham, MA) according to DIN-EN ISO 11885 at the given wavelengths with adaption for feed and food. Se content was analysed by flow-injection hydride atomic absorption spectrometry (AAnalyst 100/FIA 400, Perkin Elmer Inc.) by using an absorption wavelength of 196.0 nm. Prior to analysis, Se (VI) ions were reduced in hydrochloric acid medium by addition of sodium borohydride to SeH_2 (VDLUFA, 2003).

2.2. Roasting of nuts

The different nut varieties were roasted at laboratory scale using an FRC-T.1 drum roaster (Probat GmbH, Emmerich am Rhein, Germany) in charges of 6–10 kg. Roasting conditions were adjusted for each nut variety depending on the specific nut properties to obtain constant residual moisture contents. Therefore, the final roasting temperatures and times varied for the different types of nuts (123 °C/25 min to 185.5 °C/25 min; Table 1). For comparison to laboratory roasting conditions, industrially roasted hazelnuts and almonds were derived from two local nut processing companies. Industrial roasting of hazelnuts was carried out in a continuous roaster (I1; Stollwerck GmbH, Köln, Germany) at final roasting temperatures of 140 and 159 °C for 25 min. Additionally, industrial roasting of hazelnuts and almonds (I2; Viba Sweets GmbH, Floh, Germany) was performed in a conventional drum roaster with roasting conditions of 160 °C/30 min, 180 °C/15 min (Probat Type SG150), and 140 °C/23.4 min, 160 °C/12.3 min and 180 °C/11.3 min (Probat Type Probatone 5), respectively .

2.3. Characterisation of raw and roasted nuts

2.3.1. Fatty acid composition

Lipids were extracted from 3 g ground nuts and fatty acid content analysis was performed using GC (GC-17 V3; Shimadzu Corporation, Kyoto, Japan) equipped with an autosampler (AOC-5000) and a flame ionisation detector, as described in Kuhnt, Kraft, Moeckel, and Jahreis (2006). Lipid extracts were transesterified under alkaline conditions with sodium methoxide ($NaOCH_3$; 0.5 M in methanol at room temperature for 5 min) to produce fatty acid methyl esters (FAME). To analyse fatty acids ranging from 4 to 26 carbon atoms a fused-silica capillary column DB-225ms (60 m × 0.25 mm i.d., film thickness 0.25 μm; J&W Scientific Inc., Agilent, Santa Clara, CA) was used. The injector and detector temperatures were constant at 260 and 270 °C, respectively, using H_2 as carrier gas. Fatty acid concentrations were expressed as percentage of the total area of all FAME (% of total FAME) using GC Solution software (Shimadzu Corporation).

2.3.2. Extraction and determination of thiobarbituric acid reactive substances

TBARS extraction and determination were performed according to Papastergiadis, Mubiru, Van, and De (2012). In brief, 1 g of freshly ground nut sample was weighed in a 50-mL Falcon tube and 3 mL of a mixture of 7.5% TCA (w/v; trichloroacetic acid), 0.1% (w/v) of EDTA and 0.1% (w/v) of propyl gallate were added. The mixture was homogenised using an Ultraturrax (IKA-Werke GmbH & Co. KG, Staufen, Germany) with 4–5 pulses per 10 s. Then, the mixture was centrifuged for 15 min at 3000*g* and filtered through 150-mm filter paper.

For the photometric determination of MDA (malondialdehyde) equivalents, a 0.53% (w/v) TBA (thiobarbituric acid, Merck KGaA, Germany) solution was freshly prepared by dissolving 80 mg TBA in 7.5 mL 20% (v/v) acetic acid at 50 °C. After adjusting the volume to 15 mL with distilled water, the pH of the solution was brought to 3.5 by adding 5 N NaOH. Two-hundred microlitres of the TBARS extract, 50 μL of 8.1% (w/v) SDS (sodium dodecyl sulphate) and 600 μL of TBA reagent were combined in a test tube and heated in a thermoshaker at 95 °C for 1 h. The reaction mixture was chilled, and 800 μL of *n*-butanol/pyridine (15/1 v/v) were added.

Table 1
Laboratory scale roasting parameters (temperature and time).

RC[a]	Hazelnuts	Almonds	Macadamia nuts	Pistachios	Walnuts
	°C/min				
1	139.2/18	139.2/25	138.4/17	123.6/25	139.7/25
2	140.6/25	151.1/25	138.9/25	140.8/25	141.5/25
3	155.1/20	161.5/20	150.8/20	152.1/20	154.5/20
4	168.9/15	162.1/25	160.1/15	160.1/15	170.3/15
5	180.4/21	170.8/15	170.7/13	185.1/21	185.5/25

[a] RC, roasting condition.