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Effect of vacuum roasting on acrylamide formation and reduction in coffee beans

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ABSTRACT

Coffea arabica beans were roasted in an oven at 200 °C for increasing lengths of time under vacuum (i.e. 0.15 kPa). The samples were then analysed for colour, weight loss, acrylamide concentration and sensory properties. Data were compared with those obtained from coffee roasted at atmospheric pressure (i.e. conventional roasting), as well as at atmospheric pressure for 10 min followed by vacuum treatment (0.15 kPa; i.e. conventional-vacuum roasting). To compare the different treatments, weight loss, colour and acrylamide changes were expressed as a function of the thermal effect received by the coffee beans during the different roasting processes. Vacuum-processed coffee with medium roast degree had approximately 50% less acrylamide than its conventionally roasted counterpart. It was inferred that the low pressure generated inside the oven during the vacuum process exerted a stripping effect preventing acrylamide from being accumulated. Vacuum-processed coffee showed similar colour and sensory properties to conventionally roasted coffee.

1. Introduction

As known, the suspected carcinogen acrylamide can form in a wide range of cooked foods, including potato derivatives, bakery products and roasted coffee (Claeys, De Vleeschouer, & Hendrickx, 2005; Friedman & Levin, 2008). The main route of acrylamide formation is represented by the Maillard reaction, which involves the reaction of asparagine with a carbonyl compound (Mottram, Wedzicha, & Dodson, 2002; Stadler et al., 2002).

Due to its toxicity, efforts have been carried out to find possible technological interventions to reduce acrylamide levels in foods and thus consumer exposure. These include pre-treatments as well as formulation and/or process changes (Food Drink Europe, 2011). The application of low-pressure treatments to reduce acrylamide levels has been also explored. Vacuum can be used to remove acrylamide or to prevent its formation. In the former case, vacuum is applied to the finished product after the cooking process has been completed, in order to remove the already formed molecule. In principle, according to this approach, acrylamide can be removed by exploiting its physicochemical properties (Budavari, O'Neil, Smith, Heckelman, & Kinneary, 1996). This strategy allowed the significant removal of acrylamide from biscuits and potato chips previously hydrated at a high water content (Anese, Suman, & Nicoli, 2010). Vacuum can be also applied during the heating process to minimise acrylamide formation. Vacuum frying effectively reduced (up to 94%) acrylamide formation in potato chips without affecting the colour and texture attributes, compared with samples fried under atmospheric conditions (Granda & Moreira, 2005; Granda, Moreira, & Tichy, 2004). The authors attributed this effect to the much lower temperatures used during vacuum frying. Moreover, it was observed that this technology allowed oil uptake to be greatly reduced in fried snack foods and nutrients, such as ascorbic acid and carotenoids, to be better preserved, compared to atmospheric frying (Dueik & Bouchon, 2011; Sobukola, Dueik, Munoz, & Bouchon, 2013).

Although bakery products together with potato derivatives are the most important sources of acrylamide, coffee may markedly contribute to the total acrylamide content of the diet, mainly in North European countries, where its consumption is very high (Dybing et al., 2005; Granby & Fagt, 2004; Guenther, Anklam, Wenzl, & Stadler, 2007). In fact, coffee accounts for about 13% of total acrylamide in the diet of the whole population of The Netherlands, and for 27% and 39% in that of adults in Norway and Sweden, respectively (Dybing et al., 2005). However, until today, there are no viable strategies for minimising the acrylamide content in coffee, without adversely affecting the sensory quality of the finished product (EFSA, 2010; Guenther et al., 2007; Lantz, Ternité, Wilkens, H önicke, Guenther, & Van der Stegen, 2006).

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The aim of this work was to investigate the effect of vacuum roasting on acrylamide formation and reduction in coffee beans. To this purpose, low-pressure treatments combined or not with roasting at atmospheric pressure were applied, in order to achieve roasted beans comparable in terms of weight loss, residual moisture and colour. In order to compare the effects of the different roasting processes, data were expressed as a function of the thermal effect *F*, which represents the time–temperature combination received by coffee beans at each roasting time. The effect of the roasting processes on coffee sensory properties was also evaluated.

2. Materials and methods

2.1. Coffee beans

Green coffee beans of *Coffea arabica* with moisture content of 7.60 ± 0.01% by weight were used. They had length, width and depth mean values ($n = 20$) of 8.6 ± 0.6, 7.0 ± 0.3 and 3.4 ± 0.2 mm, respectively, and a sphericity of 0.01824 ± 0.00023 (Severa, Buchar, & Nedomovà, 2012).

2.2. Roasting

Experiments were conducted by using an apparatus consisting of an oven (5Pascal, VS-25 SC, Trezzano S/N, Milano, Italy), equipped with heated plates for optimal heat transfer under vacuum conditions, and connected to a vacuum pump. Roasting was carried out for increasing lengths of time at atmospheric pressure (hereafter called conventional roasting), at atmospheric pressure for 10 min followed by vacuum treatment (0.15 kPa; hereafter called combined conventional-vacuum roasting), or under vacuum (i.e. 0.15 kPa; hereafter called vacuum roasting).

Once the desired temperature was reached (i.e. 200 ± 1 °C), weighed aluminium dishes containing approximately 10 g of green coffee beans were introduced in the geometrical centre of the oven on a heated plate and the vacuum pump was immediately switched on. The time needed to achieve the desired vacuum was less than 10 s. Computation of treatment duration started once the set pressure value was achieved.

After the treatments, samples were immediately removed from the oven and cooled to room temperature. Afterwards they were transferred to plastic vessels with pressure lids and stored at −18 °C until analyses were performed. In all cases, the time between the end of the vacuum treatment and analytical determinations never exceeded 24 h.

2.3. Analysis of acrylamide

Acrylamide determination was performed according to the method of Bortolomeazzi, Munari, Anese, and Verardo (2012). In brief, acrylamide was extracted by 10 mL of water and the extract purified by a single SPE column consisting of 0.5 g of a mixture of C18, strong cation (SCX) and anion exchange (SAX) sorbents in the ratio 2/1.5/1.5 (w/w/w). The quantitation was carried out by liquid chromatography-tandem mass spectrometry using d_3-acrylamide as internal standard. The relative response factor of acrylamide with respect to d_3-acrylamide was calculated daily as the average of the response factors obtained by analysing a standard solution a minimum of three times.

2.4. Determination of total solid content

Total solid content was determined by gravimetric method (AOAC, 1995).

2.5. Weight loss

Sample weight roast loss (WL) was calculated as the percentage weight difference between the initial and final weights of the roasted sample.

2.6. Colour analysis

Colour analysis was carried out on ground sample using a tristimulus colorimeter (Chromameter-2 Reflectance, Minolta, Osaka, Japan) equipped with a CR-300 measuring head. The instrument was standardised against a white tile before measurements. Colour was expressed in L^*, a^* and b^* scale parameters and a^* and b^* were used to compute the hue angle ($\tan^{-1}\ b^*a^*$) (Clydesdale, 1978).

2.7. Temperature monitoring and thermal effect determination

Temperature changes of coffee during roasting were measured by a copper-constantan thermocouple probe (Ellab A/S, Hilleroed, Denmark), whose tip (2.0 mm) was placed on the coffee bean surface. The thermal effect *F* (min) was computed using the following equation (Ball, 1923):

$$F = \int_0^t 10^{(T-T_r)/z} \cdot dt \quad (1)$$

where T_r is the reference temperature, which was chosen equal to 200 °C, roasting processes being generally carried out at temperatures around 200 °C (Clarke, 1987), T is the actual temperature of the treatment (°C), t is the time (min) of the treatment, and z represents the increase in temperature that causes a 10-fold increase in the reaction rate, which was reported to be equal to 56 °C for the browning reaction of coffee (Sacchetti, Di Mattia, Pittia, & Mastrocola, 2009).

2.8. Sensory analysis

The procedure described by Manzocco and Lagazio (2009) was followed. A panel of twelve Italian assessors was selected. Judges were usual coffee consumers, aged between 20 and 60 years and approximately balanced between males and females. They all had a minimum of 2 years of experience in discrimination and descriptive sensory methods. For sensory testing, 5 g of coffee powder were served in 50-mL capacity odourless plastic cups at ambient temperature. Coffee samples were indicated by a three-digit code and submitted to the panel paired with a reference sample (i.e. the conventionally roasted coffee powder). Assessors were asked to sniff the samples after the reference one and evaluate the intensity of odour, differentiating the treated sample from the reference sample on a 9-cm unstructured scale anchored with "reference" corresponding to the highest odour intensity. Due to coffee persistent flavour, only one sample was evaluated at each session and assessors evaluated the samples twice at different sessions.

2.9. Image acquisition

Coffee powder images were acquired by using an image acquisition cabinet (Immagini & Computer, Bareggio, Italy) equipped with a digital camera (EOS 550D, Canon, Milano, Italy). In particular, the digital camera was placed on an adjustable stand positioned 60 cm above a black cardboard base where the Petri dish containing the sample was placed. Light was provided by 4 100-W frosted photographic floodlights, in a position allowing minimum shadow and glare. Images were saved in *jpeg* format resulting in 3456 × 2304 pixels.