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Steam pressure treatment of defective *Coffea canephora* beans improves the volatile profile and sensory acceptance of roasted coffee blends

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2,3-Pentanedione (PubChem CID: 11747)
Acetoin (PubChem CID: 179)
Furfuryl acetate (PubChem CID: 12170)
3-Methylbutanal (PubChem CID: 11552)
Pyridine (PubChem CID: 1049)
2-Furfurylthiol (PubChem CID: 7363)
Vanillin (PubChem CID: 1183)
Phenylethyl alcohol (PubChem CID: 6054)
Dimethyldisulfide (PubChem CID: 12232)
Acetic acid (PubChem CID: 176)

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ABSTRACT

Between 15 and 20% of Brazilian coffee production corresponds to defective beans (PVA), which decreases the quality of the coffee brew. Steam treatment has been reported as an alternative to improve the volatile profile and cup quality of coffee. The aim of this study was to propose a steam treatment of defective *Coffea canephora* beans to improve the volatile profile of the roasted coffee. The sensory impacts of adding steamed coffee (SC) in *Coffea arabica* blends were evaluated. The steam treatments studied modified the volatile profile of roasted SCs, increasing the contents of acetoin, benzyl alcohol, maltol, 2,6-dimethylpyrazine, 2-furfurylthiol, and 5-methylfurfural and decreasing the contents of 4-ethylguaiacol, isovaleric acid, methional, 2,3-diethyl-5-methylpyrazine, and 3-methoxy-3-methylpyrazine. Among the evaluated parameters, the best condition to maximized the content of the volatiles with a potential positive impact and minimize those with a potential negative impact was 5 bar/16 min (SC 5). The thresholds of consumer rejection and of detection indicate that up to 30% SC 5 can be added to a high cup quality *Coffea arabica* coffee without perception or rejection of the coffee brew. A blend of 30% of SC 5 and 70% of *Coffea arabica* was well accepted.

1. Introduction

Brazil is the world's largest coffee producer and exporter, producing the following two main commercial species: *Coffea arabica* L. (arabica coffee) and *Coffea canephora* Pierre (robusta coffee).

The ripe fruits or cherry coffees provide high quality brews, and therefore, they are more valued in the market. Defective coffee beans are usually present in Brazilian coffee due to the strip-picking harvesting and processing practices used by the coffee producers. Approximately 20% of all coffee produced in Brazil is defective beans, which are considered inappropriate for export and are usually incorporated into the internal market. In addition to the differences in their composition compared to non-defective coffee (Craig, Franca, & Oliveira, 2012), defective beans markedly decrease cup quality (Bandeira, Toci, Trugo, & Farah, 2009; Toci & Farah, 2014).

The main defective beans related to coffee cup quality are the intrinsically defective ones known as PVA, from the Portuguese “preto” (black beans), “verde” (green or immature beans) and “ardido” (sour beans). Immature beans originate mainly from immature fruits; sour beans can be generated through abnormal fermentation; and black beans often originate from over-ripened cherries that fall and remain in contact with the soil, which favors fermentation during post-harvesting (Mendonça, Franca, & Oliveira, 2009; Mendonça, Franca, Oliveira, & Nunes, 2008).

Some volatile compounds were cited as potential markers for defective coffee. Compared to non-defective coffees, higher differences in the volatile profile were observed for black and sour beans (probably due to fermentation) (Franca & Oliveira, 2008) than for immature beans (Toci & Farah, 2014). The compound 2,3,5,6-tetramethylpyrazine was reported for medium roasted black and sour beans

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(Toci & Farah, 2014), while 2,3-butanedione, 2-methylbutanal, 3-methylbutanal, 4-ethylguaiacol, 4-methylthiazole were reported for roasted PVA mixture (Toledo, Pezza, Pezza, & Toci, 2016). Meanwhile volatiles as 2,5-dimethylpyrazine, 2,6-dimethylpyrazine, 2-acetyl-3,5-dimethylpyrazine, 2,3-dimethylpyrazine and pyridine were detected in all beans (black, sour, immature and non-defective coffees) (Toci & Farah, 2014).

C. canephora is the main raw material for the instant coffee industry. However, another of its relevant uses is roasted and ground coffee, blended with *C. arabica*. The total production of *C. canephora* in Brazil reached 11.19 million 60 kg bags in 2015 (Companhia Nacional de Abastecimento (CONAB), 2016). *C. canephora* presents a higher content of soluble solids and a higher yield after the roasting process compared to *C. arabica;* on the other hand, it also presents lower commercial value and sensory quality. *C. canephora* can have objectionable tarry, earthy, and bitter flavor notes associated with undesirable volatiles (Ponzoni, Protomastro, & Stefanucci, 1973), and its sensory quality can be further downgraded due to the presence of defects.

Steam processing has been applied to coffee to reduce unwanted taste components in *C. canephora*, mainly by increasing the pressure during treatment. The process improves the volatile profile generated by the roasting process, an important characteristic for the quality of the roasted coffee brew. Early research in this area includes mainly patents (Becker, Schlabs, & Ag, 1991; Dar, Bruckmann, & Kelly, 1985; Manfred, 1997). Regarding the impact of volatile compounds on the characteristics and the cup quality of a coffee brew, several compounds present in roasted coffees, which were studied in this research, have been classified by previous studies into positive or negative olfactometric groups considering their sensory characteristics, as can be seen in Table 1, which summarizes some literature data (Table 1).

Literature about the volatile profile of *C. canephora* defective beans is scarce (Bandeira et al., 2009; De Conti, 2013; Mendonça et al., 2008; Mendonça et al., 2009). Additionally, there is no research on the effect of steam treatment on *C. canephora* PVA beans. It is generally reported that the addition of up to 20% of *C. canephora* in *C. arabica* blends does not affect sensory characteristics and is not perceived by consumers (Santos, Deliza, Freitas, & Corrêa, 2013). However, there is no information regarding the impact of the use of *C. canephora* defective beans in coffee blends.

The aim of this study was to propose a steam pressure treatment for *C. canephora* defective beans to improve the volatile profile of the roasted coffee. The sensory effect of the process was evaluated in blends of *C. arabica* with *C. canephora* steamed coffees through the threshold of rejection/detection and an acceptance test.

2. Materials and methods

2.1. Coffees

Coffee samples were provided by Cia Iguaçu (Cornélio Procópio, Paraná, Brazil). The separation and classification of coffees were also made in the industry, by trained employees.

Sun-dried *C. canephora* coffee (natural coffee) from the 2014 crop from Rondônia State (Brazil) was used to obtain defective beans for the study. The *C. canephora* raw coffee was subjected to selection on an industrial optical electronic sorter (Giga Mode G10000), that separates the non-defective coffee from defective beans based on color, until 20 kg of rejected beans was obtained. The raw material was characterized by visual assessment as 34.9% black, 8.9% immature, 37.9% sour, 15.7% non-defective beans, and 2.6% other (including shells and sticks, excluding stones). This material was used for the steamed coffee preparation.

A high cup quality sun-dried *C. arabica* coffee (natural coffee) type NY 2 (corresponding to 6 defects per 300 g of sample – more details on classification see Franca, Oliveira, Mendonça, & Silva, 2005) from the 2015 crop from the Mogiana region (São Paulo, Brazil) was used in the sensory tests.

2.2. Preparation of steamed coffees

Batches of 1.5 kg of the rejected beans (81.7% PVA beans) were submitted to steam treatment following a full factorial design 2^2 with 3 repetitions on the central point, considering the variables steam pressure (from 2 to 8 bar) and process time (from 3 to 29 min) (Table 2). An untreated sample was maintained as the control.

The steam treatments were performed in an equipment based on the one used by De Conti (2013). The basket consists of a cylindrical stainless steel container AISI standard, with 1200 mm of height and 60 mm of diameter. The container surface has holes of 3.0 mm in diameter, resulting in a 20% area opened for steam passage. The container was placed inside a pressure vessel where the steam was injected from biomass boiler. The inlet pressure in the vessel was adjusted through a controlling valve installed in the steam pipe and a manometer recorded the applied pressure (Fig. 1).

Before the roasting process, the steamed coffee beans (SC) were previously dried in vacuum oven (Q819V2, Quimis, São Paulo, Brazil) at 70 °C until moisture reached 7.4 to 9.5% (w/w). It was essential to standardize the moisture of the samples set in order to achieve a better control of the roasting process.

2.3. Standardization of the roasting process for steamed coffees and characterization of samples

Subsequently to moisture standardization, each dry steamed coffee was subjected to a medium roasting process in a pilot-type Rod-Bel roaster (São Paulo, Brazil) (maximum capacity 300 g). Roasting temperature of approximately 230 °C, suggested as optimal for *C. canephora* (Mendes, De Menezes, & Silva, 2001) was applied.

The roasting process time was standardized based on L* value, as detailed described in the Results. Coffee beans submitted to the most drastic steam treatment (SC 4) took less time (5 min) to reach the desired color (L*) compared to those subject to the mild steam treatment (SC1), whose only achieved the same color after 14 min (the most extended roasting time). Intermediate roasting times were used to other design conditions. The weight loss was also determined (by the difference between the mass before and after roasting) as additional information.

Color measurements were performed in triplicate on coffee samples placed into a CR A50 accessory of a colorimeter (CR-410, Konica Minolta, Tokyo, Japan). The analyses were recorded under the conditions of standard illuminant C and a 10° observer and data were reported on CIELAB color scale.

Regarding the *C. arabica* used in the sensory analysis, the coffee was roasted to medium degree (roasting time of 19 min, L* of 24.5, moisture of 1.9%; w/w).

In order to obtain an standardized roasting procedure among batches of the same samples (for sensory analysis), the process was monitored by time of roasting, weight loss and L*. Coeficient of variation of L* value up to 2% among batches were observed (data not shown).

The roasted coffees were middle ground (0.7% retained in sieve size 1.18 mm; 73% retained in sieve size 0.60 mm, and 20% passing a sieve size 0.60 mm) in a Burr Grinder GVX2 (Krups, Solingen, Germany) and stored in plastic flasks at −18 °C. Moisture content of roasted and grounded coffees was measured by infrared moisture analyzer (MB200, Ohaus, Mumbai, India) at 105 °C for 7 min (triplicate analysis).

2.4. Evaluation of volatile compounds

2.4.1. GC analysis

Volatile compounds analysis was performed through isolation using solid-phase micro extraction (SPME) followed by quantification using an Agilent 6890 N gas chromatograph (California, USA) equipped with an Agilent 5973 mass spectrometric detector and MSD Chemstation software. Sample preparation and chromatograph conditions were