TITLE: Influence of coffee/water ratio on the final quality of Espresso Coffee.

RUNNING TITLE: Coffee/water ratio on Espresso Coffee quality

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ABSTRACT

Espresso Coffee is a poliphasic beverage which physicochemical and sensory characteristics obviously depend on both the selection of ground roasted coffee and the percolation process technical conditions. The aim of this work was to evaluate the influence of coffee/water ratio on the physicochemical and sensory quality of espresso coffee. Furthermore, the influence of botanical varieties (Arabica and Robusta) and the type of roast (conventional and torrefacto) on the selection of coffee/water ratio was studied. The relationship between pH and acidity intensity perception was discussed as influenced by coffee/water ratio, type of coffee and roast. The optimization of other technical parameters in previous works seemed to minimize the influence of the increase of coffee/water ratio on the extraction of soluble and solid compounds. In fact, only some sensory attributes, such as bitterness, astringency and burnt, acrid and earthy/musty flavors were proposed as relevant to the selection of 6.5g/40mL or 7.5g/40mL in conventional roasted coffees (Arabica 100% and Robusta blend), and 6.5g/40mL in Torrefacto roasted coffees. On the other hand, the addition of sugar during roasting process in torrefacto roast coffees seemed to contribute to a higher generation of acids, melanoidins and other compounds by Maillard reaction or caramelization which led us to the selection of the lowest coffee/water ratio.

KEYWORDS: coffee, espresso coffee, coffee/water ratio, sensory analysis, aroma, Torrefacto roast

INTRODUCTION

Espresso Coffee is a poliphasic beverage prepared only with ground roasted coffee and water, and constituted by a foam layer of small bubbles with a particular tiger-tail pattern, on the top of an emulsion of microscopic oil droplets in an aqueous solution of sugars, acids, protein-like material and caffeine, with dispersed gas bubbles and colloidal solids[1]. These physico-chemical characteristics of espresso coffee are responsible for their peculiar sensorial properties which include a strong body, a full fine aroma, a bitter/acid balance taste and a pleasant lingering aftertaste, exempt from unpleasant flavor defects[1].

The physicochemical and sensory characteristics of an espresso coffee obviously depend on both the selection of ground roasted coffee and the percolation process technical conditions that should be adjusted according to coffee[2]. In previous works, optimal water temperature and pressure to obtain a good quality espresso coffee were established at 92ºC and 9 atm[3,4]. However, other technical conditions related to coffee, such as grinding grade, should be different whether coffee was roasted by conventional or torrefacto process[5]. Torrefacto is a roasting process where sugar is added to Robusta coffees. This type of roast contributes to the brownish color of the coffee brew by the caramelization of sugar and the enhancing of the Maillard reaction products (MRPs). Also, torrefacto roast was initially used to mask the negative sensory characteristics of low quality Robusta coffees. This roasting technique is used in several countries of Southern Europe and South America, where some segments of population prefer espresso coffees with a high amount of foam, a dark brown color, a very intense aroma, and a strong taste, with a bitter dominance[1].

The coffee/water ratio is another factor that could influence on the coffee compounds extraction and quality. An excessive amount of coffee could not allow a sufficient expansion during wetting, thus causing over-compacting, which disturbs percolation originating deposit of solids into the cup. On the contrary, too little coffee could originate over-extracted and bitter flavor[1,6]. Petracco[1], based on commercial and technical experience, proposed a range between 5g and 8g of ground coffee for preparing one cup of espresso, depending on the coffee blend. However, only few works about the influence of coffee/water ratio in coffee brew have been found and these studies are focused on the kinetics and mechanisms of caffeine or solubles extraction in pressureless systems[7,8], but not to study the chemical and sensory characteristics of espresso coffees.

The aim of this work was to evaluate the influence of coffee/water ratio on the physicochemical and sensory quality of espresso coffee. Furthermore, the influence of botanical varieties (Arabica and Robusta) and the type of roast (conventional and torrefacto) on the selection of coffee/water ratio was studied.

MATERIALS AND METHODS

Materials. Three ground roasted coffee samples, **pure *Coffea arabica* from Colombia** (conventional espresso roast, 2% water content) (A100); **Arabica/Robusta 20:80 blend,** (conventional espresso roast, 2% water content) (A20:R80); and a blend of **Arabica/Robusta 20:80 with 50% of Torrefacto roast Robusta coffee** (A20:R80 50% Torrefacto, 1.8% water content) were provided by a local company. Two batches of each coffee sample were used. Samples were stored in similar conditions (4ºC, vacuum package, less than 2 days) before and during analysis.

Pure reference standards of acetaldehyde, 2-methylpropanal, 3-methylbutanal, 2,3-butandione, 2,3-pentandione and 2-ethyl-3,5dimethylpyrazine were purchased from Acros (New Jersey, USA); hexanal, 2-methoxyphenol (guaiacol), propanal, caffeine and 5-caffeoylquinic acid (5-CQA) were obtained from Sigma (Steinheim, Germany).

Coffee/water ratio selection. To select coffee/water ratios, espresso coffees were brewed for each sample with the experimental prototype espresso coffeemaker at conditions written below. A volume of 40±2mL, time percolation between 18 and 24 seconds, and absence of particles at the bottom of the cup were the main criteria to select coffee/water ratio. 6.5, 7.5 and 8.5g of coffee to prepare and espresso cup of 40±2mL were selected as low, medium and high coffee/water ratios, respectively.

Espresso coffee samples and preparation for analysis. Espresso coffees were prepared from each selected coffee/water ratio with the use of an experimental prototype espresso coffeemaker. Espresso coffee preparation conditions were fixed at 92ºC water temperature (corresponding to erogation temperature 86±2ºC), 9 atm of relative water pressure, 21±3s of extraction time and 38 mm of holder filter diameter. Twenty espresso coffees of each coffee/water ratio were prepared and mixed together in order to have enough coffee volume to be analyzed. Every parameter was analyzed by triplicate.

pH, Density, Viscosity, and Surface Tension. Espresso coffee samples were immediately cooled at 20ºC, and pH (Orion 420A 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 espresso coffee in milliliters, referred to 100 mL of espresso coffee total volume[1]. Volumes were measured immediately after the extraction of espresso coffee 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[1].

Total solids, Extraction and Total Solids on Filtrate. *Total solids* were determined by oven drying 40 mL of espresso coffee to a constant weight (14 h, 102±3ºC). *Extraction* was defined as the percentage of total solids with respect to ground roasted coffee dose. *Total solids on filtrate (or soluble solids)* were defined as the dry residue, expressed in mg/mL, obtained by oven drying the eluate obtained by filtration with Whatman 1 of 40mL espresso coffee to constant weight (14 h, 102±3ºC).

Total lipids. Twenty milliliters of espresso coffee was extracted by adding 20 mL of trichloromethane 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.*[9] HPLC analysis was achieved with an analytical HPLC unit (Hewlett-Packard 1100). A reversed-phase Hypersil-ODS (5µm particle size, 250 x 4.6mm) column was used. The mobile phase was acetonitrile/water (15:85) in isocratic condition at a constant flow rate of 2.0mL min^{-1} at 25ºC. Detection was accomplished with a diode-array detector, and chromatograms were recorded at 280nm.

Chlorogenic Acid (5-CQA). Extraction of 5-CQA and cleanup were carried out according to the method of Bicchi *et al.* [10] 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 1.2mL min^{-1}, at 25ºC. Wavelength of detection was at 325nm .

Volatile compounds. Volatile compounds extraction and GC analysis were carried out with the method described by Sanz *et al.* [11], adapted to espresso coffee by Maeztu *et al.*[12]. Volatiles were extracted using a static headspace sampler (Hewlett-Packard model 7694). GC analysis was achieved with a capillary HP-Wax (60m x 0.25 mm x 0.5 µm film thickness) column in a HP 6890 gas chromatograph with a HP 5973 mass selective detector (Hewlett-Packard). Volatile compounds were identified by mass spectra using Wiley database, retention times and Kovats [13, 14]. Thirteen key odorants were quantified, and results were expressed as relative percentages from volatiles total amounts.

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.* [12] 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 espresso coffee sample were obtained.

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 espresso coffee sample was defined by the percentage of judges that perceived each positive and negative flavor attribute.

Sensory Descriptive evaluation of espresso coffee samples was carried out in triplicate over 18 sessions. Three espresso coffees were analyzed per session. Each espresso coffee was prepared immediately before tasting, and served monadically in white porcelain coffee cups labeled with 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[15]. Rinse water was provided between individual samples.

Statistical analysis. Analysis of Variance (ANOVA) was applied for each type of coffee. The source of variation was coffee/water ratio. 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

The results of the physicochemical parameters and sensory attributes of espresso coffee samples are shown in Table 1 and 3, respectively. pH values were in the range proposed by Petracco[1] as normal for espresso coffee (5.2 to 5.8), except for 6.5 and 7.5 g/40 mL A20:R80 blend espresso coffees with 5.9. Arabica (A100) espresso coffees showed lower pH values than Robusta blends, as it was previously reported by other authors[16]. These results could partially explain the high perception of acidity by judges panel in A100 espresso coffees (Table 3). In A100 espresso coffee, a significant increase of the acidity with coffee/water ratio was observed. However, in Robusta blends, a clear tendency in the perception of acidity with coffee/water ratio could not be observed. Espresso acidity cannot be described only by pH[1] and, in fact, many studies have shown that there is only moderate correlation between pH and the acidity perception[16]. Consequently, although a higher extraction of acids could be proposed when coffee/water ratio was increased, the diversity of the acids, volatiles and non volatiles, organic acids such as citric, malic, chlorogenic acids and its hydrolysis derivatives (quinic, ferulic, cafeic acids), and inorganic ones, such as phosphoric acid, contribute in different proportion to acidity[17]. Furthermore, some of these acids, such as chlorogenic acids, together with caffeine and other compounds, can also contribute to bitterness modifying the typical bitterness-acidity balance of espresso coffees[1]. For all these reasons, pH does not seem to be a good reference in espresso coffee in order to propose the best coffee/water ratio when the other technical parameters were previously optimized.

On the other hand, torrefacto espresso coffees had lower pH values than A20:R80 espresso coffee, maybe due to a higher generation of acids by Maillard reaction or caramelization[18] because the addition of sugars during roasting process.

Although foam index was significantly increased with coffee/water ratio, all espresso coffees had a sufficient amount of consistent, persistent and hazelnut foam. So that, coffee/water ratio in the proposed range seems to have less influence on the foam amount and quality than other technical parameters such as water extraction pressure[3] and temperature[4], and grinding[5]. On the other hand, Robusta blends espresso coffees had higher foam indices than Arabica, maybe because the presence of unknown tensioactive substances which increase foam[1].

Density, viscosity, surface tension, total solids, total solids on filtrate and total lipids were significantly increased with coffee/water ratio (table 1). However, only significant stronger body was appreciated by judges panel in Robusta blends, mainly with Torrefacto roast (Table 3). Furthermore, higher viscosity was observed in Arabica espresso coffee which also had higher amounts of lipids, because viscosity is influenced by the amount of lipid droplets in emulsion[1]. And, although total solids increased with coffee/water ratio, extraction yields which are dose dependent, were slightly decreased or maintained because espresso coffee extraction had been optimized in previous works[3-5]. Similar but stronger pattern was observed by Cammenga *et al.* [8].

The extraction of caffeine and chlorogenic acid, compounds related to bitterness and astringency, increased when the coffee/water ratio was higher. However, only in Robusta blends espresso coffees, and mainly in Torrefacto ones, significant increases in bitterness and astringency were perceived. This could be partially due to the higher amount of caffeine and trigonelline in Robusta variety[1,19,20], and, consequently, higher extraction in Espresso coffees. Furthermore, the formation of other unidentified bitter compounds derived from Maillard reactions and caramelization during roast of Robusta coffees, and mainly in Torrefacto roast, could also contribute to the higher bitterness and astringency of Robusta blends espresso coffee. A bitterness intensity higher than 7.5

on a 10-scale should be proposed to reject 8.5g/40mL in both Robusta blends espresso coffees and also 7.5g/40mL in torrefacto ones.

Aroma/flavor results are shown in table 2 and figure 1. In Arabica (A100) espresso coffee, profiles of the majority of key odorants were significantly similar throughout the three coffee/water ratios. However, in 8.5g/40mL A100 espresso coffee, burnt/roasty, acrid and fermented flavors were perceived by significantly higher percentage of judges, and freshness was less detected with coffee/water ratio increase. This sensory flavor profile led us to reject 8.5g/40mL coffee/water ratio in Arabica coffee.

2-Methylpropanal, 2-Methylbutanal, 3-Methylbutanal, Strecker degradation products of valine, isoleucine and leucine related to the malty flavor in coffee brews[21,22], were lower extracted in 6.5g/40mL A20:R80 espresso coffees. On the other hand, pyrazines, which have been related to negative flavors such as burnt/roasty, woody/papery and earthy/musty in ground and brewed coffees including espresso coffee[12,23,24], were in similar percentages in all A20:R80 espresso coffees. However, surprisingly, more judges perceived malty/cereal flavors in 6.5g/40mL A20:R80 espresso coffees whereas in 7.5 and particularly 8.5g/40mL A20:R80 espresso coffees, negative flavors (burnt/roasty, acrid, fermented and earthy/musty) were better perceived. These differences between instrumental and sensory analyses, and among coffee/water ratios could be explained by the well-known more sensitivity of judges, and by the masking effect over positive flavors of some potent odorants, such as pyrazines[23] and others that still remain unidentified, which could be higher extracted with the coffee/water ratio increase.

A similar pattern in the volatile compounds analysis and sensory flavor profile was observed in both Robusta blends espresso coffees. Nevertheless, in Torrefacto roast coffees, less positive flavor notes related to freshness were perceived, maybe due to the ability of melanoidins to bind specific volatile compounds[25]. Furthermore, acrid flavor was significantly perceived by higher percentage of judges in Torrefacto espresso coffees prepared with more than 6.5g/40mL coffee/water ratio. This latter observation, joined to bitterness intensity higher than 7.5, led us to the selection of 6.5g/40mL coffee/water ratio as the most suitable in A20:R80, 50% Torrefacto coffee.

In conclusion, the previous optimization of other technical parameters such as water extraction, pressure and temperature, and grinding[3-5] seemed to minimize the influence of the increase of coffee/water ratio on the extraction of soluble and solid compounds. In fact, only some sensory attributes, such as bitterness, astringency and burnt, acrid and earthy/musty flavors were proposed as relevant to the selection of 6.5g/40mL or 7.5g/40mL in conventional roasted coffees (A100 and A20:R80), and 6.5g/40mL in Torrefacto roasted coffees (A20:R80, 50% Torrefacto). On the other hand, the addition of sugar during roasting process in torrefacto roast coffees seemed to contribute to a higher generation of acids, melanoidins and other compounds by Maillard reaction or caramelization which led us to the selection of the lowest coffee/water ratio. Further investigations in soluble compounds related to taste and in volatiles related to aroma profiles, and their relationships, are required because up to now sensory analysis seems to be more sensitive and definitive than instrumental to evaluate the coffee quality.

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MEETING PRESENTATION DATA

Part of this paper was presented at the 5th Pangborn Sensory Science Symposium, July 2003, Boston (MA), USA.

Table 1: Influence of coffee/water ratio (g/40mL) on physico-chemical parameters of Espresso Coffee samples.

	A100			**A20:R80**			**A20:R80, 50% Torrefacto**		
	6.5	**7.5**	**8.5**	**6.5**	**7.5**	**8.5**	**6.5**	**7.5**	**8.5**
pH	5.5; 0.0 [b]	5.4; 0.0 [a]	5.4; 0.0 [a]	5.9; 0.1 [b]	5.9; 0.0 [b]	5.8; 0.0 [a]	5.8; 0.0 [c]	5.7; 0.0 [b]	5.6; 0.0 [a]
Density (g/mL)	1.005; 0.001 [a]	1.010; 0.000 [b]	1.010; 0.000 [b]	1.010; 0.000 [a]	1.010; 0.000 [a]	1.012; 0.000 [b]	1.005; 0.001 [a]	1.010; 0.000 [b]	1.010; 0.000 [b]
Viscosity ($mN/m^2 x s$)	1.23; 0.01 [a]	1.29; 0.02 [c]	1.26; 0.01 [b]	1.14; 0.01 [a]	1.17; 0.02 [b]	1.17; 0.01 [b]	1.15; 0.00 [a]	1.19; 0.04 [b]	1.21; 0.00 [b]
Surface Tension (mN/m)	48.37; 0.90 [a]	48.81; 0.99 [ab]	50.61; 0.96 [b]	39.39; 0.00 [a]	51.58; 1.05 [b]	51.00; 0.00 [b]	47.81; 0.00 [a]	51.58; 1.05 [b]	50.90; 0.00 [b]
Foam index (%)	12.3; 0.3 [a]	14.4; 1.0 [b]	17.7; 0.6 [c]	15.8; 0.0 [a]	21.9; 0.0 [b]	30.8; 0.7 [c]	20.4; 2.7 [a]	20.8; 6.6 [a]	22.9; 0.8 [b]
Persistence of foam (min)	25.33; 0.51 [a]	30.00; 0.00 [b]	30.00; 0.00 [b]	30.00; 0.00 [a]	30.00; 0.00 [a]	30.00; 0.00 [a]	20.00; 0.00 [a]	30.00; 0.00 [b]	30.00; 0.00 [b]
Total Solids (mg/mL)	34.03; 0.21 [a]	37.24; 0.73 [b]	42.07; 0.39 [c]	35.58; 0.41 [a]	36.01; 0.41 [b]	40.76; 0.60 [c]	36.17; 0.17 [a]	38.20; 0.97 [b]	43.11; 0.33 [c]
Extraction (%)	20.9; 0.2 [b]	19.9; 0.4 [a]	19.8; 0.2 [a]	20.7; 0.2 [b]	19.2; 0.4 [a]	19.2; 0.2 [a]	22.3; 0.1 [b]	20.4; 0.5 [a]	20.3; 0.2 [a]
Total Solids on Filtrate (mg/mL)	32.0; 0.3 [a]	35.2; 0.5 [b]	39.7; 0.9 [c]	30.7; 0.9 [a]	35.6; 0.7 [b]	38.8; 0.8 [c]	33.0; 0.1 [a]	34.4; 0.7 [b]	40.9; 0.1 [c]
Total Lipids (mg/mL)	4.80; 0.17 [a]	5.06; 0.04 [b]	5.13; 0.09 [b]	3.34; 0.10 [a]	3.77; 0.03 [b]	3.92; 0.08 [c]	3.46; 0.06 [a]	3.76; 0.02 [b]	4.06; 0.08 [c]
Caffeine (mg/mL)	1.80; 0.04 [a]	1.88; 0.12 [a]	2.21; 0.05 [b]	3.01; 0.08 [a]	3.17; 0.07 [a]	3.31; 0.18 [b]	2.49; 0.23 [a]	2.76; 0.07 [b]	3.15; 0.05 [c]
Trigonelline (mg/mL)	0.73; 0.06 [a]	0.72; 0.05 [a]	0.94; 0.09 [b]	1.49; 0.17 [b]	1.55; 0.15 [b]	1.29; 0.08 [a]	1.66; 0.17 [b]	1.74; 0.07 [b]	0.93; 0.06 [a]
Chlorogenic Acid (5-CQA) (mg/mL)	1.16; 0.17 [a]	1.38; 0.04 [b]	1.80; 0.06 [c]	1.18; 0.07 [a]	1.45; 0.02 [b]	1.52; 0.03 [c]	1.28; 0.07 [a]	1.39; 0.02 [b]	1.50; 0.08 [c]

All values are shown as mean; standard deviation (n=6).
In each row, different letters indicate significant difference ($p<0.05$) among different coffee/water ratio in each type of coffee.

Table 2. Influence of coffee/water ratio (g/40mL) on the relative percentage of key odorants in Espresso Coffee samples.

KI [1]	ID [2]	Key odorant	A100			A20:R80			A20:R80, 50% Torrefacto		
			6.5	7.5	8.5	6.5	7.5	8.5	6.5	7.5	8.5
		SULFUR COMPOUNDS									
635	C	**Methanothiole**	0.16; 0.01 [a]	0.24; 0.01 [b]	0.22; 0.02 [b]	0.10; 0.00 [a]	0.12; 0.01 [b]	0.12; 0.02 [b]	0.15; 0.01 [a]	0.16; 0.00 [b]	0.16; 0.00 [b]
		ALDEHYDES									
645	A	**Acetaldehyde**	0.49; 0.04 [a]	0.54; 0.04 [a]	0.51; 0.05 [a]	0.34; 0.02 [a]	0.35; 0.03 [a]	0.38; 0.02 [a]	0.37; 0.01 [b]	0.32; 0.02 [a]	0.39; 0.03 [b]
712	A	**Propanal**	0.71; 0.10 [a]	0.74; 0.08 [a]	0.74; 0.09 [a]	0.47; 0.04 [a]	0.49; 0.04 [a]	0.54; 0.01 [b]	0.45; 0.03 [ab]	0.43; 0.02 [a]	0.47; 0.03 [b]
747	A	**2-Methylpropanal**	2.36; 0.38 [a]	2.75; 0.26 [a]	2.74; 0.23 [a]	2.00; 0.18 [a]	2.27; 0.19 [b]	2.41; 0.19 [b]	2.05; 0.15 [ab]	1.93; 0.21 [a]	2.17; 0.08 [b]
880	C	**2-Methylbutanal**	1.36; 0.20 [a]	1.60; 0.20 [a]	1.53; 0.12 [a]	1.26; 0.14 [a]	1.43; 0.15 [ab]	1.58; 0.20 [b]	1.24; 0.09 [a]	1.20; 0.17 [a]	1.25; 0.05 [a]
884	A	**3-Methylbutanal**	3.60; 0.51 [a]	4.28; 0.48 [a]	4.09; 0.37 [a]	2.35; 0.29 [a]	2.65; 0.23 [ab]	2.79; 0.15 [b]	2.56; 0.18 [a]	2.44; 0.30 [a]	2.46; 0.33 [a]
1084	A	**Hexanal**	0.08; 0.02 [a]	0.07; 0.03 [a]	0.06; 0.01 [a]	0.10; 0.03 [a]	0.09; 0.02 [a]	0.07; 0.01 [a]	0.07; 0.01 [a]	0.04; 0.01 [a]	0.04; 0.01 [a]
		KETONES									
962	A	**2,3-Butandione**	0.53; 0.09 [a]	0.57; 0.08 [a]	0.54; 0.04 [a]	0.34; 0.04 [a]	0.32; 0.02 [a]	0.36; 0.01 [a]	0.32; 0.02 [ab]	0.30; 0.01 [a]	0.33; 0.02 [b]
1058	A	**2,3-Pentandione**	0.83; 0.12 [a]	0.87; 0.07 [a]	0.85; 0.09 [a]	0.46; 0.04 [a]	0.45; 0.04 [a]	0.48; 0.01 [a]	0.44; 0.01 [b]	0.40; 0.01 [a]	0.45; 0.04 [b]
		PYRAZINES									
1359	C	**Ethylpyrazine**	0.14; 0.01 [b]	0.11; 0.02 [a]	0.11; 0.01 [a]	0.17; 0.01 [ab]	0.16; 0.01 [a]	0.19; 0.01 [b]	0.12; 0.01 [ab]	0.12; 0.00 [a]	0.13; 0.01 [b]
1411	C	**2-ethyl-6-methylpyrazine**	0.04; 0.00 [a]	0.04; 0.00 [a]	0.04; 0.00 [a]	0.07; 0.00 [b]	0.06; 0.00 [b]	0.07; 0.00 [a]	0.06; 0.01 [b]	0.05; 0.01 [b]	0.05; 0.00 [a]
1475	A	**2-ethyl-3,5-dimethylpyrazine**	0.05; 0.00 [a]	0.05; 0.00 [a]	0.04; 0.00 [a]	0.08; 0.00 [a]	0.08; 0.01 [a]	0.08; 0.01 [a]	0.13; 0.04 [a]	0.06; 0.00 [a]	0.06; 0.00 [a]
		PHENOLIC COMPOUNDS									
	A	**2-methoxyphenol (Guaiacol)**	0.03; 0.00 [a]	0.04; 0.00 [ab]	0.08; 0.04 [b]	0.04; 0.00 [a]	0.04; 0.00 [a]	0.04; 0.00 [a]	0.04; 0.00 [a]	0.04; 0.00 [a]	0.04; 0.00 [a]

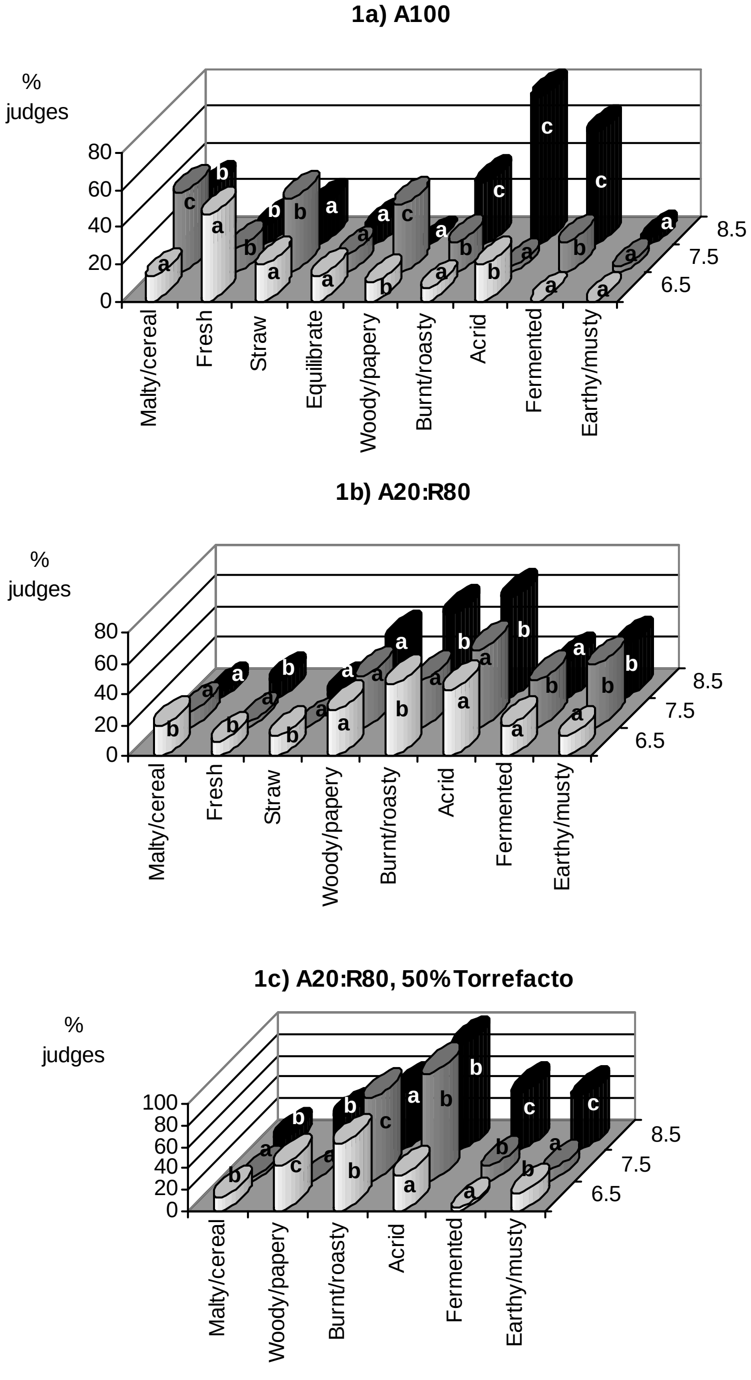
All values are shown as mean; standard deviation (n=6). In each row, different letters indicate significant difference ($p<0.05$) among different coffee/water ratio in each coffee sample. [1]KI, Kovats index calculated for the HP-Wax capillary column. [2] The reliability of the identification proposal 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.

Table 3. Influence of coffee/water ratio (g/40mL) on sensory attributes of Espresso Coffee samples.

	A100			A20:R80			A20:R80, 50% Torrefacto		
	6.5	**7.5**	**8.5**	**6.5**	**7.5**	**8.5**	**6.5**	**7.5**	**8.5**
Odor Intensity	6.3; 0.8 [a]	6.5; 0.7 [a]	6.6; 0.7 [a]	6.3; 0.8 [a]	6.2; 0.5 [a]	6.2; 1.0 [a]	6.1; 0.8 [a]	6.0; 0.7 [a]	6.4; 0.8 [b]
Body	6.1; 0.7 [a]	6.0; 0.6 [a]	6.1; 0.7 [a]	6.1; 0.7 [a]	6.2; 0.6 [a]	7.0; 0.9 [b]	6.4; 0.9 [a]	6.9; 1.0 [b]	7.3; 0.7 [c]
Acidity	5.4; 0.8 [a]	6.0; 1.0 [b]	6.4; 1.0 [c]	1.6; 0.6 [a]	2.0; 0.7 [b]	1.4; 0.7 [a]	3.5; 0.7 [b]	3.6; 1.0 [b]	1.8; 0.9 [a]
Bitterness	6.6; 1.3 [a]	6.7; 1.0 [a]	7.0; 0.8 [a]	6.9; 1.1 [a]	7.3; 1.2 [a]	8.2; 1.2 [b]	6.8; 0.9 [a]	7.5; 0.9 [b]	8.2; 1.0 [c]
Astringency	6.1; 1.0 [a]	5.8; 0.9 [a]	6.0; 0.9 [a]	6.0; 0.9 [a]	6.4; 0.9 [a]	7.6; 1.4 [b]	5.7; 0.6 [a]	6.4; 0.8 [b]	7.2; 1.0 [c]
Flavor intensity	6.7; 0.9 [a]	6.7; 0.9 [a]	6.8; 0.6 [a]	6.5; 0.9 [a]	6.6; 0.8 [a]	7.7; 0.9 [b]	6.4; 0.9 [a]	6.7; 0.7 [b]	7.1; 0.8 [c]
Aftertaste intensity	6.1; 0.8 [a]	6.3; 0.8 [a]	6.6; 0.7 [b]	6.8; 1.0 [a]	6.9; 0.9 [a]	7.7; 1.1 [b]	6.6; 1.0 [a]	6.9; 0.9 [ab]	7.2; 0.9 [b]

All values are shown as mean; standard deviation (n=6).
In each row, different letters indicate significant difference ($p<0.05$) among different coffee/water ratio in each type of coffee.

Figure 1. Influence of coffee/water ratio (g/40mL) on espresso coffee flavor profile.



For each parameter, different letters indicate significant differences ($p<0.05$) among different coffee/water ratios.