Core Collection—Quality Evaluation

2021

May 20, 2022

Project summary

Organization name	World Coffee Research
Project title	Core Collection
Location	Flor Amarilla, El Salvador
Duration	2020/2021 (harvest/cupping)
Key performance indicators	23 accessions 16 cuppers 10 companies in 3 countries
Project goal	Evaluate the cupping performance of accessions of the WCR/CATIE core collection to identify accessions with high quality that could be used for research and breeding and underline the value of conserving the collection.
Key deliverables	Analysis of cupping data (1 year, 1 site, 23 accessions)
Partners/participants	J. Hill y Cia, cuppers from 10 companies
Project budget	$1,965

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1. Executive Summary

A collection of 100 genetically diverse *Coffea arabica* accession, called the WCR/CATIE Core Collection, has been propagated and installed in field trials in three locations: In El Salvador at the World Coffee Research farm, in Costa Rica at Finca Alsacia, and at the Rubona Research Station of the Rwanda Agricultural Board in Rwanda.

In 2020/21, a subset of 23 core collection accessions from the WCR research farm in El Salvador were harvested, processed, and shipped to international cuppers for cup quality evaluation. Evaluating the cupping performance of accessions of the WCR/CATIE Core Collection allows us to identify accessions with high quality that could be used for research and breeding and underline the value of conserving the collection.

On average there was a range of total score between 80 to 85.5. There is moderately high heritable variation in the cupping score of the accessions of the core collection, meaning that selection towards increasing cupping score can be feasible through breeding and selection. There is also variation within cuppers and the specific preferences of cuppers. This suggests that to it is important to evaluate samples with a variety of cuppers, to get an good overall estimate, and on the other hand some cuppers might prefer not the highest overall accession, but a specific accession that might have some distinct profile for a certain use. In this samples and cuppers, the components that had the highest effect in total cupping score were flagrance/aroma, balance and sweetness. From the descriptors Sweet(taste) and Burnt had the most positive and negative effect predicting total cupping score.

2. Context and Problem Statement

There are nearly 1,000 unique *Coffea arabica* accessions[1] at the CATIE International Coffee Collection of coffee germplasm in Costa Rica, which houses the largest collection of *C. arabica* genetic diversity available today in the public domain.[2] In 2016-17, WCR and CATIE genetically tested (genotyped) 947 individual plants from the collection—*809 C. arabica* plants, 58 *C. canephora* (robusta), 17 "Arabustas," 10 *C.eugenioides*, 12 *C. sessiliflora*, and 7 each of *C. pseudozanguebariae*, *C. anthonii*, and *C. brevipes* samples. The study identified a subset of the *C. arabica* plants in the collection—100 accessions in all—that captured ~90% of the total genetic diversity available in the species. These are the 100 most diverse *C. arabica* plants available from the CATIE germplasm collection. This group of diverse plants, called the WCR/CATIE Core Collection, has been propagated and installed for backup conservation and characterization in field trials in three locations: In El Salvador at the World Coffee Research farm, in Costa Rica at Finca Alsacia, and in Rwanda at the Rubona Research Station of the Rwanda Agricultural Board.

In order for the collection to be useful for future breeding and to make the case for the urgency of conserving the threatened collection, it needs to be further characterized, meaning the attributes of these unique accessions need to be measured and described.

Currently, WCR does not have plans to utilize Core Collection accessions in breeding; however, the collection is important to characterize for possible future use by others.

Current objective

In 2020/21, a subset of 23 core collection accessions from the WCR research farm in El Salvador were harvested, processed, and shipped to international cuppers for cup quality evaluation. Evaluating the cupping performance of accessions of the WCR/CATIE Core Collection allows us to identify accessions with high quality that could be used for research and breeding, to determine if cup quality is a heritable trait in these accessions,[3] and to underline the value of conserving the collection.

[1] [1] An accession is a distinct, uniquely identifiable individual plant representing a cultivar, breeding line or a population, which is maintained in storage for conservation and use. Accessions in the Core Collection are individuals in a population of 100 genetically diverse *Coffea arabica* plants from the larger CATIE germplasm collection in Turrialba, Costa Rica.

[2] For more information about the CATIE collection and priorities for it's conservation, see Dulloo et al (2021) at https://www.frontiersin.org/articles/10.3389/fsufs.2021.777415/full

[3] Heritability is a plant breeding term describing a measurement of **t**he proportion of variance among individuals in a population that is due to heritable genetic effects. Broadly, it if there is high heritability of a trait, it means that the trait is likely to be passed down to offspring during the breeding process. Breeders might then preferentially select plants with high heritability of desirable traits for crossing.

Future objective
The data for this report from a single site and a single harvest year. WCR is also in the process of analyzing data from multiple sites and years to form a richer picture of the cup quality potential and field performance of these materials, in particular to understand the stability of cup quality, yield, and coffee leaf rust susceptibility over different years and across different environments.

3. Timeline and key activities

2021 Cupping
December 2020: Harvest and wet milling
June: Dry milling + export
August 2021: Samples shipped to cuppers

Prior quality evaluations [to be combined into meta-analysis in 2022]

Harvest year	Cupping year	Site	# accessions	Cuppers	Format	Design
2018	2019	Flor Amarilla	64	J. Hill y Cia	In-person	SCA standard
2019	2020	Flor Amarilla	41	J. Hill y Cia	In-person	SCA standard
2019	2020	Flor Amarilla	31	CSC	In-person	SCA standard
2019	2020	Alsacia	38	Association de Cafes Finos	In-person	SCA standard
2020	2021	Flor Amarilla	23	International cuppers	Virtual (mail)	SCA standard +

4. Methods summary

- 23 accessions
- Grown in the Flor Amarilla Farm in El Salvador
- 13 cuppers from 10 companies
- Sample randomization
- SCA protocol + check-all-that-apply flavor descriptors, + Likert scale questions

5. Research questions

- Which accessions have the highest SCA cup quality scores?
- Which accessions candidates meet current industry product needs?

- Are there segments of buyers with unique preferences for specific quality attributes and specific accessions?

6. Samples

23 samples available from Flor Amarilla for quality evaluation in 2021

Experiment code	Core Collection Accession Code	CATIE accession code (international Identification)	Introduced into CATIE from country	Introduction date into CATIE collection	Collecting mission
C1	4477_FA	E-030	Ethiopia	1965/06	FAO
C2	4517_FA	E-068	Ethiopia	1965/06	FAO
C4	4558_FA	E-486	Ethiopia	1965/06	FAO
C5	4567_FA	E-087	Ethiopia	1965/06	FAO
C6	4588_FA	E-330	Ethiopia	1965/06	FAO
C7	4591_FA	E-333	Ethiopia	1965/06	FAO
C8	4598_FA	E-340	Ethiopia	1965/06	FAO
C9	4679_FA	E-165	Ethiopia	1965/06	FAO
C10	4730_FA	E-207	Ethiopia	1965/06	FAO
C11	4732_FA	E-209	Ethiopia	1965/06	FAO
C12	4824_FA	E-424	Ethiopia	1965/06	FAO
C13	4828_FA	E-428	Ethiopia	1965/06	FAO
C14	4863_FA	E-463	Ethiopia	1965/06	FAO
C15	4873_FA	E-506	Ethiopia	1965/06	FAO
C16	16705_FA	ET-16	France	1985/08	ORSTOM
C17	16713_FA	ET-26	France	1985/08	ORSTOM
C18	16714_FA	ET-27	France	1985/08	ORSTOM
C19	17173_FA	ET-01	Cameroon	1986/01	ORSTOM
C20	21281_FA	ET-21	France	1995/08	ORSTOM
C21	21290_FA	ET-29	France	1995/08	ORSTOM
C22	21295_FA	ET-33B	France	1995/08	ORSTOM
C23	21315_FA	ET-59	France	1995/08	ORSTOM

Sample preparation

- Wet processed, milled, and dried to 10-12% moisture
- Shipped to US as green coffee
- 100g samples portioned into 2-ounce barrier pouches + labelled with codes
- Because some samples had lower harvest quantity than others, not all samples were sent to all cuppers; samples were randomized and boxes containing 19 green coffee samples were prepared and mailed to each of the 10 participating companies
- Cuppers were instructed to roast the coffee according to their internal company sample evaluation protocol (different roasters typically roast differently when evaluating samples for purchase)

- Cuppers were instructed to prepare the roasted coffee for cupping following the SCA cupping protocol[4], following SCA water quality standards[5]

Cupper selection

- Coffee samples were sent to 16 cuppers from 10 of WCR's diverse community of member companies participated; 2 cuppers did not submit scores; 1 cupper submitted unusually low scores = 13 cuppers' data used in final analysis
- Companies included 7 roasters, 1 green coffee supplier, and 1 allied company
- Companies were geographically located in the US, UK, and Italy
- Cupper selection is not representative

Participating cuppers

Company	Name of cupper
Workshop Coffee	James Bailey
Accademia del Caffè Espresso	Massimo Battaglia
Community Coffee Company, L.L.C.	Mark Howell
Olam Specialty Coffee	Maria Ximena Cortes
Olam Specialty Coffee	Joshua Marsceau
Tony's Coffee	David Yake
Tony's Coffee	Andrew Bowman
Counter Culture Coffee	Kyle Tush
Counter Culture Coffee	Jeff McArthur
Counter Culture Coffee	Alex Stoffregen
Allegro Coffee	Jessica Brooks
Intelligentsia Coffee	Sam Sabori
illycaffè S.p.A.	Fulvia Pamfili
illycaffè S.p.A.	Alice Bassi
Origin Coffee	Freda Yuan
Origin Coffee	David Ahren

[4]See SCA Protocols, "Cupping Protocol at https://sca.coffee/research/protocols-best-practices
[5] See "Heritage Water Standards" at https://sca.coffee/heritage-coffee-standards

Data

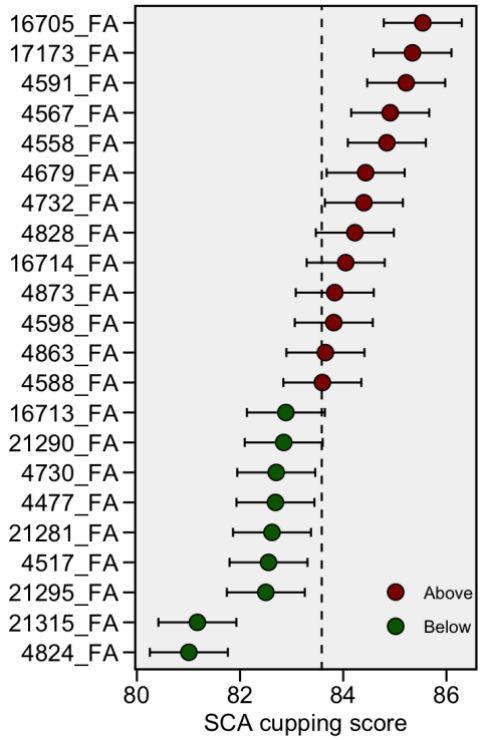
For each sample, the following data were collected from cuppers. Data were entered by cuppers onto a paper form (see Appendix 1) and then transcribed into an online Google Form by each cupper.

SCA cupping score	The SCA cupping protocol is an industry standard way of evaluating cup quality by roasters and green coffee suppliers prior to making coffee purchasing decisions and for quality control purposes. While cupping is widely used across the industry, research demonstrates that SCA cupping is not an entirely objective, replicable way to measure cup quality.
Check-all-that-apply (CATA) flavor, aroma, and texture descriptors	By constraining user choice, the CATA method increases reliability of sensory descriptor data. It has been validated by research to be replicable. To select the CATA options for inclusion on the evaluation form, we chose to use the two inner-most "rings" of the SCA/WCR/UC Davis Coffee Taster's Flavor Wheel representing broad sensory categories, such that, for example, "fruit" and "citrus" were included, but not the more specific descriptors "lemon" and "lime."
Fitness for purpose Likert scale ("does this coffee meet quality specifications for current or planned product offerings?")	Supplemental data to determine market interest/demand in variety candidates alongside cup scores. The rationale for including this scale is that SCA score is not always correlated with product needs—for example, some buyers may love a coffee and assign a very high score (~87) but not have a home for that coffee in their product lineup. Since market demand is a critical input into variety release decision-making, it is important to seek additional data beyond SCA cup scores regarding market needs.
Specialtyness Likert scale ("Is this coffee specialty?")	This question was added to form to evaluate whether perceptions of a coffee's "specialtyness" is highly correlated to SCA cup score, and in order to "bridge" the data from this evaluation to a prior experiment in which this question was asked ("WCR arabica quality targets" project) and used to evaluate if variety candidates cluster into quality segments. This was not used in the current analysis.

Analysis

Mean SCA total cupping score

There were significant differences in the total SCA cupping score for the accessions included in the evaluation ($p<0.001$). Overall, the mean score for all the accessions was 83.5. Accessions ranged from a low of 80.39 (accession 21315_FA) to a high of 85.51 (accession 16705_FA). Thirteen of the accessions had average total cup scores above the mean.



Experiment code	Accession	Total cupping score	Confidence interval	
C16	16705_FA	85.51	84.67	86.35
C19	17173_FA	85.32	84.47	86.16
C7	4591_FA	85.20	84.36	86.04
C5	4567_FA	84.85	84.01	85.69
C4	4558_FA	84.79	83.95	85.63
C9	4679_FA	84.42	83.58	85.26
C11	4732_FA	84.39	83.55	85.23
C13	4828_FA	84.22	83.38	85.06
C18	16714_FA	84.04	83.20	84.88
C15	4873_FA	83.84	83.00	84.68
C8	4598_FA	83.76	82.92	84.60
C14	4863_FA	83.66	82.82	84.51
C6	4588_FA	83.56	82.72	84.40
C17	16713_FA	82.90	82.06	83.74
C21	21290_FA	82.86	82.02	83.70
C10	4730_FA	82.73	81.88	83.57
C1	4477_FA	82.70	81.86	83.54
C20	21281_FA	82.63	81.79	83.47
C2	4517_FA	82.57	81.73	83.41
C22	21295_FA	82.53	81.69	83.37
C12	4824_FA	81.05	80.21	81.89
C23	21315_FA	80.39	79.55	81.23

Heritability

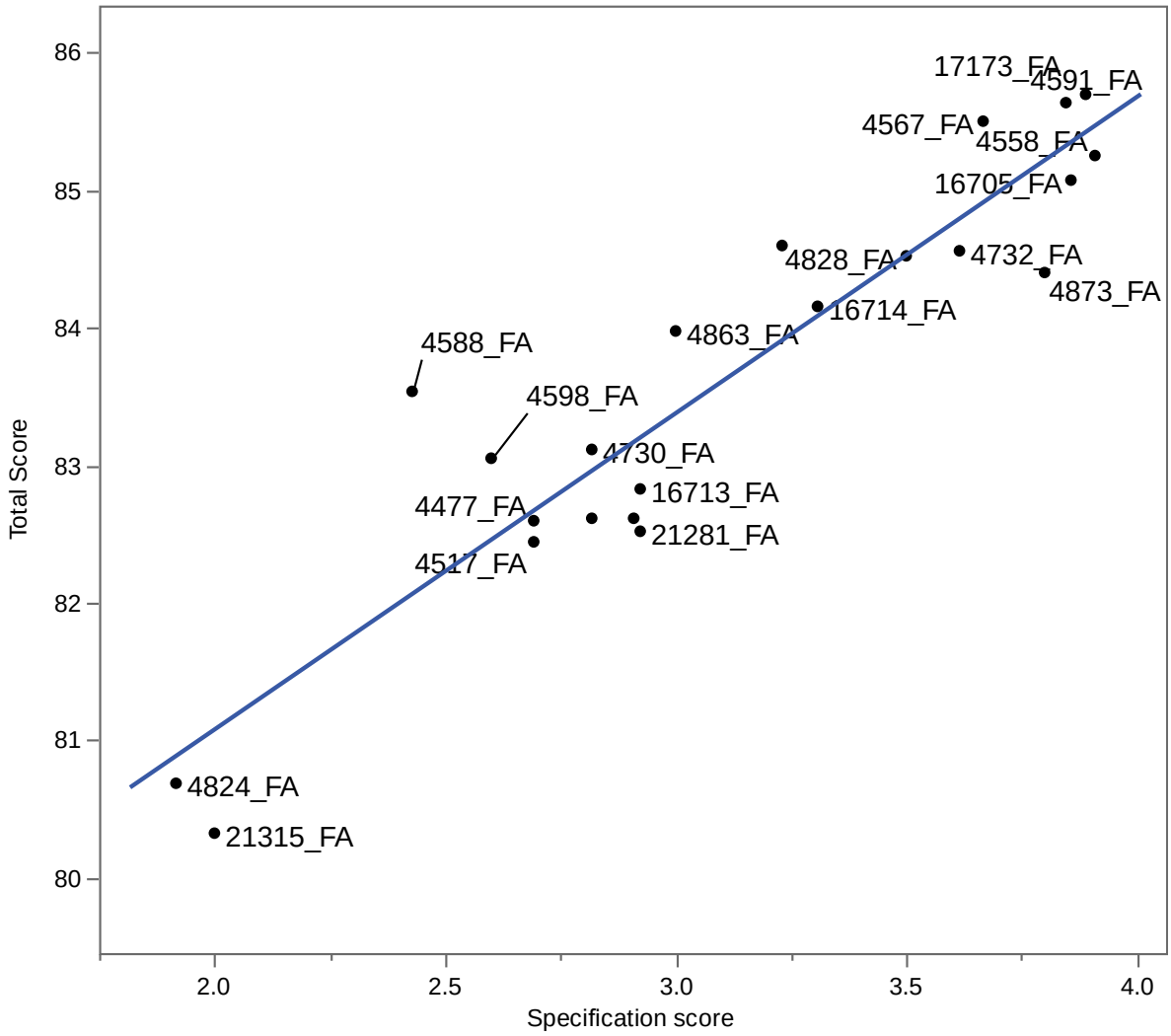
Total cupping score had a medium broad sense heritability of 0.32[6]. It is therefore feasible to do selection in a breeding program improving high cup quality and have some confidence that the cup quality will carry through to offspring if accessions are used in

[6] Broad sense heritability here is the proportion of the variation in cup scores that is attributable to the genetic differences between accessions. It goes from zero (lowest) to 1.0 (the highest). It is calculated by analyses of variances that includes genotypes and non-genotype effects (cupper preferences, and processing, roasting, or brewing between evaluators).

breeding. This is important information for breeders to have in order to more efficiently target useful traits in a breeding program.

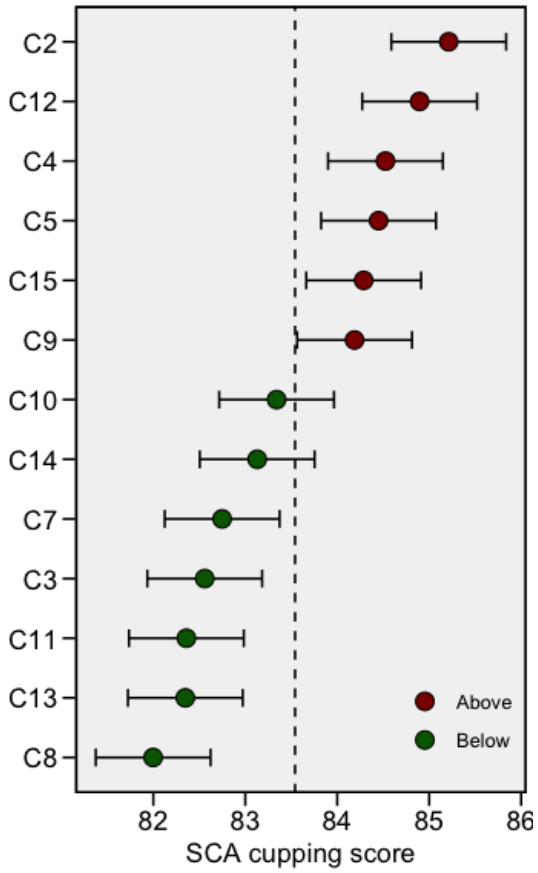
Market demand

There was a very high correlation (r=0.92) between total SCA score and answers to the question “Does this coffee meet your needs for current or planned product offerings” (“specification score”). A specification score of 1 corresponds to the answer “absolutely not” while a score of 5 corresponds to “absolutely yes.” The sample that fitted the least was 4588_FA. While it had a relatively high cup score (83.5), the “meeting specification” score was lower than would be predicted by the model.



Cupper reliability

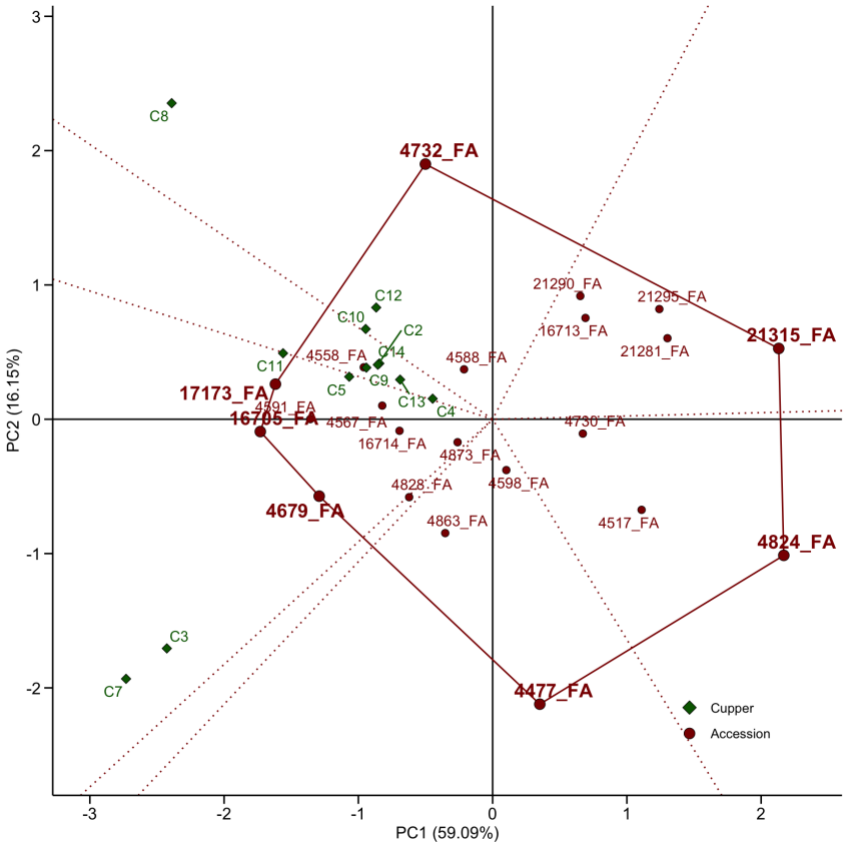
There were significant differences among cuppers, meaning there was variation in how high and low the cuppers scored samples overall. When individual cupper data for all samples was averaged, some cuppers tended to score lower (the lowest-scoring cupper averaged 82 across samples) and some scored higher (average 85). Cupper identity has been masked for privacy.



Cupper	Total cupping score	Confidence interval	
C2	85.21	84.59	85.84
C12	84.90	84.27	85.52
C4	84.52	83.90	85.15
C5	84.45	83.83	85.07
C15	84.29	83.66	84.91
C9	84.19	83.56	84.81
C10	83.34	82.72	83.97
C14	83.13	82.51	83.75
C7	82.75	82.12	83.37
C3	82.56	81.93	83.18
C11	82.36	81.74	82.98
C13	82.35	81.72	82.97
C8	82.00	81.37	82.62

Cupper preferences and interaction between cuppers and accessions

Cuppers prefer some coffees more than others. Using a type of statistical analysis called principle component analysis (PCA), we can visualize the relationship between cuppers and the samples they rate most highly (SCA total cup score). When green dots (representing cuppers) and red dots (representing accessions) are close together, it means that they cupper scored that accession highly. When green cupper dots are close together, it means the cuppers were similar in how they scored the different coffees in the evaluation; when red accession dots are close together, it means the coffees were similar in overall cup scores. When dots are far apart and on opposite poles, it means they perform in an opposite way. This shows that there is not only variation in the how high or low the cuppers score, but that cuppers are preferences for different accessions.



Example observations:

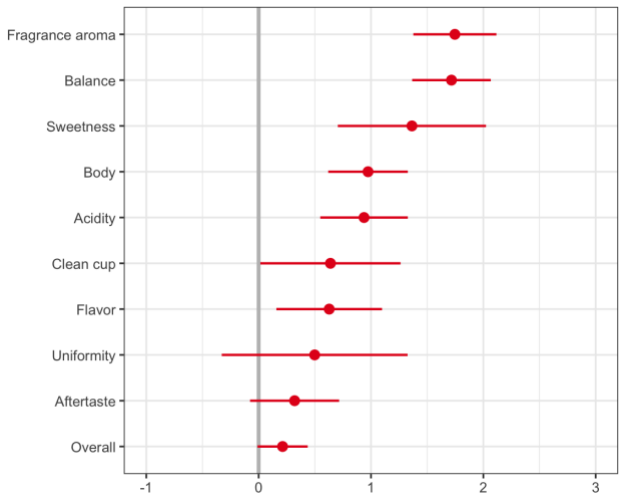
- The dotted red lines show “clusters” of cuppers. The bolded red dots (accessions) are the vertex accessions for each cluster, which were are the most responsive. In the first cluster, we can see that cuppers 10, 12, and 8 preferred accession 4732; and the third cluster containing many cuppers preferred samples 16705 and 4679.
- Cupper 11 is very close to the dot for coffee FA_17173, meaning cupper 11 scored this coffee highly.

- 16705_FA and 4591_FA appear close together, meaning they were scored similarly by cuppers. Both of these accessions had high overall mean scores; on the PCA plot, they are on an opposite pole from FA_21315 (on the right-most right side in the x axis), meaning they performed opposite of 16705_FA and 4591_FA (and the above analysis of means confirms that FA_21315 had low overall mean scores).
- Cuppers 8, 3 and 7 scored quite differently from most of the other cuppers (8 is in the far top left quadrant, while 3 and 7 are in the bottom left quadrant). Cupper 7 and 3 scored similarly to one another, but opposite of cupper 8.

Technical discussion: This is a genotype plus genotype-by-cupper interaction PCA. It uses singular value decomposition of cupper-centered multi-cupper data. The plot shows the space of variation using principal components, the first one on the x axis explains the most variation (59%) and the second component on the y axis with 15%.

Factors affecting cupping score

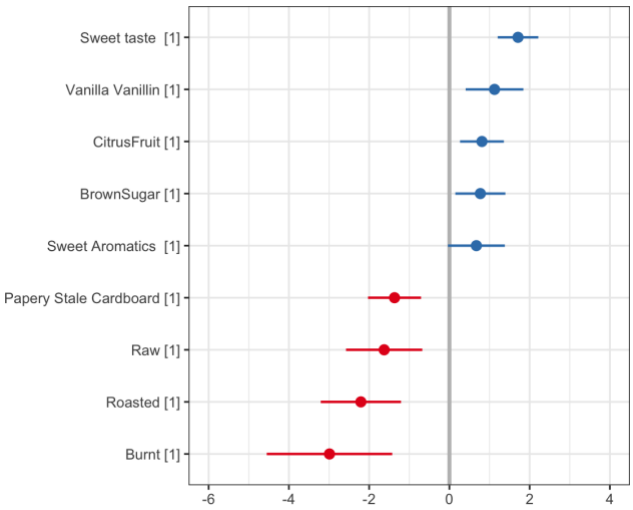
The SCA total cupping score is created by summing scores for multiple components (fragrance/aroma, flavor, aftertaste, acidity, body, uniformity, balance, clean cup, sweetness, and “overall”), which add up to a maximum of 100 points. A linear model was used to quantify the effect of the different components of total cupping score on total scores. The below chart shows the effect on the total score when the component is increased by one unit, when all other factors are held constant. (E.g., if the fragrance/aroma component score for a coffee sample was 1 point higher than for another coffee, with all other factors held constant, it would produce a nearly 2-point increase in the overall SCA score).



Overall, flagrance/aroma, balance and sweetness were the main components driving higher total cupping scores.

In addition to component and total SCA scoring, cuppers also used a “select all that apply” process for identifying the presence of key sensory attributes (flavor, aroma, and texture) in the coffee samples. A model selection was used to identify the sensory descriptors that best predict higher total SCA cupping scores. For example, if the cupper indicated that the sample had Sweet(taste) it increased the total SCA cupping score by almost 2 points, while Burnt decreased the score by 3 points.

From the final model, Sweet (taste), Vanilla/Vanillin, Citrus, Brown sugar and Sweet (aromatics) had a positive effect on total SCA cupping score, while Raw, Roasted and Burnt had a negative effect. Most of the negative sensory attributes are likely due to processing and sample handling issues (vs. intrinsic genetic differences). For example, Burnt and Roasted are sensory attributes associated with the roasting process; papery/stale/cardboard is associated with coffee that has “aged” (e.g., is too long past its harvest date and possibly improperly stored). On average, the accessions with high cupping scores had many cuppers indicating they were sweet, vanilla and citrus, while the worst were marked as burnt, roasted.



Conclusion

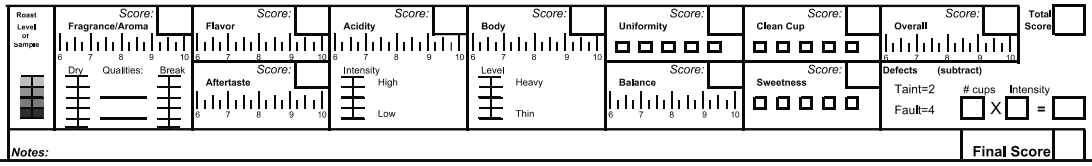
On average there was a range of total score between 80 to 85.5. There is moderately high heritable variation in the cupping score of the accessions of the core collection, meaning that selection towards increasing cupping score can be feasible through breeding and selection. There is also variation within cuppers and the specific preferences of cuppers. This suggests that to it is important to evaluate samples with a variety of cuppers, to get an good overall estimate, and on the other hand some cuppers might prefer not the highest overall accession, but a specific accession that might have some distinct profile for a certain use. In this samples and cuppers, the components that had the highest effect in total cupping score were flagrance/aroma, balance and sweetness. From the descriptors Sweet(taste) and Burnt had the most positive and negative effect predicting total cupping score.

Appendix 1 – Cupper evaluation form

Cupper Name: **Sample Number:**

Cupper company:

1. SCA cupping score *Please follow the SCA cupping protocol and enter your cup scores in their entirety below*



2. Descriptors *Please circle all that apply—if the attribute is present in the coffee sample, circle it*

Floral	**Sour**	**Roasted**	**Nutty**	**Papery/Stale/Cardboard**
Black Tea	**Fermented/Overripe**	**Tobacco/Pipe Tobacco**	**Cocoa/Chocolate**	**Musty/Moldy**
Fruity	**Alcohol**	**Burnt**	**Sweet**	**Animalic/Phenolic/Meaty-Brothy**
Berry fruit	**Green Vegetable**	**Cereal**	**Sweet Aromatics**	**Metallic (mouthfeel)**
Dried Fruit	**Beany**	**Brown/Baking Spices**	**Brown Sugar**	**Thick (mouthfeel)**
Citrus Fruit	**Olive Oil**	**Pepper**	**Vanilla/Vanillin**	**Oily (mouthfeel)**
Other Fruit	**Raw**	**Pungent**	**Chemical**	**Mouth drying (mouthfeel)**

3. Is this sample a specialty coffee? *Check one box*

☐ 1 Absolutely no	☐ 2 Probably no	☐ 3 Maybe, I don't know	☐ 4 Probably yes	☐ 5 Absolutely yes

4. Does this coffee meet your quality specifications for current/planned product offerings? *Check one box*

☐ 1 Absolutely no	☐ 2 Probably no	☐ 3 Maybe, I don't know	☐ 4 Probably yes	☐ 5 Absolutely yes