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Proceeding Paper

Coffee Flower as a Promising Novel Food—Chemical Characterization and Sensory Evaluation †

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Abstract: The use of the flowers (blossoms) of the coffee plant (genus *Coffea*) has been neglected over the years, as the focus was primarily on cost-efficient production of coffee beans. Because of societal changes and economic pressures, there is an increasing demand for sustainability, so that the focus widened also toward the various by-products of the coffee production. The coffee flower is a by-product because it can be harvested following pollination without any risk to the bean production. The coffee flower can be used as a whole or as floral water in some food and cosmetic products. The flower can also be prepared as a tea-like beverage with hot water infusion. Another side-chain product in coffee plantations is the so-called coffee flower honey, which is rarely monofloral due to the short flowering period. To date, there have been few studies on coffee flowers and their sensory characterization. In this work, various compounds in *Coffea arabica*, *C. canephora* and *C. liberica* flowers were identified and quantified by high-performance liquid chromatography (HPLC) with diode array detection (DAD), nuclear magnetic resonance spectroscopy (NMR), and near-infrared (NIR) spectroscopy. Caffeine, chlorogenic acids, organic acids, trigonelline, and sugars were quantified. Additionally, sensory testing of coffee flower infusions according to the German norm DIN 10 809 was performed. With the acquired data, a principal component analysis (PCA) was performed in which hay, hops, sage, dried apricot, and honey were identified as major flavor descriptors in addition to the floral coffee flower flavors. The coffee flower is judged as a promising ingredient, which needs to be further assessed regarding its possible approval within the novel food regulation of the European Union.

Keywords: coffee by-products; coffee flower; coffee blossom; tea; infusion; analysis; HPLC; NMR; NIR; novel food

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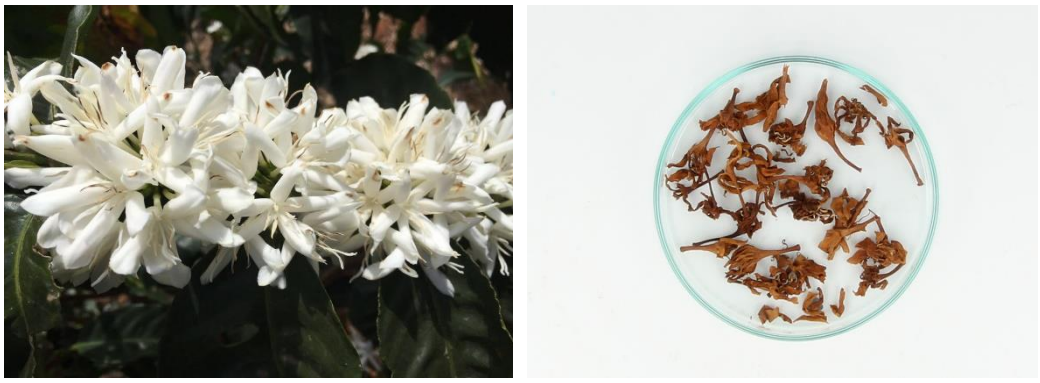
1. Introduction

In 1713, the first botanical description of the coffee tree was known as *Jasminum arabicum*. This classification arose because of the flower aroma, which was very reminiscent of jasmine, and therefore, the coffee flower (blossom) was often confused with jasmine. It was not until 1737 that Linnaeus classified the coffee tree in its own genus *Coffea*, with the only known species at that time being *C. arabica* [1]. The coffee flower (Figure 1) is a by-product because it can be harvested following pollination without any risk to the bean production [2]. The flower can be used as a whole or as floral water in some food and cosmetic products [3–5], or it can be prepared as a tea-like beverage with hot water infusion [3,6]. Another side-

chain product in coffee plantations is the so-called coffee flower honey, which is rarely monofloral due to the short flowering period [7,8]. Despite the known possibilities of using the coffee flower as food, there have been few studies on coffee flowers and their sensory characterization, to this day. It is known, that they contain bioactive components such as, for example, caffeine, trigonelline, chlorogenic acid (5-caffeoylquinic acid), protocatechuic acid, gallic acid, melanoidins, and sugars [9,10]. This study investigates coffee flower compounds, aiming toward food uses and a possible approval according to the novel food regulation of the European Union in the future.



(**a**) (**b**)

Figure 1. Coffee flowers, (**a**) on the tree during the short flowering period, and (**b**) in the air-dried state similar to the samples analyzed in this study.

2. Materials and Methods

In this work, various compounds in 35 different *Coffea arabica*, *C. canephora* and *C. liberica* flowers from El Salvador, Malaysia, India and Thailand were identified and quantified using high-performance liquid chromatography (HPLC) with diode array detection (DAD), nuclear magnetic resonance spectroscopy (NMR), and near-infrared (NIR) spectroscopy. Additionally, sensory testing of coffee flower infusions according to the German norm DIN 10809 was performed. With the acquired data, a principal component analysis (PCA) was performed. All samples were analyzed in the air-dried state. Also, a roasted coffee flower tea of *C. arabica* from the trade was analyzed. To ensure the homogeneity of the samples, each of them was finely ground and stored in air- and light-impermeable bags until use. In general, established analytical methods for coffee or tea were applied, so that only the specific sample preparation for coffee flowers will be specified in the following.

2.1. Sample Preparation

An aliquot was taken from each coffee flower. Before processing for analysis, they were ground and homogenized using an analytical mill and then stored in an airtight plastic container.

2.2. High-Performance Liquid Chromatography (HPLC)

For HPLC analysis, ISO 14502-2:2007-12 was used [11]. For this purpose, 200 mg of the sample material was weighed into a 10 mL extraction tube with a screw cap. The samples were then mixed with 5 mL of a 70% methanol extraction solution, which had previously been temperated at 70 °C in a water bath, and then sealed. This was followed by mixing the extraction tube with the sample solution using a vortex mixer and bathing in 70 °C water for 5 min. After extraction was complete, the extraction mixture was cooled to room temperature (T = 20 °C) and centrifuged (rcf = 3500× *g* for 10 min). The supernatant was then decanted into a 10 mL volumetric flask and the procedure was repeated with the sample remaining in the extraction tube.

2.3. Nuclear Magnetic Resonance (NMR) Spectroscopy

2.3.1. Extraction of Water-Soluble Compounds for ^{1}H-NMR

150 mg of the ground coffee flower was weighed into a 15 mL Falcon tube as a triplicate. Then, 8 mL of distilled water was added to the coffee flower sample, the tube was capped and extracted for 20 min using a vertical shaker. The mixture was then filtered through a syringe-attached membrane filter. Then, 70 µL of TSP and 100 µL of buffer were pipetted with 600 µL of the extract into a 4 mL screw-top glass tube. The tube was sealed and the contents were mixed using a vortex mixer. After mixing the diluted extract, 600 µL was removed and pipetted into a 5 mm NMR tube.

2.3.2. Extraction of Fat-Soluble Compounds for ^{1}H-NMR

150 mg of coffee flower was weighed as a triplicate in 4 mL screw-top glass vial. Then, 1500 µL of chloroform solvent was added, which was spiked with tetramethylsilane (TMS). After sealing the sample, it was extracted on a shaker for 20 min. Then, the mixture was filtered using a membrane filter. Finally, 600 µL of the diluted coffee flower extract was taken and transferred to a 5 mm NMR tube.

2.4. Near Infrared (NIR) Spectroscopy

The homogenized coffee flower was distributed in a layer of about 1 cm into a round glass Petri dish so that the entire bottom was covered. After filling, the sample was pressed firmly with a metal stamp and placed on the Petri dish holder above the measuring beam. In the spectrometer, the sample cell was measured in diffuse reflectance mode over the entire wavelength range of λ = 800–2500 nm.

2.5. Sensory Analysis

To achieve comparable conditions between the individual flower samples, the coffee flower tea was prepared according to DIN 10809 in infusion vessels and bowls [12]. After 5 min, the tea was poured into a bowl and could be tasted after a short cooling period. Tasting was conducted using cupping spoons. The flavor profile of each flower was evaluated using a test panel with intensities ranging from 0 to 4 (0 = very weak intensity; 4 = very strong intensity). The result of the tasting of each flower sample was documented as a summarized overall result by agreement between the test group. Two of the coffee flowers were excluded from the evaluation because they were not suitable for consumption due to off-flavors. The remaining samples were evaluated after final assessment by Excel statistical software (Xlstat, Addinsoft, Paris, France) and a principal component analysis was generated from the data obtained.

3. Results

3.1. HPLC/NMR Analysis

Compounds, such as caffeine, 5-chlorogenic acid, 3,4-Dicaffeoylquinic acid, 3,5-Dicaffeoylquinic acid were detected and quantified using HPLC and NMR (Table 1). Caffeine and chlorogenic acid were analyzed with both methods. The NMR analysis allowed the quantification of several water-soluble compounds such as organic acids and sugars.

Table 1. Determination of organic compounds in coffee flower samples (n = 35).

	Parameters	Average (mg/100 g)	Minimum (mg/100 g)	Maximum (mg/100 g)
HPLC	Caffeine	860	417	1171
	Chlorogenic acid	1334	129	2638
	3,4-Dicaffeoylquinic acid	104	11	252
	3,5-Dicaffeoylquinic acid	2684	186	5837

NMR (water-soluble compounds)	Caffeine	841	313	1267
	Chlorogenic acid	885	55	1896
	Trigonelline	1377	755	1965
	Malic acid	1475	187	2167
	Formic acid	109	9	196
	Succinic acid	69	22	150
	Quinic acid	1789	319	2250
	Acetic acid	72	20	102
	Fumaric acid	8	2	36
	Lactic acid	225	69	317
	Arabinose	346	56	481
	Mannose	203	84	325
	Glucose	3091	103	6976

The fat-soluble compounds were only qualitatively detected during NMR analysis. However, several fatty acids were identifiable. These include saturated, mono- and poly-unsaturated fatty acids.

3.2. NIR Analysis

The results of the NIR analysis are shown in Table 2. The analyzed compounds were water, ash and protein content. Also, the concentration of essential oils within four of the samples were measured.

Table 2. Determination of water, ash and protein in coffee flowers (n = 15).

	Parameters	**Average (g/100 g)**	**Minimum (g/100 g)**	**Maximum (g/100 g)**
NIR	Water	10.0	7.8	11.9
	Ash	7.5	6.7	9.4
	Protein	9.1	3.9	15.5
	Essential oils	0.2	n.d.	0.4

3.3. Sensory Analysis

With the acquired data from the sensory analysis, a principal component analysis (PCA) was performed in which hay, hops, sage, dried apricot and honey were identified as major flavor descriptors in addition to the floral coffee flower flavors. The results of this analysis are shown in Figure 2.

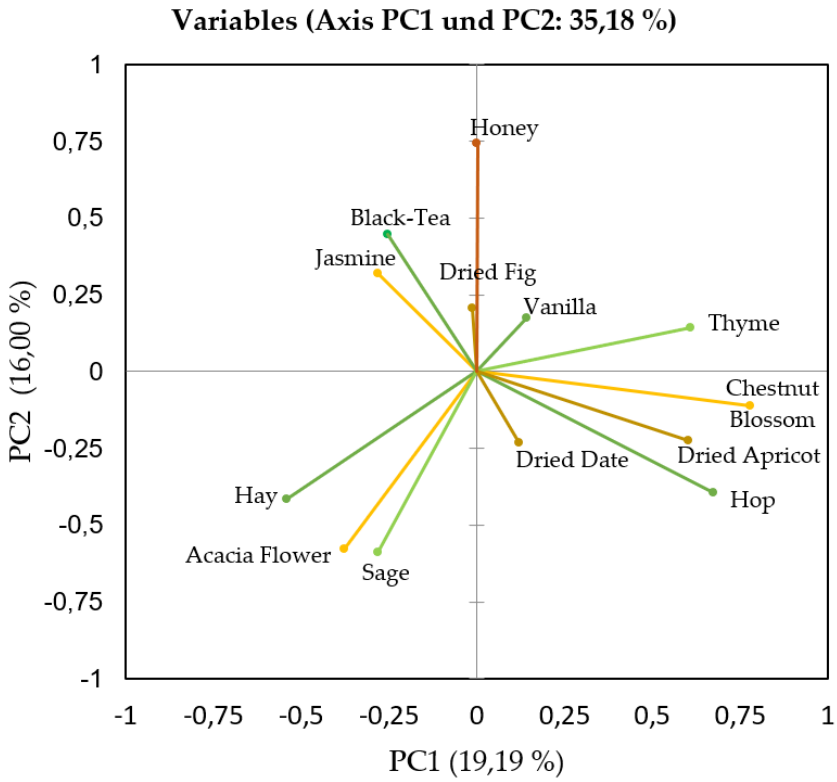


Figure 2. Principal component analysis of the sensory analysis results of 33 coffee flower samples.

4. Conclusions

This work quantified compounds such as caffeine, chlorogenic acids, organic acids, trigonelline and sugars within coffee flowers. Furthermore, several fatty acids could be identified. With the acquired data from the sensory analysis, a principal component analysis (PCA) was performed in which hay, hops, sage, dried apricot and honey were identified as major flavor descriptors in addition to the floral coffee flower flavors.

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Conflicts of Interest: S.S. is owner of Coffee Consulate, Mannheim, Germany. Coffee Consulate is an independent training and research center. Coffee Consulate is currently researching the potential of coffee by-products. However, S.S. reports no conflict of interest related to the work under consideration. The other authors declare no conflict of interest.

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