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COFFEE AS SUSTAINABLE COMMODITY: A STUDY TO BETTER UNDERSTAND THE FACTORS MARKING COFFEE QUALITY ALONG THE VALUE CHAIN.

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Abstract

This paper explores the correlation between quality, organoleptic properties, taste and certifications, discussing the main relations around the sustainability of this commodity. The data reported herein are part of an initial research on different Italian brands of coffee ground for moka. For the chemical composition assessment, the brewed coffees have been analyzed with respect to their caffeine and polyphenolic antioxidants content, evaluated by an HPLC/DAD method. The chemical analyses and the information stated on the label (e.g. ethical and environmental certifications) have been discussed, also taking into account any additional information on the labelling, as the indication of origin of the product. On the whole, social, economic, and environmental issues have been evaluated in order to define the quality of the product, taking into consideration all the phases of the value chain.

Keywords: sustainability, coffee value chain, certifications, labelling, quality

1. INTRODUCTION

Coffee, one of the most frequently consumed beverages in the world, is crucial in the global economy, second only to petroleum in importance in commodity trade. It is also enormously valuable to the economies of many developing countries. The coffee quality, in a context of overproduction worldwide, has to be pursued for an improvement of this crop. It is undoubted that the quality is a trait difficult to hold in a very simple definition. For coffee, the definition of quality can be differently expressed along the value chain.

In this initial research, seven brands of Italian coffees for moka, taken from the large-scale retail trade, have been considered, in order to have a first heterogeneous group of the best-selling coffees in Italy. These samples have been firstly analyzed with respect to their caffeine and polyphenolic antioxidants content, evaluated by a High Performance Liquid Chromatography (HPLC) with DAD (Diode Array Detector) method. Since the quality of the product depends on multiple factors along the supply and value chain, the chemical analyses and the information stated on the label (e.g. ethical and environmental certifications) have been discussed, also taking into account any additional information about the indication of origin and social, economic, environmental issues.

This paper explores the correlation between quality, chemical composition, organoleptic properties, taste and certifications, with the aim to outline the main relations around the sustainability of this commodity, and the associated characteristics (e.g. natural and accidental), influencing the retail price and consumers' preferences. Consumers are even more aware take into account quality factors, while they are choosing a coffee, and taste seems doesn't play no more the unique role in such choice. This research about commercial coffees is also in relation to a choice experiment, carried out before and after a coffee tasting of two selected samples among those selected in this study. The first results of the choice experiment have been reported in the paper "New trends in the coffee consumption assessment: organoleptic characteristics and chemical analysis evaluated through a choice experiment" by Pinelli P., Nikiforova N.D., and Berni R. (AISME 2018).

2. MATERIALS AND METHOD

2.1 Coffee brewing

Seven different types of coffee ground for moka (100% Arabica, and blending of Arabica and Robusta varieties) available at Italian large-scale retailers were brewed and, then, diluted 1:10 with water and, finally, analyzed by HPLC after centrifugation.

2.2 HPLC analysis

The HPLC/DAD analyses have been performed with an HP 1100L liquid chromatograph equipped with HP DAD (Agilent Technologies, Palo Alto, CA). In detail, the analytical column used was a Luna C18, 250×4.60 mm, 5µm (Phenomenex). The eluents were H_2O adjusted to pH 3.2 by HCOOH (solvent A) and CH_3CN (solvent B). The following multi-step linear gradient was applied: from 100% to 75% of A in 15 min, which was maintained for 5 min, 5 min to reach 60% A, which was maintained for 5 min, then 5 min to arrive at 0% A, which was maintained for 5 min and 3 min to arrive at 100% A. Total time of analysis was 43-min, flow rate 0.8 mL/min and oven temperature 27±0.5°C. UV-Vis spectra were recorded in the 190–600 nm range and the chromatograms were acquired at 264, 274 and 330 nm.

2.3 Qualitative and quantitative analysis

The identity of the phenolic compounds was ascertained using data from the HPLC/DAD analyses by comparing their retention times and UV/Vis spectra with those of authentic standards Each compound was quantified by HPLC/DAD using a five-point regression curve ($r^2 \geq 0.9998$) built with the available standard (chlorogenic acid and caffeine). More specifically, all the caffeic acid derivatives (monocaffeoyl quinic esters, MCC; dicaffeoylquinic esters, DCC) were calculated at 330 nm using chlorogenic acid (or 5-*O*-caffeoylquinic acid) as a reference; caffeine was calibrated at 274 nm using the authentic standard. The concentrations of these chemical components was carried out in triplicate. Figure 2 shows the results, recorded as mean values of three samplings.

3. RESULTS AND DISCUSSION

Most widely cultivated species are *Coffea arabica* - Arabica, accounting for approximately 75% of global production and *Coffea canephora* - Robusta, accounting for approximately 24% of global production. Despite its poorer sensory quality, Robusta has the advantage of allowing extraction of large amounts of soluble solids, which enables its use in blends and in soluble coffee industry. The main biochemical compounds related to coffee quality are caffeine, sugars, chlorogenic acids and lipids. Polyphenols such as chlorogenic acids (CGAs), phenolic acids and methyxanthines (with caffeine the main component), are known natural constituents of coffee (Alonso-Salces et al., 2009) and, besides sugars and lipids, are related to quality traits, both in the raw material (green coffee) and in the final beverage (brewed coffee). CGAs are the main polyphenols in green coffee, being esters formed between one or more residues of several trans-cinnamic acids (caffeic acid, ferulic acid, *p*-coumaric acid) and quinic acid. CGAs representing 6–12% of coffee constituents in mass (De Maria et al., 1995) are known to be responsible for coffee pigmentation, aroma formation, and astringency.

At the farmer level, the quality of coffee is a combination of multiple inputs, influencing production yield, easiness of culture and costs. Moreover, climate, altitude, and shade play together an important role through temperature, availability of light and water during the ripening period and generally chlorogenic acids and fat content have been found to increase with elevation in the Arabica variety. Altitude is undoubtedly the most important environmental factor. Thus, the cultivation of Arabica at high altitude provides the best quality (i.e. increase of chlorogenic acids and fat contents), also thanks to the reduction of daily temperatures (being the optimal range between 18 and 21°C). Lower temperatures slow down the maturation, ensure a longer time to the coffee bean to harden, becoming more dense (Tolessa et al., 2016) and favored the accumulation of a higher content of aromatic precursors (Vaast et al., 2006).

Concerning the variation of quality in function of harvest and postharvest procedures, it is well known that the traditional hand-picking has to be preferred to mechanical harvest, due to the reduction of defects on the collected beans. During the postharvest, the dry processing is generally avoided for premium samples as it enhances a bitter taste in the final beverage. Generally, the coffee post-harvest process concerns different steps:

1. submersion and washing in water to eliminate the floating drupes
2. depulping and fermentation
3. washing in clean water and removal of floating grains
4. dehydration in drier until reaching 11% of beans humidity.

For the import/export demand, coffee quality is related to bean size, lack of defects, physical characteristics and price. Bean size, defined as grade from a commercial point of view, is an important factor, since small beans of the same variety can bring lower prices. During the roasting process, coffee quality depends on moisture content, origin, biochemical compounds and organoleptic evaluation. The roasting process should preferentially be carried out with beans of the same size, to avoid the burning of the smallest and the under-roasting of the largest ones. When the roasting is improperly performed, both the visual appearance and the cup quality are affected (Leroy et al., 2006). Moreover, it should be pointed out that each country market may define different sensory qualities.

At the consumer level, coffee quality deals with price, taste and flavor, as well as healthy properties, geographical origin, environmental and social aspects (e.g. organic coffee, fair trade). Actually, the "health quality" is a characteristic more and more taken into account by consumers and it mainly depends on the chemical components, as phenolic antioxidants and caffeine. In fact, it should be noted that coffee is a complex beverage containing more than 1,000 compounds. Among the many with known biological activity, there are caffeine, a potent stimulant and bronchodilator, and chlorogenic acid, one of the more important antioxidants and anti-inflammatory compounds found in coffee. In the last two decades, coffee consumption has been associated with reductions in the risk of several chronic diseases, including type 2 diabetes mellitus, Parkinson's disease and liver disease, such as cirrhosis and hepatocellular carcinoma (Higdon et al., 2006; Cano-Marquina et al., 2013). Large epidemiological studies suggest that regular coffee drinkers have reduced risks of mortality, both CV and all-cause. A daily intake of 2 to 3 cups of coffee appears to be safe and is associated with neutral to beneficial effects for most of the studied health outcomes. Moreover, recent studies report that coffee consumption may reduce the risk of type 2 diabetes and hypertension, as other conditions associated with cardiovascular risk, such as obesity (O'Keefe et al., 2013).

Concerning the ethical aspects, "fair trade" and "organic" are credence attributes (Poelman et al, 2008) that constitute an important dimension that adds value to the product and contributes in the definition of its price. Consumers associate the organic food to naturally produced and environmental sustainable foodstuff, while fair trade label focuses mainly to the well-being of workers and farmers in the developing countries. Many European consumers value environmental performance, however, and consequently, a substantial part of fair trade labelled coffee is also produced and certified according to organic standard (Oosterveer et al., 2012). In a study about the consumers' preferences, the role of "organic" and "fair trade" labels in the choice of a product was investigated, considering the interaction existing between these certifications and the taste of the product (Tagbata and Sirieix, 2008). From this study, more profiles of consumers, which differently react to "organic" and "fair trade" were defined. In nearly half of the analyzed consumers, the reaction to such certifications was not of utmost importance, being in higher consideration other criteria, as price, taste and health issues. Conversely, in the other half of the group, the presence of such indication on the product, contributed to 20-30% of the product price, meaning that these consumers were willing to pay (WTP) 20-30% more than for conventional coffees. Interestingly, the WTP in conjunction with the tasting was lower than the WTP indicated on the sole basis of the labels. This revealed a gap between the expected quality and the "tested quality" emerged by an evaluation such as tasting.

Each coffee ground for moka taken by the GDO (seven different brand of coffee) was brewed and, then, analyzed by HPLC/DAD method for the assessment of caffeine and polyphenolic antioxidant content. Figure 1 shows the chromatographic profile registered at 330 nm of the identified compounds of a coffee (sample 5). The quantitative analysis of each coffee sample was performed in triplicate and the results are reported in Figure 2. The main compound present in brewed coffee are caffeine (Peak 4) and chlorogenic acid (Peak 5). The caffeine content seems very low in Figure 1 but only because the maximum wavelength of absorption is not at 330 nm (the maximum wavelength of absorption of chlorogenic and the other caffeoylquinic acids) but at 274 nm.

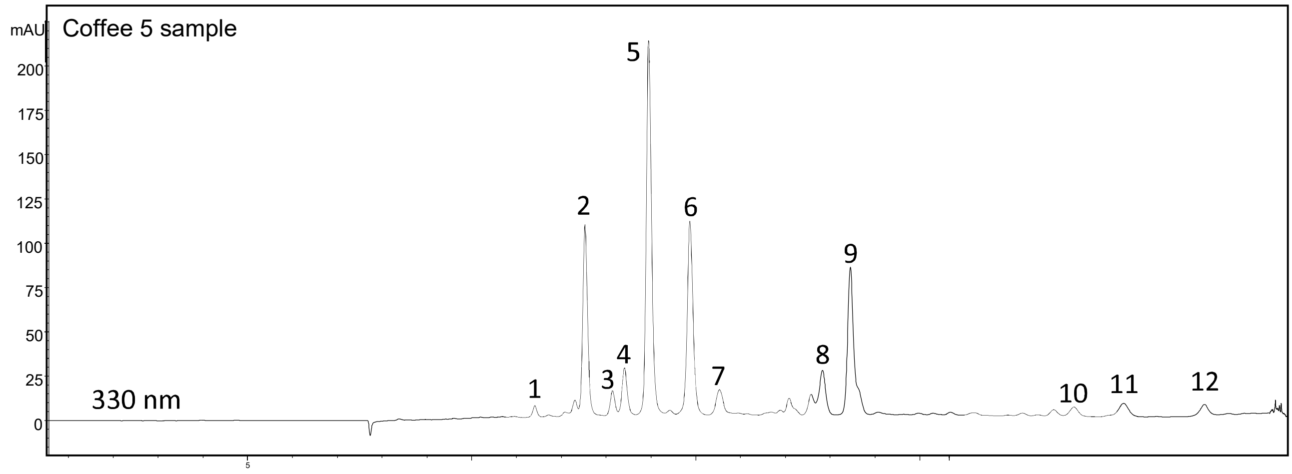


Figure 1. HPLC/DAD profile registered at 330 nm of a coffee brewed for moka. Compounds: (1-3 and 6) mono-caffeoyl-quinic acids; (4) caffeine; (5) chlorogenic acid, (7-12) di-caffeoyl-quinic acids.

The histogram of Figure 2 reports the HPLC/DAD quantitative results for coffee samples listed for the decreasing content of antioxidants (as a sum chlorogenic acid and the other caffeoylquinic derivatives). The quantitative data are related to a volume of a cup of coffee for moka (40 mL).

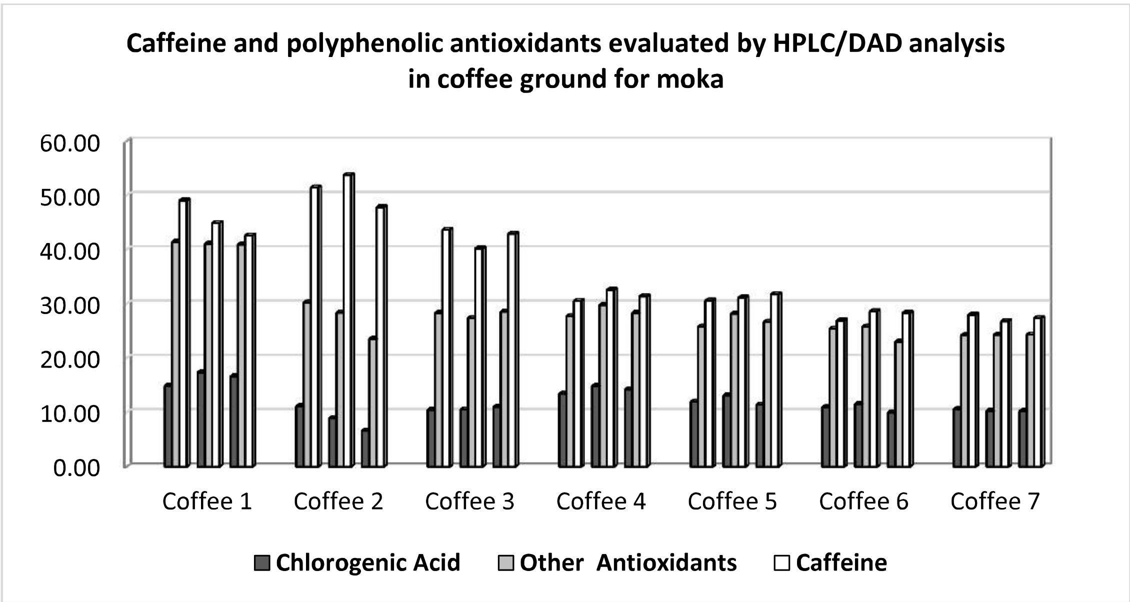


Figure 2. HPLC/DAD analysis of caffeine, chlorogenic acid and other caffeoyl-quinic antioxidants in coffee ground for moka. Data are expressed as mg in 40 mL (the cup volume).

It is wort of noting that the concentrations of caffeine are really variables, depending of the coffee sample; whereas the chlorogenic acid and the other antioxidants seem to vary at lower extend, among the investigated coffees. Moreover, from this first group of samples it seems that the selected coffees can be distinguished into two groups. In particular, adding the chlorogenic acid content and the other polyphenolic antioxidants, there are coffees, whose caffeine content is equal to that of polyphenolic antioxidants (samples 2 and 3) and a group of coffees where the caffeine content is about two thirds or less with respect the total polyphenolic antioxidants. It must be underlined that the first three coffees (samples 1, 2 and 3) have the highest caffeine content.

On the whole, the characteristics of the selected coffees are indicated in Table 1, specifically, type of coffee (100% Arabica or a blending Arabica and Robusta), label indications (indication of origin, presence of certifications, as organic, fair trade and so on), price, type of packaging and sensorial description eventually indicated on the labelling/packaging.

Table 1. List of the investigated coffee samples for moka with the main descriptor, concerning type of coffee, indication of origin, presence of certifications, price and sensorial description.

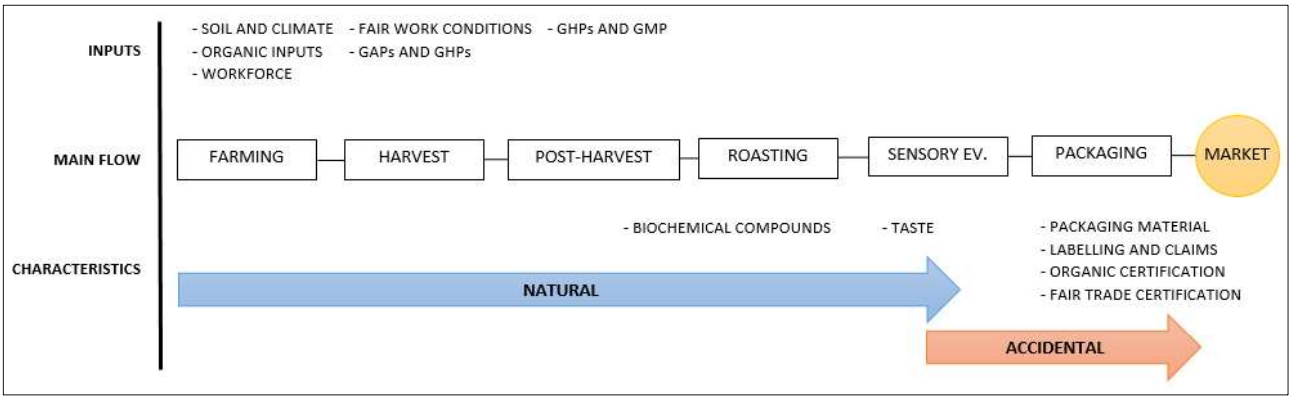
Sample #	Type of coffee/ Indication of Origin	Certification	Price* €/Kg	Type of packaging	Sensorial specifications on the labelling
1	Blending Arabica and Robusta / Yes	None	10.20	Vacuum bag	Soft and velvety blending. Organoleptic profile: aroma (3), body (3), sweetness (5), intensity (3), roundness (5).
2	Blending Arabica and Robusta / None	None	10.20	Vacuum bag	None
3	Blending Arabica and Robusta / None	UNI EN ISO 14001:2004	15.72	Vacuum bag	Rich and persistent taste: aromaticity (5), body (5), sweetness (3), intensity (5), roundness (3).
4	100% Arabica / Yes	Products made without discrimination and exploitation of labor (private standard)	14.44	Jar in modified atmosphere	Balanced blending, intense aroma, roundness and persistent aftertaste.
5	100% Arabica / None	Responsible Supply Chain Process (RSCP)	26.20	Jar in modified atmosphere	Soft taste with delicate notes of caramel and toasted bread.
6	100% Arabica / Yes	UNI EN ISO 14001:2004	15.80	Jar in modified atmosphere	Soft taste, sweetness, and roundness: aroma (4), body (4), sweetness (5), intensity (3), roundness (4).
7	100% Arabica / Yes	Fair Trade + Organic	15.64	Vacuum bag	Soft taste and intense aroma.

** Refers to prices in large-scale retail trade in 2016.*

Source: Authors'

As shown in Table 1, coffee samples from 4 to 7 are a 100% Arabica blending and it is in accordance with the lower content of caffeine with respect the first three samples. Moreover, this coffee type is normally associate to higher prices. In particular, for the sample 5, the feature 100% Arabica, the type of packaging and the presence of RSCP, are the characteristics associated to the higher price. The aim of a sustainable supply chain management is a strong interest to environmental and social issues that encompasses the main objectives typical of fair trade and organic certifications. It should be noted that the demand for organic coffee in Western Europe exceeds the present supply, which is still small, accounted for about 2 percent of the total coffee market in Western Europe in 2008 (Bakker and Bunte, 2009). Nevertheless, from an agronomic point of view, there is a considerable criticism about the principles of organic farming when applied to coffee. For instance, to sustain economically viable yield levels (1 t green coffee ha^{-1} year^{-1}) large additional amounts of composted organic matter will have to come from external sources to meet nutrient requirements (especially N and K) and most smallholders are unable to acquire such quantities and have to face declining yields. In an important review exploring this and other aspects peculiar to the preconditions of organic coffee production (Van Der Vossen, 2005), arises the concept of “organic” not fully sustainable. On the other hand, sustainable coffee production is feasible by applying best practices of crop production and post-harvest processing. In the context of a significant increase of climate change, the improvement of coffee quality have to be realized in accordance with sustainability and implementation of guidelines to provide producers to introduce more and better agricultural practices. Moreover, the market segmentation, as a result of an increasing demand for high-quality coffee (specialty coffee), has created a potential for growth and new opportunities for producing countries but the certifications should help and not marginalize the small farmers that risk to remain in poverty despite being connected to fair trade organic markets. Figure 3 shows, for the main steps along the supply chain, the associated inputs and the resulting characteristics. In particular natural characteristics include the presence of biochemical compounds and the taste (and aroma as well) profile, while accidental characteristics include packaging material, label information and claims and certifications (organic or ethical).

Figure 3. Main flow of coffee and associated inputs and main characteristics.



Source: Authors’

In conclusion, the present study, in association to the results of a choice experiment (Pinelli et al., 2018) could be useful for better understand the multiple aspects that mark the quality of coffee along the supply and the value chain.

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