Setting a Protocol for Hazelnut Roasting using Sensory and Colorimetric Analysis: Influence of the Roasting Temperature on the Quality of Tonda Gentile delle Langhe Cv. Hazelnut

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Abstract

Donno D., Beccaro G.L., Mellano M.G., Di Prima S., Cavicchioli M., Cerutti A.K., Bounous G. (2013): **Setting a protocol for hazelnut roasting using sensory and colorimetric analysis: Influence of the roasting temperature on the quality Tonda Gentile delle Langhe cv. hazelnut**. Czech J. Food Sci., **31**: 390–400.

The influence of roasting temperature on the final quality of Piedmont hazelnut (cultivar Tonda Gentile delle Langhe) was evaluated. Sensory and colorimetric analyses were performed to define a quality profile of the fruit relating to the roasting technique parameters. Sensory analysis was conducted on roasted kernels through a trained panel. The effects of the different temperatures on colour were evaluated with two different techniques, colorimeter and scan-marker (scanner), in order to define the best method to individuate correlations between roasting temperature and colorimetric results. The quality traits of nuts roasted at different temperatures were compared: the samples roasted at lower temperature showed lighter colour; the hue values were higher in the roasted chopped nuts, while the chroma was higher in the paste samples. For both paste and chopped kernels a larger range of values was found in comparison with the results given by the colorimeter. As for the sensory analysis, we found that "hazelnut odour" varied significantly among the samples: this descriptor is able to significantly differentiate between different samples. Our study showed that the modulation temperature is a very important parameter with a strong influence on the characteristic roasted flavour and colour of the product.

Keywords: qualitative assessment; hazelnut paste; chopped kernels; colorimeter; panel test

The main purpose of roasting is to improve the flavour, the colour, and the crispy and crunchy texture of the product.

The roasting process is very important to determine the characteristic roasted flavour and colour of the product: in particular, temperature modulation is an important independent variable significantly affecting the quality features of hazelnuts.

This study was performed in order to determine the effect of roasting temperature modulation on the main quality attributes of roasted hazelnuts, in particular colour and final consumer perception.

Hazelnuts are the kernels of the hazelnut (*Corylus* spp.) tree. All the different species of hazelnut trees produce edible nuts, but the common hazelnut (*Corylus avellana*) is the most extensively grown. Hazelnuts are one of the most nutritious nuts, with a protein content of about 12%. They are also a good source of energy, with a fat content of about 60%, and an excellent source of carbohydrates, half of which are dietary fibre. Hazelnuts also contain minerals (Ca, Mg, P, K), vitamins (E and B), and antioxidants. Thanks to their flavour, hazelnuts are often used in food production, especially in confectionery: they are often found in pastries, chocolate spreads, ice creams, cereal bars, cookies, nougat, etc. (Platteau *et al.,* 2011).

Hazelnut (*Corylus avellana* L.) belongs to the family Betulaceae and is a popular nut tree worldwide; it is mainly distributed along the coasts of the Black Sea region of Turkey, in southern Europe (Italy, Spain, Portugal, and France), and in some areas of the United States (Oregon and Washington). Hazelnut is also grown in New Zealand, China, Azerbaijan, Chile, Iran, and Georgia. Turkey is the world's largest producer of hazelnuts (510 000 megatons in 2011, in shell basis), contributing to around 63.6% of the total global production, followed by Italy (15.6%, 110 000 t/year), Azerbaijan (5.6%), Georgia (4.4%), United States (4.3%), and Spain (3.1%). Other countries contribute only to 3.4% of the total global production (FAOSTAT 2010; Inc. Global Statistics 2011). In Northern Italy, hazelnut plantings are situated mainly in the hilly areas of Langhe, Monferrato and Roero, in the Cuneo province (Piedmont).

Tonda Gentile delle Langhe (TGL) is the most widespread cultivar. The recent increase in production has been due mainly to the ever higher use of nuts in the food industry.

Hazelnuts may be consumed raw or preferably roasted, chopped, or processed into a praline paste. Hazelnuts are usually processed integrally into food products, although hazelnut oil is also often used for cooking (Platteau *et al*. 2011). Due to the positive changes of its organoleptic properties during the roasting process, hazelnut is generally roasted before using it in sweets, confectionery, chocolate and biscuits (Demir & Cronin 2005).

The main purpose of roasting is to improve the flavour, the colour, and the crispy and crunchy texture of the product (Langourieux *et al*. 2000; Alasalvar *et al*. 2003, 2012; Burdack-Freitag & Schieberle 2010). Hazelnuts are also roasted to widen the variety of colours of the final products: whitened hazelnuts, golden yellow, dark roast, and very dark roast (Ozdemir & Devres 2000).

Besides its potential health benefits and nutritional value (Mercanligil *et al*. 2007; Alasalvar & Shahidi 2009; Alasalvar *et al*. 2009; Yucesan *et al*. 2010), hazelnut as a food ingredient provides a unique and distinctive flavour (Alasalvar *et al*. 2003, 2004, 2010; Burdack-Freitag & Schieberle 2010) and pleasant crispness (Saklar *et al*. 2001). Since raw hazelnuts have a rather bland aroma, it can be assumed that the odorants responsible for the characteristic hazelnut odour are generated by the roasting procedure from odourless precursors present in the raw nut (Burdack-Freitag & Schieberle 2010).

Roasting can be defined as the dry heat treatment of seeds and nuts carried out not so much for dehydration as for flavour, colour and texture improvement (Fincke 1965). A common method for hazelnut roasting is a convective heat transfer process, such as in hot-air roasters working in continuous or batch systems (Perren & Escher 2007), under various time-temperature combinations. The roasting conditions generally used by processors are 100–160°C and 10–60 minutes. Perren and Escher (1996a,b) suggested the use of roasting temperatures below 150°C with an initial pre-roasting step at about 135°C, depending on the desired product.

The present research was carried out to evaluate the influence of roasting temperature on the final quality of Piedmont hazelnut kernels. Two different techniques (colorimeter and scan-marker coupled to pc-software for image reworking) were compared in the colour assessment. Sensory analysis was performed to determine differences in the sensory profile of roasted hazelnuts.

MATERIAL AND METHODS

Nut samples. In 2008, an Italian hazelnut patisserie introduced a new hazelnut roaster in the processing chain. The study was carried out in that firm. A protocol was set carrying out analytical measurements and studying the effect of the new roaster on hazelnut quality: the Tonda Gentile delle Langhe cultivar was used for the trials.

Samplings on hazelnuts were carried out both before and after roasting. Eight different roasting protocols were tested, divided into high (170°C), medium (148°C) and low (122°C) modulation temperature protocols. Samples were roasted for 30 min with a conduction roaster and 500 g for each sample were used. After roasting hazelnuts were put in vacuum bags labelled with a code (Table 1). Commercial hazelnuts were used as control. The samples were stored in a cool, dry and dark place (at 5°C and 55% RH) to maintain the chemical, physical, and sensory characteristics.

Table 1. Roasting condition and sample codes

Raw hazelnuts	Roasting conditions	Modulation temperature	Sample code
L1C	A	medium 148°C	L1A
	B		L2B
	D		L3D
L2C	E	low 122°C	L4E
	F		L5F
L6C	G	high 170°C	L6G
	H		L7H
	I		L8I

Sensory evaluation. Descriptors to evaluate roasted hazelnuts were generated using data shown in literature and sensory analysis was carried out in collaboration with the research group of the O.N.A.Frut (Fruit Taster National Organization) tasters, specifically trained on roasted hazelnuts (Mellano 2008), after defining a specific protocol on the basis of literature (Stone & Sidel 1985; Meilgaard *et al*. 1987; Porretta 1992; Kader 2008). After each sample, the tasters restored their initial tasting conditions by drinking mineral water.

The(Quantitative Descriptive Analysis (QDA) analytical-descriptive sensory analysis was used: the QDA describes a product by means of a series of parameters whose intensity is measured quantitatively according to the reactions of panels of tasters (Künsch 2001; Zeppa *et al*. 2003; Mellano *et al*. 2005). After the preliminary training session, according to Saklar *et al*. (1999), Alasalvar (2003, 2012), Vázquez-Araújo (2011), Bett-Garber (2012), and Suwonsichon (2012) 18 specific sensory descriptors were chosen besides the overall judgment (Table 2). The hazelnut samples were presented to the tasters in small glasses (Valentini *et al*. 2003).

Table 2. Lexicon of sensory texture attributes and their associated reference standards

Descriptors	Sensory attribute definitions	Standards and reference materials
Hazelnut odour	aromatic associated with nuts or nut meats, i.e	hazelnuts, pecans, almonds, peanuts, sesame seeds
Wood odour	odour of hazelnut hard shell or hazelnut tree	hazelnut wood or hard shell
Bread odour	aromatic associated with cooked mash, hot cereal aromas, i.e	hot bread
Caramel odour	sweet aromatics associated with brown or cooked sugars and other carbohydrates; does not include burnt or scorched	golden brown sugar
Smoke odour	smell grilled meat, burnt smell	over roasted hazelnut (at 200°C for 20 min)
Hardness	force required to compress the sample with the back teeth	ripe banana and raw carrot
Crunchiness	amount of noise generated when the sample is chewed at a fast rate with the back teeth	ripe banana and row celery
Pastiness	amount of soft, smooth mass that does not release moisture during chewing	watermelon and peanut butter
Sweet taste	taste associated with sugar or sweetener	diluted sucrose solution (5%)
Acid taste	taste associated with citric acid	diluted citric acid solution (0.43 g/l)
Bitter taste	taste associated with caffeine	diluted caffeine solution (0.195 g/l)
Hazelnut aroma	delicate, characteristics flavour of tree nut products	taste of hazelnut, almond, or walnut
Wood aroma	the sweet, brown, musty, dark, and dry aromatics associated with the tree bark	oil of cedar wood
Bread aroma	a general term used to describe the aromatics in the flavour associated with uncooked grains such as corn, oats and wheat; it is an overall grainy impression characterised as sweet, brown, sometimes dusty, and sometimes generic nutty or starchy	ground mixture of rice flour, white flour, yellow cornmeal, and oatmeal, birdseed
Caramel aroma	flavour of burnt sugar or butter	burnt cream/burnt sugar
Smoke aroma	perception of any type of smoke flavour or burnt toast	liquid smoke
Rancid aroma	associated with old or oxidised fat	oxidised hazelnut or fish oils
Oily aroma	oily taste or mouth feel	taste of hazelnut or vegetable oils

Each descriptor was assessed on a partially structured continuous scale with intervals from 0 (absence of the characteristic) to 10 (maximum intensity) (Mellano *et al.* 2009; Donno *et al.* 2012).

Colorimetric analysis. The colour values were measured with a colorimeter (meter CR-400 Konica Minolta CR-A33d; Konica Minolta, Langenhagen, Germany) and a scanner (ScanMarker i900-Microtek; Microtek, Hsinchu, Taiwan), both coupled to pc-software: Spectra Magic® and Adobe® Photoshop CS2, respectively.

Roasted hazelnut samples were chopped with a mixer and processed to a paste or kept as chopped kernels. The paste and chopped kernels were put in a structure (plastic POMc) formed by two slabs: one drilled and the other used as a support base. An optical glass was positioned on this structure to avoid interferences with the colour. For the scanner analysis the structure was put in the reverse position and covered with a black box.

The CIELAB or $L^*a^*b^*$ space was used to describe the colour. This colour space is device-independent and able to create consistent colours regardless of the device used to acquire the image. L^* is the luminance or lightness component, which ranges from 0 to 100, while a^* (green to red) and b^* (blue to yellow) are two chromatic components, with values varying from –120 to +120 (Yam & Papakadis 2004). The cylindrical version of the $L^*a^*b^*$ system resembles the Munsell colour order system corresponding to the perceptual attributes of lightness (L^*), hue ($h = a^*/b^*$) and chroma ($C^* = (a^2 + b^2)^{1/2}$) (McLaren 1976).

Then ΔE represents the difference in colour between samples.

The values of L^*, a^*, and b^* were measured with a colorimeter and a scanner.

Colorimeter. After the calibration of the colorimeter, three measurements for each replication were taken and data were analysed using Spectra Magic® software. The values were expressed in the CIEL$^*a^*b^*$ space and hue, chroma and ΔE were calculated from these data.

Scanner. Three measurements for each replication were done and data were analysed using Adobe® Photoshop CS2 (L, a, b) after selection with the "Istogram" instrument. The conversion of values into the CIEL$^*a^*b^*$ space was necessary to calculate

Table 3. Sensory mean data and their standard deviation in hazelnut samples

	Reference	L1A	L2B	L3D	L4E	L5F	L6G	L7H	L8I
Hazelnut odour	5.43 ± 1.02	6.79 ± 1.29	4.40 ± 1.97	5.22 ± 1.44	3.95 ± 1.72	3.28 ± 1.54	6.06 ± 1.83	5.00 ± 1.68	7.07 ± 0.61
Wood odour	1.83 ± 2.30	3.07 ± 1.69	2.22 ± 1.72	1.44 ± 1.07	1.50 ± 1.72	1.81 ± 1.36	3.72 ± 1.86	2.10 ± 1.90	3.14 ± 2.29
Bread odour	2.33 ± 2.09	2.42 ± 1.50	2.21 ± 1.41	1.50 ± 1.50	2.07 ± 1.34	2.29 ± 1.47	2.94 ± 2.47	2.21 ± 1.55	2.20 ± 1.64
Caramel odour	1.33 ± 1.40	2.10 ± 0.74	1.69 ± 1.71	1.00 ± 1.22	1.13 ± 1.43	0.50 ± 0.71	1.56 ± 1.45	1.75 ± 1.73	2.20 ± 1.35
Smoke odour	2.58 ± 2.05	1.86 ± 1.65	1.28 ± 1.30	0.86 ± 1.46	1.33 ± 1.66	1.21 ± 1.44	1.19 ± 1.87	1.40 ± 1.33	1.36 ± 1.63
Hardness	5.90 ± 1.30	5.07 ± 0.67	5.40 ± 1.22	5.44 ± 1.51	5.80 ± 1.77	5.83 ± 1.70	5.50 ± 1.62	6.05 ± 1.07	5.57 ± 1.30
Crunchiness	5.58 ± 1.35	5.79 ± 1.38	5.95 ± 0.86	5.33 ± 1.22	6.45 ± 1.44	5.83 ± 1.30	5.94 ± 1.76	6.50 ± 1.39	6.07 ± 1.57
Pastiness	4.50 ± 1.98	4.00 ± 2.93	4.65 ± 2.61	4.06 ± 2.27	4.55 ± 2.67	4.00 ± 2.54	3.78 ± 1.73	3.90 ± 2.47	4.75 ± 2.82
Sweet taste	4.58 ± 1.41	5.07 ± 1.27	3.90 ± 2.05	3.94 ± 1.79	3.75 ± 1.87	4.00 ± 1.98	3.89 ± 1.50	3.70 ± 1.44	4.57 ± 1.57
Acid taste	0.75 ± 0.64	0.43 ± 0.73	0.30 ± 0.48	0.28 ± 0.57	0.55 ± 0.80	0.22 ± 0.51	0.22 ± 0.36	0.05 ± 0.16	0.50 ± 0.76
Bitter taste	1.33 ± 1.25	1.43 ± 1.13	0.70 ± 0.75	0.72 ± 0.87	0.80 ± 0.67	0.94 ± 0.77	1.17 ± 0.79	1.65 ± 1.92	1.67 ± 1.51
Hazelnut aroma	5.33 ± 1.64	5.86 ± 1.21	5.30 ± 1.53	5.44 ± 1.79	5.90 ± 1.74	5.33 ± 1.89	5.11 ± 1.62	5.55 ± 1.14	5.86 ± 1.31
Wood aroma	2.33 ± 2.02	3.07 ± 1.27	2.60 ± 3.15	1.94 ± 1.49	2.10 ± 1.84	2.61 ± 1.83	2.56 ± 1.83	2.30 ± 1.80	2.71 ± 1.87
Bread aroma	2.00 ± 0.71	1.17 ± 1.17	1.81 ± 1.53	1.31 ± 1.83	1.21 ± 1.38	1.31 ± 1.69	1.29 ± 1.70	2.14 ± 1.41	1.00 ± 0.89
Caramel aroma	1.50 ± 1.08	0.60 ± 0.55	1.56 ± 2.10	0.94 ± 1.47	1.19 ± 1.69	0.88 ± 1.75	0.63 ± 1.09	1.72 ± 2.28	1.40 ± 1.67
Smoke aroma	1.58 ± 1.97	1.00 ± 1.04	1.30 ± 1.62	0.58 ± 0.92	1.13 ± 1.38	0.50 ± 0.75	1.38 ± 1.16	1.06 ± 1.40	1.29 ± 1.38
Rancid aroma	0.40 ± 0.89	0.17 ± 0.41	0.30 ± 0.54	0.69 ± 1.03	0.06 ± 0.17	0.88 ± 2.28	0.44 ± 0.68	0.75 ± 1.56	0.75 ± 1.84
Oily aroma	1.25 ± 2.04	2.75 ± 2.68	2.17 ± 1.87	2.11 ± 1.73	2.38 ± 1.60	2.00 ± 1.94	2.13 ± 1.81	2.06 ± 1.55	3.17 ± 2.48
General judgment	5.83 ± 1.12	7.07 ± 0.84	5.83 ± 1.46	6.00 ± 1.87	5.61 ± 1.50	5.83 ± 1.84	5.94 ± 1.47	5.40 ± 1.54	6.43 ± 1.30

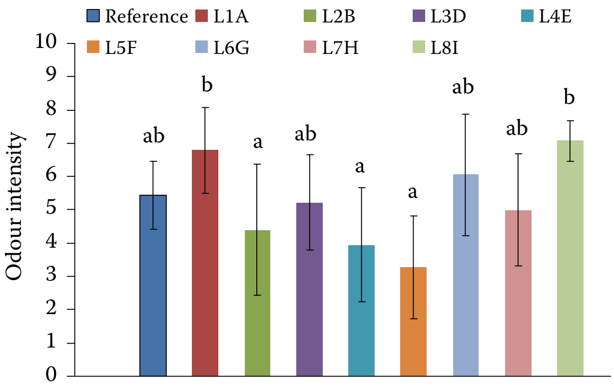

Figure 1. Hazelnut odour intensity of the eight analysed samples compared to the reference. Different letters for each sample indicate significant differences at $P < 0.05$

hue, chroma, and ΔE. For the conversion the following formulas were used (Riva 2003):

$L^* = (L/255) \times 100$

$a^* = (240a/255) - 100$

$b^* = (240b/255) - 120$

Statistical analysis. Results were subjected to ANOVA for means comparison and HSD Tukey's multiple range test at $P < 0.05$ and $P < 0.01$. Correlations were evaluated by the Pearson coefficient.

RESULTS

Sensory analysis

Sensory analysis data are reported in Table 3, where all the 8 hazelnut samples are compared with the commercial control. In the samples, tasters perceived a small intensity of caramel odour,

Table 4. Pearson correlation coefficients between sensory descriptors and overall judgment

Hazelnut odour	**
Wood odour	/
Bread odour	/
Caramel odour	*
Smoke odour	/
Hardness	/
Crunchiness	/
Pastiness	**
Sweet taste	*
Acid taste	/
Bitter taste	/
Hazelnut aroma	**
Wood aroma	/
Bread aroma	/
Caramel aroma	*
Smoke aroma	/
Rancid aroma	**
Oily aroma	/

*$P \leq 0.05$; **$P \leq 0.01$; / = no correlation

while wood, and bread ones showed higher values: in particular, the L6G sample stood out for these parameters. Smoke odour was perceived with low intensity in all samples, whereas it was strongly detected in the reference. Hazelnut odour presented significant statistical differences among the analysed samples [F = 4.652; P(F) = 2.304×10^{-4}]: the L4E (3.95) and L5F (3.28) samples had the lowest values of intensity, while the L8I (7.07) sample showed the highest value of hazelnut odour (Figure 1). Moreover, this descriptor is strongly correlated with general judgment (ρ = 0.70), wood odour (ρ = 0.73) and caramel odour (ρ = 0.82).

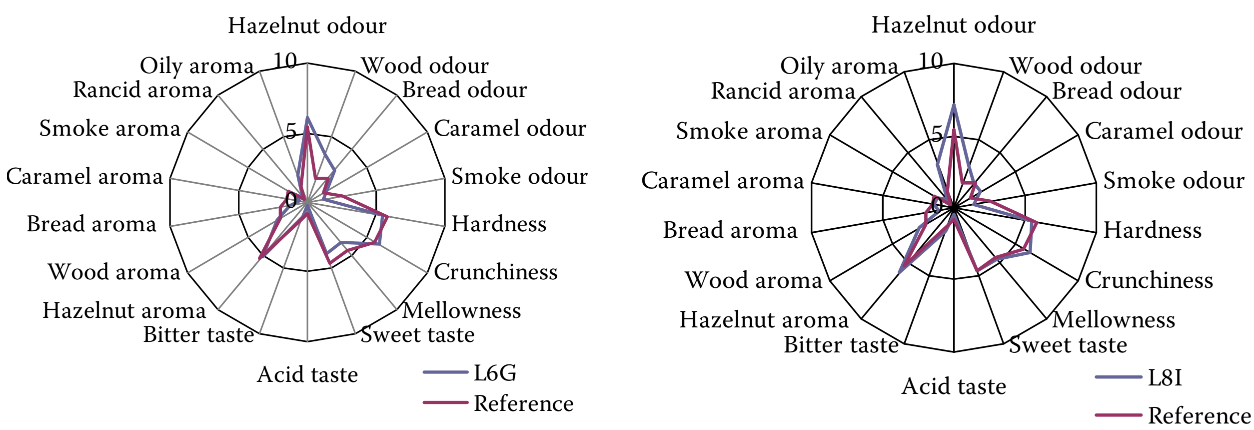

Figure 2. Sensory profiles of two appreciated samples (L6G and L8I) compared to the reference

Table 5. Colorimetric mean data (colorimeter and scanner analysis)

Sample	Chopped nuts					Paste				
	L^*	a^*	b^*	hue	chroma	L^*	a^*	b^*	hue	chroma
Colorimeter										
L1A	54.46 ± 0.30^{bc}	5.65 ± 0.17^{abc}	19.64 ± 0.16^{b}	0.29 ± 0.01^{ab}	20.43 ± 0.16^{b}	49.58 ± 0.65^{cd}	5.96 ± 0.11^{b}	23.67 ± 0.62^{bc}	0.25 ± 0.01^{b}	24.41 ± 0.62^{abc}
L2B	54.89 ± 0.86^{bc}	6.11 ± 0.37^{ab}	20.39 ± 0.46^{b}	0.30 ± 0.01^{a}	21.38 ± 0.54^{ab}	49.42 ± 0.14^{d}	6.26 ± 0.08^{a}	23.98 ± 0.14^{ab}	0.26 ± 0.00	24.78 ± 0.15^{ab}
L3D	58.5 ± 01.69^{a}	6.16 ± 0.61^{ab}	21.37 ± 0.43^{ab}	0.29 ± 0.02^{ab}	22.24 ± 0.55^{ab}	50.52 ± 0.13^{b}	5.51 ± 0.11^{d}	23.69 ± 0.08^{bc}	0.23 ± 0.00^{cd}	24.32 ± 0.10^{bc}
L4E	58.93 ± 5.43^{a}	5.23 ± 0.68^{c}	19.70 ± 3.08^{b}	0.27 ± 0.01^{b}	20.39 ± 3.14^{b}	49.93 ± 0.18^{c}	4.86 ± 0.14^{e}	21.83 ± 0.19^{e}	0.22 ± 0.00^{e}	22.37 ± 0.21^{e}
L5F	57.30 ± 1.96^{ab}	5.39 ± 0.72^{bc}	19.91 ± 1.47^{b}	0.27 ± 0.03^{b}	20.63 ± 1.55^{b}	50.86 ± 0.12^{ab}	4.82 ± 0.07^{e}	22.40 ± 0.15^{d}	0.22 ± 0.00^{e}	22.91 ± 0.15^{d}
L6G	52.19 ± 1.29^{c}	6.01 ± 0.38^{abc}	19.96 ± 0.75^{b}	0.30 ± 0.01^{a}	20.85 ± 0.83^{b}	49.89 ± 0.11^{c}	5.82 ± 0.08^{bc}	23.49 ± 0.15^{c}	0.25 ± 0.00^{b}	24.21 ± 0.15^{c}
L7H	55.55 ± 2.37^{abc}	6.12 ± 0.27^{ab}	20.65 ± 1.10^{ab}	0.30 ± 0.01^{a}	21.54 ± 1.12^{ab}	51.20 ± 0.14^{a}	5.52 ± 0.11^{d}	23.93 ± 0.14^{abc}	0.23 ± 0.00^{d}	24.56 ± 0.16^{abc}
L8I	57.75 ± 0.46^{ab}	6.45 ± 0.07^{a}	22.42 ± 0.47^{a}	0.29 ± 0.01^{ab}	23.33 ± 0.46^{a}	49.58 ± 0.65^{cd}	5.96 ± 0.11^{b}	23.67 ± 0.62^{bc}	0.25 ± 0.01^{b}	24.41 ± 0.62^{abc}
Scanner										
L1A	59.26 ± 0.46^{b}	10.37 ± 0.67^{ab}	37.76 ± 0.82^{bc}	0.27 ± 0.01^{ab}	39.16 ± 0.96^{b}	52.12 ± 0.45^{cd}	10.12 ± 0.11^{ab}	41.49 ± 0.24^{ab}	0.24 ± 0.01^{ab}	42.71 ± 0.44^{ab}
L2B	57.60 ± 0.18^{c}	11.76 ± 0.54^{a}	39.91 ± 0.85^{a}	0.29 ± 0.01^{a}	41.61 ± 0.92^{a}	51.04 ± 0.23^{e}	10.40 ± 0.14^{a}	42.19 ± 0.36^{a}	0.25 ± 0.01^{ab}	43.46 ± 0.35^{a}
L3D	60.69 ± 0.73^{a}	10.20 ± 0.38^{b}	37.47 ± 0.46^{c}	0.27 ± 0.01^{ab}	38.83 ± 0.47^{b}	52.37 ± 0.24^{bc}	9.83 ± 0.19^{abc}	40.87 ± 0.24^{abc}	0.24 ± 0.00^{ab}	42.03 ± 0.32^{abc}
L4A	59.94 ± 0.30^{ab}	8.40 ± 0.52^{c}	33.74 ± 0.34^{d}	0.25 ± 0.01^{b}	34.77 ± 0.44^{c}	51.75 ± 0.34^{cde}	8.79 ± 0.12^{c}	39.01 ± 0.29^{bc}	0.23 ± 0.00^{b}	39.99 ± 0.36^{bc}
L5F	60.67 ± 0.30^{a}	8.30 ± 0.23^{c}	33.33 ± 0.42^{d}	0.25 ± 0.01^{b}	34.35 ± 0.37^{c}	53.39 ± 0.27^{a}	9.07 ± 0.09^{bc}	38.49 ± 0.21^{c}	0.24 ± 0.00^{ab}	39.55 ± 0.27^{c}
L6G	57.67 ± 0.30^{c}	11.78 ± 0.25^{a}	39.57 ± 0.36^{ab}	0.30 ± 0.01^{a}	41.28 ± 0.33^{a}	51.41 ± 0.26^{de}	10.55 ± 0.11^{a}	40.72 ± 0.19^{abc}	0.26 ± 0.01^{a}	42.06 ± 0.16^{abc}
L7H	60.58 ± 0.19^{ab}	10.65 ± 0.08^{ab}	37.42 ± 0.42^{c}	0.28 ± 0.00^{ab}	38.91 ± 0.41^{b}	53.03 ± 0.33^{ab}	8.86 ± 0.12^{c}	38.36 ± 0.19^{c}	0.23 ± 0.00^{ab}	39.37 ± 0.20^{c}
L8I	59.24 ± 0.42^{b}	9.94 ± 0.39^{b}	36.87 ± 0.44^{c}	0.27 ± 0.01^{ab}	38.19 ± 0.35^{b}	52.50 ± 0.31^{bc}	9.17 ± 0.08^{bc}	39.01 ± 0.27^{bc}	0.24 ± 0.01^{ab}	40.07 ± 0.19^{bc}

Different letters for each sample indicate the significant differences at $P < 0.01$

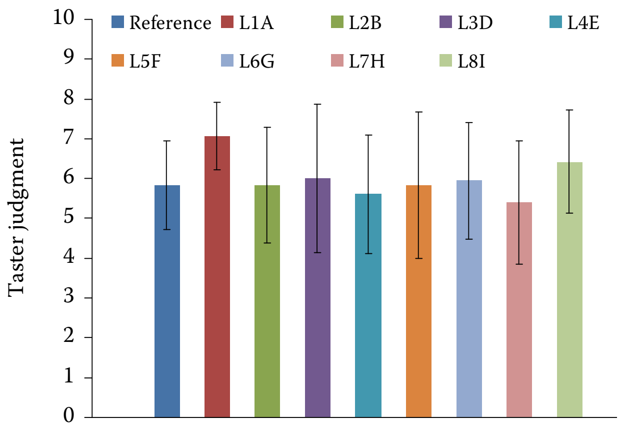

Figure 3. Tasters' judgment on the eight analysed samples compared to the reference

As for the structure descriptors, the different samples presented high hardness and crunchiness and medium pastiness. The samples showed a low intensity of acid and bitter tastes, while the sweet taste had a medium intensity: the nuts of the L1A (5.07) and L8I (4.57) samples were the sweetest ones. The total sensory profile showed a low intensity of rancid, smoke and caramel flavours in most of the samples, while the oily and wood aromas had slightly higher values. The profiles of the four samples with the highest sensory data values (L1A, L3D, L6G, L8I), compared to the reference, are illustrated in Figure 2.

The tasters were also asked to express a subjective judgment of appreciation on the samples (Figure 3). In general, all samples were acceptable [no statistically significant differences, F = 0.684 and $P(F)$ = 0.703], but this result should be considered only as indicative of the possible satisfaction of consumers. The overall judgment was correlated with some of the descriptors: it was positively correlated with odour and aroma of hazelnut, pastiness, odour and aroma of caramel and intensity of sweet taste. Rancid aroma, as expected, is negatively correlated with the overall judgment (Table 4).

Colorimetric analysis

Colorimetric data obtained by the analysis with pc-ScanMarker and colorimeter are shown in Table 5.

The samples roasted at a lower temperature (122°C) had lower chroma values and consequently lighter colour than the other samples. A better sensitivity in colour evaluation was obtained using the scanner rather than the colorimeter: both paste and chopped nuts showed a wider range of values compared to the results obtained using the colorimeter.

Samples roasted at lower temperatures had lower saturation values and brighter colour, as reported in previous researches (Ozdemir *et al*. 2000; Valentini *et al*. 2003; Di Prima 2009).

Comparing the values obtained with the colorimeter on roasted samples of chopped nuts and paste, the hue values were higher in the roasted chopped nuts with a mean value of 0.29, while the chroma was higher in the paste samples with a mean value of 24.05 (Figure 4).

In the scanner analysis (Figure 5), the sample of roasted chopped nuts had higher hue values than the paste samples: the mean value was 0.27. For chroma values the situation was the opposite: paste samples had higher values than roasted chopped nuts samples, with a mean value of 41.16.

Regarding ΔE, chopped nuts showed a wider colour range than the paste ones, whose colours were more similar to each other (Figure 6).

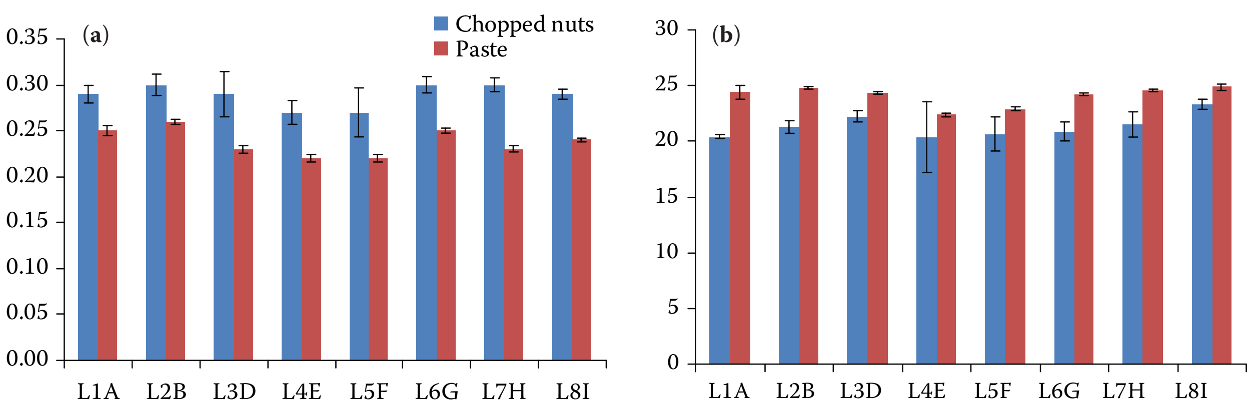

Figure 4. Paste and chopped (**a**) hue and (**b**) chroma as measured by colorimeter

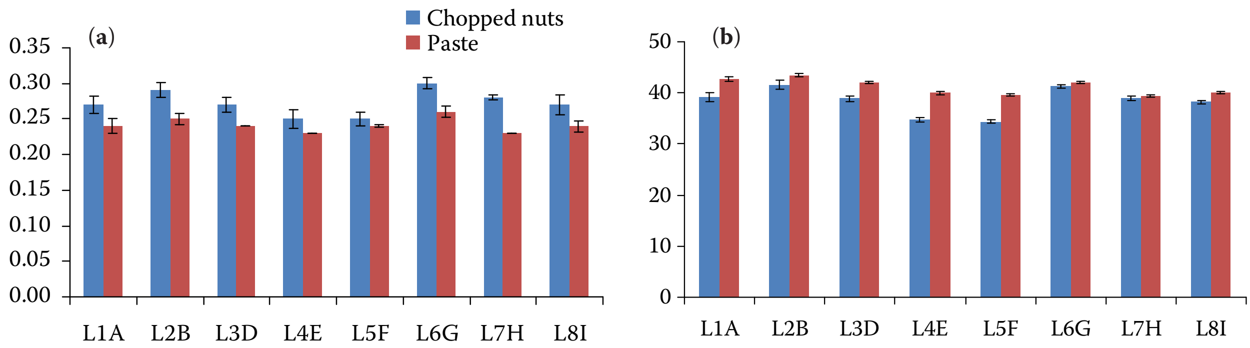

Figure 5. Paste and chopped (**a**) hue and (**b**) chroma as measured by scanner

DISCUSSION

In this study, several odour and aroma descriptors were considered in order to highlight the presence of a direct influence of the hazelnut roasting parameters on some of the sensory characteristics and to detect whether this influence could be perceived by the consumer.

Roasting temperature is the most important factor affecting the nut quality indicators (Locatelli *et al.* 2010; Youn & Chung 2012). According to Alasalvar *et al.* (2003, 2012), the descriptor that varied the most among samples is hazelnut odour. This descriptor was perceived with particular intensity in the L8I sample, which has been subjected to high temperature modulation (170°C). The L4E and L5F samples showed a lower hazelnut odour intensity because they were roasted at lower temperatures. The hazelnut odour perception on the samples roasted at intermediate temperatures was more variable. The results of this study were, in general, comparable with those published in literature (Alasalvar *et al.* 2003).

According to Alasalvar *et al.* (2012), intensities for a number of flavour attributes such as hazelnut, oily and sweet taste were significantly higher ($P < 0.01$) in roasted hazelnuts than in the raw counterparts. However, in raw hazelnuts caramel, hazelnut and wood aroma were rated significantly higher ($P < 0.01$) than in their roasted counterparts.

Recently, Burdack-Freitag and Schieberle (2010) measured the aroma profile analysis using a sensory panel and key odorants in natural and roasted Italian hazelnuts. In the aroma profile of raw hazelnuts, an intense hazelnut aroma predominated, followed by oily and fresh leaves attributes. In roasted hazelnuts, however, popcorn-like, coffee-like, and smoke aroma attributes predominated, whereas the hazelnut and oily odour was not different from that of raw hazelnuts.

During roasting, smoke and hazelnut flavour increased: at a high air temperature, the increase in roasted hazelnut flavour intensity was higher than that in smoke flavour intensity. At these roasting conditions, chemical compounds were formed which had a very strong roasted hazelnut yet not

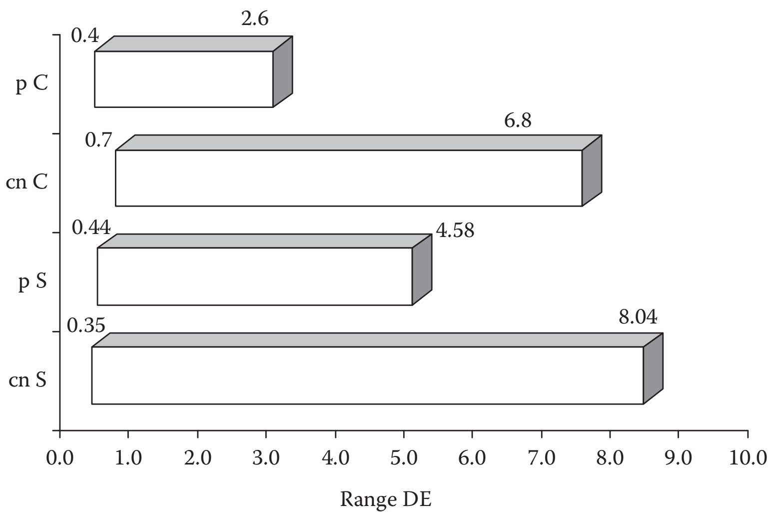

Figure 6. ΔE colour range of paste (p) and chopped nuts (cn) obtained by colorimeter (C) and scanner (S) analysis

smoke aroma (Saklar *et al.* 2001; Burdack-Freitag & Schieberle 2010).

The results of structure descriptors of roasted hazelnuts were similar to those obtained by Saklar *et al.* (1999).

Colour is an important quality attribute of hazelnuts (Driscoll & Madamba 1994). The results of this study showed that roasting temperature is an important factor affecting colour development during the roasting process. Many authors use colour as a quality control indicator of processing because brown pigments increase as the browning and candying reactions progress (Moss & Otten 1989; Cammarn *et al.* 1990). The quality control of roasted products is based on visual observations made by an operator to determine the level of roasting. This parameter is nonetheless subjective and selection of a roasting on the basis of this method alone could lead to flavour defects (Moss & Otten 1989).

According to Saklar *et al.* (2001), in hazelnut roasting, L-value decreased and a- and b-values increased with increasing temperature. The increase in a-value was greater than that in b-value, as a result of the darkening of the interior part of hazelnuts. ΔE values increased with increasing modulation temperature, similarly like the a- and b-values. According to Ozdemir and Devres (2000), for a significant colour change in the outside colour of kernels, a roasting temperature above 140°C is required. They also supported the finding that roasting temperature was the main factor governing the colour modification.

Among the colour attributes of roasted hazelnuts, the b-value is not suitable for monitoring hazelnut roasting since it is not fully affected by roasting conditions. Although the a- and L-values are significantly affected by roasting conditions, the L-value is preferred for monitoring colour development during hazelnut roasting, because the L-value (relative lightness of a product) is analogous to the colour observation made by the operator (Moss & Otten 1989; Perren & Escher 1996b; Ozdemir & Devres 2000).

CONCLUSIONS

This study was performed in order to determine the effect of roasting temperature modulation on the main quality attributes of roasted hazelnuts, in particular colour and final consumer perception.

The samples roasted at lower temperatures were lighter and the scanner allowed a high sensitivity for the colour evaluation; for both paste and chopped kernels a larger range of values was found in comparison with the results given by the colorimeter. The higher sensitivity in colour evaluation performed with the scanner was an unexpected result that should be confirmed by further analysis.

The sensory analysis was a useful tool to indicate the final consumer perception and it was found that the "hazelnut odour" descriptor was able to significantly differentiate between different samples.

Roasting process is very important to determine the characteristic roasted flavour and colour of the product: in particular, temperature modulation is an important independent variable significantly affecting the quality features of hazelnuts.

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Received for publication October 4, 2012
Accepted after corrections April 2, 2013

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