The influence of transport on the chemical and organoleptic qualities of coffee: a comparison between the Bourbon, Pacamara and Maracaturra varieties .

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Abstract

This study, a collaboration between ANACAFE, CDR, and the Accademia del Caffè Espresso, investigates the impact of post-harvest processes on the chemical and sensory stability of coffee. By analyzing three varieties—Bourbon, Pacamara , and Maracaturra —subjected to different processing methods (natural, washed, and mechanical demucillation), the research monitors the evolution of the bean from its origin in Guatemala to its arrival in Italy. Using the CDR CoffeeLab® system, it was possible to quantify variations in sugars, organic acids, and caffeine, comparing the analytical data with the scores obtained in the Cupping Tasting Panels (SCA). The article demonstrates how green coffee undergoes significant alterations in its chemical structure even under optimal transport conditions and short processing times. The results highlight the crucial role of the sugar-acidity ratio as a predictive indicator of final quality and underscore the need for constant analytical monitoring throughout the supply chain to ensure the consistency of the organoleptic profile intended for the consumer.

Introduction

Coffee production is a long and complex process that begins with the harvesting of the fruit, continues with processing, and ends with roasting, not to mention transportation and distribution. Managing these two phases is equally important to ensure the high quality of the final product that reaches the consumer. Coffee is produced in more than 75 countries along the equator: South America (Brazil, Colombia), Central America (Guatemala, Costa Rica), Africa (Ethiopia, Kenya, Tanzania), and Southeast Asia (Vietnam, Indonesia). Coffee's long journey begins in the plantations, where farmers sometimes travel to altitudes of over 2,500 meters for the best cherries. Once the bags are filled, the farmers descend to the processing plants, where the coffee is processed and shipped. Coffee beans are transported before the roasting process, as green coffee. Their tendency to absorb moisture requires storage in bags, usually made of natural fibers (jute), that allow for air circulation; sealed bags could promote condensation, resulting in product damage. Transportation covers long distances and is usually done by sea, arriving at storage facilities where it can be stored for extended periods before being roasted and consumed. During this period, coffee undergoes numerous changes that can affect its quality.

Environmental conditions, such as temperature, humidity, and exposure, are critical factors that influence chemical and physical composition of the beans. Green coffee is a living product that continues vary chemically even after harvesting. The moisture content of the beans, the internal temperature of the bags, and the temperature fluctuations that green coffee experiences during transportation and storage can accelerate or slow these processes, resulting in the development of unwanted fermentations or a loss of freshness.

This problem is well known to those working in the sector, but it has never been investigated in depth from a scientific and chemical point of view.

This study aims to analyze the chemical characteristics of three coffee varieties, comparing them before and after a short period of storage. To avoid any alterations attributable to transport conditions, the samples were vacuum-packed and shipped quickly by air. A deeper understanding of the chemical dynamics that occur during the storage phase of green coffee could contribute to the development of more effective solutions, ensuring a higher quality of the final product. This would have important implications for the entire supply chain, with significant economic, qualitative, and environmental implications.

The **National Coffee Association (ANACAFE)** together with **CDR srl** and the **Accademia del Caffè Espresso** chemically and sensorially analyzed a production of *Bourbon*, *Pacamara* and *Maracaturra coffees*, treated with different methods, in order to investigate the characteristics of these two varieties in more depth.

The study

Three varieties were selected for this study: *Bourbon*, *Pacamara* and *Maracaturra*.

Each one was treated according to a standard protocol defined by ANACAFE with 3 different methods (mechanically cleaned, washed , and natural) and subsequently dried to reach a humidity between 9 and 12%.

All analyses were performed using **CDR CoffeeLab®** a tool for analyzing the chemical profile of coffee at various stages of the production process. The analyzer allows for the determination of total acidity, various organic acids, sugars, caffeine, and chlorogenic acids. Finally, the coffee was selected and tasted at the Anacafe catación laboratory.

The same batch was sent to the Espresso Coffee Academy in Italy: approximately 1 kg of each type of coffee was sent in sealed plastic bags. The coffee was roasted again and tasted according to the **SCA tasting protocol** and analyzed again using CDR CoffeeLab®.
It is worth considering that the coffee sent to Italy for this study underwent less stress than coffee commonly shipped by ship.

Green coffee

The first phase of the study involved the selection of three different coffee varieties, which were then fermented using three different methods and analyzed.
The first method is the *natural,* or dry, method, which is one of the oldest and most traditional. The drupes are spread out in the sun on raised beds known as "African beds" with their skin, pulp, parchment , and seeds intact. The cherries start with an initial humidity of 60 to 65%, which drops to 12% after constant ventilation and movement for about 25 to 30 days. This process must be maintained consistently to avoid excessive fermentation of the pulp and the conversion of sugars into acids.
The second method is the *washed* one, often one of the most common for processing *specialty coffees*. After removing the outer pulp, the drupes, still covered in mucilage, are immersed in tanks of water. Here, fermentation takes place, lasting between 12 and 72 hours, and the perfectly ripe cherries are separated from the immature or defective ones that remain on the surface.
The final method is *mechanical cleaning* or mucilage removal: instead of using water to remove the mucilage, a mechanical mucilage remover is used . The pulp is removed by the machine through friction and small jets of pressurized water.
The green coffee was analyzed in the Anacafè laboratory using the CDR CoffeeLab® before being shipped to Italy. The following table shows the results obtained from the analysis session:

		Citric acid (g/kg)	Malic acid (g/kg)	Lactic acid (g/Kg)	Acetic acid (g/Kg)	TTA (g/Kg of citric acid*)	Sugars (g/Kg)
Maracaturra	Natural	7.7	3.8	0.19	0.55	7.7	100.9
	Washed	10.2	6.0	< 0.15	0.62	6.7	89.5
	Non-fermented	8.6	4.8	< 0.15	0.55	6.2	92.6
Bourbon	Natural	7.0	4.4	0.29	0.72	8.3	111.4
	Washed	10.0	3.2	< 0.15	0.60	6.9	83.3
	Non-fermented	8.8	3.2	< 0.15	0.69	6.9	84.9
Pacamara	Natural	10.4	3.7	0.17	0.75	7.9	97.8
	Washed	7.7	5.4	< 0.15	0.62	10.6	79.9
	Non-fermented	9.5	6.1	0.24	0.69	6.4	86.7

*TTA: Total titratable acidity expressed as g/Kg of citric acid

Table 1Chemical profile of three coffee varieties (Maracaturra , Bourbon, Pacamara) before shipping

During the analysis session, it was possible to compare samples processed naturally or by washing with a sample, designated as **non-fermented**, obtained by mechanically removing the mucilage. The latter represents coffee not modified by any process and can be identified as the starting point before fermentation.
Observing the values obtained from the analysis of the two unfermented coffees, it can be stated that *Bourbon was initially more acidic than Pacamara* and *Maracaturra* coffees, but also that the manufacturing processes strongly modify the acidity measured in the different coffees.
The natural processing in particular seems to be the one that brings the greatest increase in acidity, although in the case of Pacamara Washed is observed the highest measured acidity.
The analysis session conducted in Italy gave rather different results as can be seen in **Table 2:**

		Citric acid (g/kg)	Malic acid (g/kg)	Lactic acid (g/Kg)	Acetic acid (g/Kg)	TTA (g/Kg of citric acid*)	Sugars (g/Kg)	Chlorogenic acids (%)	Caffeine (%)
Maracaturra	N	7.7	5.4	0.22	0.60	6.6	90.3	4	1.4
	W	11	5.5	< 0.15	0.58	5.5	101.1	5.5	1.4
	NonF	9.4	5.3	< 0.15	0.56	5.4	100.6	5.4	1.4
Bourbon	N	7.6	4.6	0.19	0.62	7.6	87.8	4.6	1.4
	W	10.9	4.2	< 0.15	0.65	5.8	84	4.4	1.3
	NonF	8.8	4.5	< 0.15	0.53	5.2	82.1	4.2	1.3
Pacamara	N	8.6	5.5	0.18	0.71	6.8	96.5	4.3	1.4
	W	10.3	5.5	< 0.15	0.63	5.6	96.9	4.5	1.4
	NonF	8.7	4.9	0.24	0.70	5.1	92.6	4.4	1.4

*TTA: Total titratable acidity expressed as g/Kg of citric acid

Table 2Chemical profile of three coffee varieties (Maracaturra , Bourbon, Pacamara) before shipping

The acetic and lactic acid content remained constant, unlike the malic and citric acid, sugar, and total acidity contents, which varied in many samples. These values highlighted a problem already known in the industry: green coffee is an extremely variable product, susceptible to storage conditions and prone to fluctuations even under optimal conditions.

Sugars and acidity as indicators of quality

Among the characteristics that make a cup of coffee unique is undoubtedly acidity, which, when properly balanced, is an important indicator of quality. Equally important is determining the sugar concentration; the initial reading is directly linked to the quality of the coffee.
The next step in green coffee processing is roasting, in which the beans are subjected to a temperature gradient for different lengths of time, according to specific profiles.
The Maillard reaction is the main pathway for aroma production during the roasting process, and sugars, along with amino acids, are the most important precursors to the reaction.
The higher sugar content (primarily sucrose, glucose, and fructose) increases the levels of pyrazines , furans, ketones, and nitrogen-containing heterocyclic compounds after roasting. These compounds contribute to the aromas of flowers, fruits, and toasted caramel.
By analyzing the various process steps, it is therefore appropriate to characterize both the acidity and sugar profiles in green coffee to obtain reliable indicators of coffee quality.
While cupping reveals the expressive and aromatic potential of coffee, measuring chemical parameters certifies its stability and biological integrity. Integrating these two disciplines means moving from a subjective assessment to a comprehensive quality control system.
The following table shows the results obtained from the Cupping tasting together with the quantity of sugars measured in the green coffee and the acidity developed by the coffee after roasting.

	Fermentation	Cupping score Anacafe	Sugars *acidity before transport	Cupping score Coffee Academy	Sugars *acidity after transport
Maracaturra	Natural	86.6	1810	78.7	1427
	Washed	86.5	1597	83.2	1769
	Non-fermented	87.4	2143	83.6	1720
Bourbon	Natural	82.5	1599	79.6	1190
	Washed	85.4	1454	82.4	1428
	Non-fermented	85.5	1528	82.8	1281
Pacamara	Natural	87.1	1828	80.6	1467
	Washed	78.8	1410	83.0	1512
	Non-fermented	85.5	1426	81.8	1296

Table 3cupping tasting results with multiplication factor obtained from sugars on green coffee and acidity on roasted coffee

The **sugar values** measured for each green coffee sample were multiplied by the acidity value measured on the roasted sample, in order to take both variables into account and the values thus obtained were compared with the results obtained in cupping.
The coffees that performed best in both cupping sessions were also found to have the highest acidity/sugar ratio, confirming how these parameters strongly influence the final quality of the coffee. These results also explain the marked differences in scores between the two cupping sessions , demonstrating that the coffee underwent significant changes in the time between the first tasting in Guatemala and the second in Italy.

The roasting:

The chemical profile continues to evolve during the roasting phase, as shown in the following table. The data show the analyses performed on post-transport samples, comparing the changes the product underwent after the thermal process.

		Citric acid (g/kg)	Malic acid (g/kg)	Lactic acid (g/Kg)	Acetic acid (g/Kg)	TTA (g/Kg of citric acid*)	Sugars (g/Kg)	Chlorogenic acids (%)	Caffeine (%)
Maracaturra	N	6.1	3.6	0.6	6.8	15.8	< 1	0.7	1.4
	W	8.5	3.4	0.5	6.5	17.5	< 1	1.5	1.4
	NonF	5.2	4.1	0.7	6.4	17.1	2.9	1.8	1.4
Bourbon	N	5.7	3.3	0.5	6.0	13.6	1.4	1.2	1.2
	W	4.6	3.3	0.5	6.4	17.0	< 1	2.2	1.3
	NonF	7.1	3.4	0.5	6.4	15.6	< 1	2.2	1.3
Pacamara	N	6.2	3.1	0.6	6.7	15.2	1.5	1.3	1.4
	W	6.4	3.5	0.5	6.7	15.6	1.8	0.9	1.4
	NonF	7.1	3.1	0.6	6.3	14.0	< 1	0.7	1.4

During coffee roasting, total acidity increases significantly, significantly influencing the final flavor of the beverage. Among the most important acids are **Chlorogenic acids**, very abundant in green beans, which degrade with heat, giving rise to phenolic compounds responsible for bitter and astringent notes, especially in dark roasts. **Citric acid**, responsible for a bright, citrusy acidity, tends to resist roasting better but progressively decreases with increasing time and temperature. **Malic acid**, which gives a very pleasant acidic sensation (hints of green apple), seems less sensitive to the roasting process and degrades less rapidly.
During roasting, acids such as **Lactic Acid** (in very small quantities) and acetic acid are also formed.
Acetic acid is formed during both the brewing process and roasting and can provide a pleasant sharpness. and complexity to the coffee. Too high concentrations impart a pungent flavor and a fermented odor, thus creating a defect. Careful monitoring during processing can prevent similar defects from appearing in the final product.
The acetic acid values recorded in the green coffee samples are very low, demonstrating the correct handling of the product during processing. On the other hand, the values measured in roasted coffee are similar, and no sample showed high acetic acid values.
During the roasting phase, the roaster must monitor the development of acetic acid and balance it according to the perfect roasting curve for the specific coffee, maximizing the positive aromatic notes. During the roasting phase, the roaster must monitor the development of acetic acid and balance it according to the perfect roasting curve for the specific coffee, in order to maximize the positive aromatic notes. This result was confirmed by cupping, which did not reveal any defects related to an excess of this acid.
The sugar determination showed extremely low values in line with what was expected: roasting in fact destroys the sugar content following the Maillard reaction, which develops the typical aromas.
It is interesting to note how the **caffeine** content remained unchanged both during the roasting and fermentation processes: the concentrations detected were very similar for all three varieties, slightly lower for the *Bourbon*.

Conclusions

The study highlighted how the quality of green coffee can undergo significant changes during storage and transportation, even under controlled conditions such as those chosen for this study. Chemical analyses performed before and after shipping showed significant variations in the amount of sugars, organic acids, and total acidity, all parameters closely related to the quality of the final product.
In particular, sugar content and acidity significantly contribute to the sensory score obtained during cupping , confirming their importance in the overall product evaluation. The differences observed between cuppings performed initially and those performed after transportation demonstrate that coffee sent to the final consumer can exhibit profoundly different chemical and sensory characteristics compared to freshly processed products. This initial study demonstrated the critical importance of monitoring and optimizing every stage of the coffee supply chain, from post-harvest to transportation and roasting, to preserve product quality and ensure a consistent, high-quality sensory experience. A more scientific and measurable approach to these steps could represent a significant opportunity for the entire coffee industry, from both a qualitative, economic, and environmental perspective.

Useful links:

- National Coffee Association (ANACAFE)
- Accademia del Caffè Espresso
- CDR CoffeeLab®
- Determination of fermentable sugars
- Determination of Chlorogenic acids
- Determination of citric acid
- Determination of malic acid
- Determination of lactic acid
- Determination of acetic acid