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Chemical and Sensorial Characteristics of Espresso Coffee As Affected by Grinding and Torrefacto Roast

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Grinding is a critical step in the preparation of espresso coffee (EC). The addition of sugar during the torrefacto roasting process could influence the degree of brittleness and grinding. The aim of this work was to study the influence of the grinding grades (coarse, fine, and very fine) in Arabica/Robusta 20:80, natural roasted (A20:R80), and Arabica/Robusta 20:80 with 50% Robusta torrefacto roasted (A20:R80 50% torrefacto) on the chemical and sensorial characteristics of EC in order to select the optimal espresso grinding grade. A higher percentage of coarse particles was found in A20:R80 ground coffee. In both ECs, the extraction of solids and soluble and aroma compounds increased inversely with particle size. Higher foam indices and extraction yields were found in A20:R80 50% torrefacto ECs probably due to the solubilization of caramelized sugar and melanoidins. It has been suggested that the range of an acceptable extraction yield could be extended to 25% in A20:R80 50% torrefacto ECs. In conclusion, the optimal grinding grade for the obtainment of an EC with A20:R80 was fine and that for A20:R80 50% torrefacto was coarse.

KEYWORDS: Grinding grade; espresso coffee; torrefacto roast; extraction; aroma; sensory analysis

INTRODUCTION

Grinding is a critical step in the preparation of coffee for brewing, and it has been empirically optimized since the beginning of coffee production. The main objective of this process is to increase the specific extraction surface, or rather to increase the extent of the interface between water and coffee, to facilitate the transfer of soluble and emulsifiable substances into the brew. At the same time, the rupture of coffee bean tissues and cells accelerates the release of carbon dioxide (CO_2) gas and volatile aroma but allows an easier extraction of the remaining aroma.

The grinding process is influenced by factors such as the variability of coffee beans, moisture, and the degree of roasting. Botanical species and varieties (*Coffea arabica* and *Coffea canephora* var. Robusta) from different countries and processes lead to a heterogeneity in the hardness of coffee beans. The loss of cell-wall elasticity and the increase of brittleness are mainly induced by coffee bean expansion due to gas production during the roasting process. Therefore, dark-roasted coffee beans become harder and more brittle than lighter roasted beans and break down in finer grinds (*1*).

The optimal combination of grinding grade and brewing method allows exposure of the maximum surface area to the action of water for the obtainment of a high-quality coffee brew. A grinding grade that is too fine could decrease extraction, yielding low volume of a bitter, overextracted coffee due to agglomeration and insufficient wetting of particles. On the other hand, a grinding grade that is too coarse could also decrease extraction, yielding underextracted coffee due to the fact that the volume specific surface would be too small to retain water and allow coffee compounds solubilization and emulsification. Therefore, medium-coarse grinds are required for boiled coffee, filter coffee, and napoletana coffee, whereas fine grinds are needed for espresso coffee (EC), and extremely fine grinds are required for Turkish coffee.

In the EC brewing method, a short percolation time and a high solids concentration are required. Because EC is a multiphase system constituted by an aqueous solution of sugars, acids, protein-like material, caffeine, an emulsion of microcopic oil droplets, a suspension of solids, and a foam of small bubbles on the top, grind control is absolutely essential for proper brewing and in order to produce a flavorful coffee brew (*1*, *2*).

To our knowledge, there are only a few scientific works that studied the influence of grinding on the extraction process. Clarke et al. (*3*) claimed that, in brew coffee, when the grinding grade is finer, the extraction of soluble and volatile compounds is higher. The influence of the grinding grade on caffeine extraction has been studied by Spiro et al. (*4*) and Bell et al. (*5*). Cappuccio et al. (*6*) studied how different parameters affect the velocity of water and therefore the extraction of substances; one such parameter was the grinding grade. On the other hand, a self-constructed pressureless extraction apparatus was used by Cammenga et al. (*7*) in order to study the influence of different variables on extraction process.

All of these works claimed that small particles increase the surface exposed to water, permitting a more efficient extraction process, but there are no works that study the influence of

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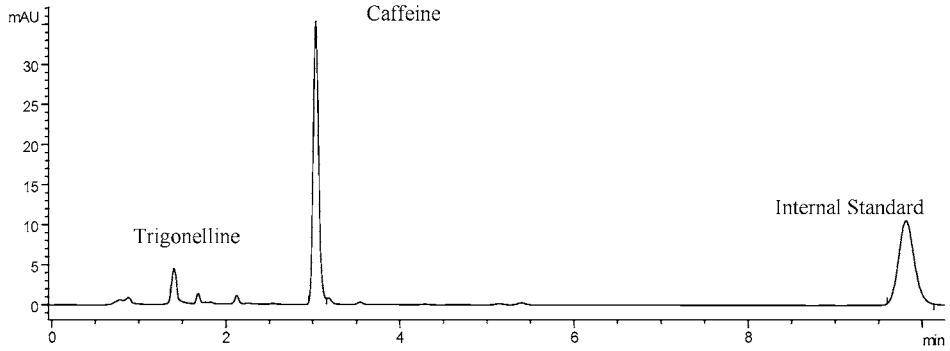

Figure 1. Chromatogram of caffeine and trigonelline analysis.

grinding grade on chemical and sensorial characteristics of brew coffee. Furthermore, no study of the influence of torrefacto roasting has been found. Torrefacto is a roasting process in which sugar is added to Robusta coffees in order to brown the coffee brew and mask negative flavors. Usually, torrefacto coffee is blended with natural roast. This roasting technique is used in several countries of southern Europe and South America, where some segments of population prefer espresso coffee with a high amount of foam, a dark brown color, a very intense aroma, and a strong taste, with a tendency to bitterness. The addition of sugar at the end of the torrefacto roasting process could also influence coffee brittleness and grinding.

The influence of torrefacto roasted coffee in ground coffee aroma (*8*) and in EC characteristics (*9*, *10*) and other technical conditions related to the EC coffeemaker, such as extraction water temperature (*11*) and pressure (*12*), have been previously reported by our research group.

The aim of this work was to study the influence of grinding and torrefacto roasting on the chemical and sensorial characteristics of espresso coffee. Furthermore, the selection of the optimal espresso grinding grade for both coffees has been carried out.

MATERIALS AND METHODS

Materials. Two ground roasted coffee samples, Arabica/Robusta 20:80 natural roasted (A20:R80) and Arabica/Robusta 20:80 with 50% of Robusta coffee roasted with sugar (A20:R80 50% torrefacto) were provided by a local company. Two batches of each coffee sample were used. Both coffees were roasted to espresso degree and were stored in similar conditions before and during analysis.

Pure reference standards of acetaldehyde, 2-methylpropanal, 3-methylbutanal, 2,3-butanedione, 2,3-pentanedione, and 2-ethyl-3,5-dimethylpyrazine were purchased from Acros (Fair Lawn, NJ); hexanal, 2-methoxyphenol (guaiacol), and propanal were obtained from Sigma (Steinheim, Germany).

Grinding. Selection and Analysis. Coffee beans were ground by means of an automatic M01 Azkoyen grinder just before EC preparation. The grinder had 19 levels of grinding, 1 for the coarsest point level and 19 for the finest.

Grinding Grade Selection. To select grinding grades, ECs were brewed from each sample with the experimental prototype espresso coffeemaker in the conditions mentioned below. Time percolation between 18 and 24 s and the absence of particles in the bottom of the EC cup were the main criteria for the selection of grinding grades. Levels 5, 8, and 10 were selected as coarse, fine, and very fine grinds, respectively. Particle size distributions are shown in **Figure 3**.

Particle Size Distribution. Seven sieves (710, 600, 500, 400, 300, 200, and 100 μm) and a 10-min shaking cycle with a sieve shaker (model R.P.09, CISA) were used to fractionate 100 g of ground coffee samples, depending on the particle size. Coffee particles of each sieve were weighed and expressed as percentage.

EC Samples and Preparation for Analysis. ECs were prepared from 7.5 g of ground roasted coffee for a volume of 40 mL, with the use of an experimental prototype espresso coffeemaker. EC preparation conditions were fixed at 92 °C water temperature (corresponding to erogation temperature of 86 ± 2 °C), 9 atm of relative water pressure, 21 ± 3 s of extraction time, and 38 mm of holder filter diameter. Twenty ECs of each coffee sample were prepared to be physicochemically analyzed in triplicate.

pH, Density, Viscosity, and Surface Tension. EC samples were inmediately cooled at 20 °C, and pH (Orion 420 A benchtop pH meter), density (densimeter), viscosity (Ostwald viscosimeter), and surface tension (Traube estalagmometer) were measured.

Foam Index and Persistence of Foam. *Foam index* was defined as the volume of EC in milliliters, referred to 100 mL of EC total volume. Volumes were measured immediately after the extraction of EC using a 100-mL graduated cylinder. *Persistence of foam* was defined as the time (in minutes) that the liquid phase below the cream layer took to appear during cooling at room temperature.

Total Solids, Extraction, Concentration, and Total Solids on Filtrate. *Total solids* were determined by oven-drying 40 mL of EC to a constant weight (14 h, 102 ± 3 °C). *Extraction* was defined as the percentage of total solids with respect to ground roasted coffee dose (7.5 g). *Concentration* was defined as the percentage of total solids with respect to the EC volume (40 mL). *Total solids on filtrate* were determined by oven-drying 40 mL of EC, after filtering with Whatman no. 1 paper, to a constant weight (14 h, 102 ± 3 °C).

Total Lipids. Twenty milliliters of EC was extracted by adding 20 mL of tricloromethane three times in a separating funnel. The organic fraction was washed with distilled water three times. Total lipids were quantified by weight after evaporation of the solvent.

Caffeine and Trigonelline. Extract preparation, cleanup, and HPLC analysis have already been described by Maeztu et al. (*10*). HPLC analysis was achieved with an analytical HPLC unit (Hewlett-Packard 1100). A reversed-phase Hypersil-ODS (5 μm particle size, 250 × 4.6 mm) column was used. The mobile phase was acetonitrile/water (15:85) in isocratic condition at a constant flow rate of 2.0 mL min^{-1} at 25 °C. Detection was accomplished with a diode array detector, and chromatograms were recorded at 280 nm (**Figure 1**).

Chlorogenic Acids (5-CQA). Extraction of 5-CQA and cleanup were carried out according to the method of Bicchi et al. (*13*) with HPLC equipment described above. Conditions of the gradient solvent system used were 100% citrate−acetic acid buffer solution (pH 3.0) for 2 min, 85:15 buffer/methanol for 8 min, both at a flow rate of 0.8 mL min^{-1}, and 85:15 buffer/methanol for 5 min at a flow rate of 1.2 mL min^{-1}, at 25 °C. Wavelength of detection was at 325 nm.

Volatile Compounds. Profiles of volatile compounds were obtained with the method described by Sanz et al. (*14*), adapted to EC and using static headspace gas chromatography−mass spectrometry (SH-GC-MS).

Six milliliters of a homogenized EC brew were introduced into a 10 mL vial, which was immediately sealed with a silicone rubber Teflon cap. Each vial was equilibrated at 60 °C (usual EC consumption temperature) for 20 min in the static headspace sampler (Hewlett-Packard model 7694). Each vial was pressurized with carrier gas for 12 s, and 3 mL of the coffee headspace sample was injected into a

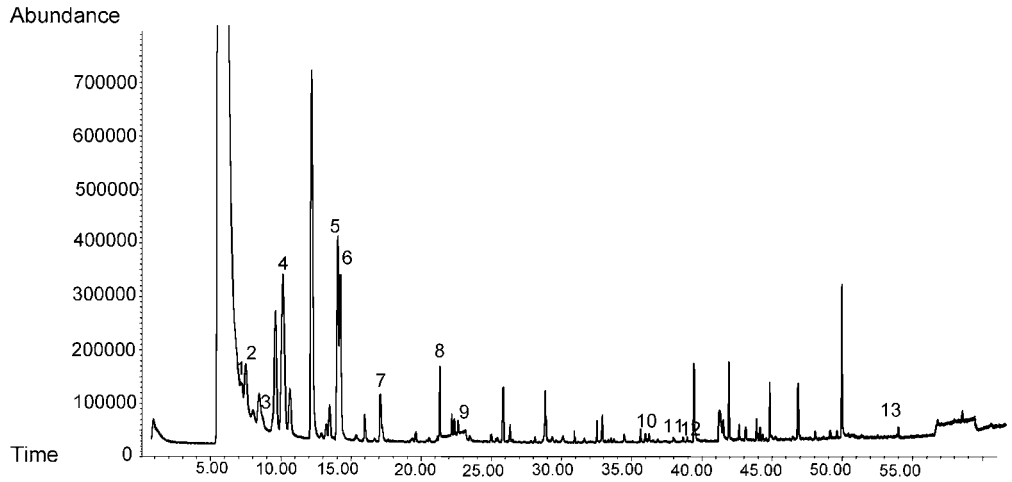

Figure 2. GC-MS chromatogram of EC volatile compounds. Identification of key odorant peaks: (1) methanethiol; (2) acetaldehyde; (3) propanal; (4) 2-methylpropanal; (5) 2-methylbutanal; (7) 2,3-butanedione; (8) 2,3-pentanedione; (9) hexanal; (10) 2-ethylpyrazine; (11) 2-ethyl-6-methylpyrazine; (12) 2-ethyl-3,5-dimethylpyrazine; (13) 2-methoxyphenol (guaiacol).

capillary column HP-Wax (60 m × 0.25 mm × 0.5 μm film thickness; Hewlett-Packard) in an HP 6890 gas chromatograph (Hewlett-Packard). Injector temperature was 180 °C, and carrier gas was helium (10 mL/min linear speed). The oven temperature was maintained at 40 °C for 6 min and then raised at 3 °C/min to 190 °C. Mass spectrometry was performed with a Hewlett-Packard mass selective detector (model 5973) operated in the electron impact ionization mode (70 eV), with a scan range of 33−300 amu. Ion source temperature was set at 230 °C. Each EC sample was analyzed in triplicate.

Identification of the Volatile Compounds. The volatile compounds studied were identified by comparing their mass spectra to those of the Wiley library and, in addition, by comparison of their retention times with those of standard compounds. The Kovats indices were also calculated according to the method of Tranchant (*15*) and compared with available literature data (*16*).

Quantitative Measurements. Methanethiol, acetaldehyde, propanal, 2-methylpropanal, 2-methylbutanal, 3-methylbutanal, 2,3-butanedione, 2,3-pentanedione, hexanal, ethylpyrazine, 2-ethyl-6-methylpyrazine, 2-ethyl-3,5-dimethylpyrazine, and 2-methoxyphenol (guaiacol) were quantified as key odorants. Peak areas were measured by calculation of the volatile total area based on integration of a single ion. The relative percentages of individual key odorants were calculated from the total contents of volatiles on the chromatograms (**Figure 2**).

Sensory Descriptive Analysis. Twenty judges were recruited among members of the Food Science and Technology Department at the University of Navarra. Selection and training were carried out as described by Maeztu et al. (*9*) to have a 10-member panel. Odor, body, acidity, bitterness, astringency, flavor, and aftertaste intensities were rated on 11-point scales from "none" (0) to "very high" (10). Mean and standard deviation for each attribute in each EC sample were obtained (**Table 2**).

Sensory Flavor Profile. The most frequently described odor/flavor attributes by judges during training process were written in the same scorecard in two columns: one for positive and another for negative flavor attributes. Positive flavor attributes were fruity/winey, malty/cereal, freshness, straw, caramel-like, equilibrate, chocolate-like, spicy, nutty, tobacco, and buttery. Negative flavor attributes were woody/papery, burnt/roasty, acrid, fermented, earthy/musty, rancid, burnt rubbery, sulfurous, flat, grassy/green/herbal, animal-like, motor oil, and ashy. In both columns, one line for "other flavors" was added. The flavor profile of each EC sample was defined by the percentage of judges that perceived each positive and negative flavor attribute.

Sensory descriptive evaluation of EC samples was carried out in triplicate over 12 sessions. Three ECs were analyzed per session. Each EC was prepared immediately before tasting and served monadically in a white porcelain coffee cup labeled with a three-digit code. The order of presentation was randomized among judges and sessions. All evaluations were conducted in isolated sensory booths illuminated with white light in the sensory laboratory under standardized conditions by UNE 87-004-79 (*17*). Rinse water was provided between individual samples.

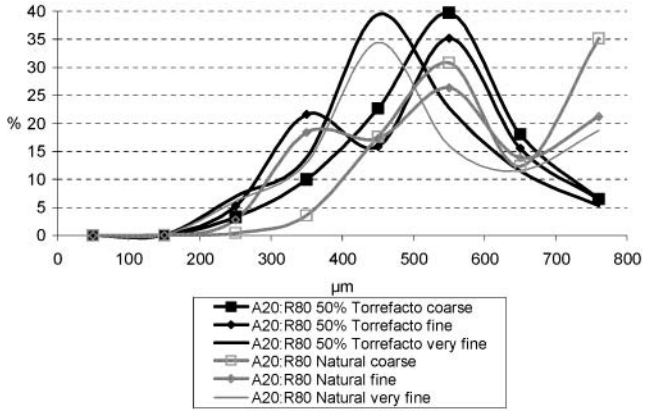

Figure 3. Particle distribution in A20:R80 natural and A20:R80 50% torrefacto ground roasted coffees.

Statistical Analysis. Analysis of variance (ANOVA) was applied for each type of roast. The source of variation was particle size. *T*-Tukey test was applied a posteriori with a level of significance of 95%. All statistical analyses were performed using the SPSS v. 10.0 software package.

RESULTS AND DISCUSSION

Grinding grade distribution of ground roasted coffee samples is shown in **Figure 3**. Similar patterns were observed in each grinding grade for both roast types (natural and torrefacto) up to a particle size of 710 μm. However, a larger amount of coarse particles (bigger than 710 μm) was found in A20:R80 natural than in A20:R80 50% torrefacto. Greater brittleness in A20:R80 50% torrefacto could be due to caramelization of sugar added during the torrefacto roasting process. A plurimodal particle size distribution is needed, with coarse particles fixing a structure that allows the correct flow through the cake and retains finer particles which facilitate the extraction of large amounts of emulsifiable soluble substances (*1*). Bimodal or plurimodal particle size distribution is shown in **Figure 3** for all of the A20:R80 natural coffees but for only the A20:R80 50% torrefacto fine grind. However, EC could be brewed from all of the samples within the percolation time, probably because

Table 1. Influence of Grinding Grade on Physicochemical Parameters of Espresso Coffee Samples[a]

	A20:R80			A20:R80 50% torrefacto		
	coarse	fine	very fine	coarse	fine	very fine
pH	5.7; 0.0a	5.7; 0.0a	5.6; 0.05b	5.7; 0.0a	5.7; 0.1a	5.6; 0.00b
density (g/mL)	1.010; 0.000a	1.011; 0.001b	1.014; 0.001c	1.010; 0.000a	1.012; 0.000b	1.013; 0.000c
viscosity (mN/m^2 s)	1.18; 0.01a	1.29; 0.05b	1.22; 0.03a	1.19; 0.04a	1.24; 0.03a	1.30; 0.04b
surface tension (mN/m)	46.88; 0.92a	45.80; 0.86a	50.49; 0.98b	51.58; 1.05b	46.98; 0.92b	46.43; 0.00a
foam index (%)	15.5; 0.2a	18.1; 0.2b	20.8; 0.4c	23.1; 0.5a	26.5; 1.3b	27.0; 1.0b
persistence of foam (min)	18.33; 2.58a	30.00; 0.00b	30.00; 0.00b	30.00; 0.00a	30.00; 0.00a	30.00; 0.00a
total solids (mg/mL)	35.53; 0.39a	39.15; 0.43b	45.29; 0.30c	38.46; 1.03a	45.86; 0.17b	47.38; 0.50c
extraction (%)	19.0; 0.2a	20.9; 0.2b	24.2; 0.2c	20.5; 0.5a	24.5; 0.0b	25.3; 0.3c
concentration (%)	3.6; 0.0a	3.9; 0.0b	4.5; 0.0c	3.8; 0.1a	4.6; 0.0b	4.7; 0.0c
total solids on filtrate (mg/mL)	34.59; 0.44a	37.90; 0.75b	42.74; 1.06c	37.58; 0.37a	43.95; 0.33b	43.68; 0.79b
total lipids (mg/mL)	3.65; 0.09a	3.80; 0.07b	4.62; 0.07c	3.57; 0.03a	3.66; 0.09b	4.29; 0.06c
caffeine (mg/mL)	3.05; 0.21a	3.19; 0.11a	3.80; 0.07b	2.43; 0.03a	2.80; 0.05b	3.12; 0.04c
trigonelline (mg/mL)	1.19; 0.09b	1.02; 0.16a	1.43; 0.03c	1.16; 0.09a	1.43; 0.16b	1.61; 0.18b
chlorogenic acids (5-CQA) (mg/mL)	0.98; 0.11a	1.10; 0.10b	1.35; 0.02c	0.89; 0.07a	0.84; 0.00a	0.95; 0.02b

[a] All values are shown as means; standard deviations ($n = 6$). In each row, different letters indicate significant difference ($p < 0.05$) among different grinding grades in each type of coffee.

Table 2. Influence of Grinding Grade on Sensory Attributes of Espresso Coffee Samples[a]

	A20:R80			A20:R80 50% torrefacto		
	coarse	fine	very fine	coarse	fine	very fine
odor intensity	6.4; 0.6a	6.8; 0.7b	6.8; 0.9b	6.3; 0.8ab	6.2; 0.9b	6.6; 0.7b
body	6.5; 1.0a	7.0; 0.8b	6.6; 0.8a	6.5; 1.0b	6.3; 0.8ab	6.0; 0.6a
acidity	1.8; 0.7b	1.4; 0.5a	1.6; 0.5a	2.8; 0.8c	1.7; 0.5b	1.1; 0.3a
bitterness	8.0; 0.7a	8.0; 1.0a	8.2; 1.0a	7.2; 1.2a	7.8; 1.3b	7.8; 0.7b
astringency	6.6; 0.9a	6.8; 1.3a	6.4; 1.1a	6.4; 1.0a	7.4; 1.3b	6.5; 0.8a
flavor intensity	7.0; 0.6a	7.3; 1.0a	7.0; 0.9a	6.6; 0.9a	7.1; 0.9b	7.0; 0.5b
aftertaste intensity	7.3; 0.8b	6.9; 1.1a	6.8; 0.8a	6.8; 1.0a	7.3; 1.1b	7.0; 0.4a

[a] All values are shown as means; standard deviations ($n = 6$). In each row, different lettters indicate significant difference ($p < 0.05$) among different grinding grades in each type of coffee.

the peaks were wide enough; this suggests the presence of coarse and fine particles. Surprisingly, particles ranging from 300 to 400 μm were found in greater amount in fine grinds than in very fine grinds; this may be due to agglomeration in the shaking process.

The results of the physicochemical parameters of EC samples are shown in **Table 1**. The presence of a consistent, persistent, and hazelnut foam with a "tiger-skin" effect is one of the main sensory characteristics of EC and is closely related to the grinding grade (*18*). In all cases, a sufficient amount of persistent foam was obtained as required for a good-quality EC [a foam index >10 mL/100 mL and a persistence of foam of at least 2 min (*1*)]. As reported by Nunes et al. (*19*) and Petracco et al. (*18*), coffee foamability is mainly influenced by melanoidin type subfraction, whereas foam stability is mainly influenced by the polysaccharide subfraction. Therefore, higher foam indices found in A20:R80 50% torrefacto could be induced by a higher formation of melanoidins (and, consequently, a higher extraction) as a result of the more intense Maillard reactions in torrefacto roast. However, persistence of foam did not seem to be affected by the type of roast.

As expected, extraction and concentration yields inversely increased with particle size. Percentages of extraction ranging from 18 to 22% have been proposed as the most acceptable, the coffees below 16% considered to be underdeveloped and those above 24% to be overextracted (*2*). Nevertheless, extraction yields >24% in A20:R80 50% torrefacto did not result in bitter and astringent ECs. In previous works (*9*, *11*), higher extraction percentages were found in A20:R80 50% torrefacto than in A20:R80 natural. These results could be due to the solubilization of caramelized sugar and melanoidins. Therefore, for torrefacto roasted coffees, the range for an acceptable extraction yield could be extended to 25%. Thus, fine ground A20:R80 50% torrefacto should be considered within the limits of acceptable extraction, but very fine ground A20:R80 50% torrefacto and A20:R80 natural could be classified as overextracted coffees.

The extraction of solid and soluble compounds, such as trigonelline, lipids, and chlorogenic acids, increased inversely with particle size. Caffeine content increased significantly with a smaller particle size in both types of coffee. Some authors have studied the influence of grinding grade in the caffeine content of coffee brew (*4*, *5*). These authors concluded that a smaller particle size led to significantly higher caffeine content.

The sensory attributes (**Table 2**) showed that there were no significant differences among the grinding grades in A20:R80 natural EC, with the exception of a decrease of odor intensity in ECs prepared with coarse ground. However, in A20:R80 50% torrefacto ECs, the samples showed an increase in bitterness and astringency with fine and very fine grind. This fact agrees with Lingle et al. (*2*), who claim that a particle size which is too fine will result in a bitter, overextracted taste.

Aroma/flavor results are shown in **Table 3** and **Figures 4** and **5**. In general, more judges perceived flavor notes with a higher grinding grade. In particular, for A20:R80 natural ECs, a higher percentage of judges observed woody/papery, fermented, and burnt/roasty notes in coffee prepared with fine and very fine grinding grade. In addition, the judges observed acrid and burnt rubbery notes in ECs prepared with coarse grinding grade. For A20:R80 50% torrefacto ECs, negative flavors related to roasting, such as woody/papery, burnt/roasty, and burnt

Table 3. Relative Percentage of Key Odorants in Espresso Coffee Samples[a]

			A20:R80			A20:R80 50% torrefacto		
KI[b]	ID[c]	key odorant	coarse	fine	very fine	coarse	fine	very fine
		sulfur compounds						
635	C	methanethiol	0.14; 0.03a	0.12; 0.08a	0.13; 0.00a	0.16; 0.00a	0.16; 0.00a	0.19; 0.01b
		aldehydes						
645	A	acetaldehyde	0.35; 0.04a	0.40; 0.05a	0.38; 0.08a	0.36; 0.01a	0.39; 0.03b	0.40; 0.01b
712	A	propanal	0.50; 0.05a	0.55; 0.05a	0.55; 0.01a	0.46; 0.03a	0.50; 0.00a	0.49; 0.04a
747	A	2-methylpropanal	1.97; 0.24a	2.83; 0.40b	3.04; 0.14b	2.38; 0.15a	2.26; 0.02a	2.38; 0.18a
880	C	2-methylbutanal	1.07; 0.13a	1.63; 0.21b	1.83; 0.15b	1.42; 0.04b	1.23; 0.16a	1.59; 0.13c
884	A	3-methylbutanal	2.26; 0.03a	3.38; 0.45b	3.16; 0.16b	2.84; 0.10a	2.94; 0.01a	2.95; 0.28a
1084	A	hexanal	0.05; 0.02a	0.08; 0.01b	0.08; 0.02b	0.07; 0.00a	0.14; 0.01c	0.09; 0.00b
		ketones						
962	A	2,3-butanedione	0.24; 0.00a	0.32; 0.01b	0.32; 0.00b	0.34; 0.02a	0.35; 0.00a	0.35; 0.01a
1058	A	2,3-pentanedione	0.37; 0.00a	0.52; 0.06b	0.52; 0.00b	0.43; 0.03a	0.47; 0.01b	0.50; 0.01b
		pyrazines						
1359	A	ethylpyrazine	0.08; 0.01a	0.11; 0.02b	0.14; 0.00c	0.15; 0.00a	0.15; 0.01a	0.18; 0.01b
1411	A	2-ethyl-6-methylpyrazine	0.02; 0.01a	0.04; 0.01b	0.04; 0.00b	0.07; 0.01c	0.05; 0.00a	0.06; 0.01b
1475	A	2-ethyl-3,5-dimethylpyrazine	0.03; 0.00a	0.05; 0.01b	0.06; 0.00c	0.07; 0.00a	0.07; 0.01a	0.08; 0.01b
		phenolic compounds						
	A	2-methoxyphenol (guaiacol)	0.01; 0.00a	0.01; 0.00b	0.01; 0.00b	0.05; 0.00ab	0.04; 0.00a	0.05; 0.00b

[a] All values are shown as means; standard deviations ($n = 6$). In each row, different letters indicate significant difference ($p < 0.05$) among different grinding grades in each coffee sample. [b] KI, Kovats index calculated for the HP-Wax capillary column. [c] The reliability of the identification proposal is indicated by the following: A, mass spectrum, retention time, and Kovats index according to standards; B, mass spectrum and Kovats index according to literature data; C, mass spectrum, compared with Wiley mass spectral databases.

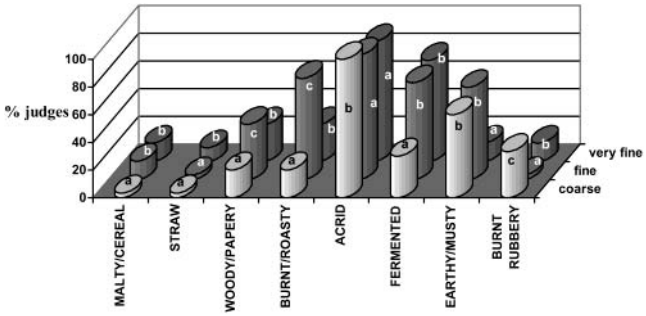

Figure 4. Influence of grinding grade on A20:R80 natural EC flavor profile. For each parameter, different letters indicate significant difference ($p < 0.05$) among different grinding grades.

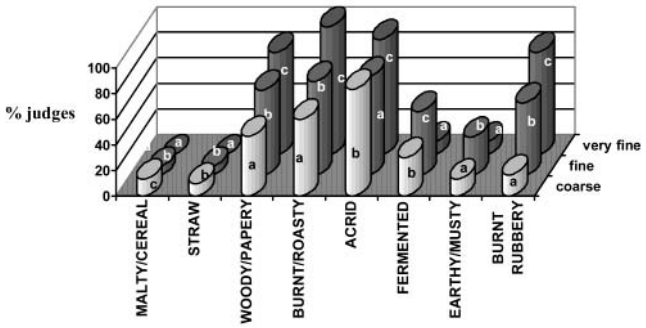

Figure 5. Influence of grinding grade on A20:R80 50% torrefacto EC flavor profile. For each parameter, different letters indicate significant difference ($p < 0.05$) among different grinding grades.

rubbery, were better perceived by judges when the particle size was very fine.

2-Methylpropanal, 2-methylbutanal, and 3-methylbutanal (Strecker degradation products of valine, isoleucine, and leucine), related to the malty flavor in coffee brew (*20*, *21*), were perceived more often in fine and very fine A20:R80 natural ECs. The quantities of 2,3-butanedione and 2,3-pentanedione [associated with buttery flavors in espresso and other brew coffees (*10*, *22*)] were also greater in finer A20:R80 natural ECs but not perceived by the judges. This is most likely due to the fact that said compounds were masked by other more potent odorants, such as pyrazines.

Pyrazines, derived during the roasting process from Maillard reactions between amino acids and sugars, have been related to roasty and earthy/musty flavors in ground roasted and brewed coffees (*22*, *23*) and also to burnt and woody/papery flavors in EC (*10*). Larger amounts of pyrazines in torrefacto roasted ECs were found; this is probably due to the addition of sugar, which intensifies Maillard reactions. These compounds could be responsible for the greater perception of woody/papery and burnt flavors, mainly in very fine grinding grade. In A20:R80 50% torrefacto ECs, key odorants related to freshness, fruity, malty, and buttery flavor (aldehydes and ketones) were very similar among the three grinding grades, whereas key odorants related to roasty, earthy/musty flavors (pyrazines) were higher in ECs prepared with very fine ground.

In conclusion, the optimal grinding grade for the obtainment of a good-quality espresso coffee with A20:R80 natural was fine, because coarse grinding grade did not allow a good development of aroma and flavor and very fine grind could be considered as slightly overextracted. However, for A20:R80 50% torrefacto, the optimal grinding grade was coarse, because, although the EC key odorants profile was very similar to that of fine grind, better taste and flavor notes were perceived by the panel judges in coarse grinding grade.

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