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REVIEW ARTICLE

Quality assessment of Arabica and Robusta green and roasted coffees – A review

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Abstract

This review is a synopsis on coffee quality assessment of green and roasted coffee beans of *Coffea arabica* and *Coffea canephora.* The particle size, medium sieve, most frequent sieve, share split, cumulative calibration, trade homogeneity, mass of 1000 beans, apparent density, strange bodies and defects, mass losses on drying, olfactory and visual parameters, chromatic parameters, soluble solids, pH and chemical characterization (chlorogenic acids, caffeine and trigonelline) is described and evaluated, considering the most important factor associated to the coffee trade, according to a technological perspective.

Keywords: Arabica coffee, Green coffee, Quality, Roasted coffee, Robusta coffee

Abbreviation list: 3-CQA – 3-O-caffeoylquinic acid; 3-FQA – 3-O-feruloylquinic acid; 3,4-diCQA – 3,4-O-dicaffeoylquinic acid; 3,5-diCQA – 3,5-O-dicaffeoylquinic acid; 4-CQA – 4-O-caffeoylquinic acid; 4,5-diCQA – 4,5-O-dicaffeoylquinic acid; 5-CQA – 5-O-caffeoylquinic acid; 5-FQA – 5-O-feruloylquinic acid; C* – Chroma; CGA – Chlorogenic acid; CQA – Caffeoylquinic acid; CQAtotal – Total caffeoylquinic acids; diCQA – Dicaffeoylquinic acid; diCQAtotal – Total dicaffeoylquinic acids; FQA – Feruloylquinic acid; FQAtotal – Total feruloylquinic acids; Hº – Hue angle; L* – Lightness

Introduction

Coffee is currently grown in about 80 countries of four continents. Brazil is the world's largest producer, followed by Vietnam and Colombia. Many African countries, including Uganda, Burundi, Rwanda and Ethiopia have coffee as their main source of foreign exchange. In addition, the vast majority of coffee plantations worldwide belongs to smallholders, which makes the activity highly important in maintaining rural lifestyles, providing an important source of income and wealth distribution, by promoting employment and local development in the producing and processing regions (DaMatta and Ramalho, 2006; Partelli et al., 2010).

Coffea arabica grows in 85% of coffee producing countries, predominantly in the American Continent, accounting for approximately 69-74% of the world coffee production. *Coffea canephora* is predominantly grown in Asia and Africa (this last continent with about 80% of total plantation), being responsible for producing circa 25-30% of coffee worldwide (Ramalho, 2002).

The world green coffee production has been growing since the sixties, with total production varying between 4.2 and 7-8 million tonnes, between 1960 and the last decade (ICO, 2009). Moreover, world consumption of green coffee, though rising since the nineties, stabilized close to 7 million tonnes per year, being only 25% consumed in producing countries.

Coffee beans quality depends on moisture content, defects, bean size, some chemical compounds and preparation of a sample to perform cup tasting (Leroy et al., 2006). Physical analysis to characterize technological quality of green coffee is also used due to its promptness and easiness, as well as to its lower costs. In this context, colour has been used for quality assessment of green coffee beans (Nelson, 2005; Bicho et al., 2005, 2008) and there have also been studies using image processing for grain quality inspection (Soedibyo et al., 2010). To perform physical quality analysis standard

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methods are being used to characterize technological quality of green coffee, namely particle size, medium sieve, most frequent sieve, share split, cumulative calibration, trade homogeneity, mass of 1000 coffee beans, apparent densities, strange bodies and defects, mass losses on drying and olfactory and visual parameters. Quality assessment of coffee genotypes at a chemical level can also be used, namely for identification of chemical clusters discriminators of the roast degree in Arabica and Robusta coffee beans, identification of nutritional descriptors of roasting intensity in beverages of Arabica and Robusta coffee beans, identification of chemical clusters discriminators of Arabica and Robusta green coffee and impact of roasting time on the sensory profile of Arabica and Robusta coffee (Bicho et al., 2010, 2011a,b, 2012, 2013a,b). In this work a synopsis of the most useful parameters to assess coffee quality is presented following a technological perspective.

Physical parameters

In Arabica and Robusta coffee beans the particle size that prevails, according to the fractional calibration, is the sieve number 17 and 19, respectively (Bicho, 2005; Esteves and Oliveira, 1970), with the medium sieve remaining between 17.4 and 19.2. The trade homogeneity usually is lower in Arabica coffee (94.3), relatively to Robusta coffee (97.0). The cumulative percentage of green coffee Arabica and Robusta accumulated until the sieve 17 might reach about 100%. This commercial characteristic resulting of undergoing calibration stages during the benefit prior to marketing determines the required homogeneity of the coffee beans for roasting, to avoid burning of smaller grains (Cortez, 2001). Moreover, depending of the roasting degree, the volume of coffee beans might vary between 40- 69% in Arabica, and 48-57% in Robusta (Bicho et al., 2012).

The mass of coffee beans of green Robusta coffee is typically higher relatively to Arabica (Coste, 1992; Fazuoli, 1986), with unitary values of about 0.21 g and 0.15 g, respectively. Moreover, apparent densities of Arabica and Robusta green coffee do not vary significantly, showing values around 0.6-0.7 g cm^{-3} (Bicho, 2005; Coste, 1992; Esteves and Oliveira, 1970). Moreover, apparent density of coffee beans can decrease to 0.4-0.3 g cm^{-3}, with increase of roasting time (Bicho, 2005; Bicho et al., 2012).

The moisture content of green coffee beans usually ranges from 9.1% to 9.3%, for Arabica and Robusta respectively, being therefore within the established range of the international market, below 12.5%, according to the technical regulation of identity and quality for classification of the benefited raw green coffee bean (Instrução Normativa Nº 8, 2003). Mass losses of coffee beans might increase 10.5-19.4% in Arabica, and 10.1-16.7% in Robusta, with increase of roasting time (Bicho et al., 2012).

The colour of Arabica and Robusta green coffee beans has a uniform yellowish. Moreover, one factor that positively contributes to further improve the appearance uniformity and colour of the beans is related to the minimization of the silverskin adherence to the bean by polishing during the benefit. Otherwise silverskin may confer to the seed a strong green tone, when carotenoids and chlorophylls are present in it or red if only carotenoids prevail (Cardoso, 1994; Clifford, 1987; Coste, 1992). In this context, the residual silverskin of the surveyed samples might have a reddish-brown colour, being almost absent in the furrow of the green coffee beans, which is an indicator of a dry processing.

The determination of the colour of green coffee bean, made with the illuminants D_{65} and C allow the collection of coordinates systems chromatic CIE L*a*b* and CIE L*C*Hº. In this context the parameters a* and b* (contribution of the green/red and blue/yellow, respectively) typically present positive values, pointing a greater contribution of the red and yellow components. The combined value of these two chromatic parameters justifies the yellowish colour visually detected for both coffee beans. Although the lightness (L*) might not be significantly different, the opposite can occur with chroma (C*) and hue angle (Hº). Jointly these three coordinates contribute to the colour of the green coffee beans. In fact, Arabica green coffee might have a greenish yellow, while Robusta green coffee can have a brownish yellow colour (most probably with the coordinates a* and b* being significantly higher). Accordingly, the red and yellow colours prevail in this coffee. Moreover, the wet processed coffee can reveal negative a* values, pointing to a major green contribution. Therefore, the greenish colour develops in this type of processing, in contrast to the yellowish colour of dry processed beans (that has a positive value for the chromatic coordinate a*). Accordingly, the coffee industry can use this difference in colour (green or yellow) as a quick way to identify the type of post-harvest processing of green coffee beans (Bicho, 2005). Nevertheless, it also must be pointed that the age of the grain can also be affected by the value of a* (Mendes et al., 2001).

Indeed, L*, a* and b* values of arabica samples can be similar to those obtained by Nelson (2005) for an aged arabica coffee from Jamaica.

In grinded green coffee, the coordinates CIE L*a*b* and CIE L*C*Hº, using illuminant D_{65}, usually indicates that coordinates a*, b*, C* and Hº did not significantly differ between the two coffee types, unlike the parameter L*, but when illuminant C is used, only b* and C* did not differ significantly (Bicho 2005). These data point to the existence of a significant correlation between coordinates a* and Hº, and coordinates b* and C*. The Hº value of grinded green coffee can be more influenced by the contribution of a* (that presents a higher variation) than of coordinate b*, thus suggesting that a* would determine the colour of green coffee. For C* calculation the b* coordinate assumes a higher importance than a* due to its higher value. Thus, the absence of b* variation might justify the absence of significant differences among C* values.

The analysis of the chromatic parameters, using the illuminants D_{65} and C, might show that lightness (L*) as well as parameters a*, b*, C* and H° are not significantly different between genotypes when comparing the same roasting degree. Moreover, within each type of roasted coffee beans, the pattern of lightness (L*) can reveal an antagonist interaction with increased roasting intensity. The parameter a* can increase significantly in roasting of Arabica and Robusta coffee due to the yellowish intensification in the initial phase of the burning process, but a decrease can be found thereafter. The coordinate b* also show an antagonist pattern with increased roasting intensity, due to an increasing browning of the beans. Accordingly, parameters C* and H° can decrease significantly along the roasting process showing an increased reduction from green coffee to a sharp roasting intensity (Bicho et al., 2012).

After milling, significant differences can be found between green Arabica and Robusta coffees in several colour parameters when D_{65} and C are used (Bicho et al., 2012). The parameter L* might decrease significantly with roasting, whereas a* (green/red contribution) can increase sharply in Arabica and Robusta in a lower roasting degree with the opposite developing thereafter with higher roasting (contributing therefore to the red colour of the roasted coffee powder), similarly to what can happen before milling the beans. Yet, after milling a* values in higher roasting degrees can be still much higher than in green coffee, contrary to what might happen for the whole bean. On the same way, parameter b* (yellow/blue contribution) can increase with a lower roasting intensity, contrary to what can be observed with whole beans, and might decrease significantly thereafter with higher roasting intensity. The parameter C* varies similarly to the chromatic coordinates a* and b* with a substantial increase with low roasting intensities and subsequent decreases thereafter for higher roasting intensities, although maintaining higher values than those of the whole bean. The parameter H° can further decrease sharply with increasing roasting intensity, following a similar pattern found in the whole bean. The brightness and tone of the coffee powder samples typically show similar variations, exhibiting antagonist patterns with increasing roast intensity (Bicho et al., 2012).

Chemical parameters

In Arabica and Robusta green coffees the contents of soluble solids corresponds to about 33-34% (Esteves and Oliveira, 1970; Mendonça et al., 2005). After roasting, depending of its intensity, soluble solids of coffee beans typically decreases to 30-26% in Arabica and to 31-27% in Robusta (Bicho et al., 2011a). The pH of Arabica and Robusta green coffee corresponds to 5.6 and 5.7, respectively (Leroy et al., 2006), whereas depending of roasting intensity, these values can vary between 5.45- 5.12 and 5.49-5.32 (Bicho et al., 2011a).

Caffeine contents, for Arabica and Robusta green coffees, can reach about 1.45% and 2.38%, respectively (Silvarolla et al., 2000; Viani, 1993), while with increasing roasting time, caffeine contents decreases to ca. 1.376-1.299% and to 2.163-2.327% (Bicho et al., 2011a).

The values found for trigonelline contents remains in ca. 1.39% and 1.01%, for Arabica and Robusta green coffees respectively (Ky et al., 2001). With increasing roasting time, trigonelline contents might decrease to 1.293-0.553% in Arabica and to 0.902-0.571% in Robusta (Bicho et al., 2011a).

CQA, diCQA, and FQA represent about 98% of total chlorogenic acids in coffee (Clifford and Staniforth, 1977). The 5-CQA is the most representative both in Arabica and Robusta green coffees representing ca. 77% of total CQA (Fortunato et al., 2010). Also, the levels of all caffeoylquinic acid isomers (3-CQA, 4-CQA and 5-CQA), as well as CQA_{total}, typically are significantly higher in the Robusta green coffee (Clifford, 1985; Correia, 1990; Ky et al., 2001; Viani, 1993). The content of each isomer of diCQA is usually significantly higher in the Robusta green coffee. Quite similar amounts of 3,4-diCQA, 3,5-diCQA and 4,5-diCQA might be found in Robusta green coffee, while the isomer 3,5-diCQA predominates in green Arabica coffee (Clifford, 1985, 1997; Ky et al., 2001). The 5-FQA isomer predominates (ca. 90% of total FQA), being the contents of the others (3-FQA and 4-FQA) much less relevant (Clifford, 1985; Correia, 1990; Ky et al., 2001; Viani, 1993). Robusta green coffee usually has higher levels of 3-FQA and 5-FQA, as well as a significantly higher total amount of FQA. The total content of each group of chlorogenic acids (CQA_{total}, $diCQA_{total}$, and FQA_{total}), as well as CGA_{total}, tends to be higher in Robusta green coffees, prevailing 5-CQA in green coffee. In fact, 5-CQA represented more than half (65 and 55%) of total CGAs in Arabica and Robusta coffees. That led to the higher weight of CQAs, representing 84% and 72% of total CGAs in Arabica and Robusta green coffees, respectively. diCQA acids prevails as the second most abundant group in the $diCQA_{total}$, corresponding to ca. 12% and 20% of total CGAs, while the FQAs represented ca. 4% and 8% of the CGA_{total} value in Arabica and Robusta green coffees, respectively. The content of total CGA in Robusta green coffee remains ca. 25% higher than in the Arabica green coffee (Bicho et al., 2013a).

Roasting promotes severe decreases in CGA contents. In this context, following the increase in roasting intensity, 3-CQA, 4-CQA, and 5-CQA decreases gradually to 17-20% in Arabica and to 27-37% in Robusta beans, thereby determining the sharp decrease in CQA_{total}. 5-CQA contents are similar for Arabica, but lower for Robusta than those obtained by others (Alves et al., 2006). Concerning 3,4-diCQA, 3,5-diCQA, and 4,5-diCQA, a even higher susceptibility to degradation can be observed. In fact, if a high roasting intensity is applied, the values can reach 5-8% in Arabica and 10-14% in Robusta, and also remains significantly higher in Robusta beans. Although less affected than CQAs and diCQAs, the FQA values usually are significantly reduced under higher roasting conditions, with 5-FQA being more reduced than 3-FQA, while 4-FQA can be considered irrelevant (Clifford, 1985; Ky et al., 2001; Viani, 1986, 1993). As for the CQAs and diCQAs, the FQA_{total} of Robusta is less affected and a significantly higher value persists when compared with Arabica beans. Among CGA compounds, the diCQAs are the most sensitive, being severely degraded with more intense roasting, while FQAs, although strongly affected, suffers a lower reduction, thus increasing its relative weight. Furthermore, in the overall CGAs of roasted coffees, the CQA fraction maintained the highest relative weight, prevailing 5-CQA (Bicho et al., 2011a).

Conclusions

The chromatic parameters, which allow a fast, reliable, low cost and non-destructive analysis that integrates the result of several processes, from plant production until storage, can partially differentiate the technological quality of Arabica and Robusta green coffee. Yet, as coordinate a* strongly affects Hº value of the green coffee in the colour analysis, the illuminant type used in the measurement must be defined and/or combined. In fact, the variation of spectral composition of incident light can lead to a different colour perception. Accordingly, through the application of colour parameters the technological quality of green coffee can be assessed. In roasted coffee beans, the parameters L*, C*, H°, and coordinate b* displays an antagonist interaction due to an increase in the roasting intensity, whereas after milling, only L* and H° might decrease progressively. Considering that the parameters L* and H° followed similar patterns using both illuminants, D65 and C, it can be concluded that they are appropriate to evaluate coffee colour changes during roasting, enabling a relationship with coffee quality.

In general, Robusta green coffee shows higher values for pH, soluble solids, caffeine, total caffeoylquinic acids, total dicaffeoylquinic acids, and total feruloylquinic acids, but the content of soluble solids might not be significantly different in both species of green coffee. The content of caffeine does not vary significantly, but trigonelline decrease with burning up intensity. The levels of chlorogenic acids also decrease with increasing roasting time. The 5-O-caffeoylquinic acid prevailed in Arabica and Robusta beverages, but the isomers of dicaffeoylquinic and feruloylquinic acids remains higher in Robusta.

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