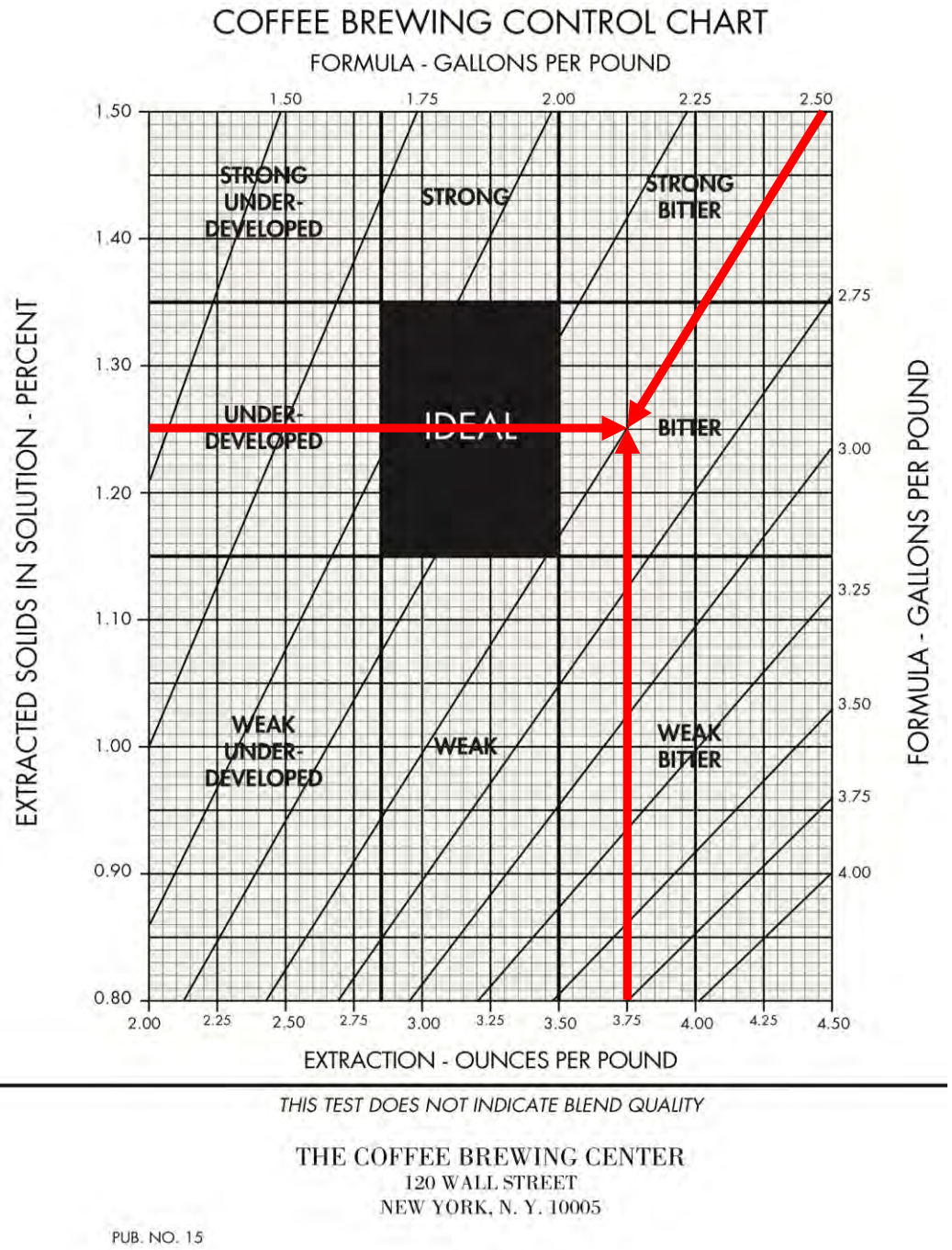
Demystifying, Updating, and Expanding the Brewing Control Chart

Scott Frost, Ph.D.
UC Davis Coffee Center

UCDAVIS
COFFEE CENTER

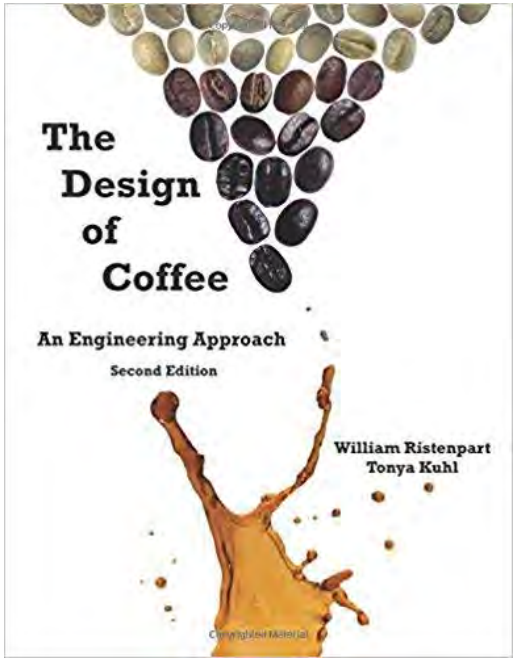
Specialty Coffee Association



*The Coffee Brewing Handbook, SCAA 2011

The **relationship** between

- Total dissolved solids – STRENGTH
- Yield - EXTRACTION
- The brew formula - DOSE
- **"Brew Index"**



Ernest Earl Lockhart

1912 – 2006
1938 Ph.D. Biochemistry from M.I.T
1939 Fellowship at the Biochemical Institute in Stockholm Sweden
1939 -1941 United States Antarctic Service Expedition (USASE)
physiologist stationed at the West Base near the Bay of Whales
1941– 1955 M.I.T Food Technology and Nutrition
1955 – 1965 Scientific Director of the Coffee Brewing Institute

ca. 1939-1941

Coffee…..

I am now a firm believer that one trained so completely in theoretical matters as I have been in the past should go away on an expedition for a year or two.
-- Earl Lockhart, 1 January 1941

The Coffee Brewing Institute (CBI)

Established 1952 by the Pan-American Coffee Bureau and the National Coffee Association

**The purpose of this organization is to encourage, through as a beverage.*

coffee needs research

By DR. ERNEST E. LOCKHART, Scientific Director
The Coffee Brewing Institute, Inc.

The only objective of scientific research is to uncover information about things and to make information available to anyone who wants to use it for a practical purpose.

Generally someone asks himself or someone else a question about something to which there is at the moment no answer. He may continue to ask other people he meets or look in books and encyclopedias to no avail. Eventually, if he is sufficiently curious and persistent or if the answer is needed urgently enough, he will seek out a place where the work necessary to give him the answer can be done.

If the work required to provide the answer involves chemistry, physics, engineer-

How should the beverage be prepared to give the best flavor? Why does the flavor of beverage change on standing, and what can be done about it? Why does water from different parts of the country make the beverage taste differently and what can be done about it?

One hundred years of work still has not yielded enough information to answer these and many other questions.

Why does coffee need scientific research? The basic and most practical reasons are to provide a solid foundation for commodity advertising and promotion, to develop knowledge that will enable the grower to produce better green beans, the roaster to manufacture better roasted beans, the equipment manufacturer to design better equipment and to teach the food service operator and the homemaker how to get the best out of the product supplied them.

Scientific research also provides information that can be used practically and beneficially to eliminate misinformation, heresay and opinion. These fall beneath the weight and force of argument supported by fact.

Coffee Facts, Ukers, 1954
Coffee & Tea Industries, January 1958

THE SOLUBLE SOLIDS IN BEVERAGE COFFEE

AS AN INDEX TO CUP QUALITY

by
ERNEST E. LOCKHART
SCIENTIFIC DIRECTOR
THE COFFEE BREWING INSTITUTE, INC.
NEW YORK 17, N. Y.

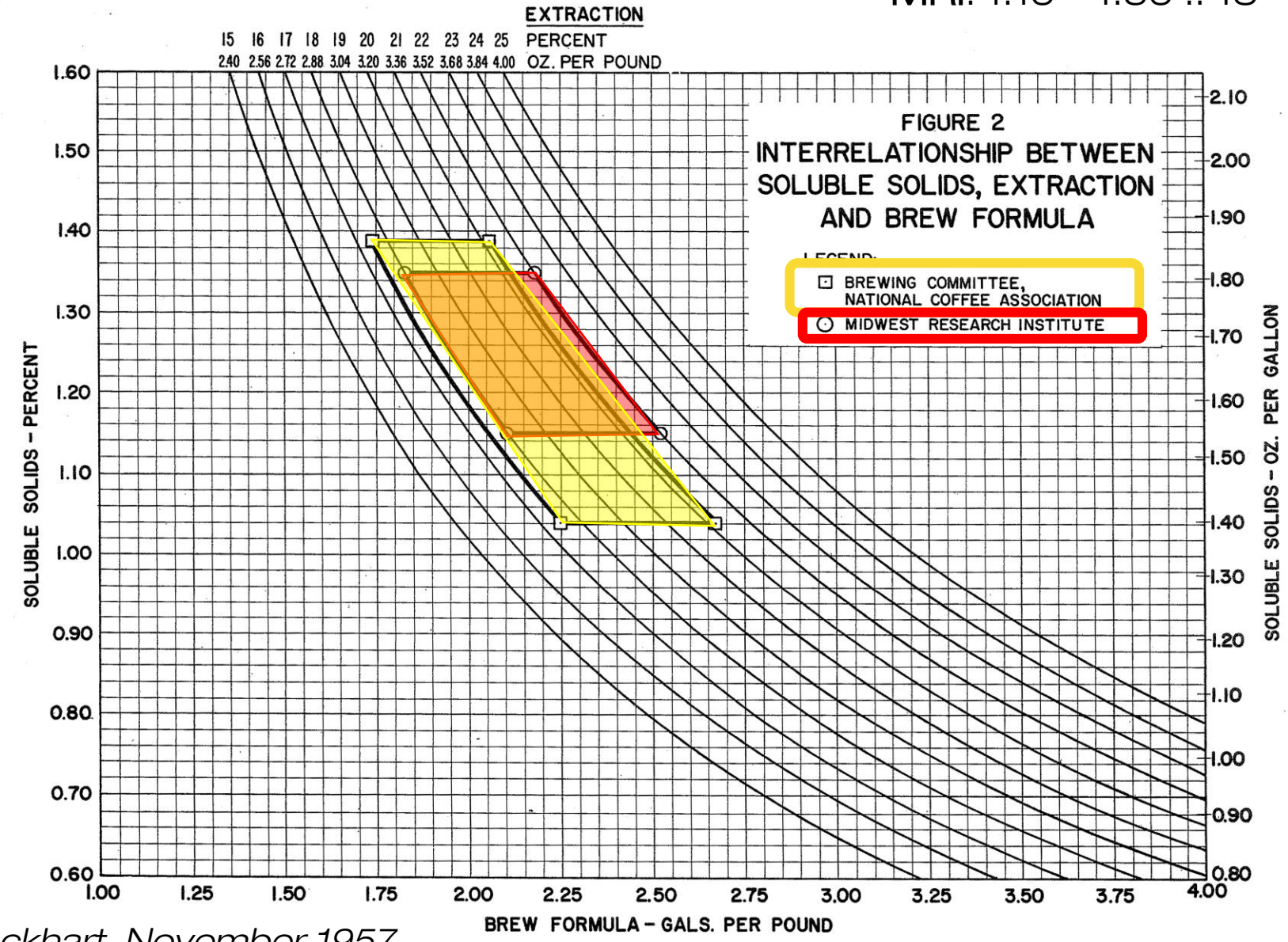
The quality or acceptability of coffee beverage or any other food product is very difficult to describe or measure. However, a study of this problem by the Coffee Brewing Institute and others has led to the development of a measurement of material extracted from grounds by water and made directly on the beverage. It provides an objective approach toward beverage evaluation. It also assists in an understanding of what happens during brewing. It offers a reasonable language for discussion of coffee, brewing and equipment performance. It eliminates to a great degree statements based upon opinion or uneducated guesses. With it a simple, practical and useful control system for beverage quality is possible.

Lockhart, November 1957

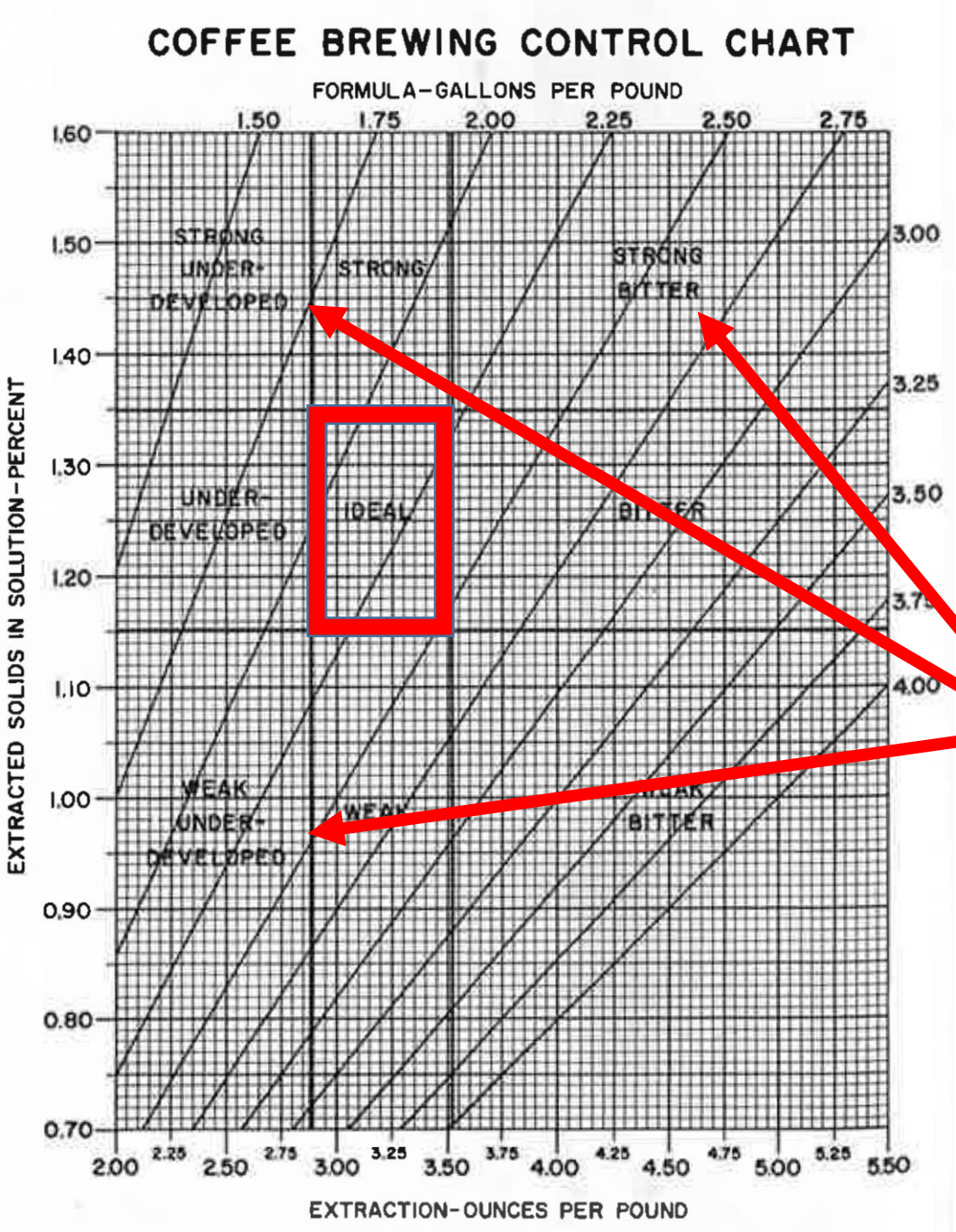
Brewing Control Chart

NCA: 1.04 – 1.39 :: 17.5 - 21.2

MRI: 1.15 – 1.35 :: 18 – 22



Lockhart, November 1957



the coffee hydrometer

By DR. ERNEST E. LOCKHART, Scientific Director
The Coffee Brewing Institute, Inc.

The Midwest Research Institute values were retained...

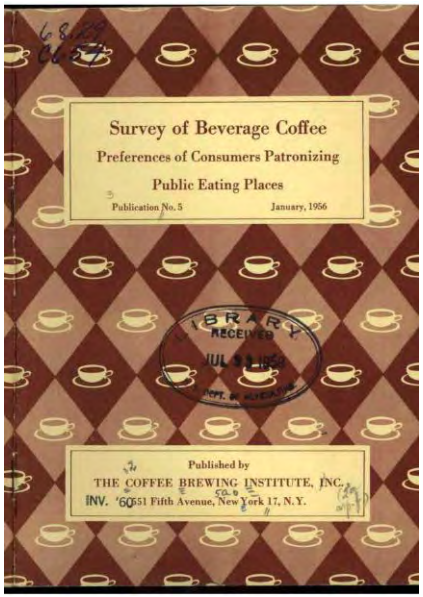
The addition of the verbiage
-Developed
-Underdeveloped
-Bitter
-Strong
-Weak

Coffee & Tea Industries, June 1959

What did the CBI do with the chart?

The similarity between the findings of these groups working on the chemical characteristics and preparative requirements of a cup of coffee that is most acceptable to a consumer, is hardly coincidental. These results have been supported by the judgment of many coffee and restaurant men, who have watched the brewing demonstrations sponsored by the Coffee Brewing Center throughout the country, and who have had an opportunity to compare the flavor of coffee prepared according to recommended procedures against watered or over extracted brews.

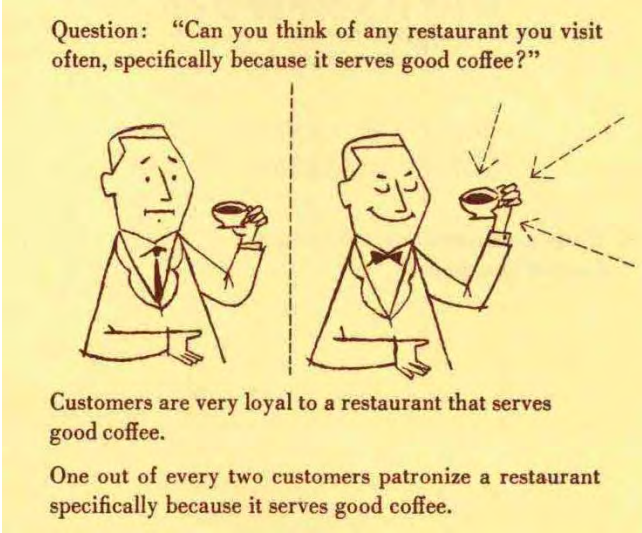
Road Show!!

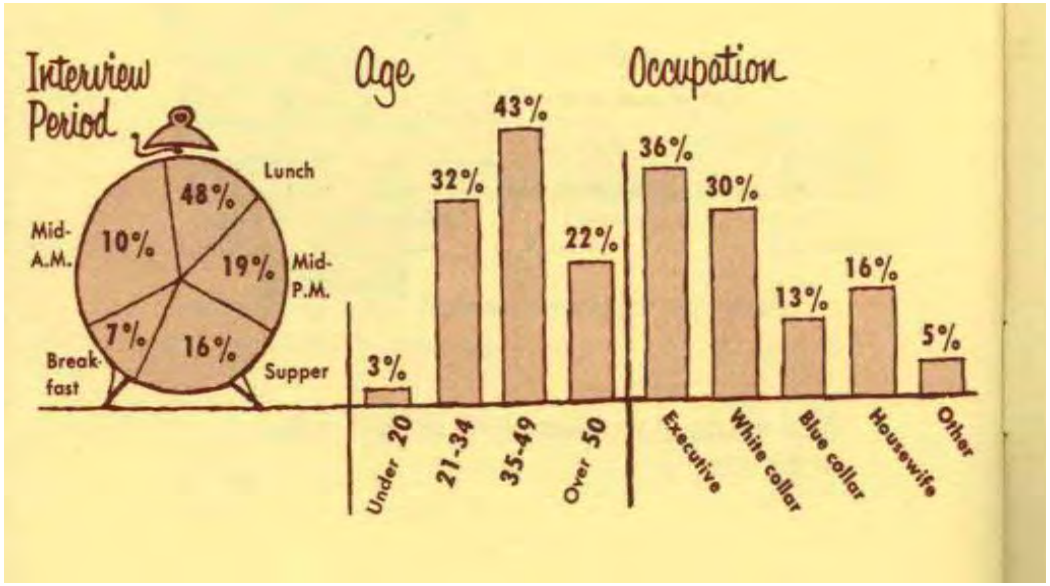


Lockhart, November 1957

Survey of Beverage Coffee

- *New York, Chicago, Los Angeles*
- 24 "mass feeding establishments" in each city
- 100 customers per establishment
- Two Phase project





Total Participants
2321 Women
2351 Men

Coffee Brewing Institute, Pub no.5, January 1956

CBI Advertising Campaign

The secret to GOOD coffee is here!!

Copyright 1957, by Carrier & Ives, New York
Courtesy of: The Henry T. Peters Collection
Museum of the City of New York

What happened to the good old-fashioned cup of coffee?

We in the coffee industry know what happened to good, old-fashioned, full-bodied coffee—with that wonderful aroma and superb flavor—*it got watered!* People began drinking weaker and weaker coffee until today's average extraction rate is 64 cups a pound—instead of the optimum of 40.

The Bureau is heading the program to restore *good* coffee. You can help by using this recipe on your bags and cans—in advertising and promotion.

It will pay off in better coffee—better sales, too.

THE SECRET OF GOOD COFFEE

Start with clean coffee maker, fresh coffee, fresh cold water. Use proper grind for maker. Measure and time carefully. *Always use at least ¼ of the capacity of any coffee maker.* For each serving, 1 standard coffee measure (2 level measuring tablespoons) to ¼ measuring cup (6 oz.) of water.

PERCOLATOR: When perking starts, reduce heat. Perk gently 6 to 8 minutes. *Time carefully.*

DRIP: Pre-heat pot. Pour in measured amount of boiling water. Brewing should be complete in 4 to 6 minutes. *Stir before serving.*

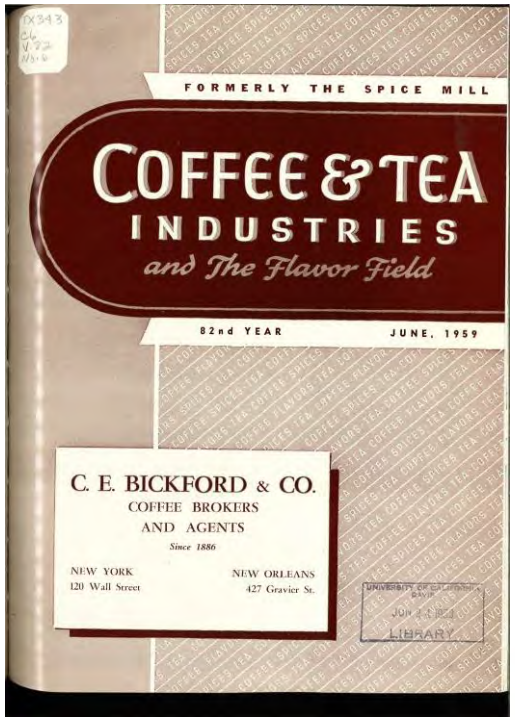
VACUUM: When water boils, reduce heat, insert upper bowl. Stir coffee and water and remove from heat. Coffee should remain in upper bowl no more than 3 minutes.

CAUTION: *Brewing too long makes coffee bitter. For weaker coffee, dilute after brewing according to above recipe.*

NOTE: If you use "instant," vary the strength to suit your taste.

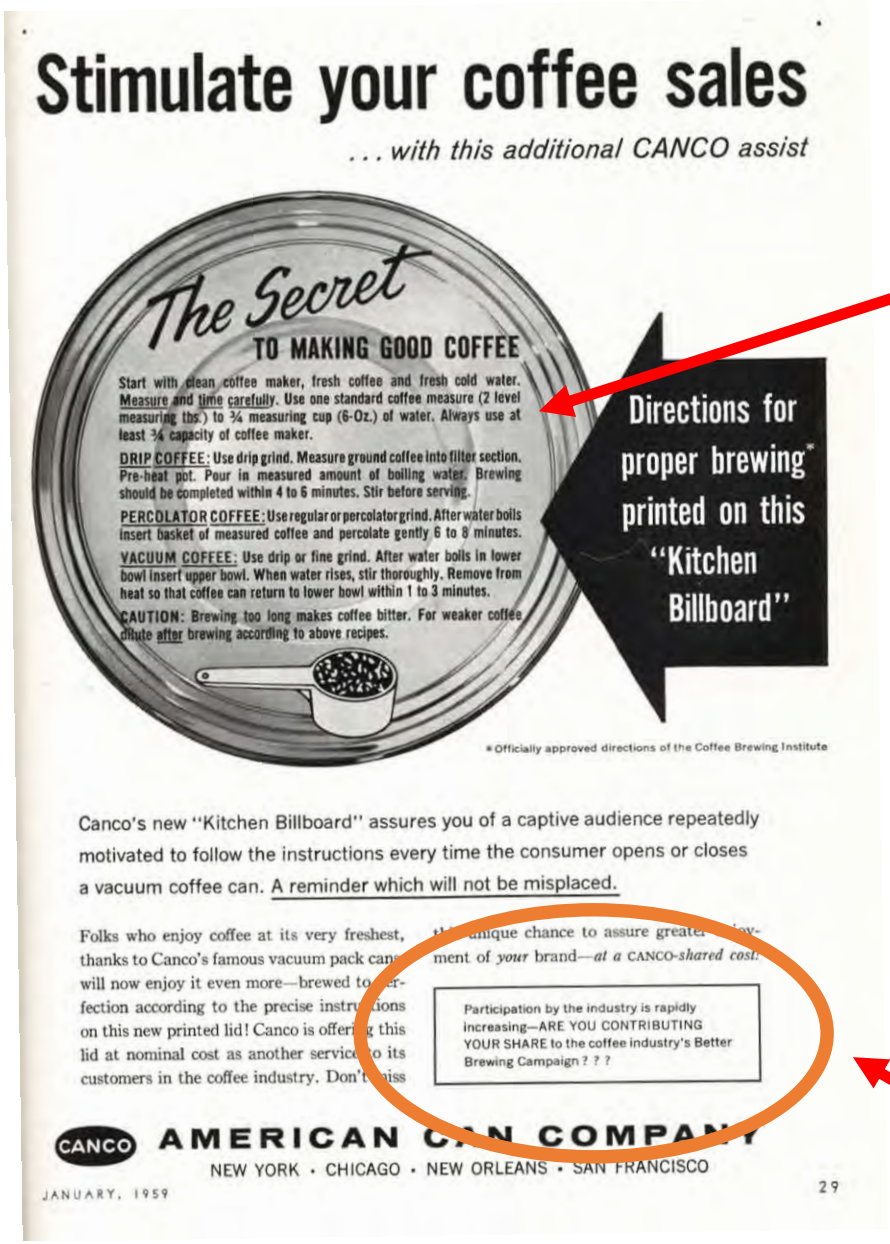
PAN-AMERICAN COFFEE BUREAU, 120 Wall Street, New York 5, N.Y.

JANUARY, 1959 7



Coffee & Tea Industries, January 1959

CBI Advertising Campaign



Stimulate your coffee sales

. . . with this additional CANCO assist

The Secret TO MAKING GOOD COFFEE

Start with clean coffee maker, fresh coffee and fresh cold water. Measure and time carefully. Use one standard coffee measure (2 level measuring tbs.) to ¾ measuring cup (6-Oz.) of water. Always use at least ¾ capacity of coffee maker.

DRIP COFFEE: Use drip grind. Measure ground coffee into filter section. Pre-heat pot. Pour in measured amount of boiling water. Brewing should be completed within 4 to 6 minutes. Stir before serving.

PERCOLATOR COFFEE: Use regular or percolator grind. After water boils insert basket of measured coffee and percolate gently 6 to 8 minutes.

VACUUM COFFEE: Use drip or fine grind. After water boils in lower bowl insert upper bowl. When water rises, stir thoroughly. Remove from heat so that coffee can return to lower bowl within 1 to 3 minutes.

CAUTION: Brewing too long makes coffee bitter. For weaker coffee dilute after brewing according to above recipes.

Directions for proper brewing* printed on this "Kitchen Billboard"

*Officially approved directions of the Coffee Brewing Institute

Canco's new "Kitchen Billboard" assures you of a captive audience repeatedly motivated to follow the instructions every time the consumer opens or closes a vacuum coffee can. A reminder which will not be misplaced.

Folks who enjoy coffee at its very freshest, thanks to Canco's famous vacuum pack can, will now enjoy it even more—brewed to perfection according to the precise instructions on this new printed lid! Canco is offering this lid at nominal cost as another service to its customers in the coffee industry. Don't miss this unique chance to assure greater enjoyment of *your* brand—*at a* CANCO-*shared cost!*

Participation by the industry is rapidly increasing—ARE YOU CONTRIBUTING YOUR SHARE to the coffee industry's Better Brewing Campaign? ? ?

CANCO AMERICAN CAN COMPANY

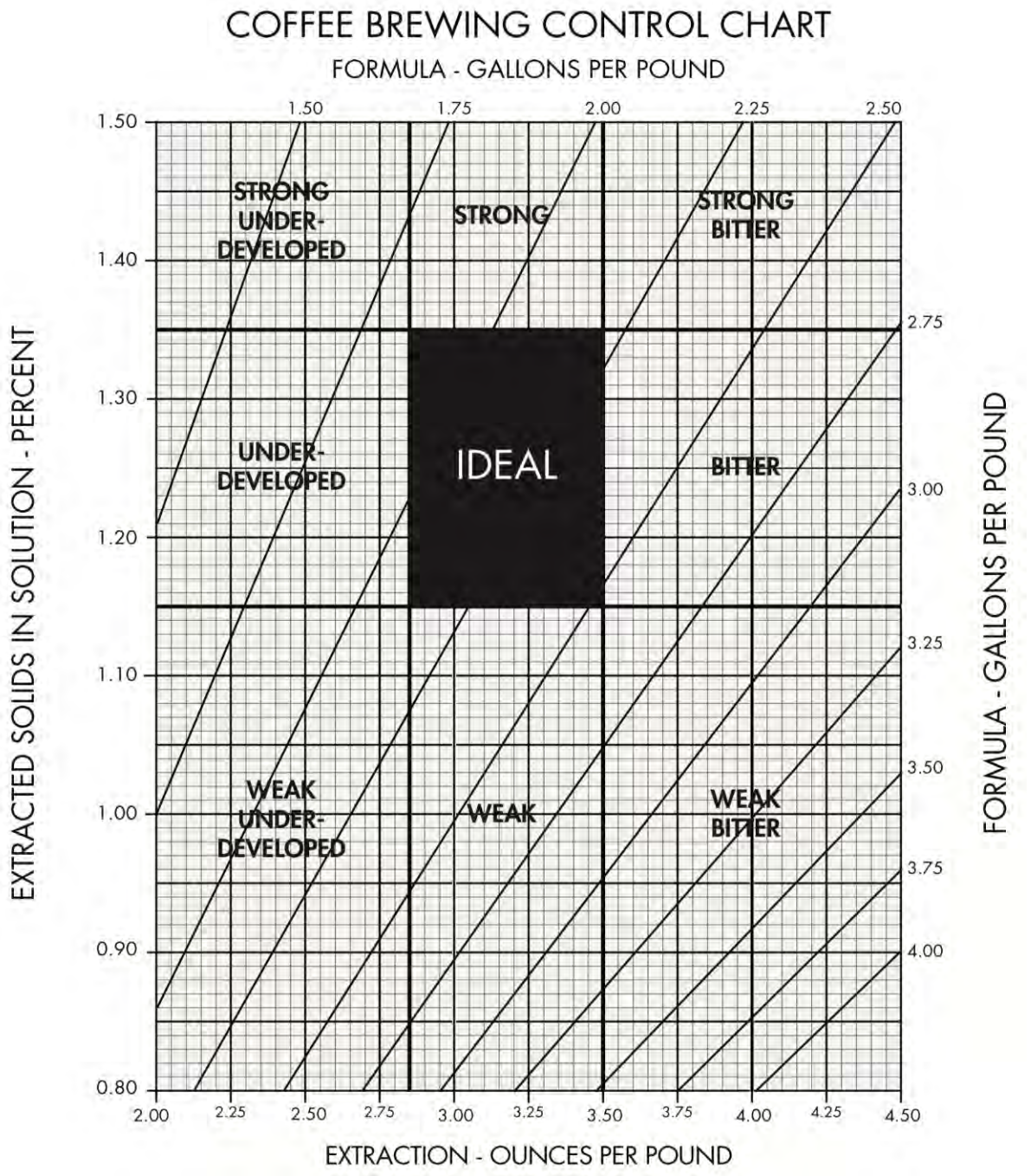
NEW YORK · CHICAGO · NEW ORLEANS · SAN FRANCISCO

JANUARY, 1959 29

Directions on the can!!

Give us $$!!

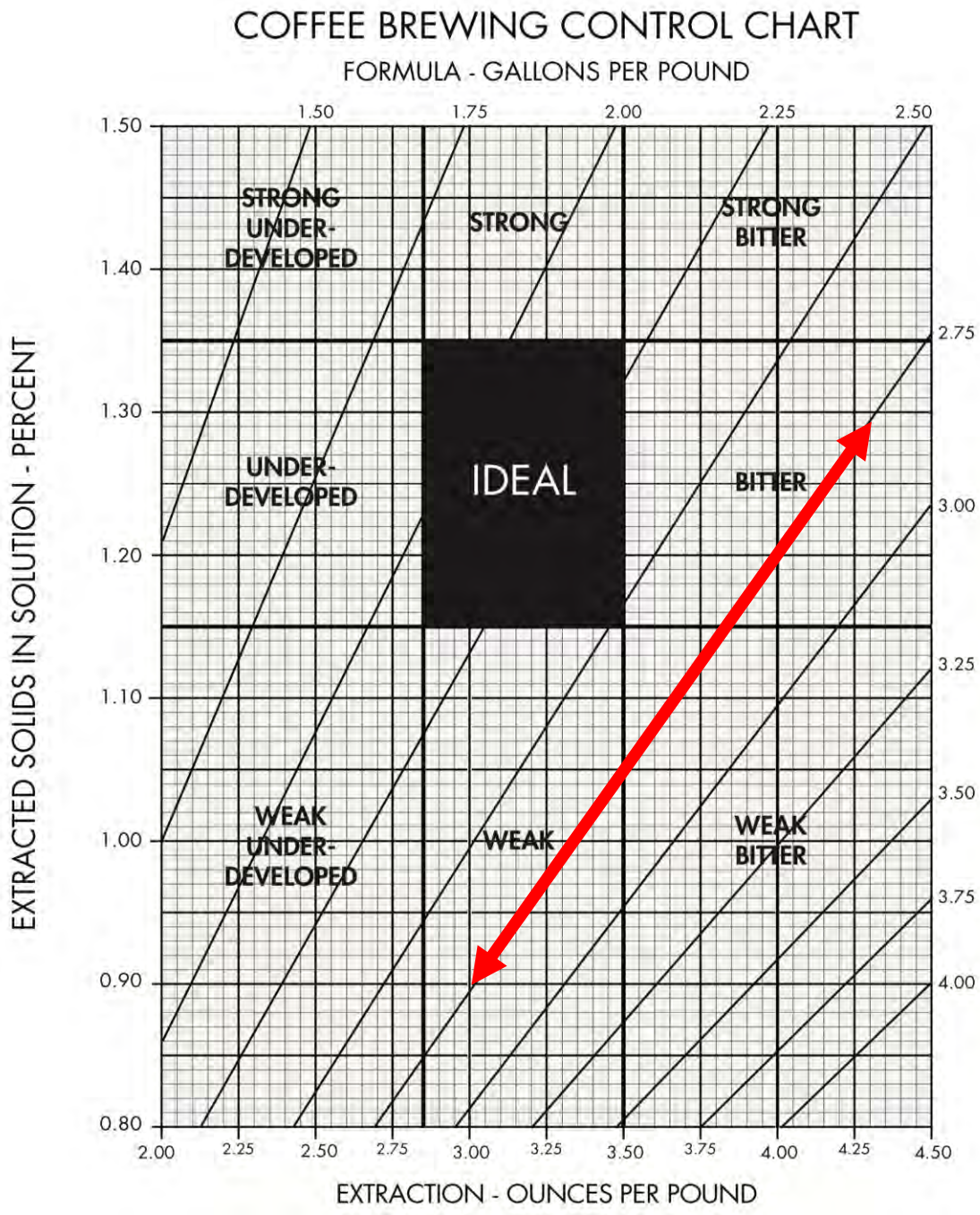
Coffee & Tea Industries, January 1959



The Coffee Brewing Handbook, SCAA 2011

The verbiage mashup!

- Preference
- Taste
- Development



How does flavor and aroma change in relation to the Brewing Control Chart?

SENSORY SCIENCE!!

*The Coffee Brewing Handbook, SCAA 2011

What is Sensory Science?

- is a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing.

Ser[illegible]on, IFT (1975)

What is Sensory Science?

The integration of neurophysiology, physiology, psychology, statistics, product evaluation and consumer information to study:

- the mechanisms of sensory perception from transduction to cognition
- the effects of physiological differences on perception
- the effects of stimuli concentration and composition on perception
- the effects of sensory and non-sensory properties of products on consumer acceptance

What is Sensory Science?

Question → Hypothesis → Experimental Design → Statistical Analysis

What is Sensory Science?

Question → Hypothesis → Experimental Design → Statistical Analysis

Is there a difference?
What is the difference?
What is the sequence of the difference?
What is the size of the difference?
Does the difference exist in multiple dimensions?
Is the difference time dependent?

What is Sensory Science?

Question → Hypothesis → Experimental Design → Statistical Analysis

If the formulation is modified, then…
If these treatments are applied, then ..

What is Sensory Science?

Question → Hypothesis → Experimental Design → Statistical Analysis

How many factors?
Levels per factor?
Number of judges
Experimental conditions
Quantitative sensory methods
Qualitative sensory methods

What is Sensory Science?

Question → Hypothesis → Experimental Design → Statistical Analysis

Univariate Analysis
Analysis of Variance
Multivariate Analysis of Variance
Principal Component Analysis

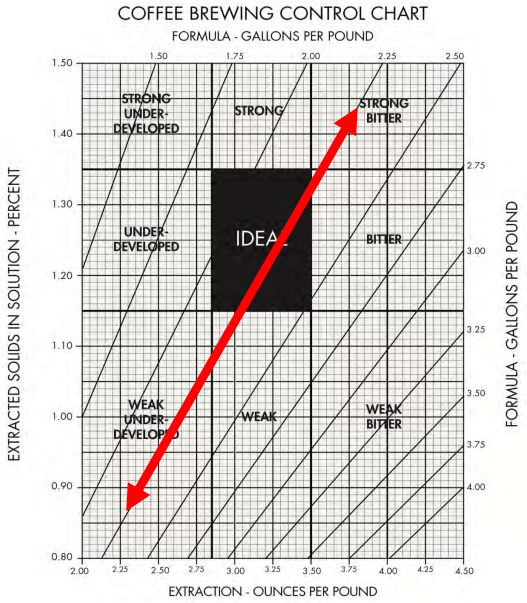
Research Objectives

Question?

How do specific sensory attributes change in respect to

Hypothesis?

If coffee is brewed at different index positions, then



Research Objectives

Experimental Design

2 x 2 x 2 factorial design

Coffee:
Dark x Light

Geometry:
Flat Bottom x Conical

Grind:
Two Settings

Dark Roast Flat Bottom Grind 3	Dark Roast Conical Grind 3	Light Roast Flat Bottom Grind 3	Light Roast Conical Grind 3
Dark Roast Flat Bottom Grind 5	Dark Roast Flat Bottom Grind 5	Light Roast Flat Bottom Grind 5	Light Roast Flat Bottom Grind 5

Coffee

Two roast levels were included

- Dark Roast – Agtron Score: 32.0
- Light(er) Roast – Agtron Score: 48.8

Geometry

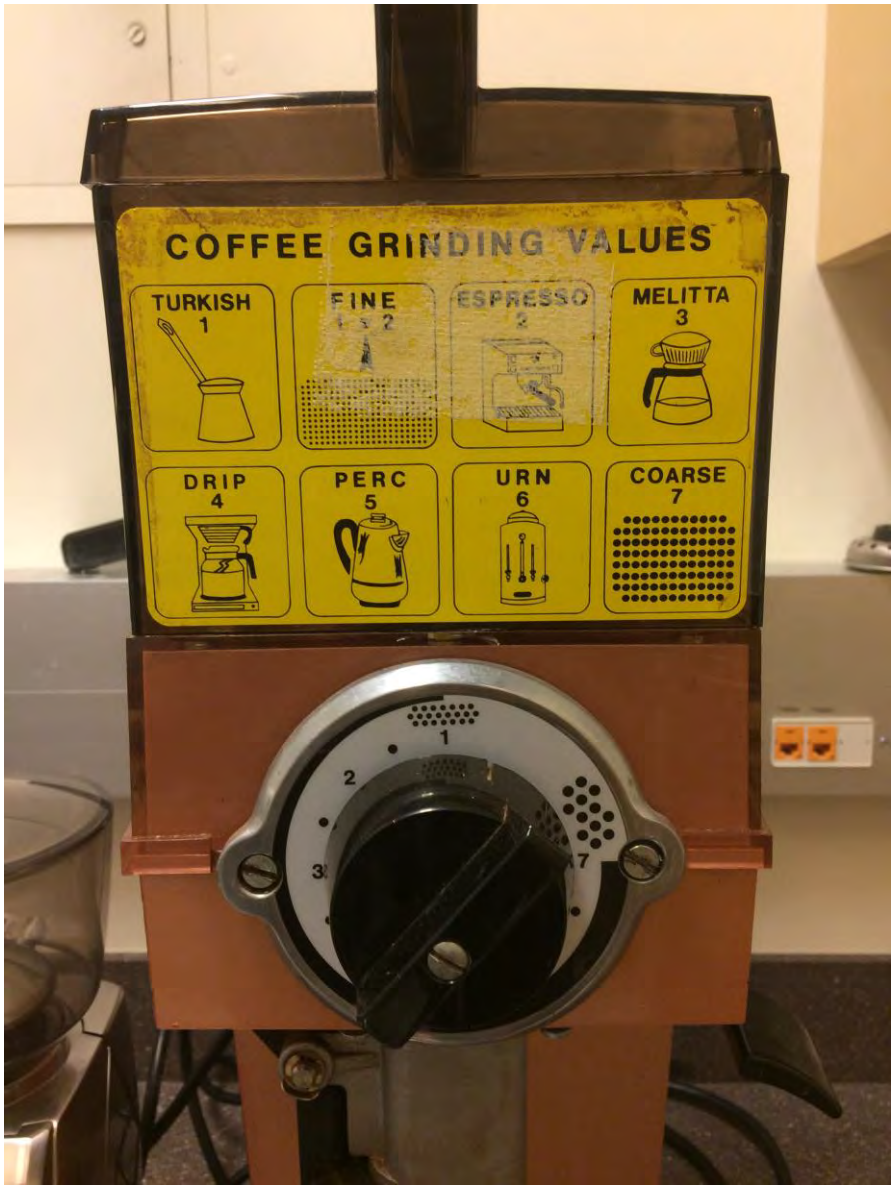
Two in one!

Grind

Two Settings

-Setting 3
“Melitta”

-Setting 5
“Perc”



Descriptive Analysis

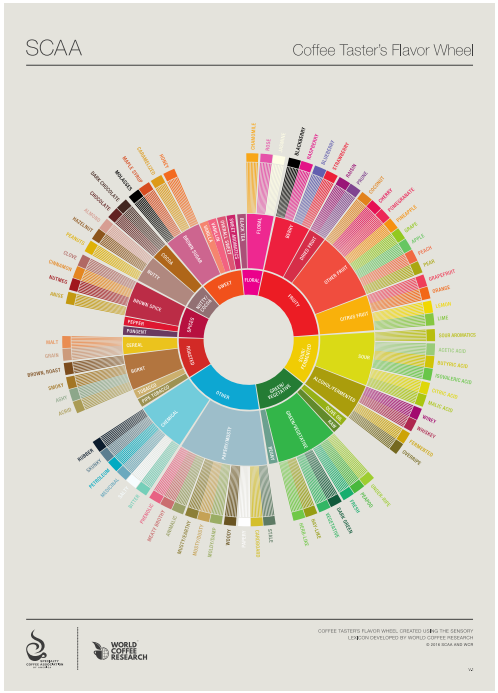
- Applied methodology to collect quantitative measures of similarity and differences in a product set

- Trained judges
- Concise lexicon
- Experimental Design
- Controlled conditions

Descriptive Analysis

Attribute generation

- Judges are blind to the product treatments
- Presented the Coffee Lexicon/ Wheel
- Panel leader remains impartial
- All terminology is panel generated



Descriptive Analysis

Vocabulary alignment through reference standards

Aroma	Ingredient
Floral/ Chamomile	Chamomile tea, dry
Smoke/ Acrid	Wright's Liquid Smoke Mesquite
Flavor	
Berry	Private Selection Triple Berry Preserves
Dried Fruit	Mixture of Sun-Maid Prunes and Prune Juice
Raisin	Sun-Maid Raisins
Citrus	Fresh lemon juice
Whiskey	Jack Daniel's Tennessee Whiskey
Dark Green/ Veg	equal parts juice green bean : spinach : asparagus
Hay-Like	McCormick Parsley Flakes
Musty/Dusty	Kretschmer Wheat Germ
Earthy	Miracle-Gro Potting Mix soil
Tobacco	Camel cigarettes (Turkish and Domestic blend)
Brown Roast	C&H Pure Cane Sugar, Golden Brown
Grain/ Malt	Equal parts Rice Chex, Wheaties and Quaker Quick Oats
Brown Spice	Equal parts cinnamon : nutmeg : clove
Hazlenut	Roast hazelnut oil
Almond	Raw almond slivers
Molasas	Grandma's Original Molasses, unsulphured, in water
Chocolate	Toll House semi-sweet morsels
Cocoa	Hershey's Cocoa Powder Natural Unsweetened, in water
Wood	popsicle sticks
Burnt Wood/ Ash	wood ash
Rubber	rubber bands

Descriptive Analysis

- In the booth for data collection
- Each Judge evaluates all coffees in triplicate

Descriptive Analysis Service

12 judges
3 replications of each coffee
26 taste and aroma attributes were evaluated
Coffee brewed and served in series
TDS, Extraction Percent, and temperature measures

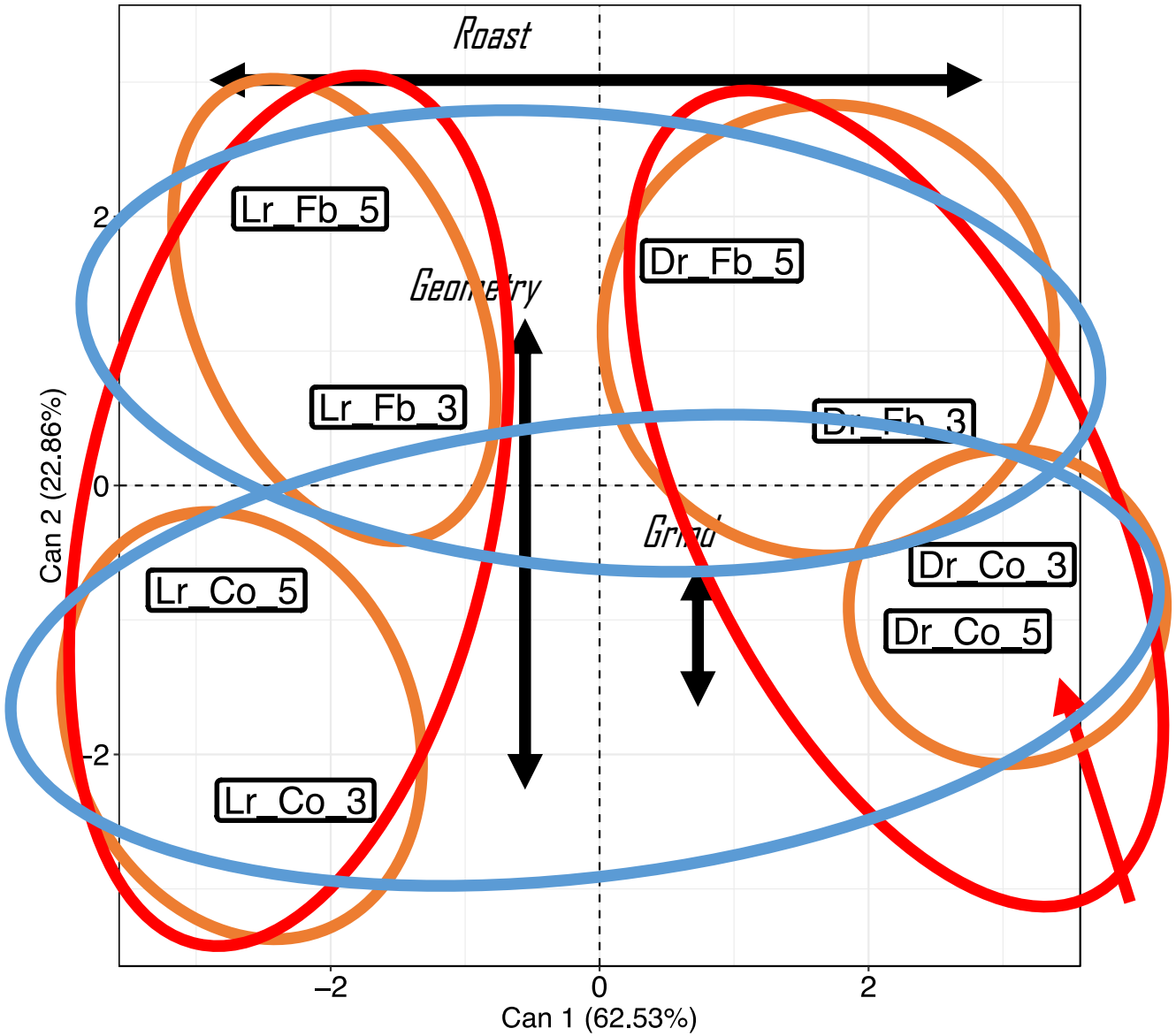
Raw Descriptive Analysis Data

Format Formatting as Table Styles

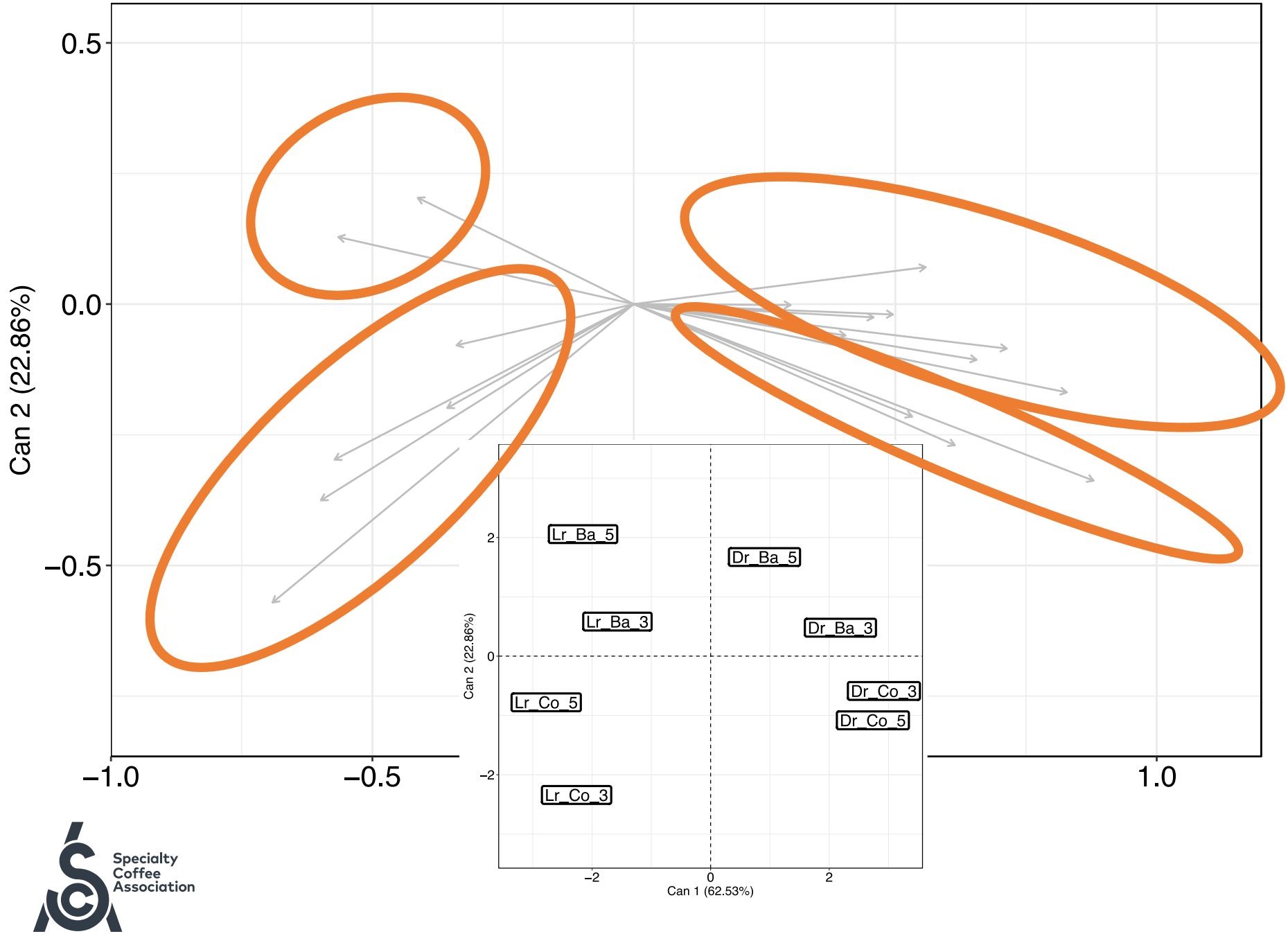
J1 fx Coffee

	A	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	Subject_Code	SampleName	Floral_A	Smoke_A	Berry_F	DriedFruit_F	Raisin_F	Citrus_F	DarkGreen_F	HayLike_F	MustyDusty_F	Earthy_F	Tobacco_F	BrownRoast_F	GainMal
2	alb	Light Roast Cone Gr3	16	43	11	11	11	32	12	10	31	37	11	51	52
3	hue	Light Roast Cone Gr3	41	72	50	22	53	69	18	30	4	24	15	39	5
4	lim	Light Roast Cone Gr3	17	29	1	25	8	15	19	0	32	0	1	9	4
5	irb	Light Roast Cone Gr3	31	59	16	19	16	14	14	13	28	24	65	52	21
6	zho	Light Roast Cone Gr3	23	14	33	10	9	15	62	13	34	18	10	10	20
7	alb	Dark Roast Cone Gr3	20	31	10	10	10	10	25	24	51	62	29	67	21
8	hue	Dark Roast Cone Gr3	13	62	35	55	58	12	3	22	5	47	57	41	46
9	lim	Dark Roast Cone Gr3	0	45	0	3	0	1	12	1	36	6	15	0	26
10	irb	Dark Roast Cone Gr3	33	63	15	16	18	15	15	16	17	41	87	61	17
11	zho	Dark Roast Cone Gr3	31	36	8	30	19	9	36	29	19	26	10	21	10
12	alb	Dark Roast Basket Gr3	27	13	10	10	10	10	18	10	18	16	10	42	45
13	hue	Dark Roast Basket Gr3	87	29	82	27	17	19	4	5	27	32	51	22	12
14	lim	Dark Roast Basket Gr3	5	32	5	13	1	0	17	11	14	19	22	2	15
15	irb	Dark Roast Basket Gr3	30	67	21	50	22	17	66	27	31	48	39	57	20
16	zho	Dark Roast Basket Gr3	12	49	20	37	10	10	30	19	31	38	37	23	10
17	alb	Light Roast Cone 5	64	10	16	26	17	51	10	10	10	24	10	25	10
18	hue	Light Roast Cone 5	88	27	49	60	16	29	9	13	3	22	33	45	15
19	lim	Light Roast Cone 5	34	15	17	25	18	19	3	4	5	7	1	23	2
20	irb	Light Roast Cone 5	89	35	32	62	32	17	46	25	12	42	11	28	19
21	zho	Light Roast Cone 5	34	34	13	11	9	34	14	16	28	28	17	23	10
22	alb	Dark Roast Cone 5	66	20	10	10	10	10	15	10	25	24	10	32	22
23	hue	Dark Roast Cone 5	39	85	44	7	5	25	16	13	4	38	56	51	71
24	lim	Dark Roast Cone 5	3	26	5	12	2	1	18	18	31	10	3	8	19
25	irb	Dark Roast Cone 5	30	67	21	17	16	18	17	31	55	26	73	47	18
26	zho	Dark Roast Cone 5	13	61	15	10	29	7	11	17	44	43	10	10	17
27	alb	Light Roast Basket Gr5	23	11	10	10	10	10	46	19	11	31	10	27	18
28	hue	Light Roast Basket Gr5	61	43	76	39	32	44	14	4	5	33	15	83	45
29	lim	Light Roast Basket Gr5	29	28	14	14	5	2	19	14	13	21	0	0	9
30	irb	Light Roast Basket Gr5	64	25	24	66	35	36	26	33	14	32	19	59	28
31	zho	Light Roast Basket Gr5	40	27	8	9	11	35	18	9	9	16	5	18	17
32	mas	Dark Roast Cone Gr3	30	38	19	17	21	17	18	29	27	48	56	44	28
33	wei	Dark Roast Cone Gr3	16	36	5	17	4	6	33	28	51	27	33	51	34

Canonical Variate Analysis (CVA)



Lr = Light Roast
Dr = Dark Roast
Co = Conical
Fb = Flat Bottom
3 = Setting 3
5 = Setting 5



Specialty Coffee Association

Factor analysis

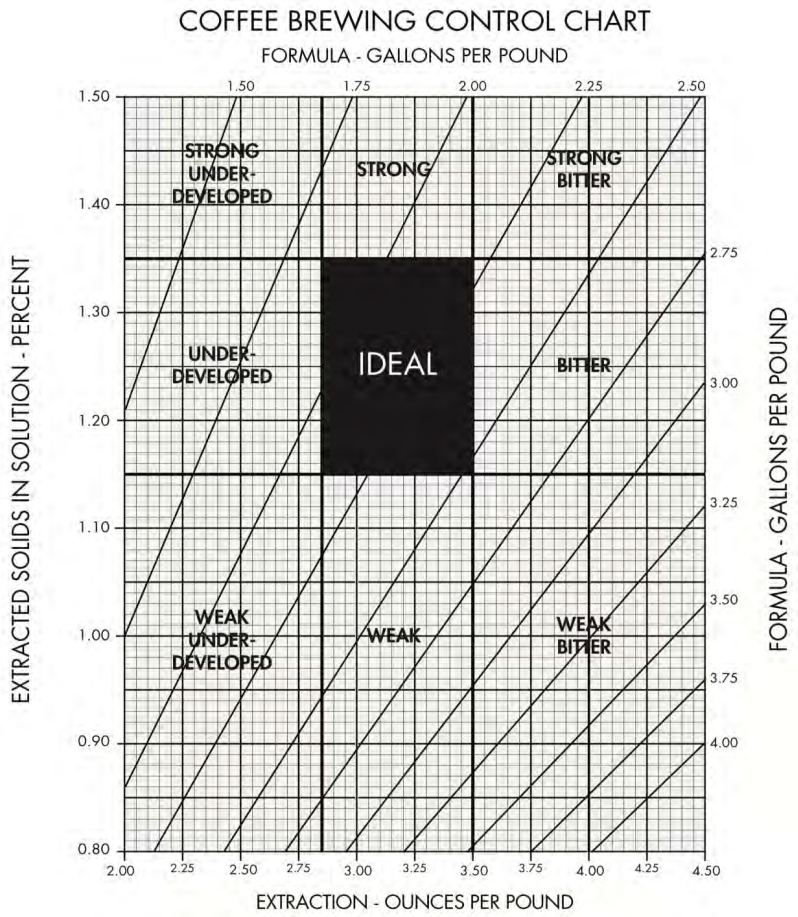
Roast	Floral	Smoke	Berry	DriedFruit	Raisin	Citrus	HayLike	MustyDusty	Earthy	Tobacco
Dark Roast	31.2	46.0	16.6	17.0	14.8	15.0	23.6	29.8	35.2	25.0
Light Roast	39.2	32.0	28.9	23.7	20.3	29.2	18.4	19.3	21.8	15.2

	Molasas	Chocolate	Cocoa	Wood	BurntWoodAsh	Rubber	Sweet	Sour	Bitter
Dark Roast	19.4	28.5	24.2	27.6	40.6	26.3	19.5	22.4	53.9
Light Roast	23.0	20.6	19.3	18.7	19.3	15.4	27.8	40.0	27.7

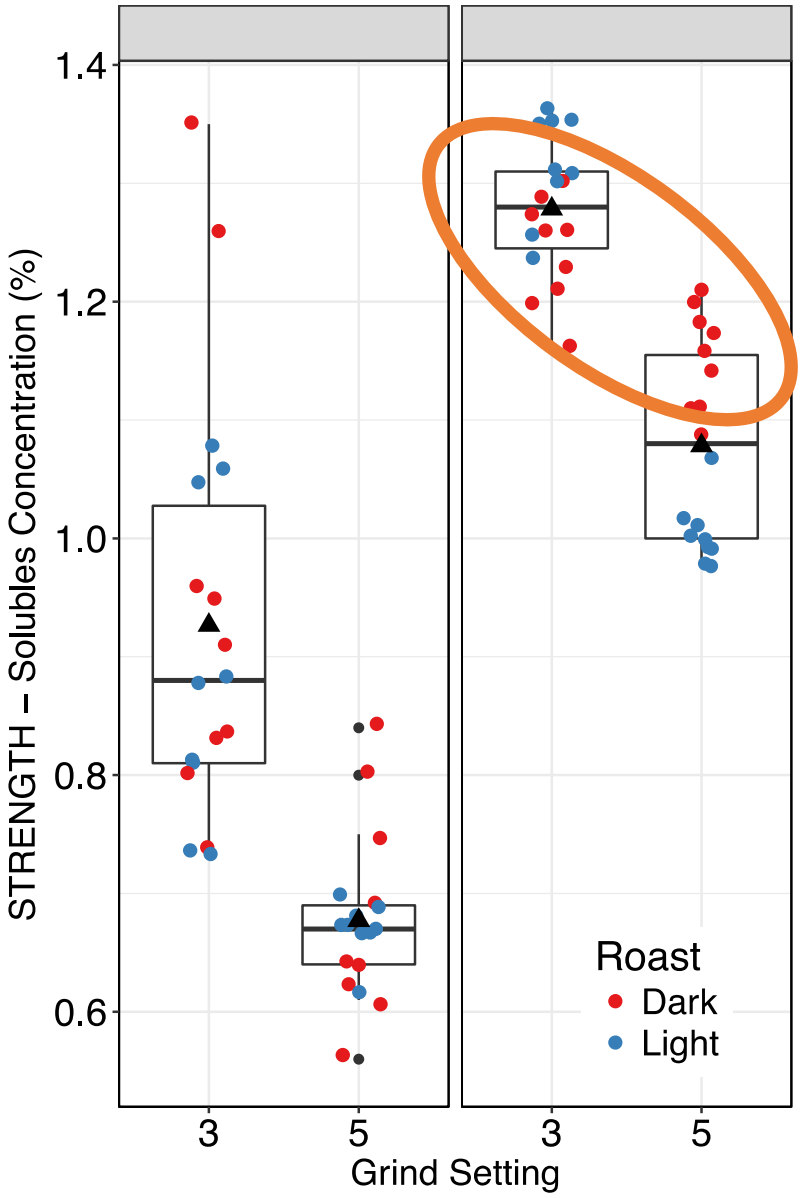
Geometry	Citrus	Tobacco	BurntWoodAsh	Rubber	Sweet	Sour	Bitter
Basket	19.5	17.0	27.3	19.0	25.3	26.5	34.7
Cone	24.7	23.3	32.6	22.7	22.0	35.9	46.9

Grind	Smoke	BrownRoast	Cocoa	BurntWoodAsh	Bitter
Grind 3	41.3	33.8	23.6	32.5	45.5
Grind 5	36.8	28.4	19.9	27.4	36.1

What about the Brewing Control Chart?



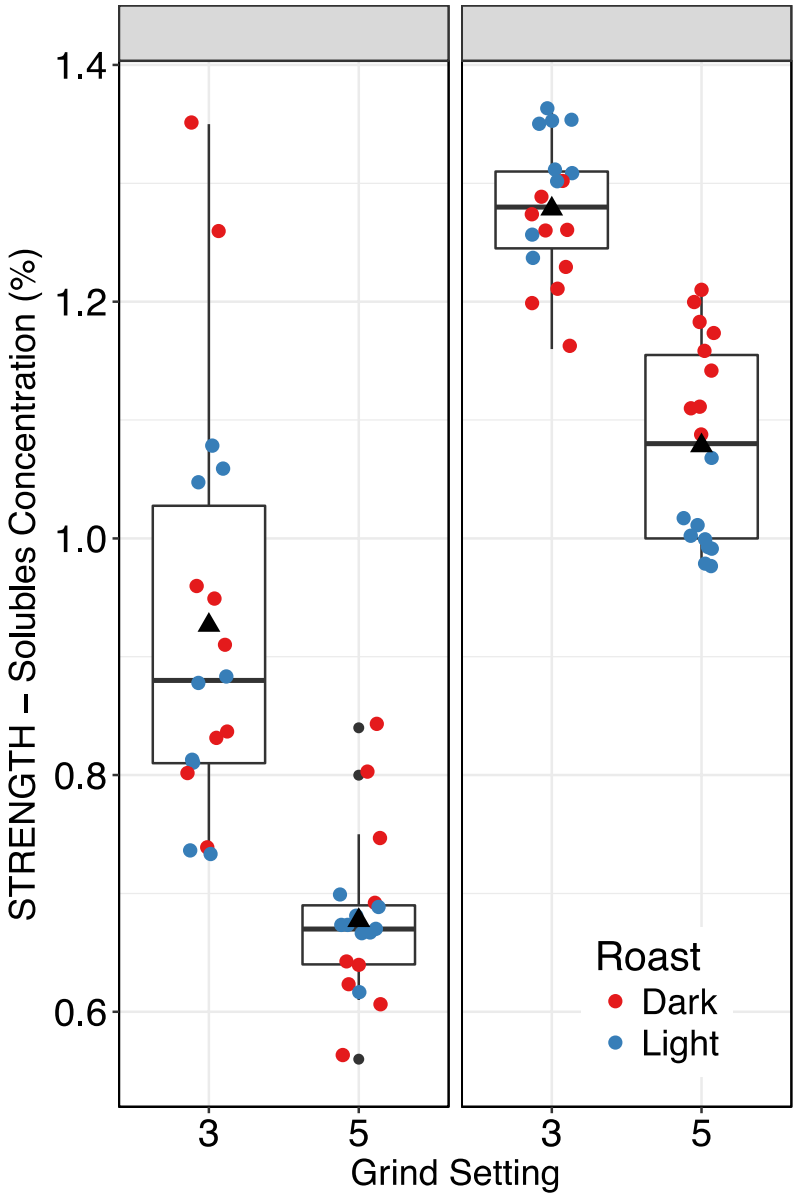
TDS measures



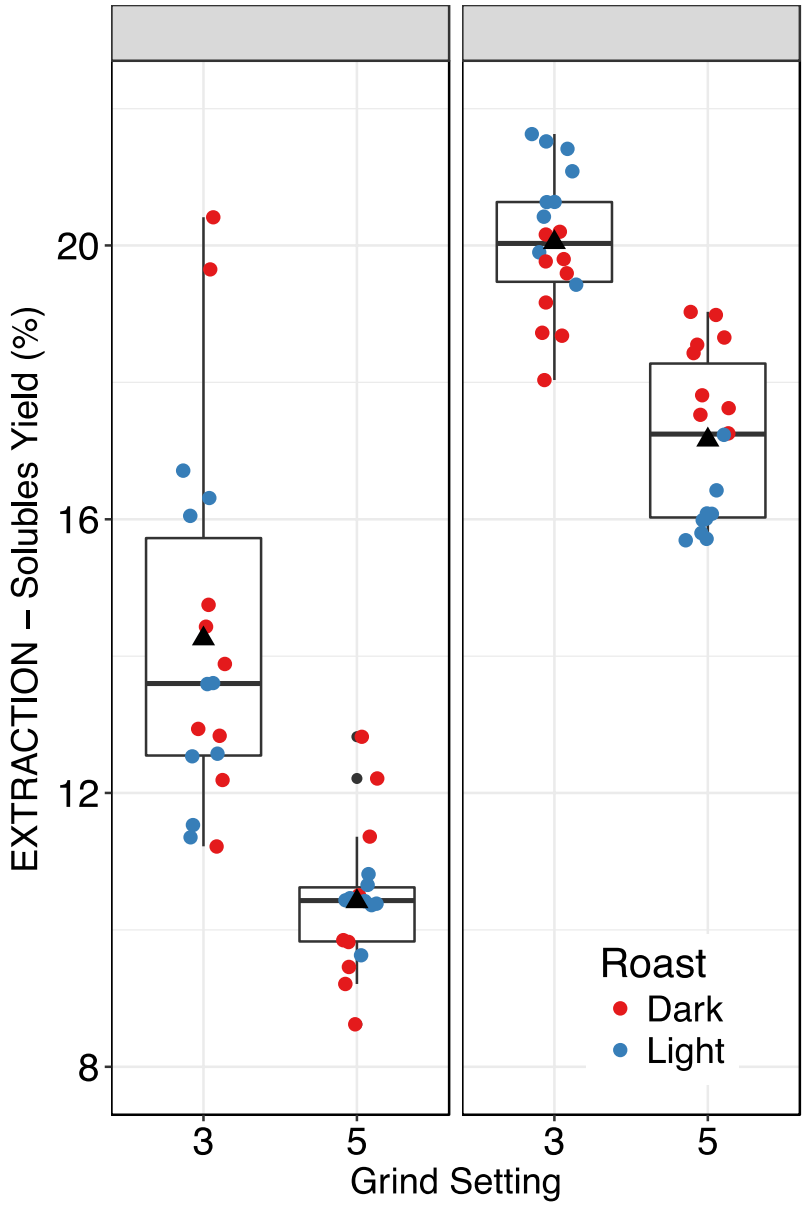
9 measures per coffee
72 total measures

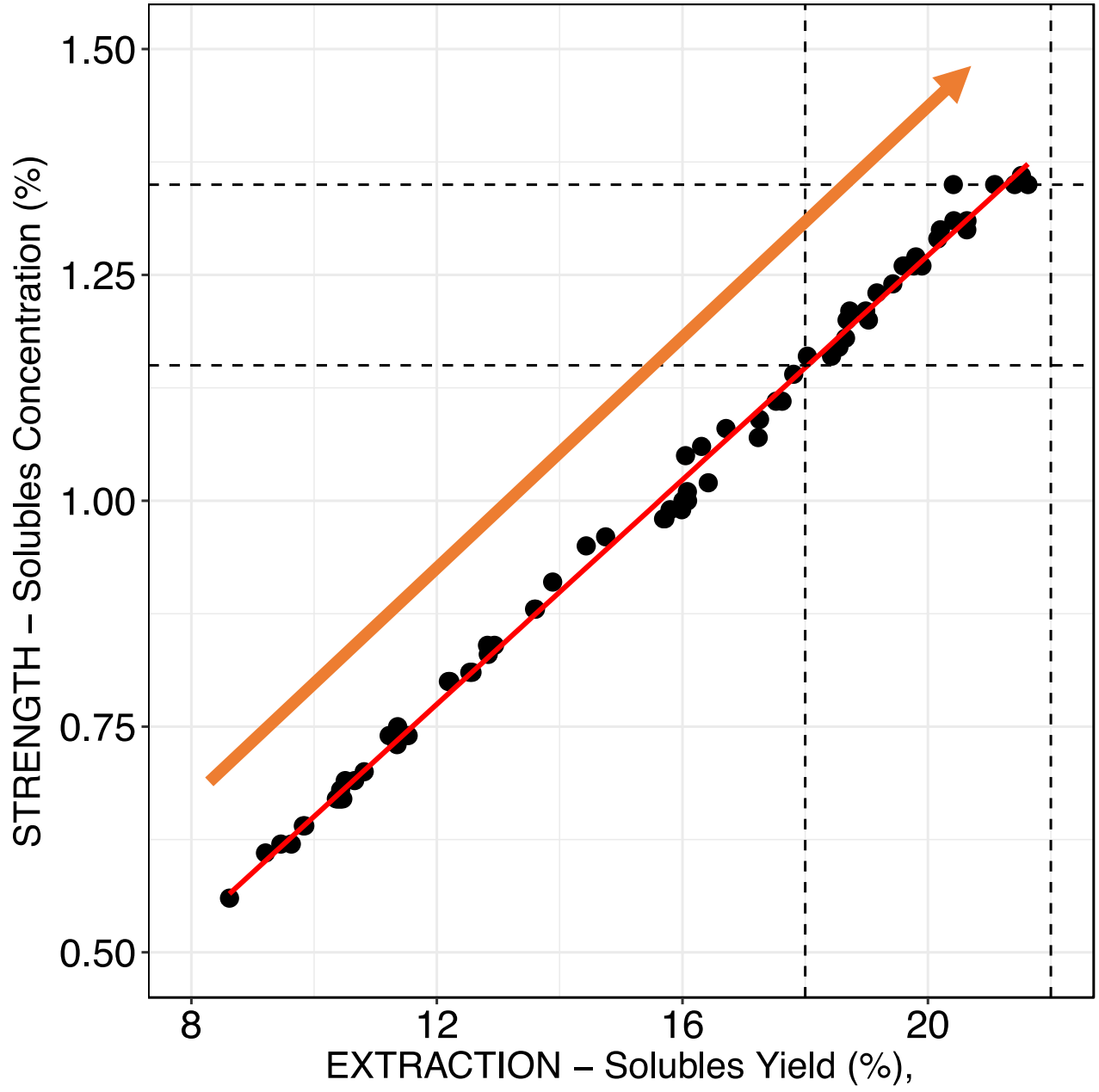
Grind showed a small effect on TDS for Dark Roast, but a Large effect by Light Roast

TDS measures



Percent Extraction

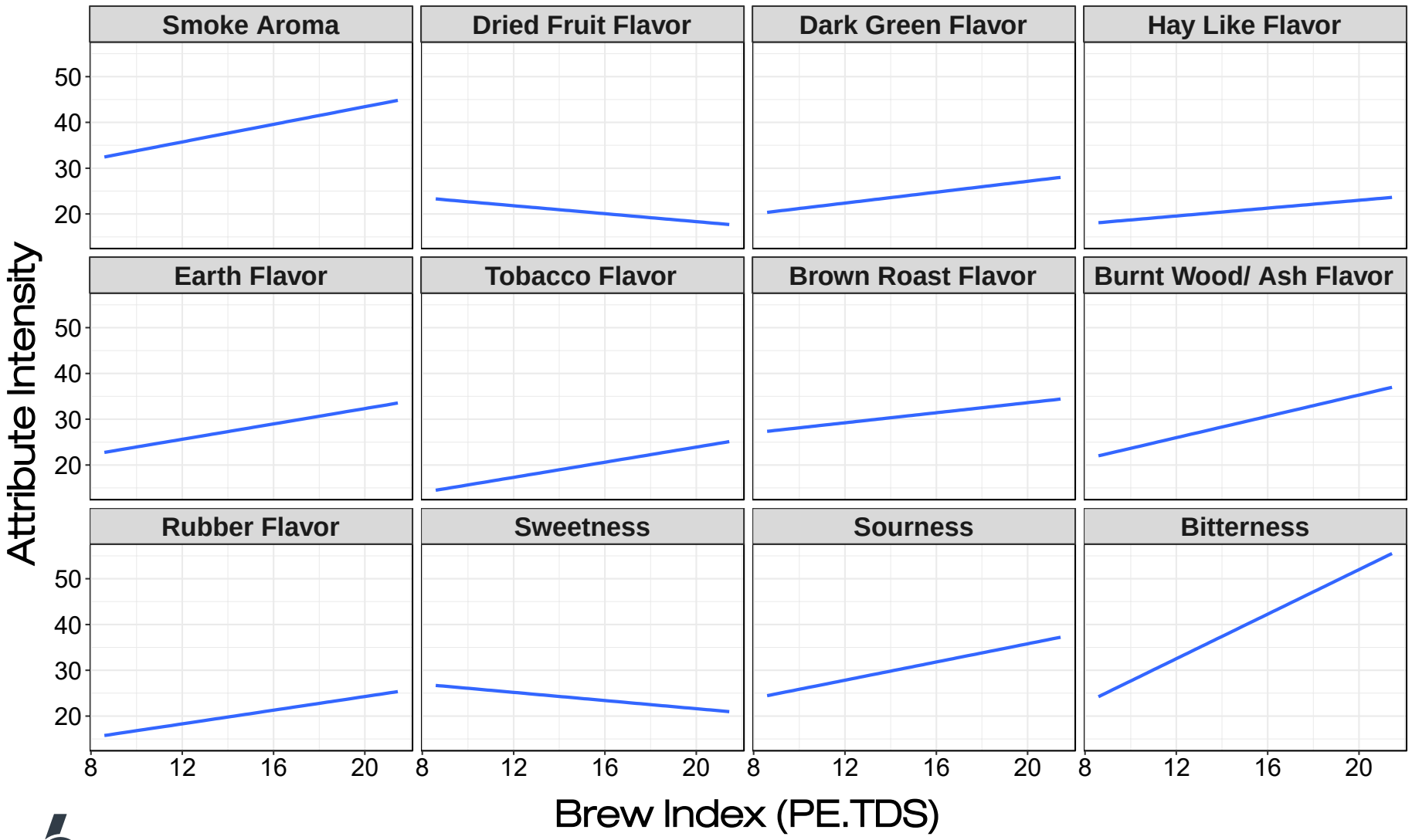




How do the measured attributes change with TDS, PE?

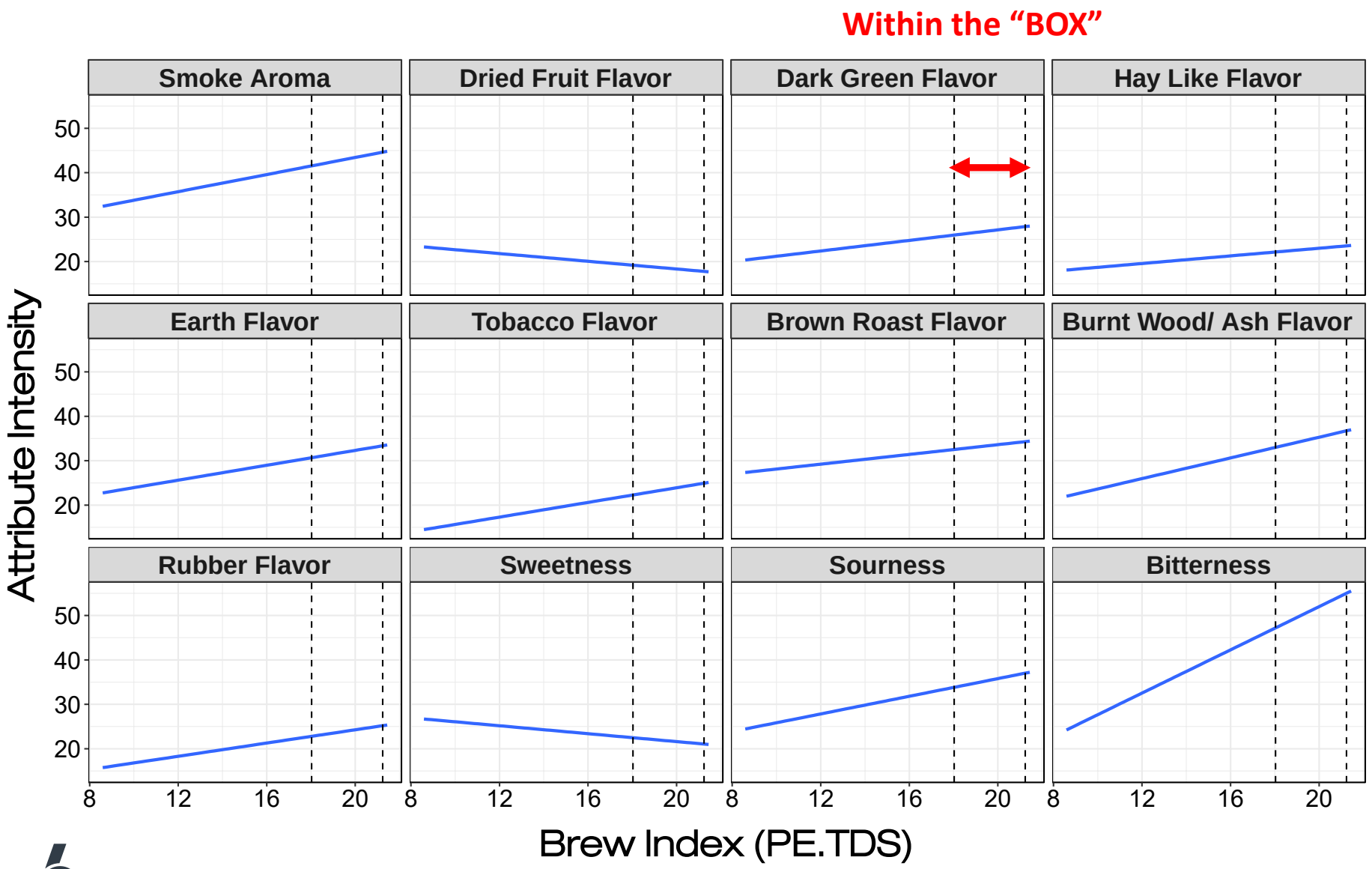
"Brew Index"

Significant Changes with Brewing Index



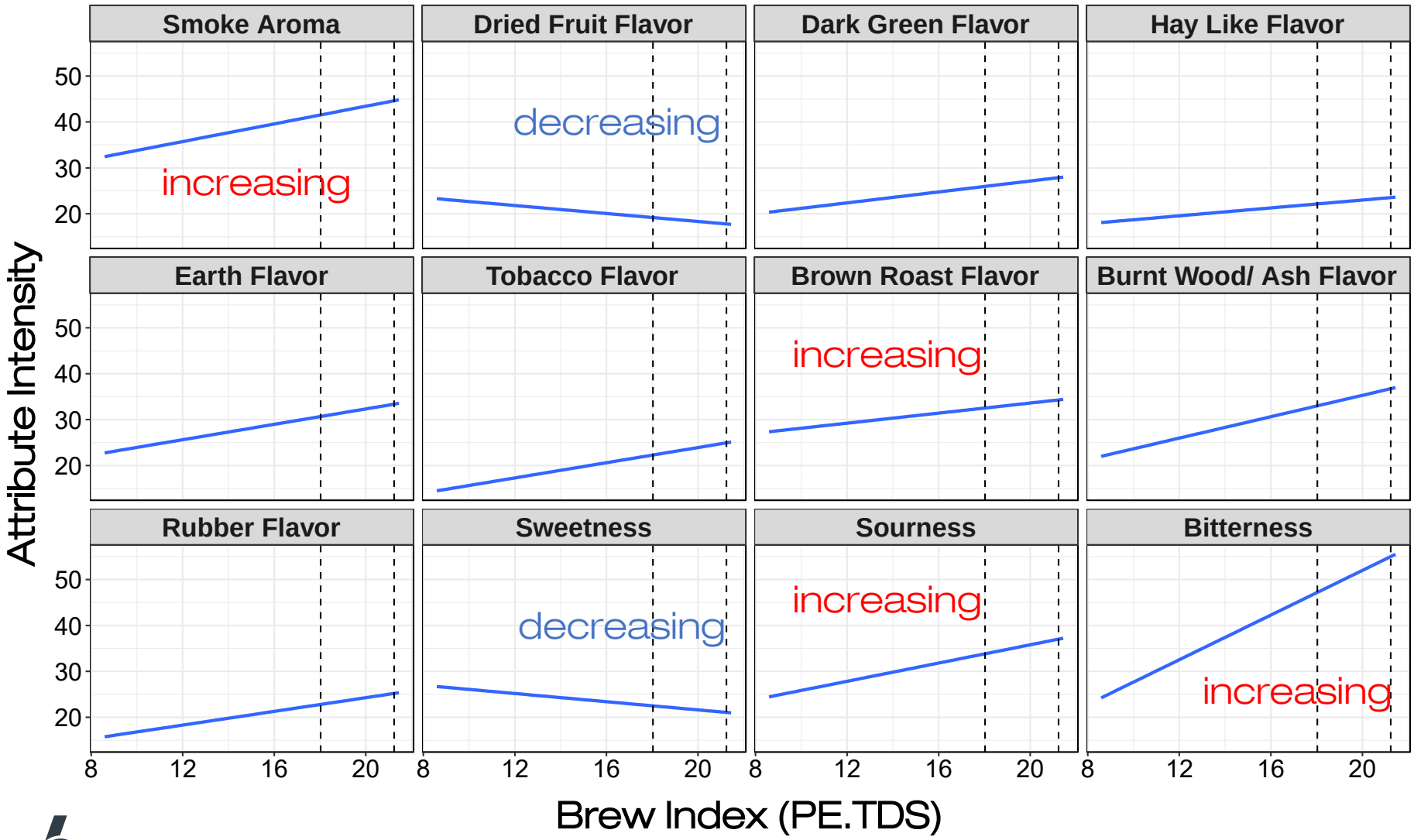
Specialty Coffee Association

Significant Changes with Brewing Index



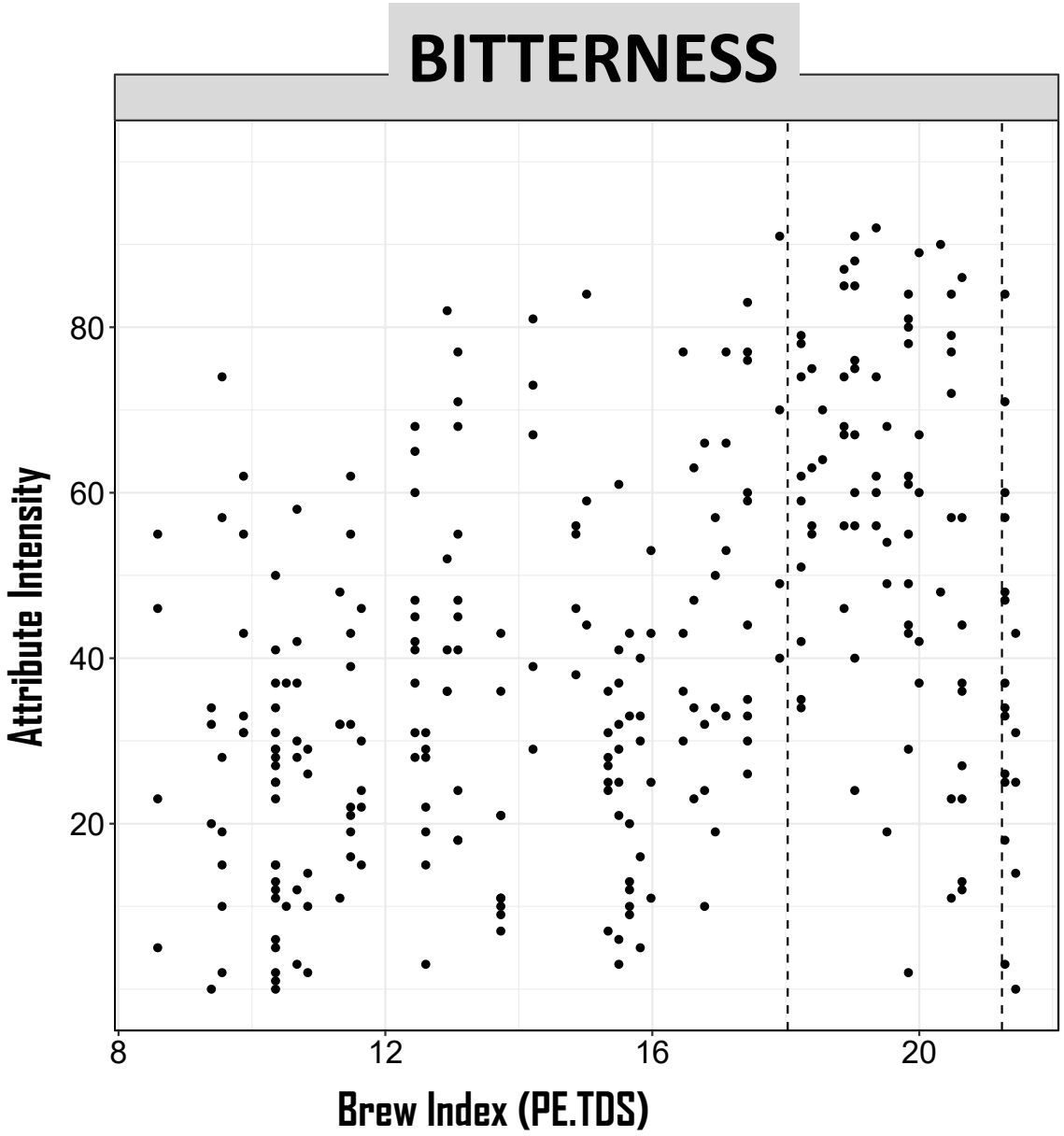
Specialty Coffee Association

Significant Changes with Brewing Index



Specialty Coffee Association

Significant Changes with Brewing Index



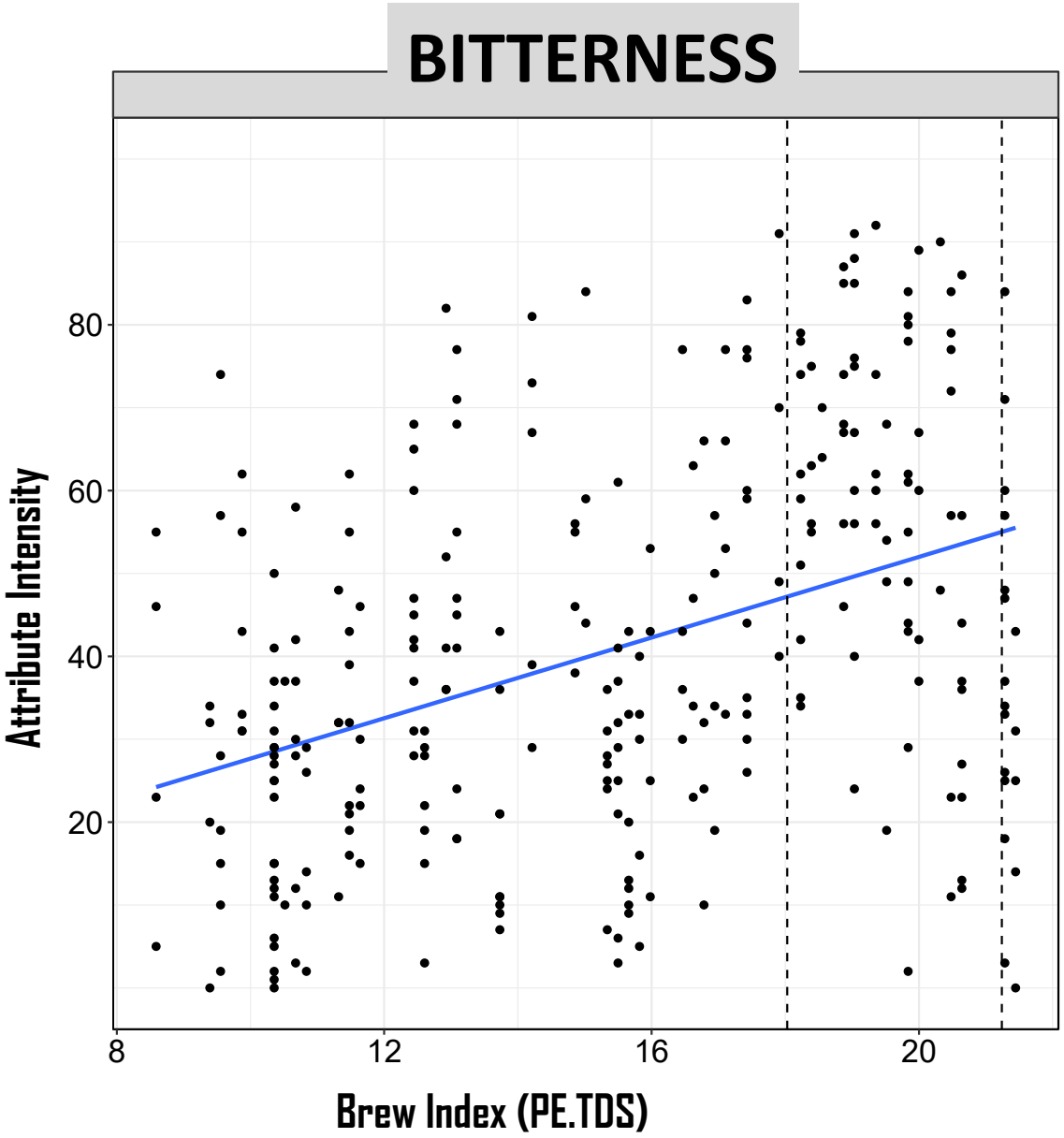
12 Judges

3 tasting replicates

8 coffees

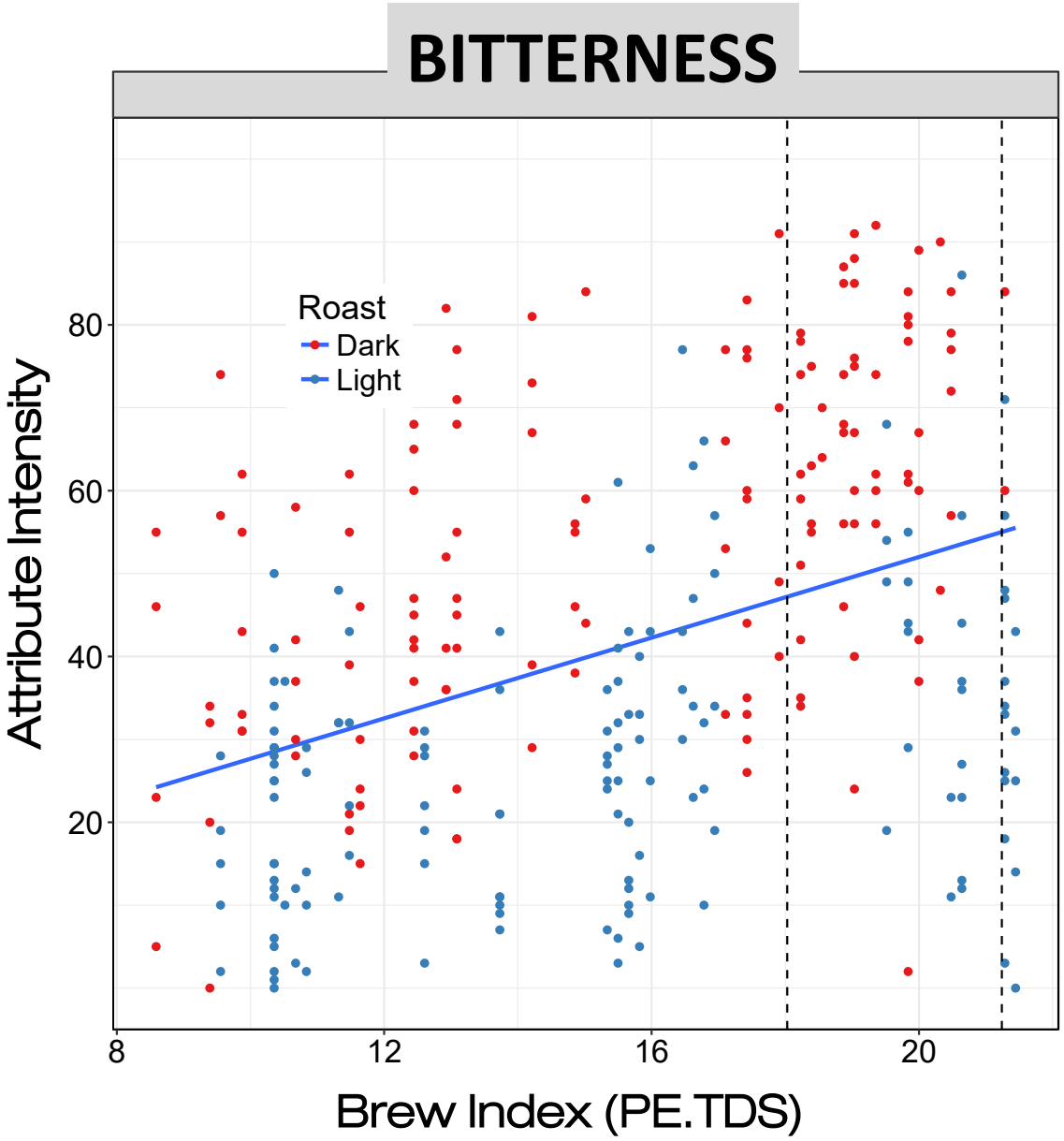
288 values

Significant Changes with Brewing Index



Significant correlation r=0.40

Significant Changes with Brewing Index

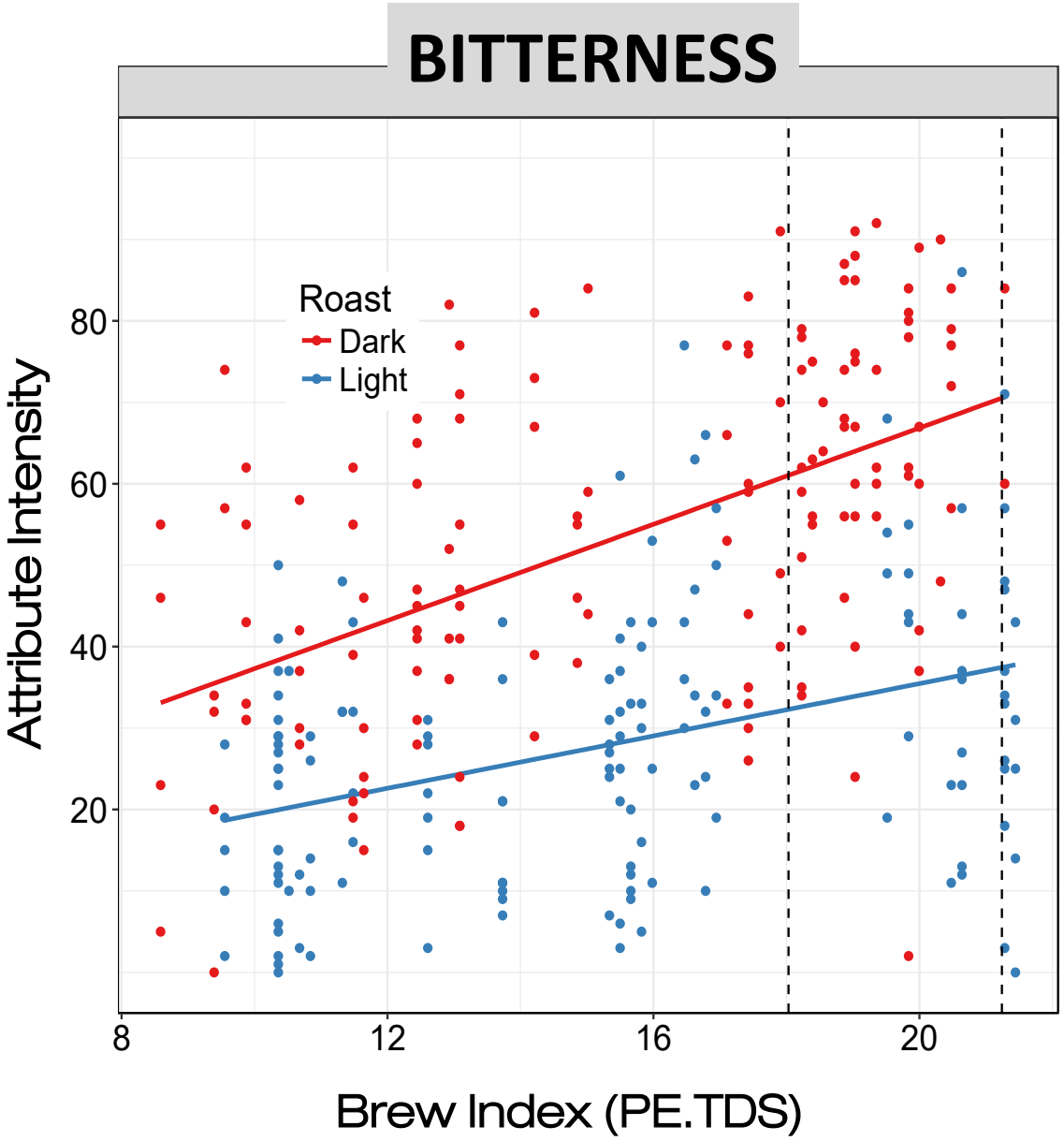


Color by ROAST

RED = Dark Roast

BLUE = Light Roast

Significant Changes with Brewing Index



Color by ROAST

RED = Dark Roast

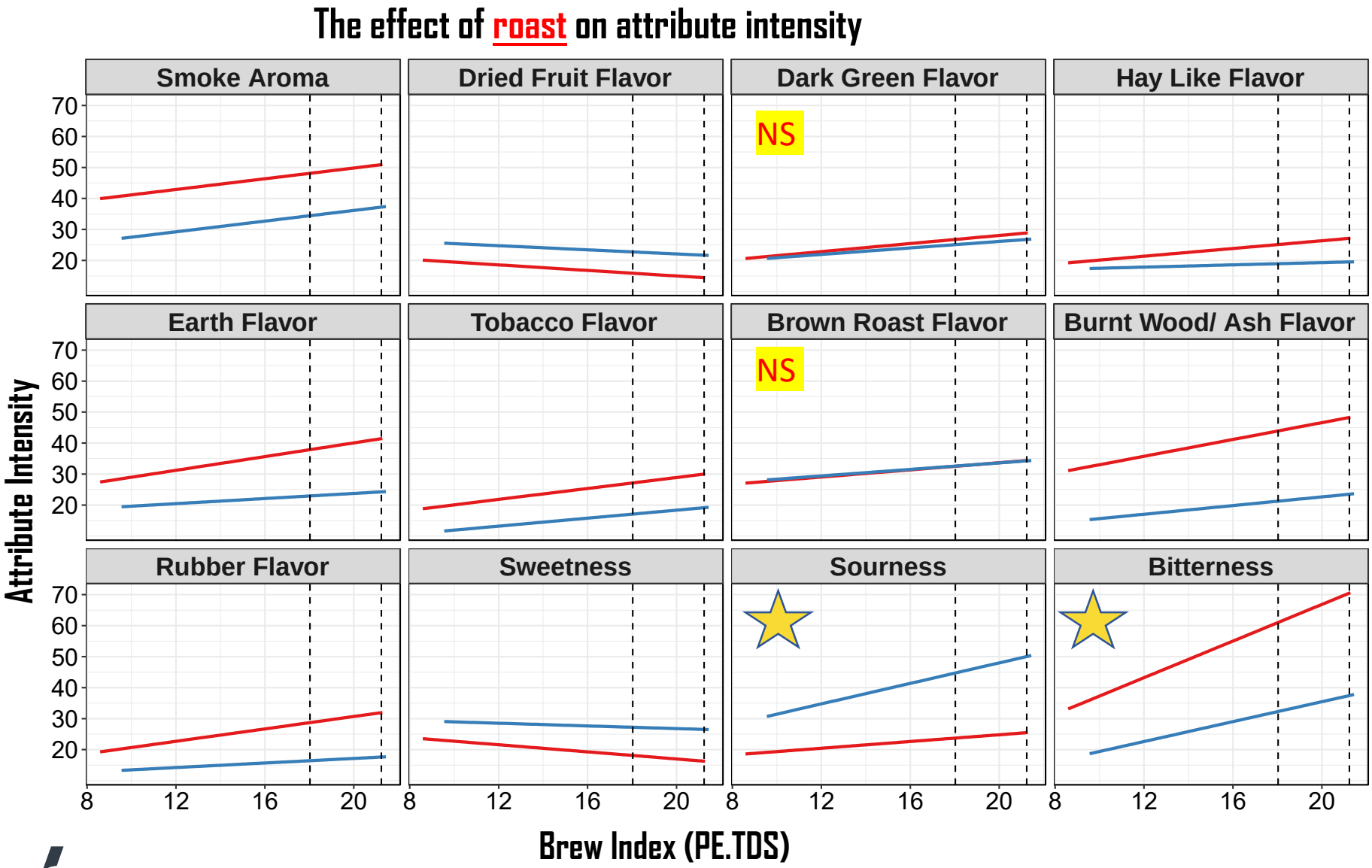
BLUE = Light Roast

Significant correlation

Dark Roast r = 0.52

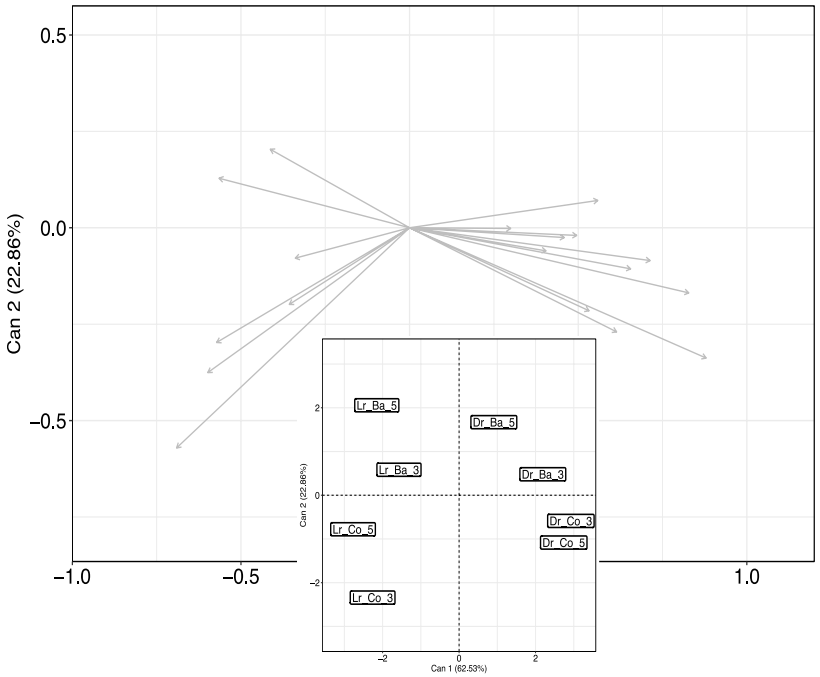
Light Roast r = 0.36

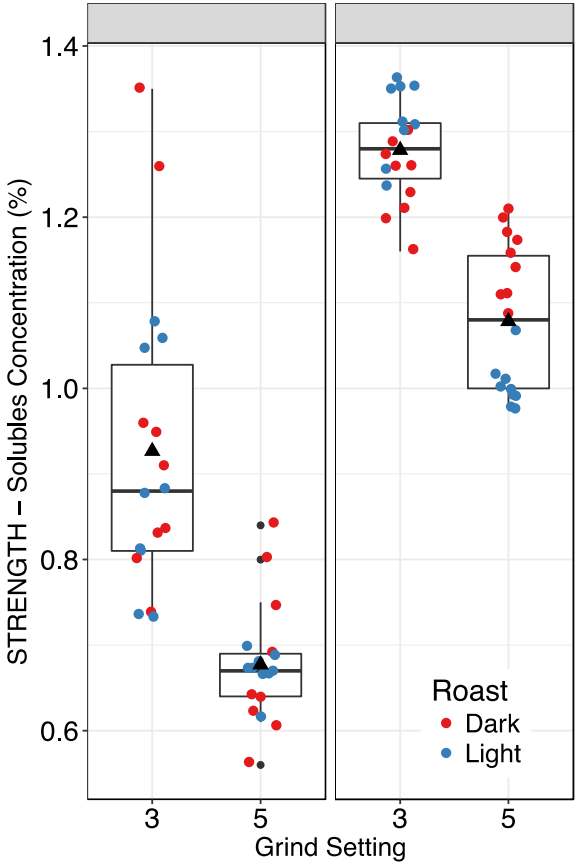
Significant Changes with Brewing Index



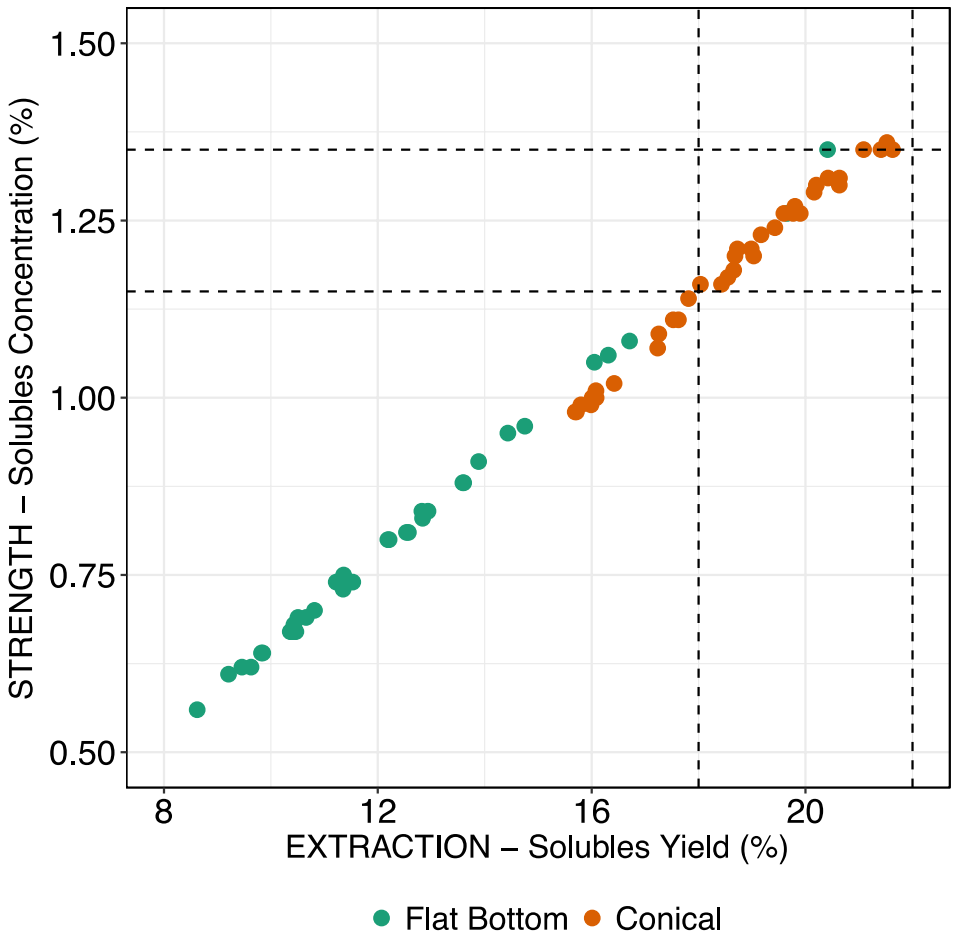
Conclusions : Roast

Roast:
Driver of sensory
Each attribute showed a different relationship with the Brew Index





Conclusions : Geometry



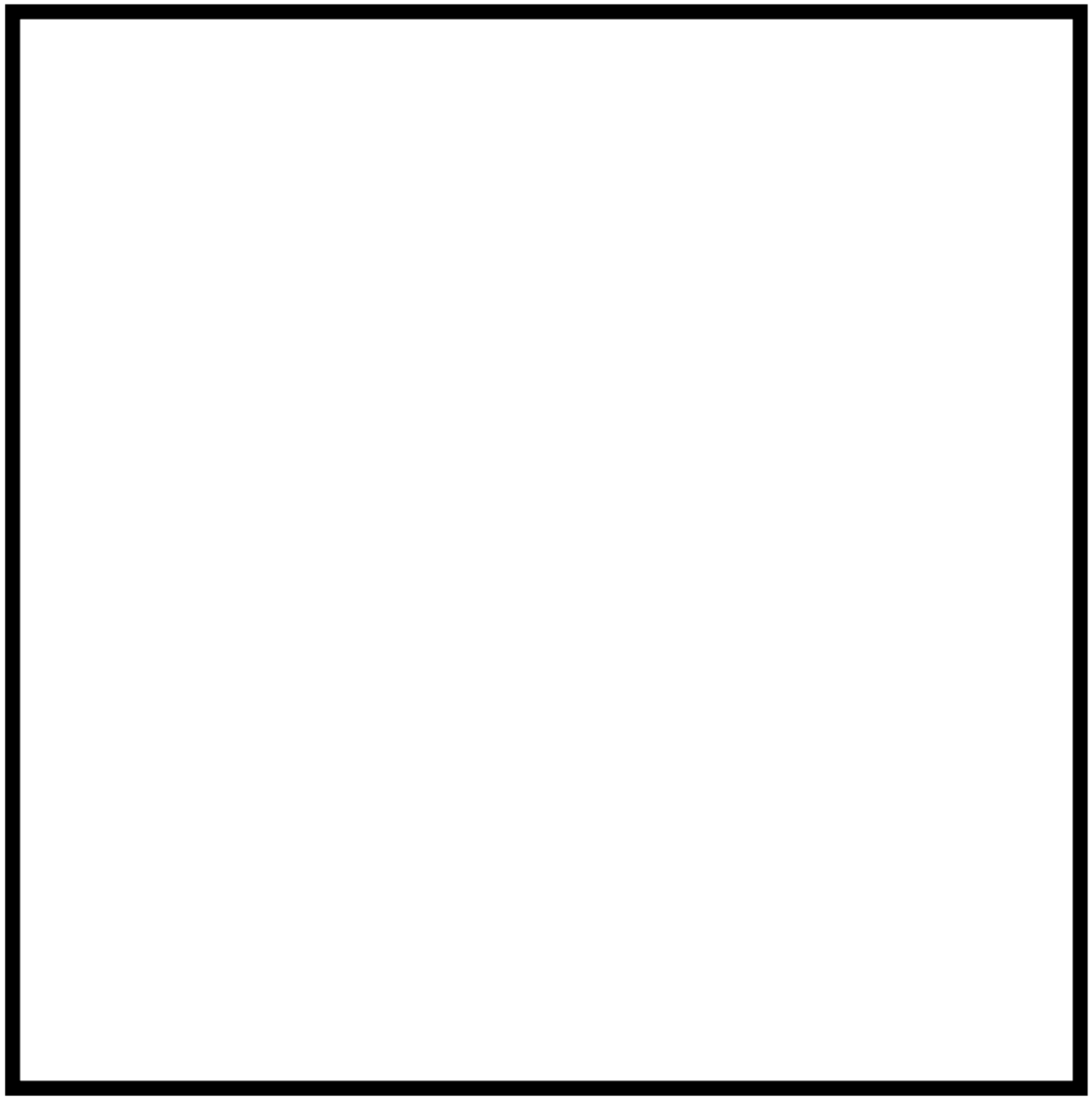
Geometry:
Significant effect on Brew Index and resulting sensory

Conical, higher TDS vs Flat bottom

Wide distribution with the Flat Bottom

Need for more **RESEARCH!**

What about the Chart……



Acknowledgements

We Thank the Specialty Coffee Association and Breville Corporation for their support!!

THE UCD COFFEE CENTER!

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Samir Akre
Reece Guyon
Dr. Jean-Xavier Guinard
Dr. William Ristenpart

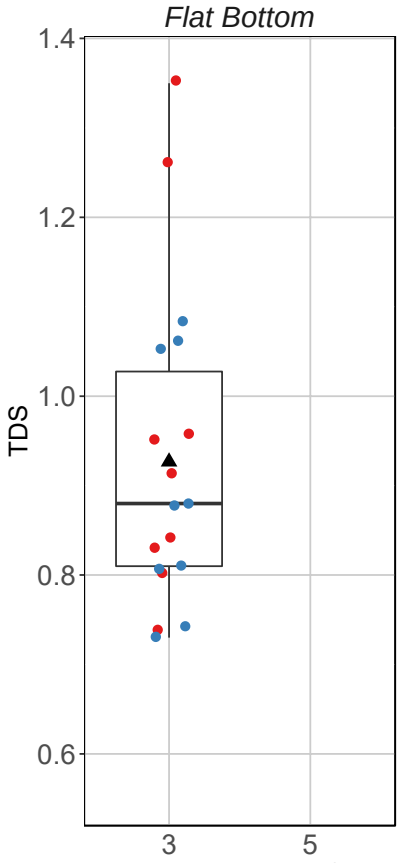
UCDAVIS COFFEE CENTER

Breville

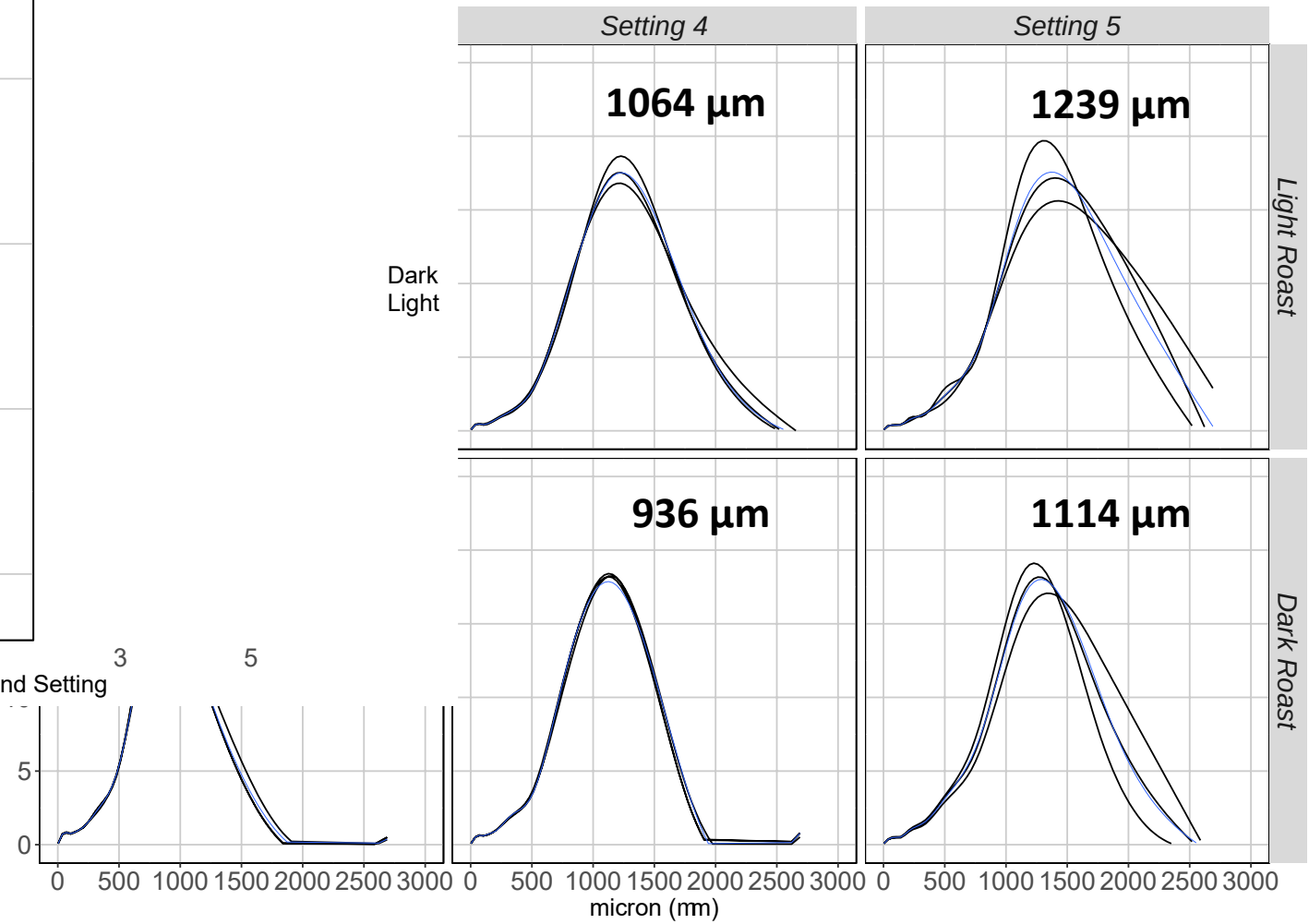
Specialty Coffee Association

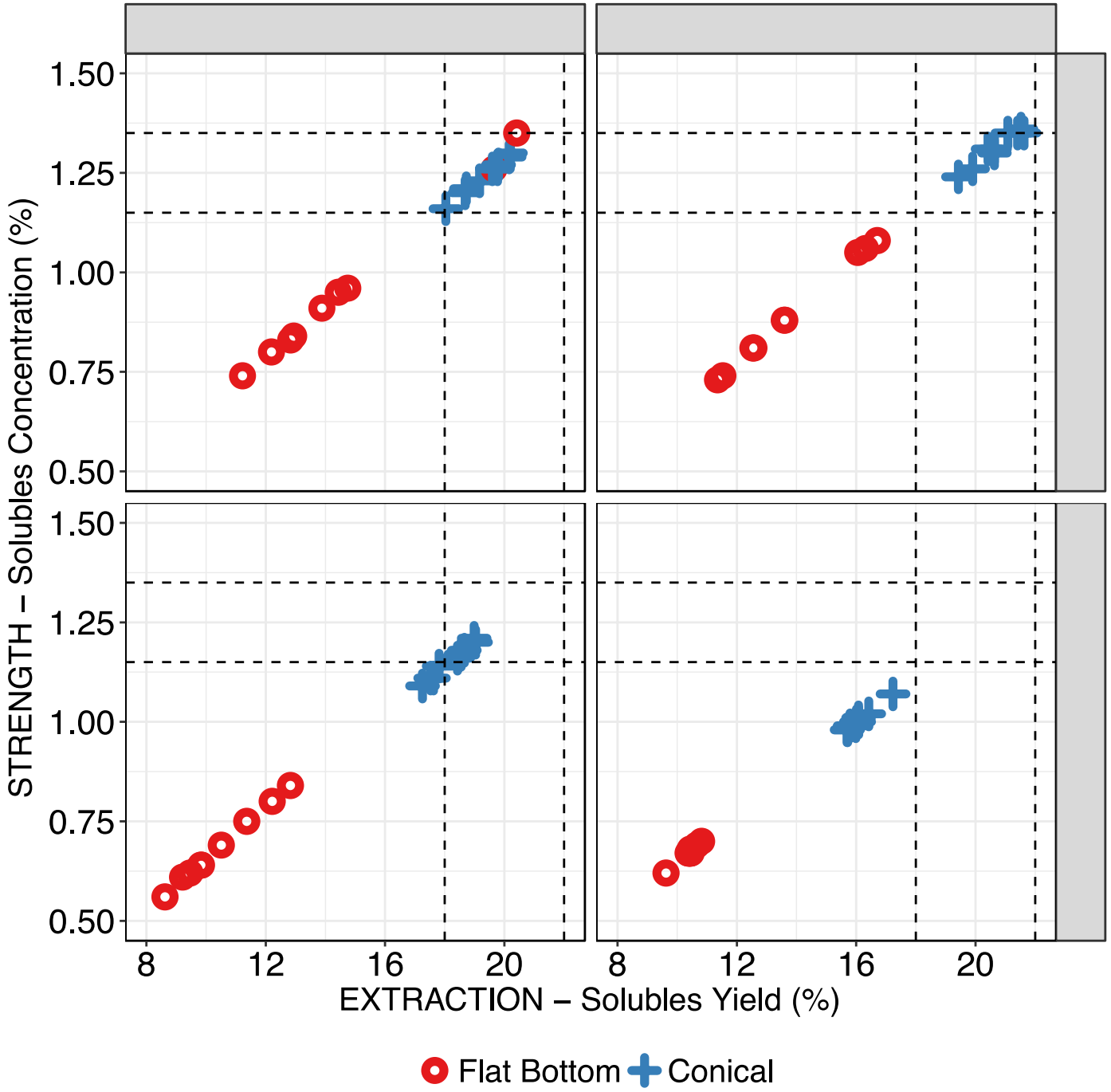

Specialty
Coffee
Association

istribution

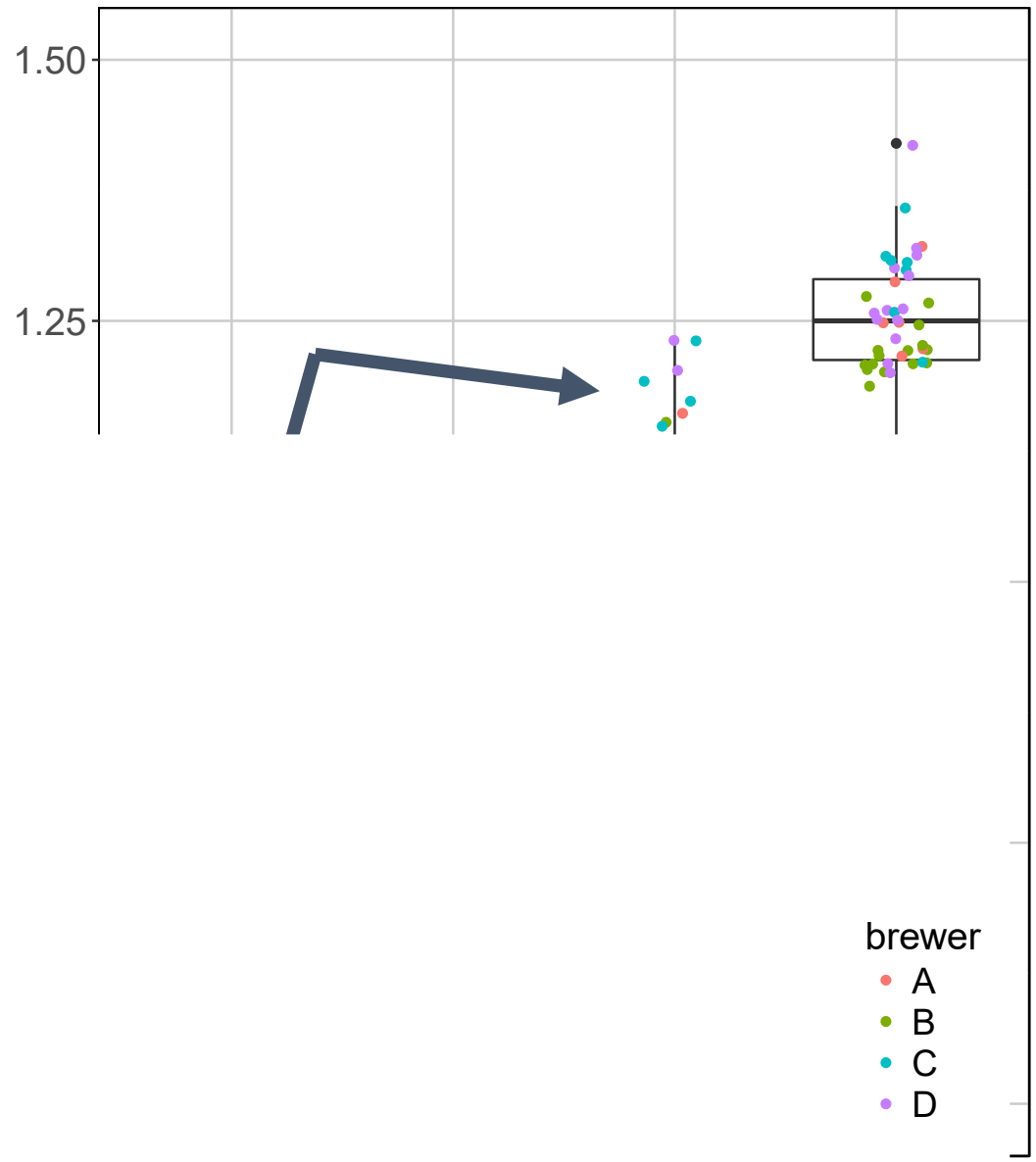


LDA



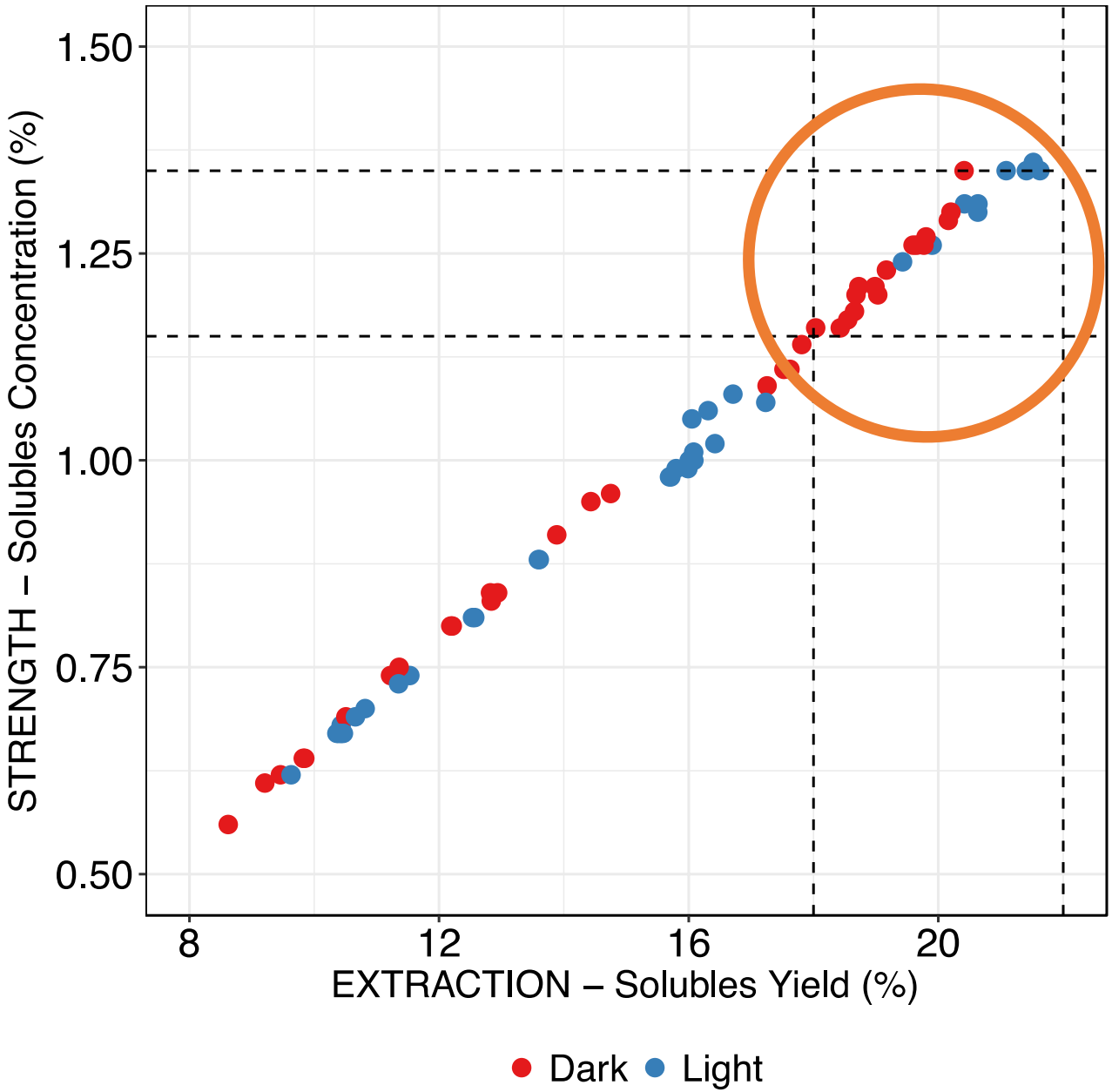

1.50
1.25
1.00
0.75
0.50
STRENGTH – Solubles Concentration (%)
8
12
16
20
EXTRACTION – Solubles Yield (%)
Flat Bottom
Conical

TDS of each brewed coffee



TDS measures

- 42 measures per treatment
- Mean TDS measures were significantly different
- Smaller grind yielded higher TDS
- Flat bottom yielded lower TDS than conical

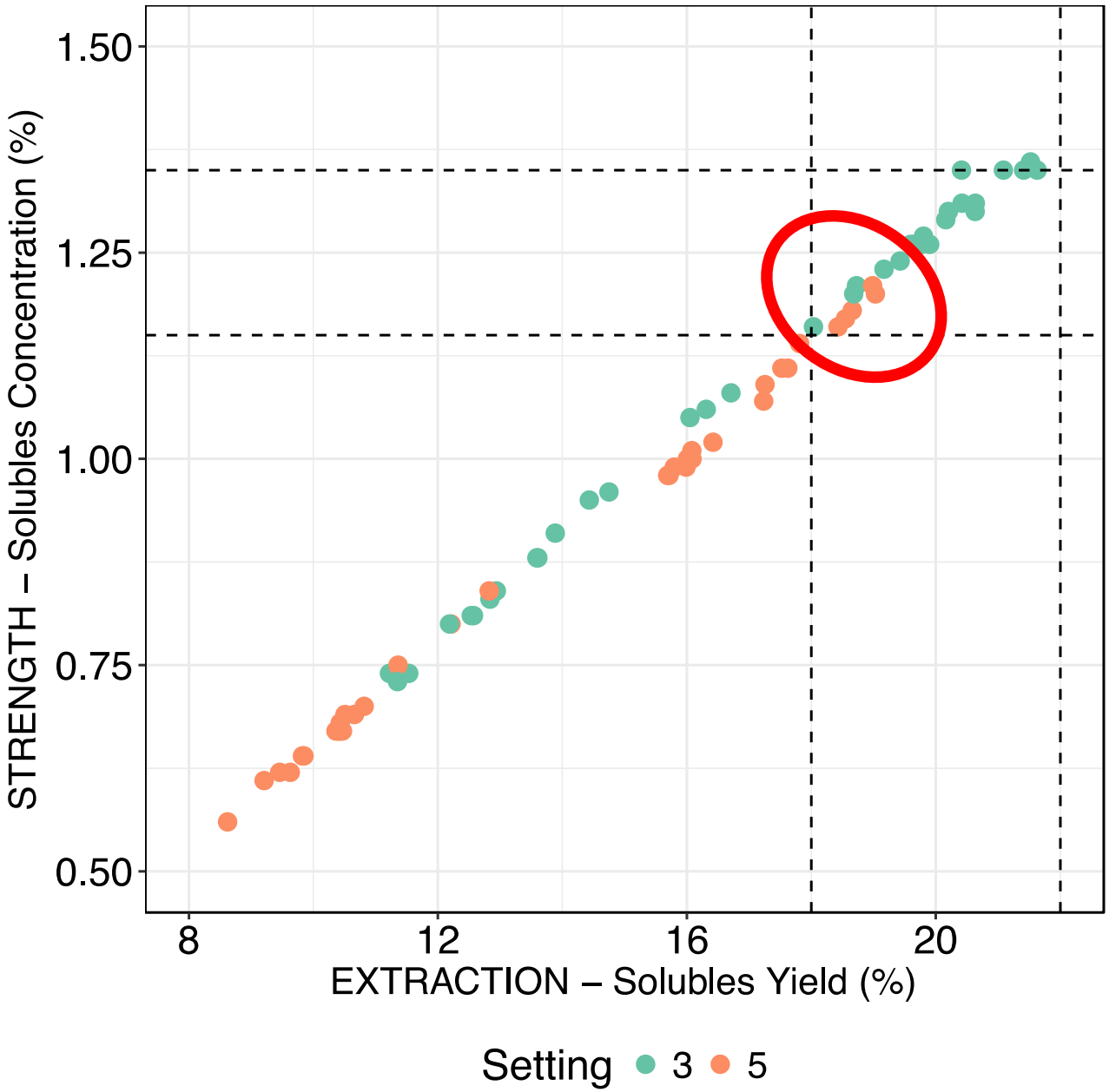


Color by ROAST

RED = Dark Roast

BLUE = Light Roast

36 measures at each roast



Color by GRIND

Aqua = Dark Roast

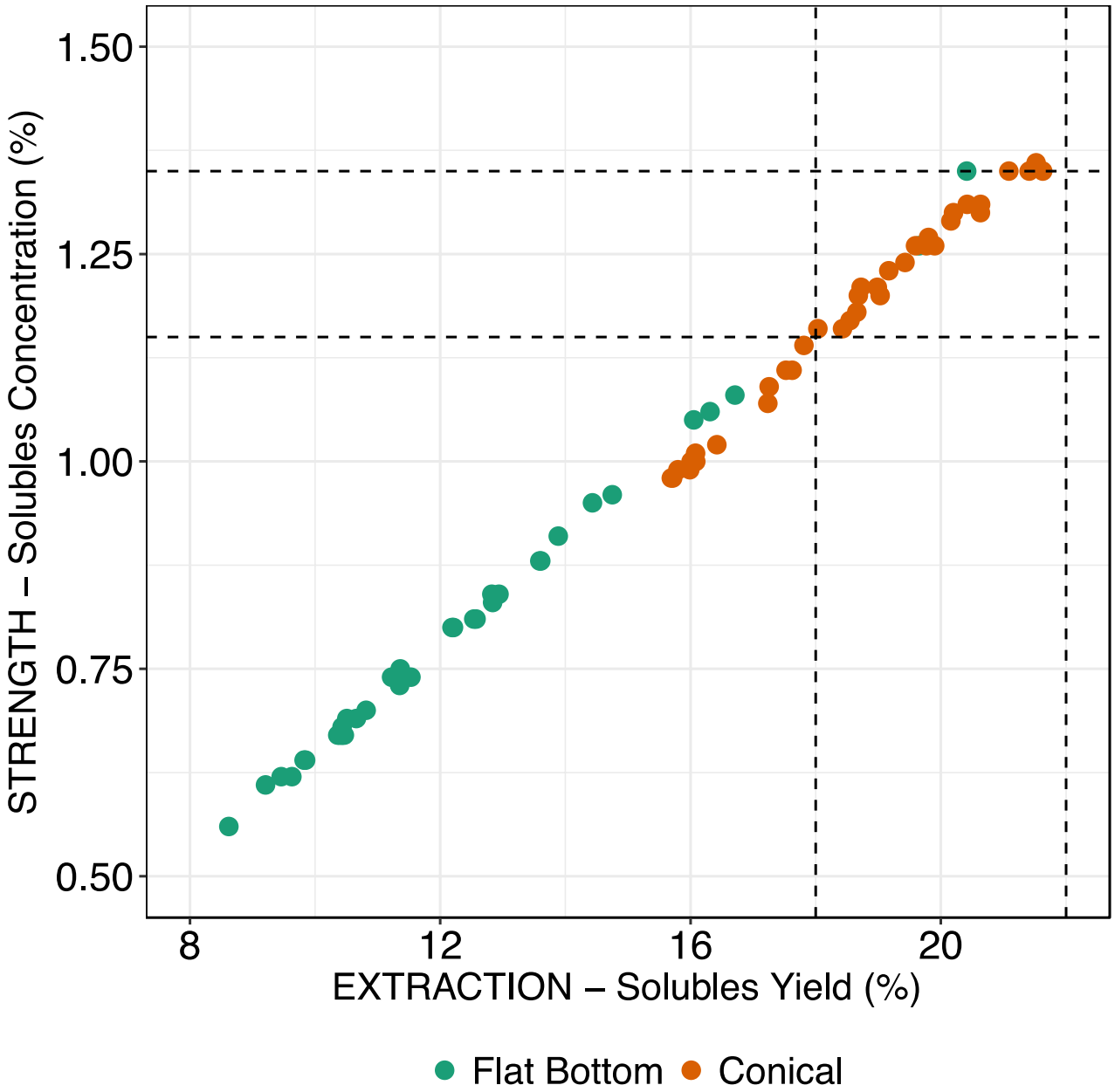
Peach = Light Roast

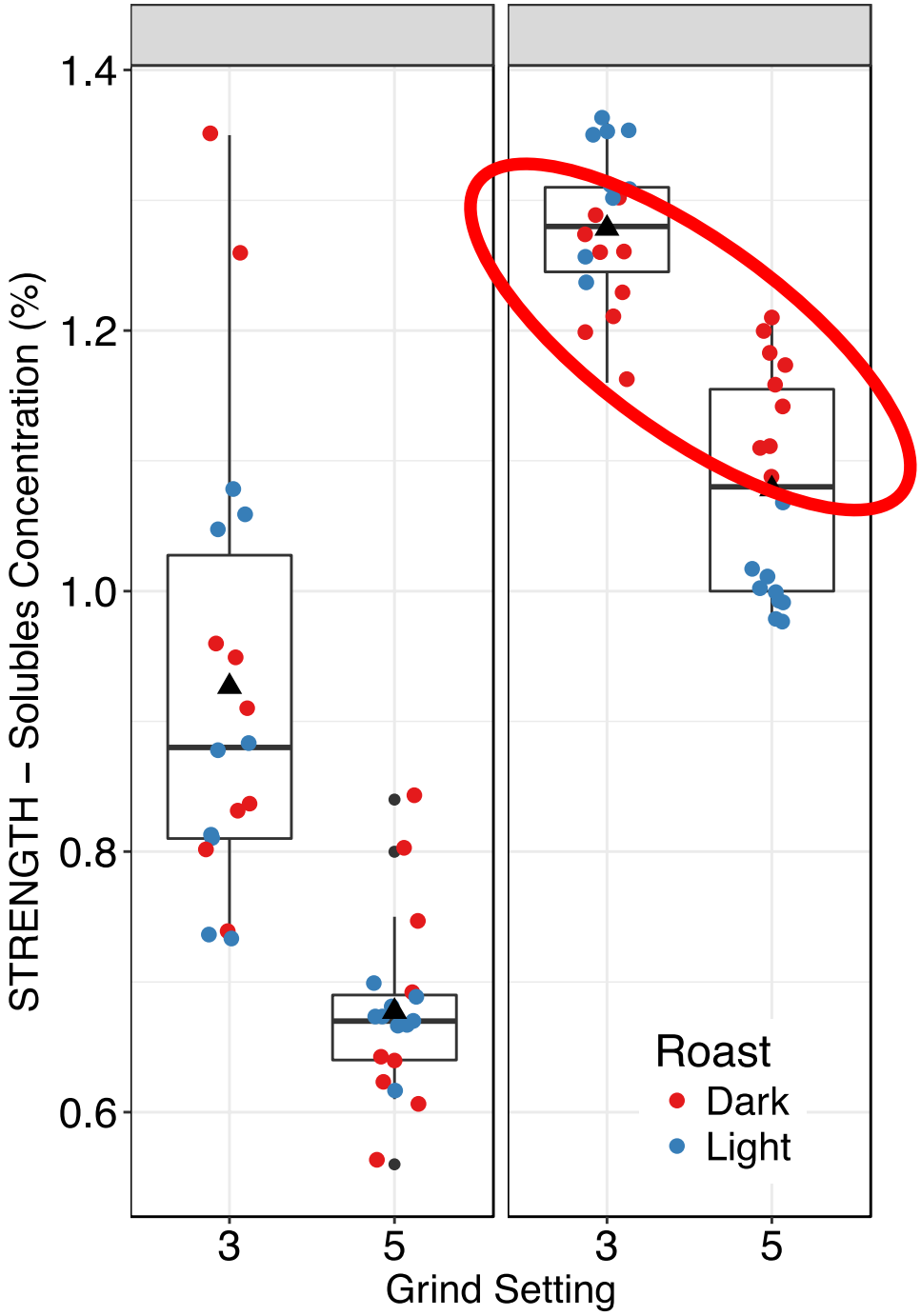
Coarse ground

Color by Geometry

Orange = Dark Roast

Green = Light Roast



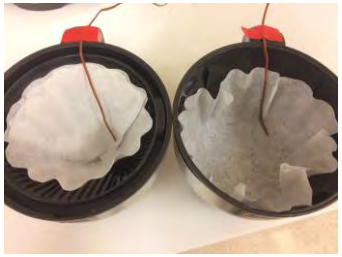


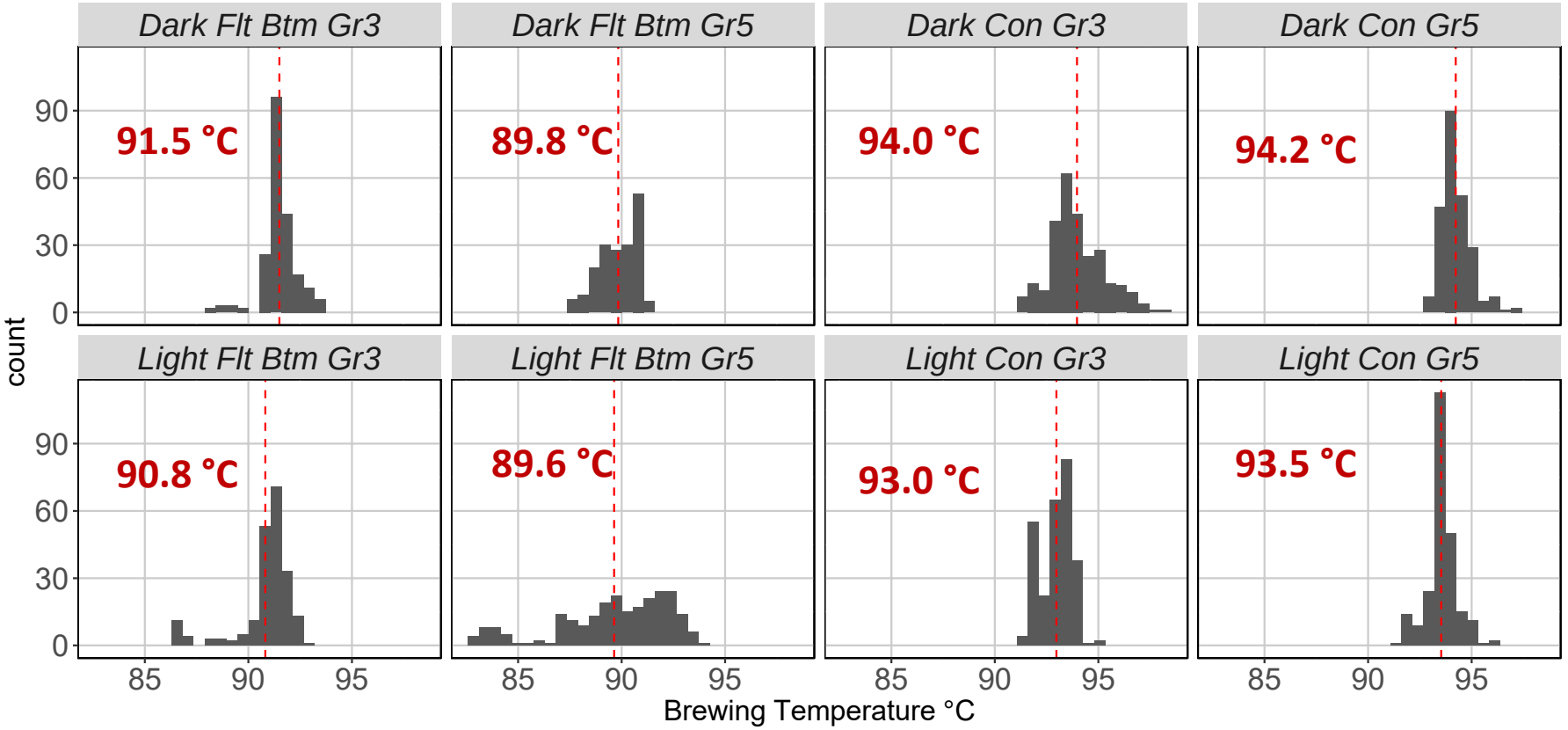
TDS measures

9 measures per coffee
72 total measures

Interaction between the conical geometry, roast, and grind

Distribution of brew basket temperatures for the hottest 150 seconds





N = 9 per condition (72 brews total)

Average of hottest 150 seconds per brew

CBI Advertising Campaign

Science

fine beverage is everybody's business

By DR. ERNEST E. LOCKHART, Scientific Director
The Coffee Brewing Institute, Inc.

Fine beverage is an ideal toward which every one must strive—no matter how close or how remote his connection with the coffee industry. If coffee is to maintain its present position as an outstanding leader in the beverage world, every one, whatever link in the chain he may represent, must work with ever increasing effort to learn more about the chain itself and to draw a true and proper perspective with respect to his own link in it.

While doing this, no one should lose sight of the very basic and important fact that *coffee beverage* is what the consumer drinks, judges and accepts or rejects.

Pleasing the consumer is an objective that must be kept in

variety of methods in commonly available equipment. Direct requests by the National Coffee Association to its members to participate led a large segment of the roaster group to use the recipes on cans and bags and to make available standard coffee measures. Close and very active cooperation by the packaging industry has been vital to the preliminary success of the campaign. Direct instruction of the housewife through visual and aural media has been successfully accomplished by The Coffee Brewing Institute, whose field staff has appeared on television and radio, often with the support of industry members. Trade journals and papers have been enthusiastically cooperative.

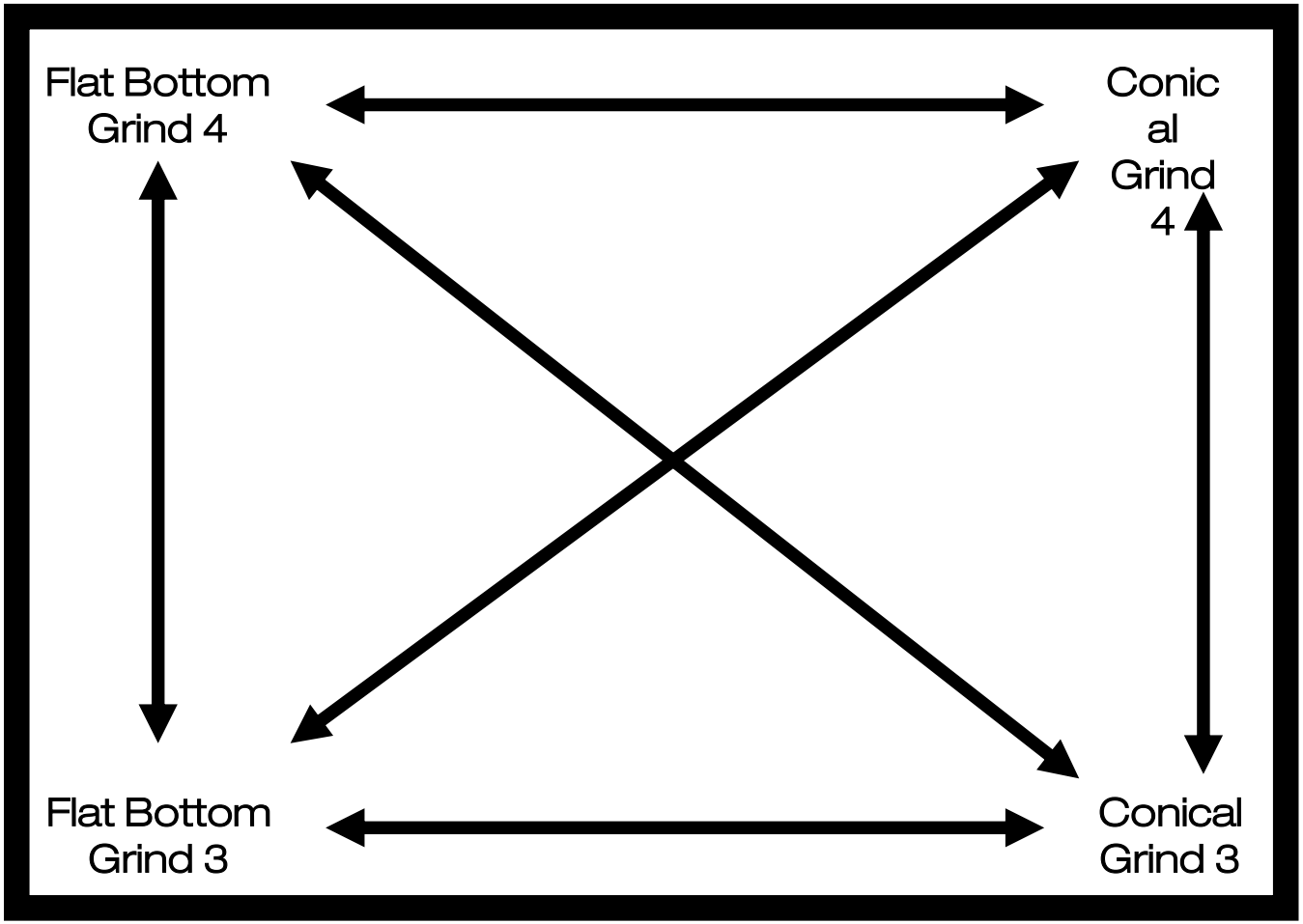
There is no doubt that the housewife wants this kind of information and is eager to have it. The industry has, only now, begun to give her something realistic. It should not stop but should intensify its effort. The "better brewing campaign" is a battle for every day, for every year.

Discrimination Testing

- Triangle tests!

- Treatments 2x2 design
- Four total treatments
  - **Flat Bottom**, **Conical**
  - Two grind settings – Mahlkönig Guatemala
    - **Setting 3** (finer) and **Setting 4** (coarse) (coarse)
- 6 total pairs were compared

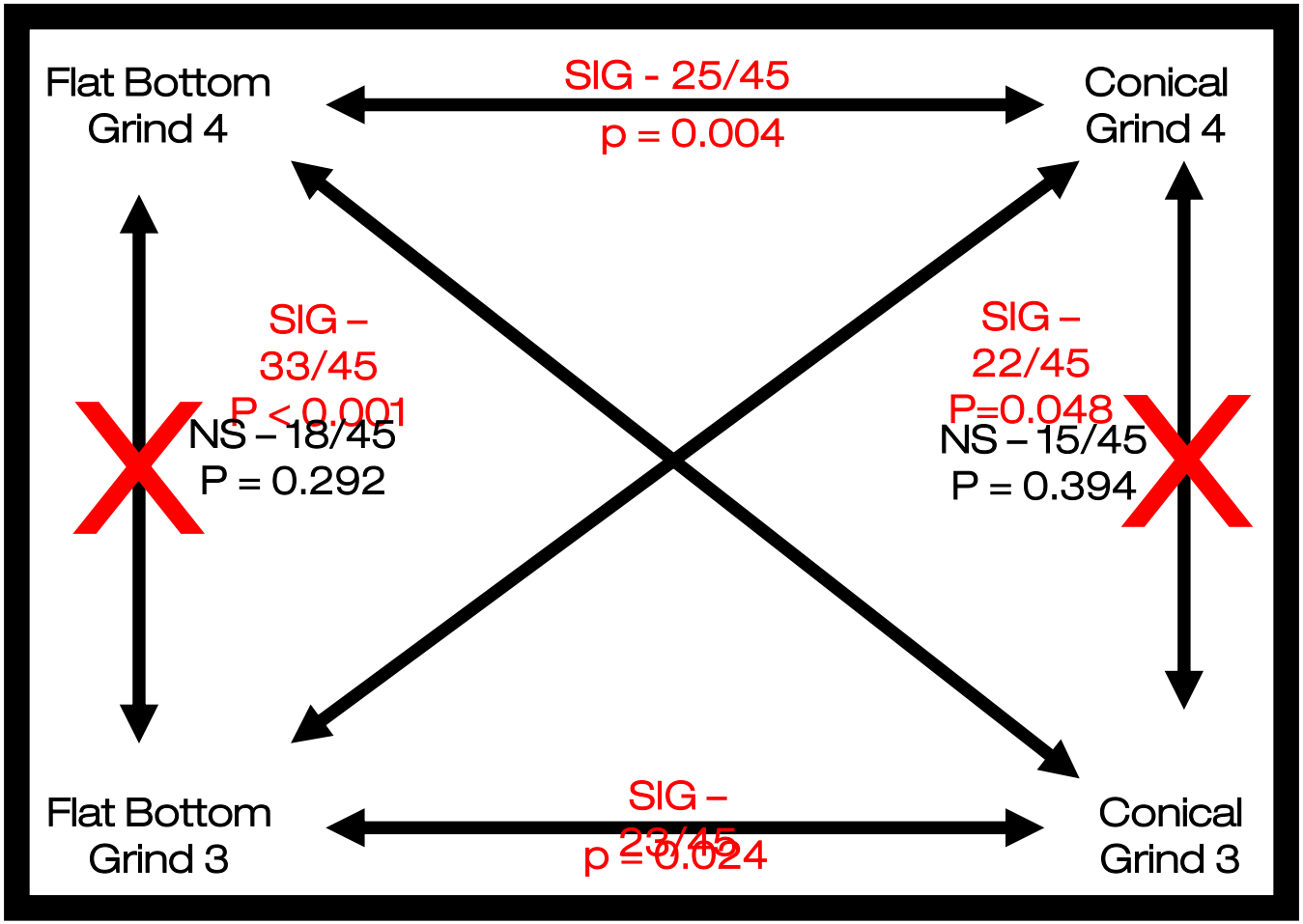
Six pairs were compared



Triangle Service

- 45 participants, each tasting all 6 triangles in random order
- All coffees were prepared at 55g coffee/ 1000 g water
- Each coffee was brewed, poured and served upon reaching 70°C

Results!!


Flat Bottom Grind 4
SIG - 25/45
p = 0.004
Conical Grind 4
SIG – 33/45
P < 0.001
NS – 18/45
P = 0.292
SIG – 22/45
P=0.048
NS – 15/45
P = 0.394
Flat Bottom Grind 3
SIG – 23/45
p = 0.024
Conical Grind 3