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# Breeding for Improved Coffee Quality

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### Introduction

Coffee quality is one of the most important traits in breeding programs for improved varieties, and its evaluation has traditionally relied on cupping. While sensory analysis remains the benchmark for defining cup quality, it is often slow, costly, and subjective. In practice, sensory evaluation classifies samples according to specific markets and consumer preferences, which makes it challenging to define objective traits for measurement. Once these traits are established, however, breeding programs can benefit from high-throughput analytical methods that allow efficient screening of genotype candidates without the time and resource demands of cupping. This project aims to identify industry-relevant quality traits and integrate sensory evaluation with spectroscopic techniques to develop reliable tools for both breeding and quality control.

#### Methods

We first conducted an industry consultation, engaging with companies across the value chain to understand their preferred traits to help define them. Industry preferences for *Coffea arabica* were distilled into breeding targets through a filtering process, prioritizing traits that are relevant for breeding goals. Next, we ran local cupping trials (utilizing the former SCA cupping protocol and form) across sites in Kenya, Nicaragua, and Rwanda, and a centralized session (using the updated SCA Coffee Value Assessment [CVA] protocol), with the same samples, hosted by J.M. Smucker Co. The cuppers from centralized cupping were initially trained to use the CVA form. Finally, FTIR spectra were collected from the samples, pre-processed for scatter correction, and analyzed using Partial Least Squares Regression (PLSR) to predict the total score.

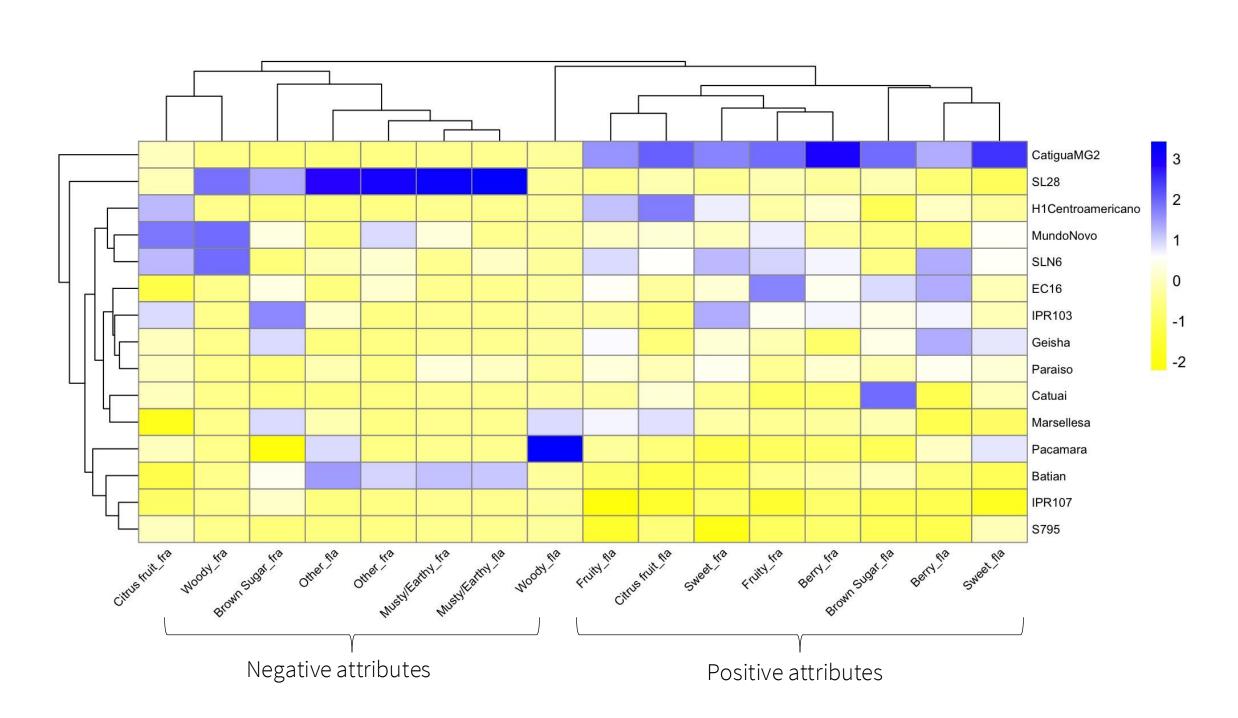


Figure 1: Heatmap of the main positive and negative attributes, considered by the industry consultation, pointed by cuppers for each sample.

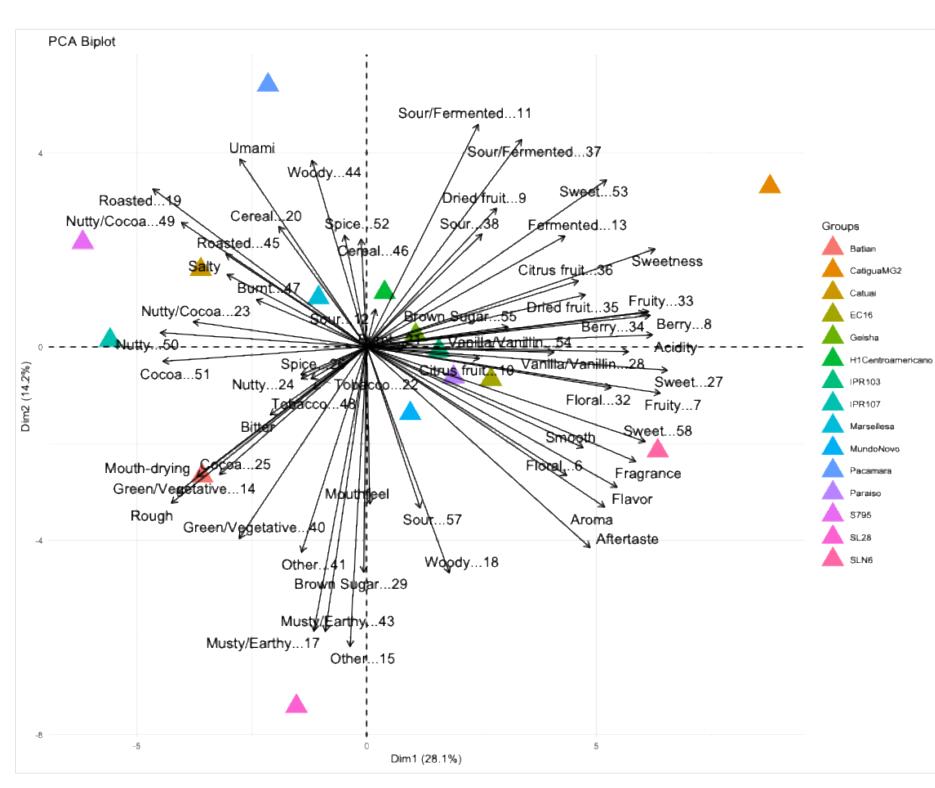


Figure 2: PCA of samples analyzed using Descriptive Coffee Value Assessment from SCA.

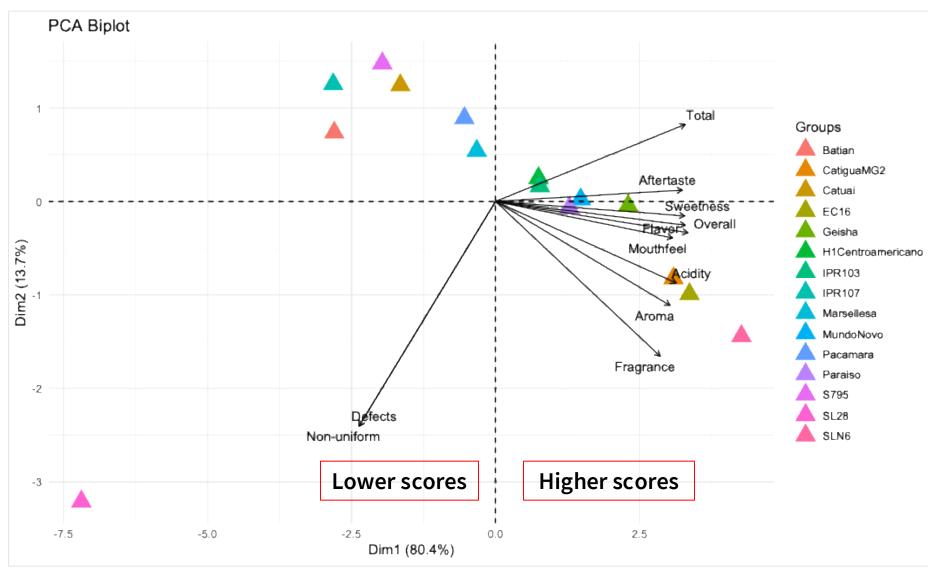


Figure 3: PCA of samples analyzed using Affective Coffee Value Assessment from SCA.

#### Results

The industry consultation to define traits associated with quality perception revealed the equal importance of the presence of positive attributes and the absence of negative ones. The most important positive and negative attributes are presented in Figure 1, also showing the sensory characteristics of samples evaluated by cuppers. Cupping data showed that centralized evaluation led to more consistent results across cuppers (p<0,05), while local cuppings introduced greater variation (p>0,05), which might reflect the CVA training received by the cuppers and the controlled conditions for a singular event. PCA analysis in Figure 2 groups the samples according to the main characteristics pointed by cuppers to define their sensory profile, displaying all the attributes presented in the CVA descriptive form. Figure 3 shows the samples grouping according to total score. Analyzing both Figures (2 and 3), it is possible to see that descriptions drive the total quality pointed out by the cuppers. The ability to describe and differentiate cup quality reinforces cupping as an essential tool to assess coffee quality.

## Spectroscopy-PLSR Models

Spectroscopy-based models (Figure 4) captured meaningful relationships with sensory traits, achieving moderate calibration performance ( $R^2c \sim 0.73$  and RMSEP = 2.04) as shown in Figure 4. However, validation remained poor, with low  $R^2v$  across datasets, reflecting the limited sample size and variability. The results are promising, given the performance for a small number of samples. We believe that with a higher data set covering a broad range of sample qualities, the models will show better fits.

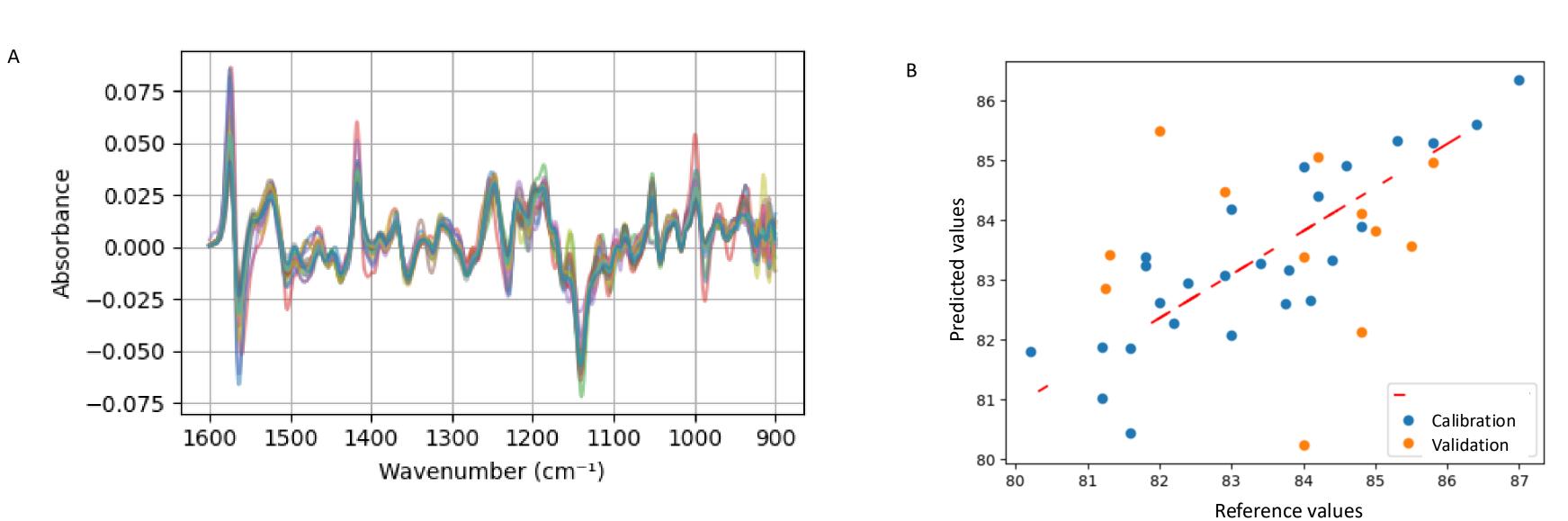


Figure 4:A) Spectra correction (1600 – 900 cm<sup>-1</sup>); B) PLSR for Total Score x Spectra data.

## Conclusions

Industry consultations identified positive and negative attributes as the most critical breeding targets for coffee quality. Centralized cupping provided more consistent evaluations than local sessions, confirming its value for standardized quality assessment. FTIR spectroscopy shows strong potential as a rapid, high-throughput predictor of sensory quality, but further data expansion, improved preprocessing, and integration with other analytical tools are needed. Together, these findings outline a path toward efficient, science-based selection of coffee varieties with desirable quality traits.