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Comparison of espresso coffee brewing techniques

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ABSTRACT

Several brewing techniques are used to make espresso coffee. Among them, the most widespread are bar machines and single-dose capsules, designed in large numbers because of their commercial popularity. As none of the current literature compares the effects of these different brewing techniques on espresso quality, this paper looks at two capsule methods and the traditional bar method. The methods were evaluated on the basis of the physico-chemical parameters and aromatic profile of nine espresso coffees prepared using the different techniques. Our results showed that with the same batch of roasted coffee, the same water and the same operative settings, the three different techniques can be distinguished by a principal component analysis. Furthermore, in terms of product reproducibility, the best results are provided by the two capsule systems.

1. Introduction

There are a large number of devices and methods to produce espresso coffee (EC). EC is defined as "a brew obtained by percolation of hot water under pressure through compacted cake of roasted ground coffee, where the energy of the water pressure is spent within the cake" (Illy et al., 2005). In this process flavors are extracted from the coffee by means of hot water. EC consists of about 35 ml of dark beverage, usually served in a small cup with a brown foam layer called *crema* covering the liquid. *Crema* is a distinctive feature of EC, as it is absent in other coffee brews and is required for consumer acceptance.

EC is conventionally brewed using bar machines (BM), which consist of a rotating pump, a heat exchanger and an extraction chamber (Illy et al., 2005). The water pressure provided by the pump strongly affects the physical and sensory properties of the brew (Andueza et al., 2002) and maximal EC quality seems to correspond to an optimal water pressure of nine bars. ECs prepared at higher pressure have negative sensorial qualities as they are excessively bitter, astringent and contain more key odorants. In conventional EC preparation pressurized water reaches the heat exchanger where its temperature rises. In this type of machine Andueza et al. (2003) found the best key odorant profile, flavor notes and highest overall acceptability at 92 °C. Coffees brewed at lower temperatures had less odor, flavor and body intensity (they are generally called "under extracted"), whereas coffees brewed at higher temperatures had a burnt/roast flavor and a higher content of negative key odorants (they are generally called "over extracted"). The extraction chamber consists of a filter where the ground coffee is placed and compacted. The filter provides the hydraulic resistance required to produce EC. During this procedure there are many variables that cannot be controlled by the extraction device (e.g. the coffee powder particle size, powder compression); these have a high impact on the properties of the final brew (Illy et al., 2005) and depend on the ability of the barman.

Among the other methods developed to make EC, pod and capsule systems have recently gained market share because they are user-friendly. They also make it easy to prepare good-quality coffees through the reduction of uncontrolled preparation variables. Furthermore, these systems preserve the quality of the ground coffee by protecting it against moisture and oxidation processes (Vanni, 2009). For these reasons, in 2005, pod and capsule sales added up to 14 billion units (Tozzi, 2007). As a result of their popularity several kinds of capsule have been developed. The simplest consists of a chamber to hold the coffee and a film that provides the needed resistance when water is added. More sophisticated capsules are equipped with devices that should lead to the production of top-quality EC. However, the environmental impact of these approaches is significantly higher than other preparation methods. This is mainly due to the production of disposable capsules that cause significant greenhouse gas emissions (Brommer et al., 2011). *In fine* EC quality is strongly affected by the operative conditions of the extraction, which differ depending on the device.

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To the best of the authors' knowledge, there are no studies that compare different preparation techniques (e.g. BM and capsule) in terms of the sensory and chemical characteristics of the resulting EC. In this work we evaluate and compare the differences in terms of quality between EC made using three different extraction procedures. The differences are assessed in terms of sensory characteristics, physical parameters, and extracted volatile key compounds. The selected methods were: the bar method (the traditional way to make EC), a simple commercial capsule method (Illy; I-Espresso System), and a more advanced commercial capsule method (Illy; HyperEspresso), primarily designed to increase the sensory attributes related to the colloidal state of the beverage (Navarini et al., 2008).

2. Materials and methods

2.1. Experimental design

The extraction methods were compared through the preparation of three ECs per day over a period of 3 days for each device, resulting in a total of 27 ECs. The order of preparation for each day was completely random.

2.2. Extraction devices

2.2.1. Bar machine (BM)

A conventional bar machine (the Alina model manufactured by Cimbali S.p.A. Italy) was used. The machine was designed to make two ECs at the same time in the same extraction chamber by splitting the exit flow equally. Therefore, the ECs were prepared with double the amount of ground coffee (14.5 ± 0.2 g). Chemical and physical analyses were only performed on one of the two ECs. The extraction parameters were: water temperature 92 °C, water pressure 9 bar, and 25–30 s of percolation time, assuming an optimal flow rate of about 1 ml s^{-1} (Illy et al., 2005).

2.2.2. Hyper Espresso method (HIP)

The capsules were brewed using the Good News coffee machine (manufactured by D.P.I. Service SNC, Italy), designed for Hyper Espresso capsules (produced by illycaffè S.p.A, Italy) at a pressure of 12 bar and an extraction temperature of 92 °C. The HIP capsules contained 6.7 ± 0.1 g of ground coffee and consisted of five parts: a cover, an upper and a lower internal filter, an infusion chamber and a flow conveyor. This design only allows the EC to flow out of the capsule when a fixed pressure is reached. During EC preparation the upper side of the capsule (the cover) is punched and the water is added (pre-infusion phase); then the water compresses the gas in the capsule and the pressure rises (infusion phase) until the capsule film bursts; once the pressure to burst the capsule is reached, the coffee flows out through a micro-hole (emulsion phase).

2.2.3. I-Espresso System (IT)

The capsules were brewed using the Mitaca machine (manufactured by illycaffè S.p.A, Italy). The capsules contained 6.9 ± 0.1 g of ground coffee and consisted of a plastic cylinder covered by a plastic film. Hot water at 92 °C is introduced into the capsule. The bottom of the capsule has a central hole allowing EC outflow when a given pressure is reached.

2.3. Espresso coffee preparation

2.3.1. Coffee

All the ECs were prepared from the same batch of roasted coffee beans, provided by illycaffè S.p.A. (Italy). Some of the roasted beans were ground (Colombini Icoperfexand grinder) and used to prepare the HIP and IT capsules. The remaining roasted beans were used for the BM trials. These beans were ground immediately before preparation, using a professional coffee grinder (KE640 model manufactured by Ditting Maschinen AG, Switzerland). The resulting particle size distribution was: 29% >500 μm; 250 μm < 47.4% < 500 μm; 125 μm < 22.2% < 250 μm; and 1.4% < 125 μm.

Table 1
The physico-chemical characteristics of mineral water as listed on the bottle's label.

Analytical parameter	Values
pH	8.1
Electrical conductivity (20 °C)	249 μS/cm
Total dissolved solids	148 mg/l
Hardness	14 °F
Kubel oxydability	0.6 mg/l
Free carbon dioxide	3.3 mg/l
Calcium (Ca^{2+})	30.1 mg/l
Magnesium (Mg^{2+})	15.0 mg/l
Sodium (Na^{+})	1.4 mg/l
Potassium (K^{+})	0.5 mg/l
Hydrogen carbonate (HCO_3^-)	157 mg/l
Sulfate (SO_4^{2-})	10.7 mg/l
Nitrate (NO_3^-)	5.0 mg/l
Chloride (Cl^-)	1.5 mg/l
Fluoride (F^-)	0.06 mg/l
Silicon dioxide (SiO_2)	6.6 mg/l

2.3.2. Water

According to Navarini and Rivetti (2010), water quality plays a key role in EC quality. Consequently, all tests were performed using the same commercial brand of mineral water. The physical and chemical characteristics of this water, according to the manufacturer's specification, are shown in Table 1.

2.4. Measurements and analyses

All brewed coffee samples were immediately collected at the outflow of the machine in a glass weighing bottle (75 ml volume, 53 mm internal diameter, 34 mm high) with a ground glass lid and equipped with two valves specifically designed for the sampling of the headspace above the coffee (described in more detail later). In order to obtain homogeneous samples, the same weight of percolated liquid was collected, regardless of flow rate or percolation time. Thus, a digital scale (max capacity 300.0 g; precision 0.1 g; manufactured by D-Mail S.R.L., Italy) was placed under the vessel and a preselected weight of 25 g of brewed coffee was collected. The resulting final brew weight was 25.7 ± 0.6 g averaged over all the samples. The temperature of the outflowing coffee was measured directly under the liquid flow with a digital thermometer (HD2107.1, manufactured by Delta OHM S.R.L., Italy).

The following parameters were analyzed and evaluated for all samples.

2.4.1. Foam Index and persistency

The foam index is defined as the ratio between the foam and liquid volume (vol vol^{-1}%) measured 30 s after extraction (the geometry of the sampling vessel is given above). Persistency is defined as the time (in minutes) before the foam breaks up, leaving an uncovered black spot on the surface of the beverage (Petracco, 2001).

2.4.2. Density, pH, and viscosity

Before taking these measurements samples, were cooled to 20 °C. Density was measured with a 25 ml pycnometer. A digital pH meter (GLP 21, manufactured by CRISON INSTRUMENTS, S.A. Spain) was used to determine the pH of the ECs. Viscosity was