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Common roasting defects in coffee: Aroma composition, sensory characterization and consumer perception

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ABSTRACT

The demand for high quality and specialty coffee is increasing worldwide. In order to meet these demands, a more uniform and standardized quality assessment of coffee is essential. The aim of this study was to make a sensory scientific and chemical characterization of common roasting defects in coffee, and to investigate their potential relevance for consumers' acceptance of coffee. To this end, six time-temperature roasting profiles based on a single origin *Arabica* bean were developed: one 'normal', representing a reference coffee free of defects, and five common roast defects ('dark', 'light', 'scorched', 'baked' and 'underdeveloped'. The coffee samples obtained from these beans were evaluated by means of (1) aroma analysis by Gas Chromatography-Mass Spectrometry (GC–MS), (2) sensory descriptive analysis (DA) by trained assessors, and (3) hedonic and sensory evaluation by consumers using a Check-All-That-Apply (CATA) questionnaire. Multivariate analyses of aroma, DA, and CATA data produced similar sample spaces, showing a clear opposition of the light roast to the dark and scorched roasts), with the normal roast having average values of key aroma compounds. The DA data confirmed this indications and showed the normal roast to have a balanced sensory profile compared to the other defects. Importantly, the normal roast was also significantly preferred in the consumer test ($N = 83$), and significantly associated to positive CATA attributes 'Harmonic', 'Pleasant', and 'Balanced'. Taken overall, the results provide a solid basis for understanding chemical and sensory markers associated with common roasting defects, which coffee professionals may use internally in both quality control and product development applications.

1. Introduction

1.1. Quality grading in the coffee industry vs. sensory analysis

With more than 2 billion cups consumed around the globe on an everyday basis, coffee is the most important beverage commodity traded in world markets (Nair, 2010; Ponte, 2002). Coffee consumption rates have increased 1–2% per year worldwide during the last decades, and the demand for specialty and high quality coffee has experienced the sharpest increase over the last years (Bhumiratana, Adhikari, & Chambers, 2011). Coffee quality is determined by numerous factors, such as the origin, post harvesting process and roasting of the coffee beans, different grinding and brewing methods, and serving conditions (Agresti, Franca, Oliveira, & Augusti, 2008; Baggenstoss, Poisson, Kaegi, Perren, & Escher, 2008; Brown & Diller, 2008; Lee & O'Mahony, 2002; Steen, Waehrens, Petersen, Münchow, & Bredie, 2017). In the coffee industry, several quality grading methods are used to classify the coffee at different stages of the production leading to a large number of classification systems related to plant type, origin, process treatment, defect count or bean size (Ribeiro, Augusto, Salva, Thomaziello, & Ferreira, 2009). Such methods, however, do not necessarily relate much to the eventual sensory quality of the brews. Therefore, sensory evaluation is a crucial tool to determine the drinking quality of the coffee.

In the coffee industry, sensory quality grading of brewed coffee, usually referred to as 'cupping', is conducted by expert 'cuppers' (Di Donfrancesco, Gutierrez Guzman, & Chambers, 2014; Feria-Morales, 2002). Typically, the procedure consists of tasting three to ten cups of the same coffee, prepared according to brewing conditions standardized with regard to temperature, contact time, water to coffee ratio, water quality and brewing method (ISO, 2008; SCAA, 2009). The cupping

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score sheet includes important flavor attributes for coffee, ranging from 0 to 10. In the current version, these are Fragrance/Aroma, Flavor, Aftertaste, Acidity, Body, Balance, Uniformity, Clean Cup, Sweetness, Defects, and Overall. However, unlike assessors in sensory descriptive analysis, cuppers do not rate the intensity but rather give a subjective appraisal of the individual attributes. For example, a high grade in "Acidity" would indicate how well the sourness of the coffee fits within the context of that particular coffee, regardless of absolute intensity. This blend of hedonic and analytical assessment marks a very important difference with scientific sensory analysis.

Generally speaking, expert cupping is more anchored in the product grading tradition than it is in proper sensory analysis. Indeed, in spite of their widespread application, from a scientific point of view current cupping procedures can be criticized on several grounds. Firstly, while sensory science methods rely of a larger pool of assessors to ensure robustness in the results, the coffee branch mostly relies on few expert tasters with years of experience. Oftentimes, only one or two tasters are responsible for the quality grading of a large number of coffee samples, sometimes amounting to more than 200 cups per day. Furthermore, the tasting is often not blind, meaning that the expert cuppers will typically have information about the coffee variety, supplier, etc. (Feria-Morales, 2002). Finally, until recently[1] there was no consensus regarding the sensory vocabulary or the use of particular scales, which still vary quite substantially depending on the country of origin of the coffee, and even on the individual company performing the cupping (Feria-Morales, 2002). Accordingly, two previous studies (Feria-Morales, 2002; Di Donfrancesco et al., 2014) have reported a poor correlations between results from 'cupping' (sensory evaluation by coffee experts) and descriptive sensory analysis with trained panelists, leading the authors to the conclusions that these two approaches are not interchangeable.

Another notable difference from sensory evaluation is that the quality judgments in cupping combine an overall quality scale (presumably reflecting consumer dislikes) with diagnostic information about defects, whereas in mainstream sensory evaluation these two functions (descriptive and consumer) would be typically separated in two distinct tests with different respondents (Lawless & Heymann, 2010). Assuming that the opinion of a single (or a few) expert can effectively predict consumer preferences is extremely questionable: in fact, particularly for coffee, recent evidence indicates that quality evaluations performed by coffee experts do not necessarily correspond to consumer preferences (Giacalone, Fosgaard, Steen, & Münchow, 2016).

A final problematic aspect with cupping protocols is the use of holistic quality attributes that rely substantially more on the experts' product knowledge and expectations regarding what is desirable in a coffee (similar to typicality judgments for wine), rather than on clearly defined sensory properties.

1.2. Motivation for the present study

One quality attribute that has recently gained attention is the concept of 'clean cup' or 'cleanliness', which has been used in the scientific literature as a sensory attribute for coffee (Ribeiro, Ferreira, & Salva, 2011; Ribeiro, Augusto, Salva, & Ferreira, 2012), and which is now included in the most important cupping protocols (ISO, 2008; SCAA, 2009). The attribute is not related to sanitary aspects (despite what the name might suggest), but is instead used as a quality attribute related to the absence of flaws/defects, which is purportedly associated to consumer preferences.

Situated within this context, the aim of this study was to understand the compositional and sensory basis of common roasting defects in coffee, as well as their relation with consumers' perception and preferences. Although defects in coffee may arise from different sources (indeed, concepts like 'clean cup' are most often associated with quality control of green coffee by experts (Feria-Morales, 2002)), we chose to focus on defects related to the roasting process resulting in off-flavours in the coffee brew, as previous research has shown that coffee's distinct aroma profile is very closely related to the time-temperature profiles used during the roasting (Baggenstoss et al., 2008; Fisk, Kettle, Hofmeister, Virdie, & Kenny, 2012; Masi, Dinnella, Barnabà, Navarini, & Monteleone, 2013; Yang et al., 2016).

Specifically, the chosen strategy was to focus on six distinct roasting profiles, obtained by varying time and temperature in the roasting process (see Section 2.1). One of them was roasted to represent a standard roast free of defects, according to recommendations of the Specialty Coffee Association of Europe (Münchow, 2016). The remaining five represented instead roast defects commonly found in the marketplace.

Moreover, this study extends a previous investigation in which the aroma volatile composition of coffee brewed from these six roasting profiles was documented (Yang et al., 2016). The goal of this earlier work was to investigate the formation of aroma compounds in these different time–temperature profiles, in order to identify marker compounds associated with each defect. Due to the complexity of aroma interactions, it is however uncertain whether those chemical changes correspond to perceptually relevant differences in the coffee. Thus, in the present paper, we continue this line of work by presenting the following new data and analyses:

1. A perceptual characterization of the same coffee samples by sensory descriptive analysis, in order to document the sensory properties associated with each roasting profile, as well as to look at the differentiation between the Normal roast and the defects;
2. An exploration of the relationship between the instrumental and sensory data, in order to evaluate the degree to which the aroma composition is predictive of the perceptual quality of the coffee;
3. A consumer test focusing on consumer perception and liking of coffee brewed from the different roasting profiles, carried out to understand whether absence of defects bears any correspondence with actual consumer preferences for coffee.

2. Materials and methods

2.1. Roasting profiles

The coffee used in the study was a single-origin washed Kenyan *Arabica* from the wet mill Ndaroini, from crop year 2012/2013 and 2013/2014. The beans were roasted using a Probat drum roaster (Probat-Werke, Germany) modified to include additional temperature sensors to monitor bean temperature. Due to the limited batch size of the Probat roaster (1 kg), the coffee was roasted on two separate occasions: one batch for the sensory evaluation, and one batch for the consumer and aroma analysis. The coffee beans samples were individually packed in odor-free air-tight package, and kept in a cold storage at 5 °C.

Six different roasting profiles were obtained by varying start temperature and roasting time. Five of the roasting profiles were created to obtain common roasting defects, whereas the last served as a control ('Normal') roast. These roasting profiles were developed by a panel of six coffee experts from the Specialty Coffee Association of Europe (SCAE), headed by the last author, to be part of SCAE roasting certification system, which provides a systematic framework for evaluation of roasting defects (Münchow, 2016). They were designed by modulating the roasting process on three different dimensions: roasting degree, time before 'first crack' (when a popping sound is first heard during roast), and time after first crack, which represent the roasting phases were the beans undergo significant the most significant chemical and

[1] Shortly after this study was conducted, a standardized vocabulary for coffee evaluation had just been released based on a comprehensive work carried out at Kansas State Univesity (https://worldcoffeeresearch.org/work/sensory-lexicon/).