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The role of fines in espresso extraction dynamics

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Coffee Excellence Center at ZHAW

- **Zurich University of Applied Sciences ZHAW** in Wädenswil (Zurich), Switzerland
- Research Center at the Institute of Chemistry and Biotechnology, founded by **Prof. Dr. Chahan Yeretzian in 2008**

Extraction

 + H_2O →  + 

m (coffee) | m (water) | m' (water) + TDS | m (coffee) - TDS + (and some water)

Dissolved solids

Measured by:
Refractometer
Evaporation

Beverage ratio
m(beverage) / m(coffee)

Brew ratio
m(water) / m(coffee)

Extaction percentage (yield)
TDS / beverage ratio

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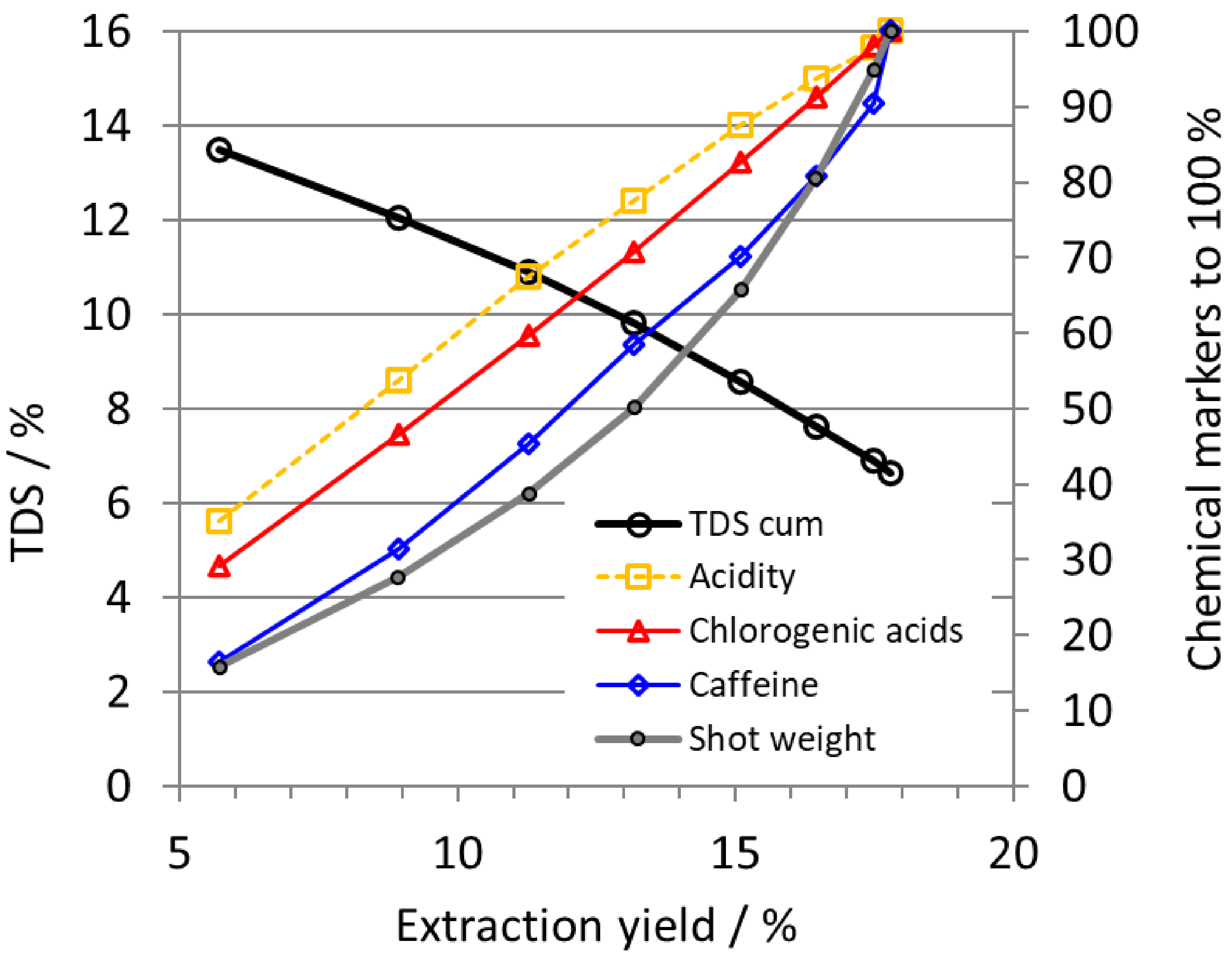
Extraction kinetics

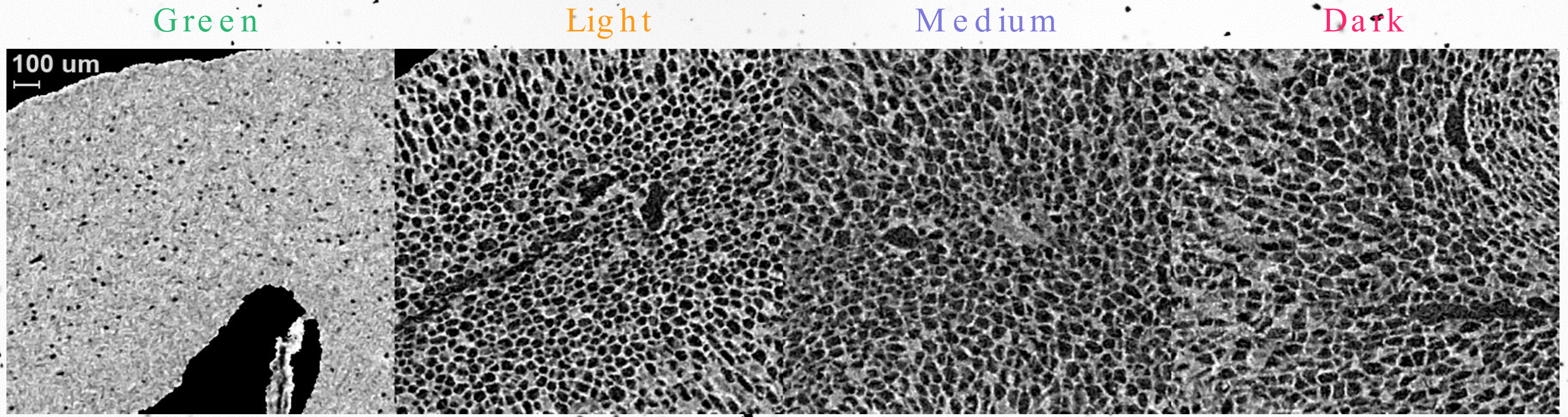


Particles

The sizes and shapes of coffee particles

Defined by the structure of the roasted bean

Two types of particle sizes: Main particles and fines.



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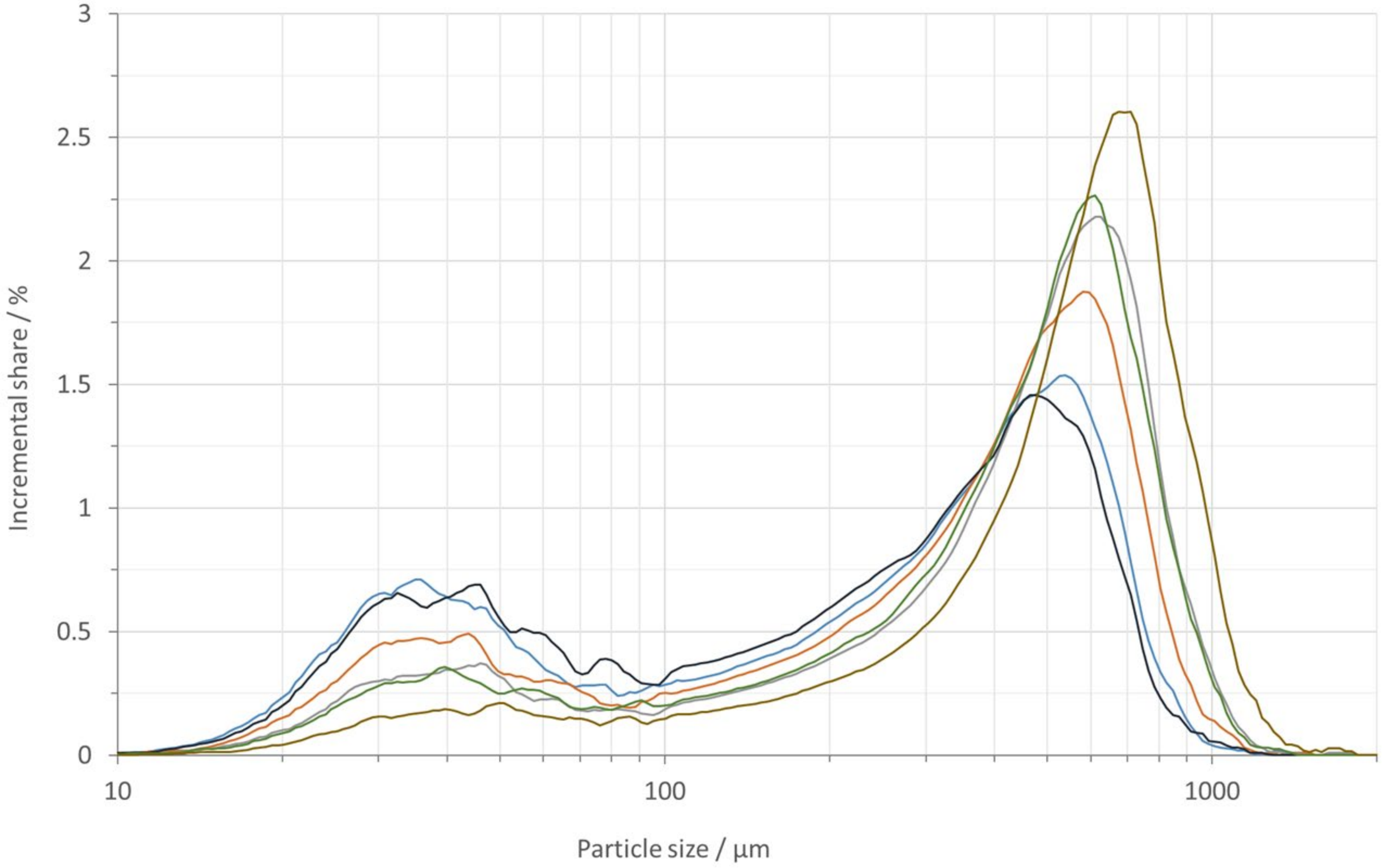
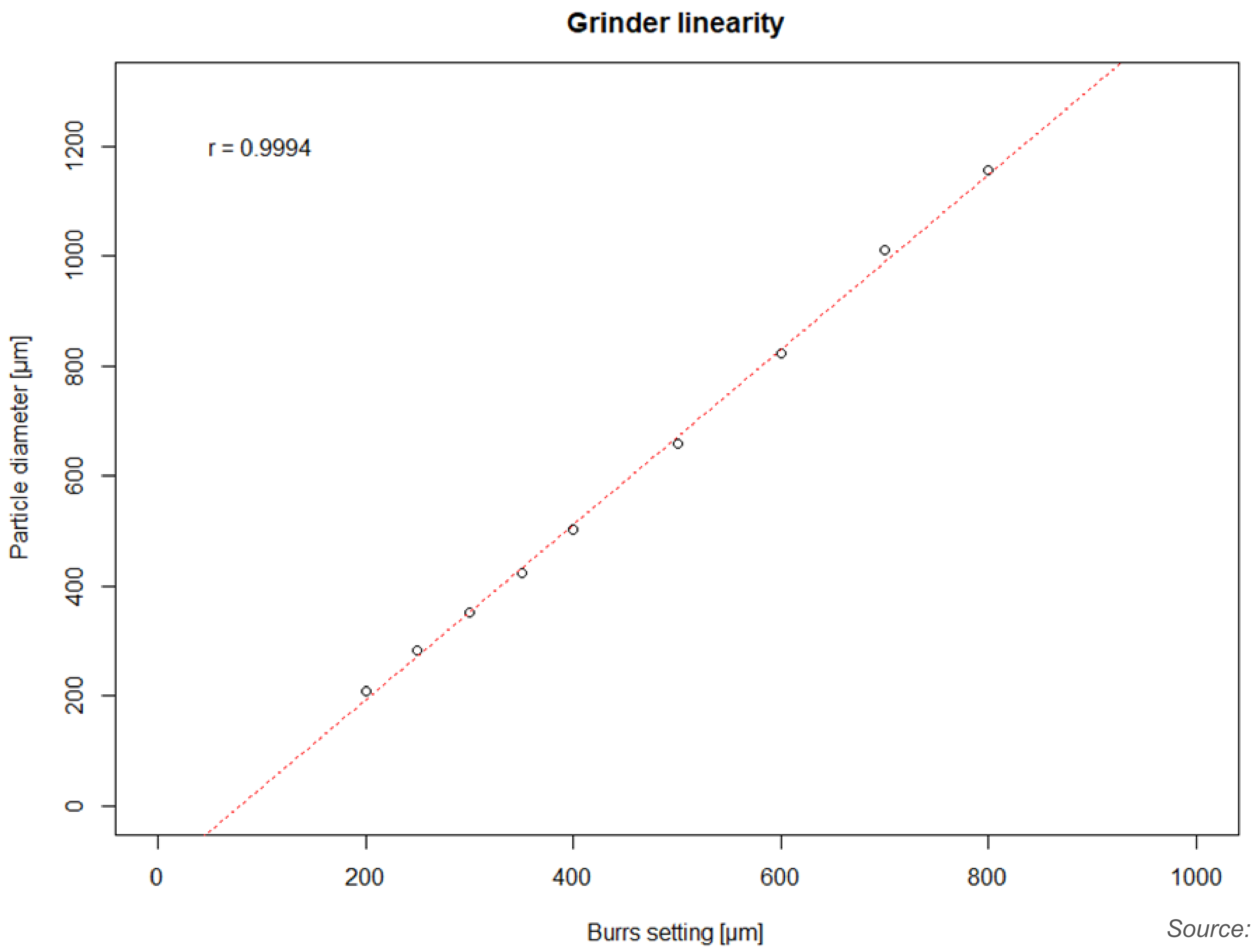
Particle size distribution



Particle size analysis: Grinder linearity



The setting of the grinder (burr spacing) corresponds to position of the main peak

Source: ZHAW (unpublished data)

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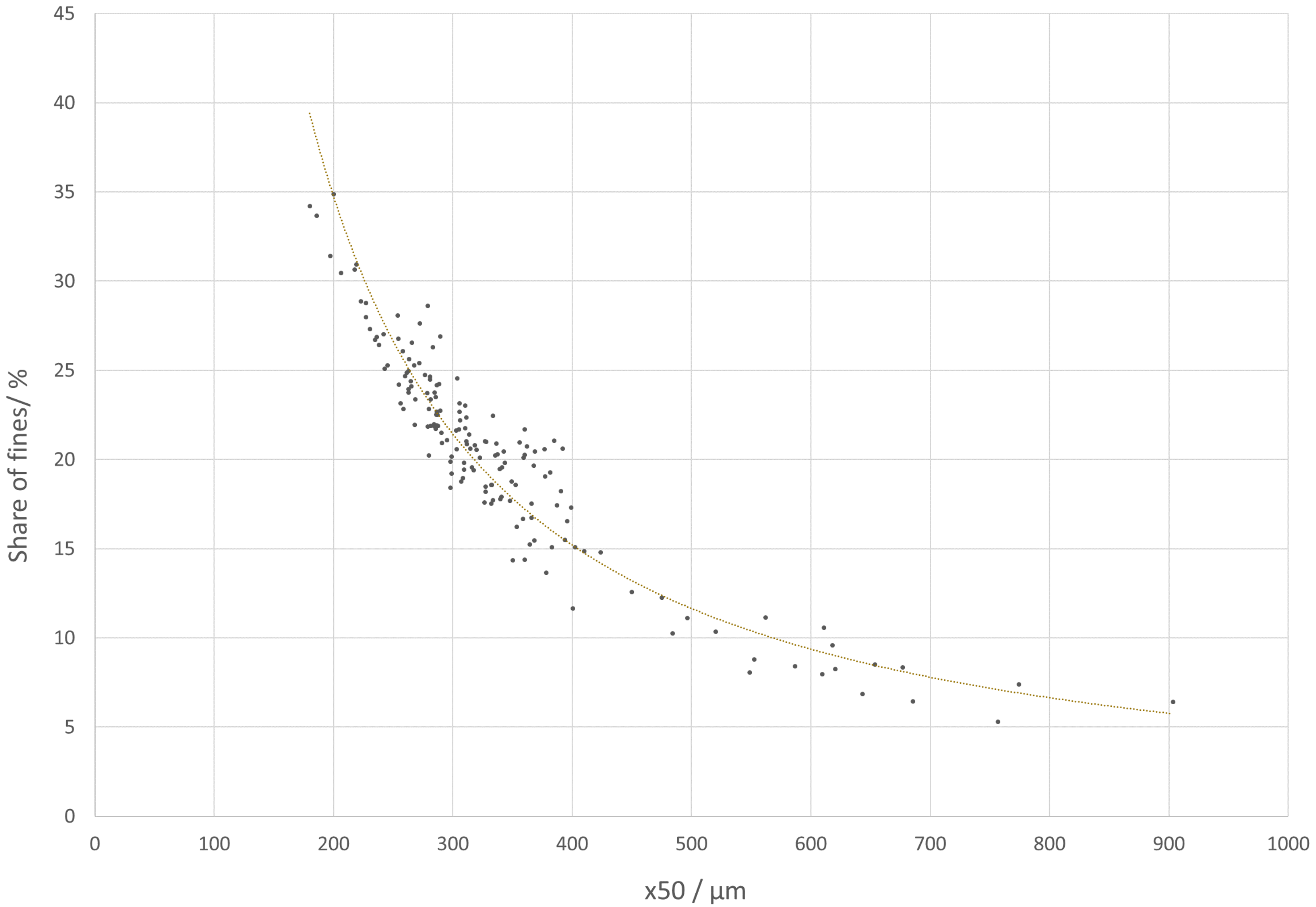
Particle size analysis: Share of fines



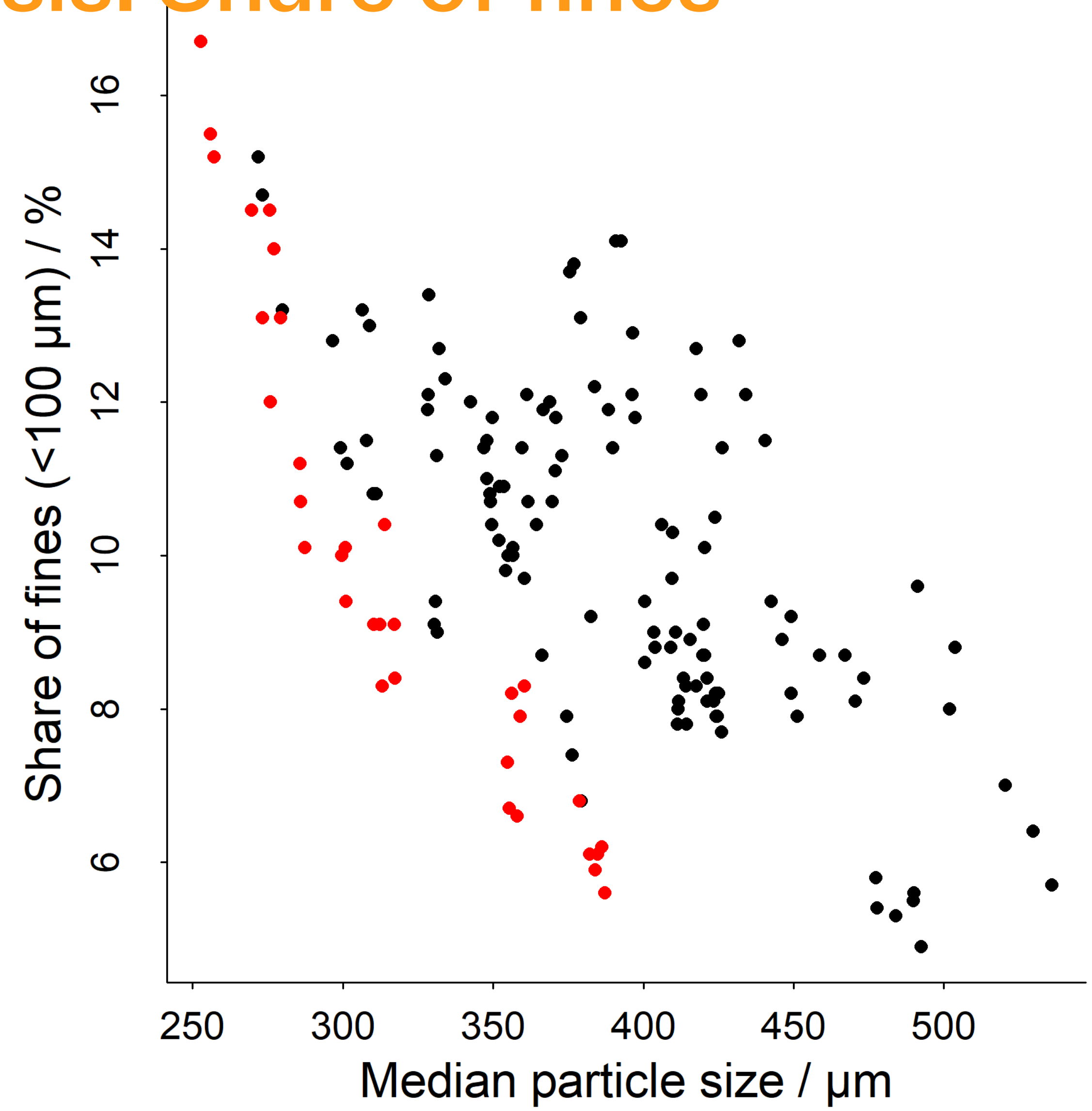
Source: ZHAW

Particle size analysis: Share of fines

Share of fines as the 'signature' of a grinder

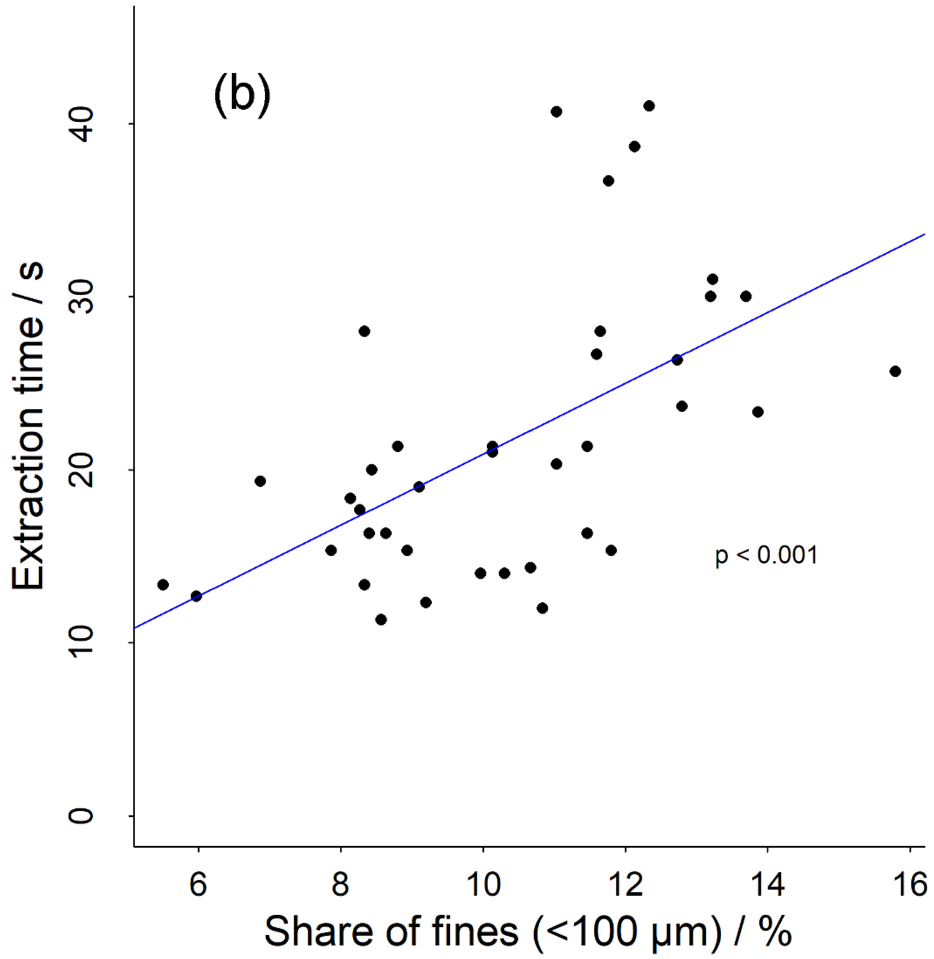
Espresso size:

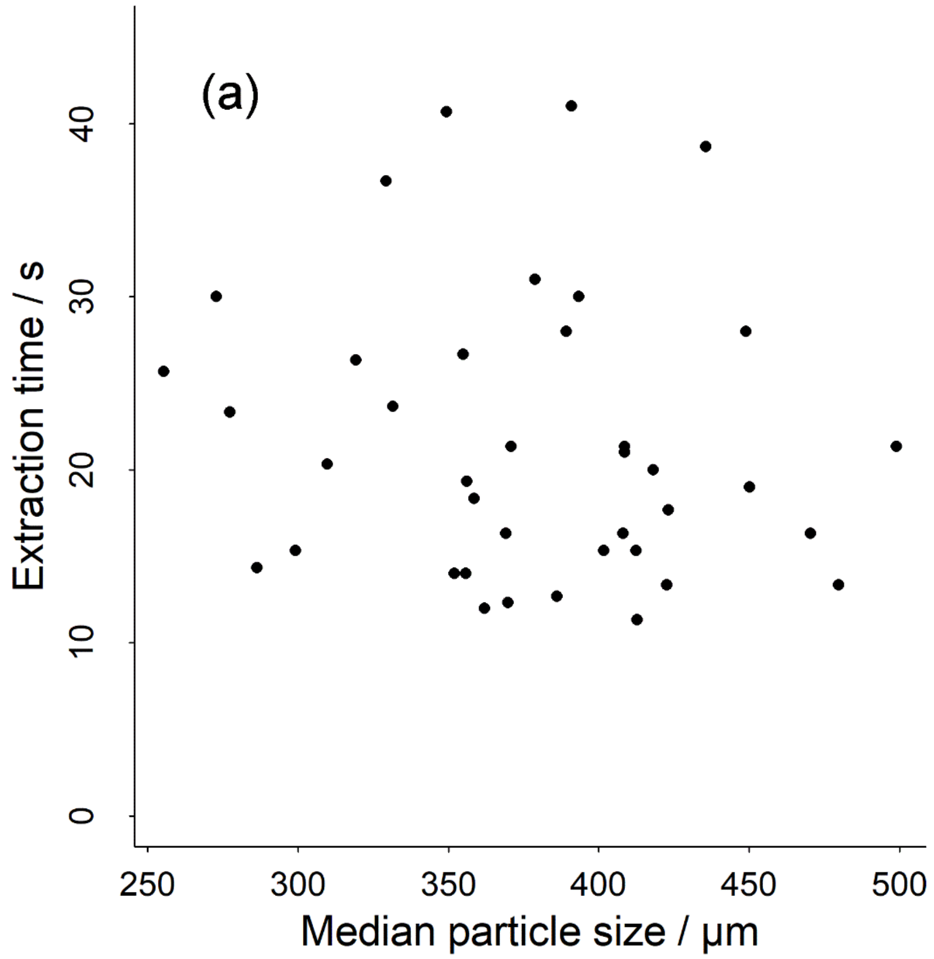
- Conical burrs: 25-35%
- Flat burs: 15-30%
- Roller grinder: 5-15%



Source: Eiermann & Smrke, et.al. (2020)

Influence of PDS on extraction time





- Extraction is highly variable between different capsules (10 to 41 s) → corresponds to average flow rates 1–4 g/s range
- Very significant positive association with Q100 µm → extraction time increases with increasing proportion of fines
- Increase in proportion of fines from 10 to 15% corresponds to an increase in the extraction time of 10 s
- Median particle size is not found to be correlated with extraction time

Equipment and materials used

Coffee: *P14 Specialty by Henauer; Costa Rica Honey processed, light roast (Colorette 141).*

Grinder: *We tested EK43 and Bentwood and did not find significant flavour differences for this particular coffee. Bentwood was chosen for its superior grind setting mechanism (real numbers in terms of relative burr spacing in um).*

Puck prep: *Weber workshops Blind Shaker followed by tap puck prep (3 palm tamps front, 3 back, 3 front).*

Tamping: *PUQ press 20kgF*

Basket: *VST 20g*

Dose in: *20 g (exact after grinding – at least 0.5 g more taken for grinding and then adjusted to 20.0g)*

Extraction: *Flat 9 bar*

Dose out: *40 g manually stopped according to scale reading*

Tests conducted – experimental plan

Grind level setting on Bentwood: *250, 210, 190, 180, 170, 160.*

Fines addition: *5%, 10% and 20%; 1 g, 2 g, 4 g*
Grind size with fines: *250, 210, 190*

Collected and measured data

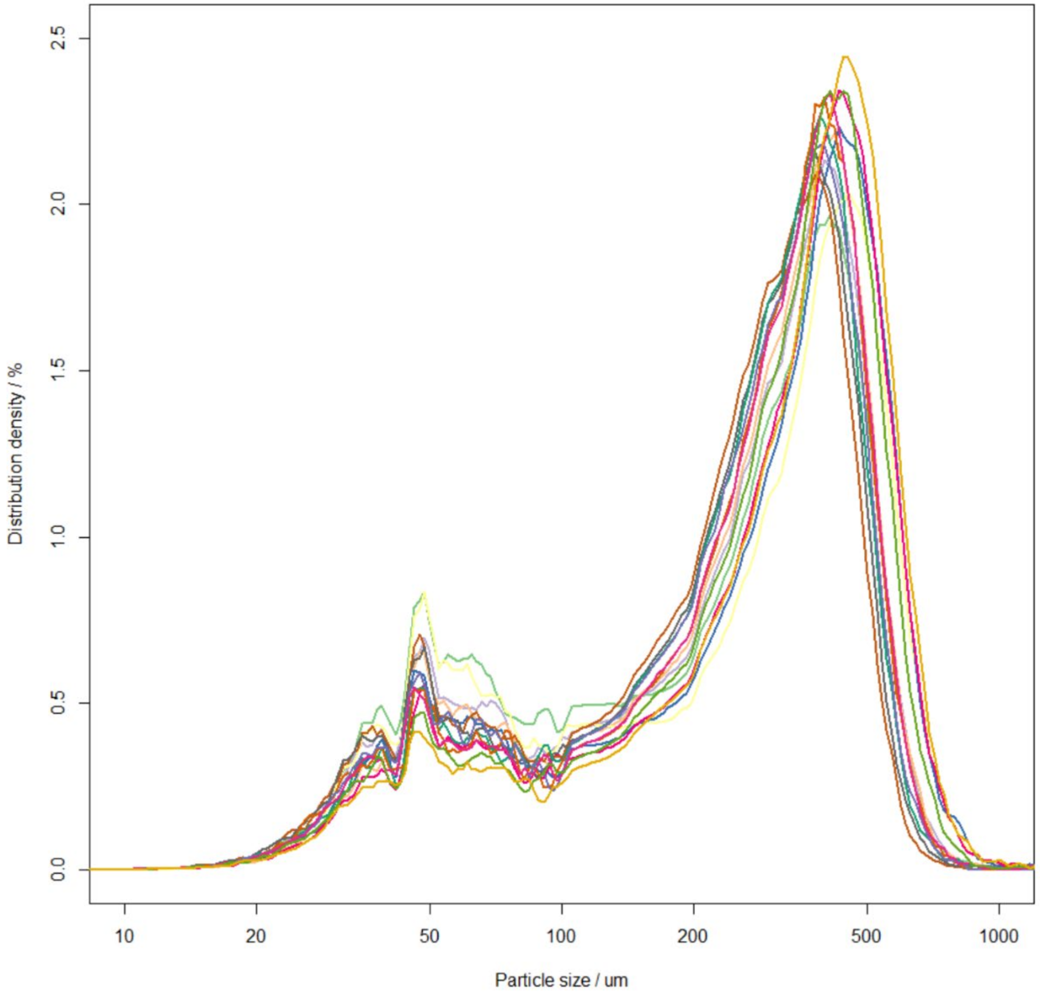
Dose out
Extraction time
TDS

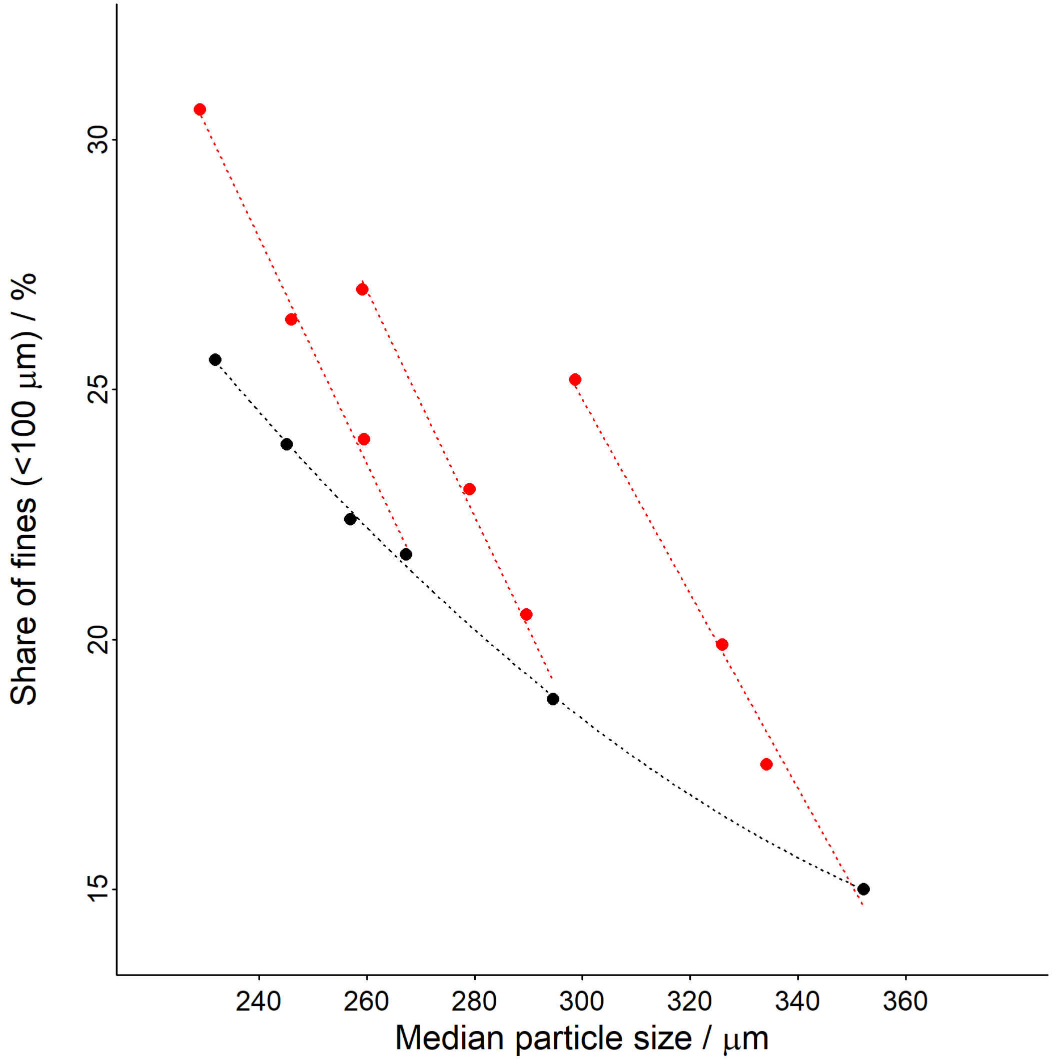
Sensory according to WBC:
Acidity, Sweetness, Bitterness, Weight, Texture, Finish; descriptive score
Taste balance, flavour, tactile; hedonic score

Particle size distribution analysis

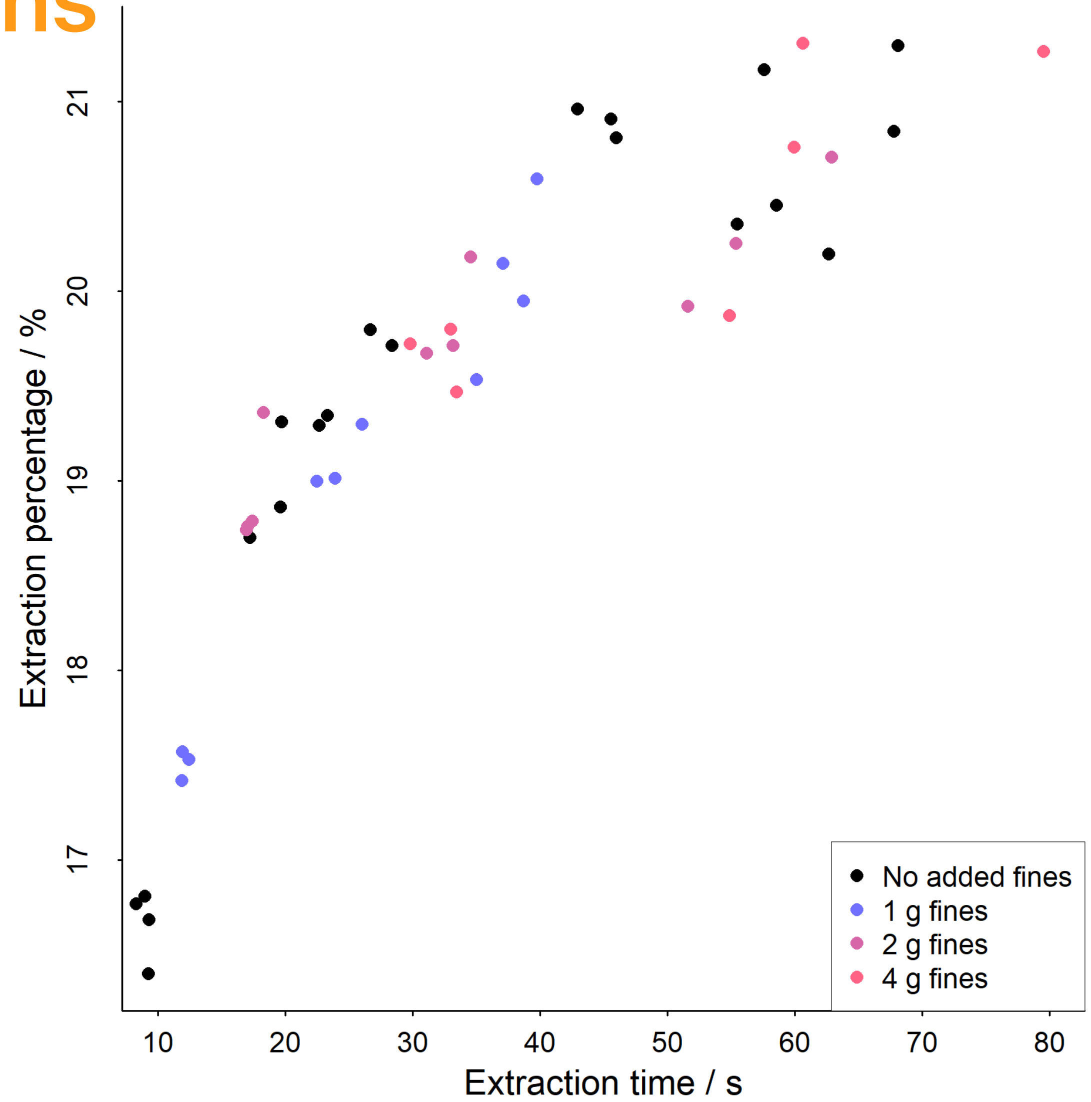
Number	Grind Settings	Grind Settings	In	Out	Brew Ratio	Time
1	250	0	20	38.8	0.515464	9.29
2	250	0	20	43	0.465116	8.29
3	250	0	20	40.5	0.493827	8.98
4	250	0	20	41	0.487805	9.23
5	250	1	20	40.3	0.496278	12.44
6	250	1	20	39.5	0.506329	11.86
7	250	1	20	39	0.512821	11.92
8	210	0	20	41	0.487805	19.7
9	210	0	20	39.5	0.506329	19.61
10	210	0	20	39.7	0.503778	17.24
11	210	1	20	39.1	0.511509	26.03
12	210	1	20	39	0.512821	23.93
13	210	1	20	39.7	0.503778	22.47
14	190	0	20	39.8	0.502513	23.33
15	190	0	20	40.4	0.49505	22.67
16	190	0	20	39.9	0.501253	28.4
17	190	0	20	39.2	0.510204	26.68
18	190	1	20	38.3	0.522193	35.02
19	190	1	20	39.6	0.505051	39.75
20	190	1	20	40.3	0.496278	38.73
21	190	1	20	40.7	0.4914	37.09
22	250	2	20	38.8	0.515464	16.94
23	250	2	20	40.4	0.49505	17.43
24	250	2	20	40.5	0.493827	18.29
25	250	2	20	40	0.5	17.05
26	210	2	20	40.4	0.49505	34.55
27	210	2	20	39.9	0.501253	31.08
28	210	2	20	39.5	0.506329	33.18
29	190	2	20	40	0.5	51.63
30	190	2	20	40.5	0.493827	55.41
31	190	2	20	41	0.487805	62.92
32	250	4	20	40.1	0.498753	33.43
33	250	4	20	39.6	0.505051	32.98
34	250	4	20	39.6	0.505051	29.83
35	210	4	20	40.8	0.490196	54.88
36	210	4	20	40.2	0.497512	60.67
37	210	4	20	40.7	0.4914	59.97
38	190	4	20	40.5	0.493827	79.53
39	190	4	20	40.3	0.496278	88.13
40	190	4	20	40.3	0.496278	85.29
41	180	0	20	41.4	0.48	45.59
42	180	0	20	40.4	0.5	45.99
43	180	0	20	40.7	0.49	42.94
44	170	0	20	41.5	0.48	57.63
45	170	0	20	40.3	0.5	55.49
46	170	0	20	40.1	0.5	58.58
47	160	0	20	39.8	0.5	68.1
48	160	0	20	39.6	0.51	62.7
49	160	0	20	39.7	0.5	67.8

Particle size distributions

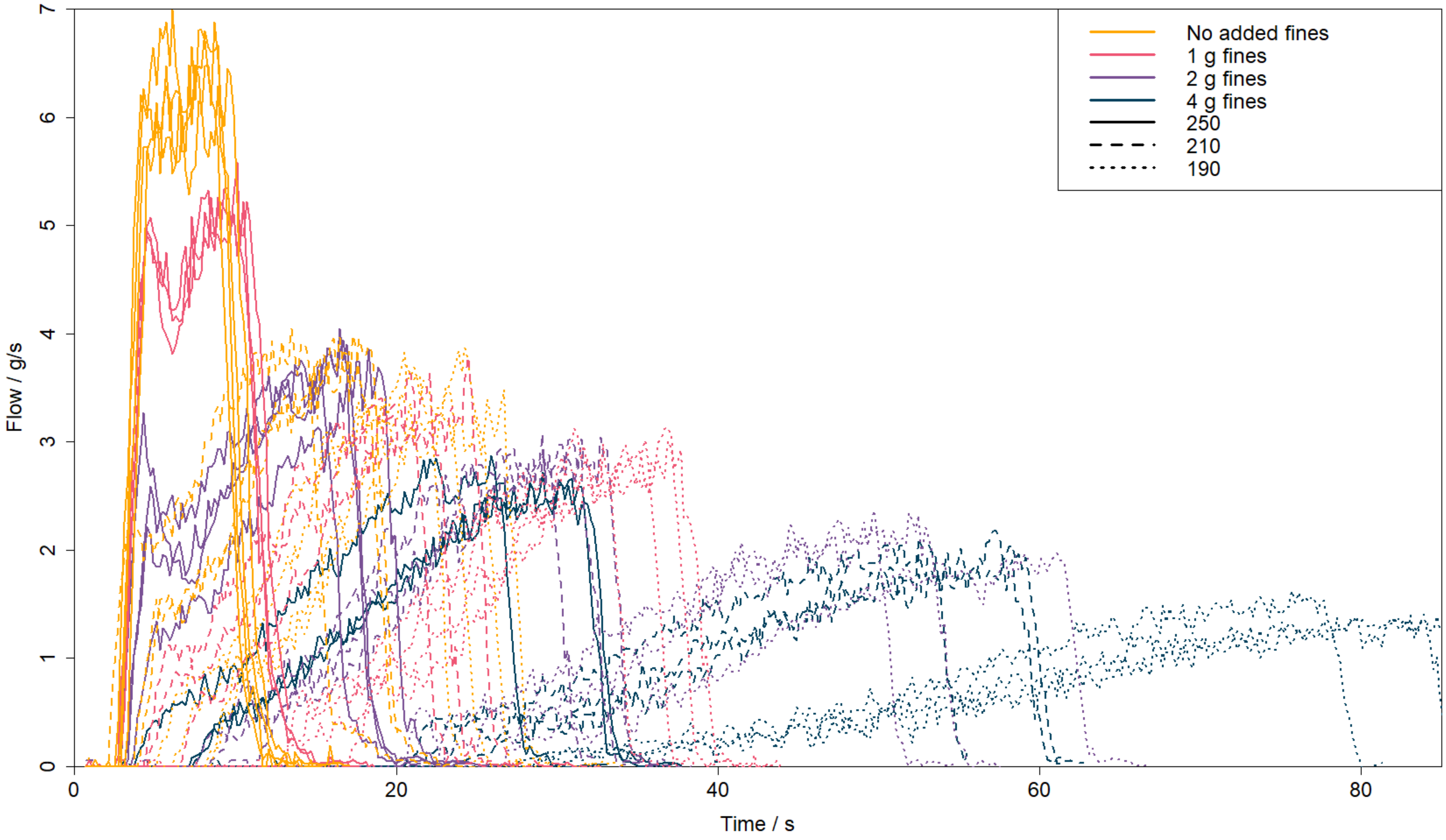




Resulting extractions



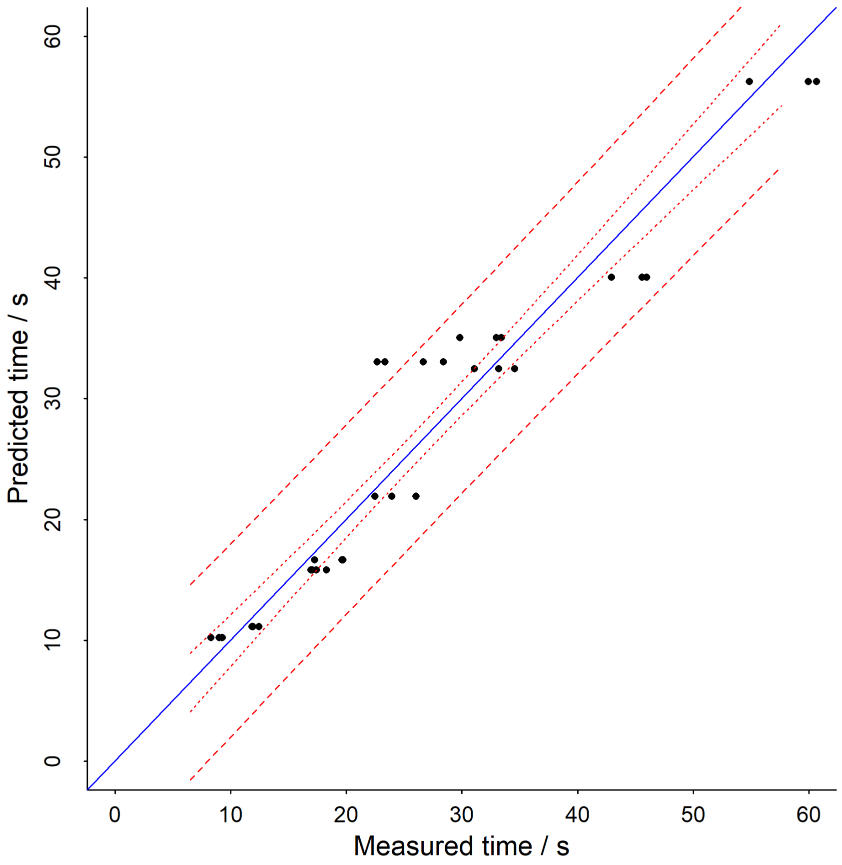
Do fines induce channelling and/or poor extraction?



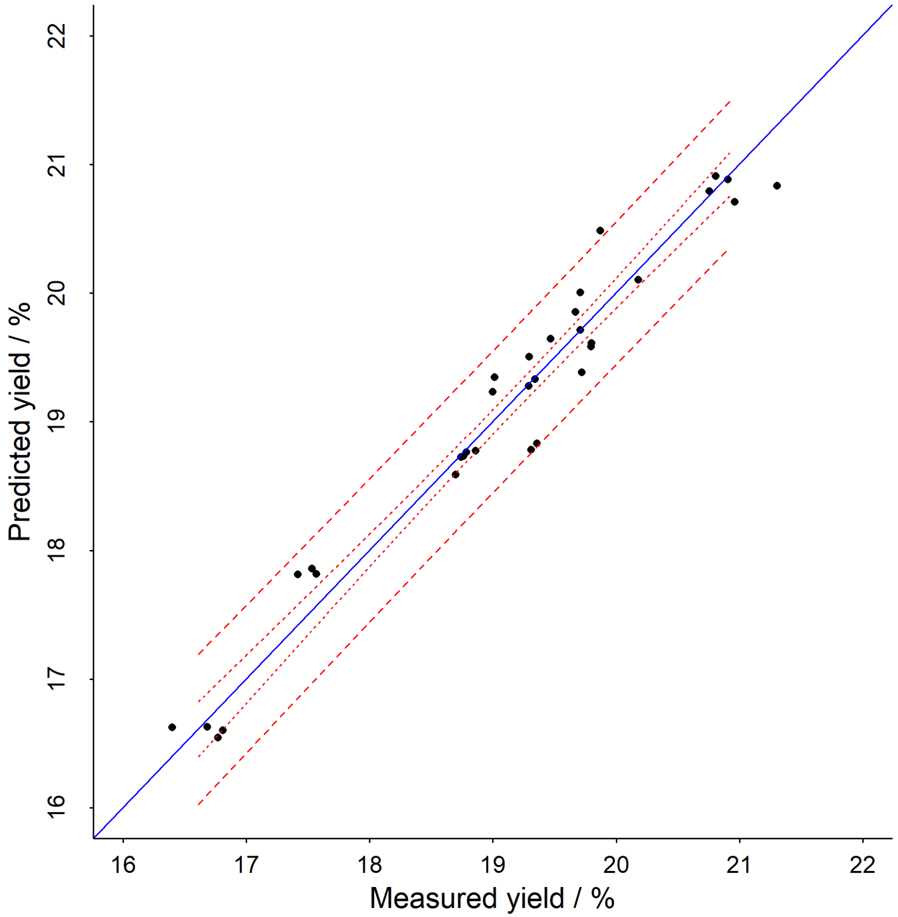
No added fines
1 g fines
2 g fines
4 g fines
250
210
190
Flow / g/s
Time / s
0
1
2
3
4
5
6
7
0
20
40
60
80

Relating grinding and extraction

Using X50 and Q100 to predict extraction time



Using X50, Q100 and extraction time to predict extraction yield



Relating grinding and extraction

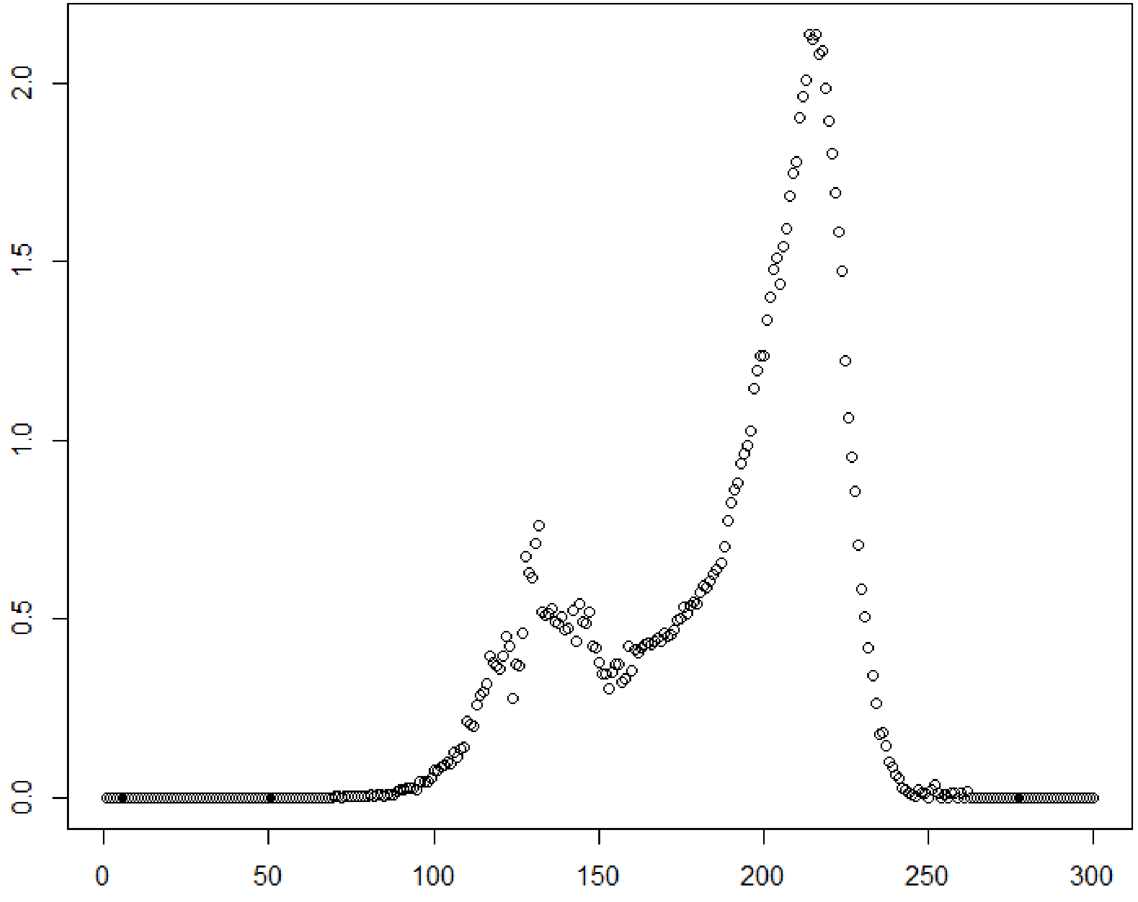
The extracted particle parameters are only a part of the whole picture

The whole particle size distribution has a role in extraction.

PLSR is a great method when we have many explanatory variables!

We use each whole PSD for the input variables of the PLSR models

The model is created to predict the extraction time!



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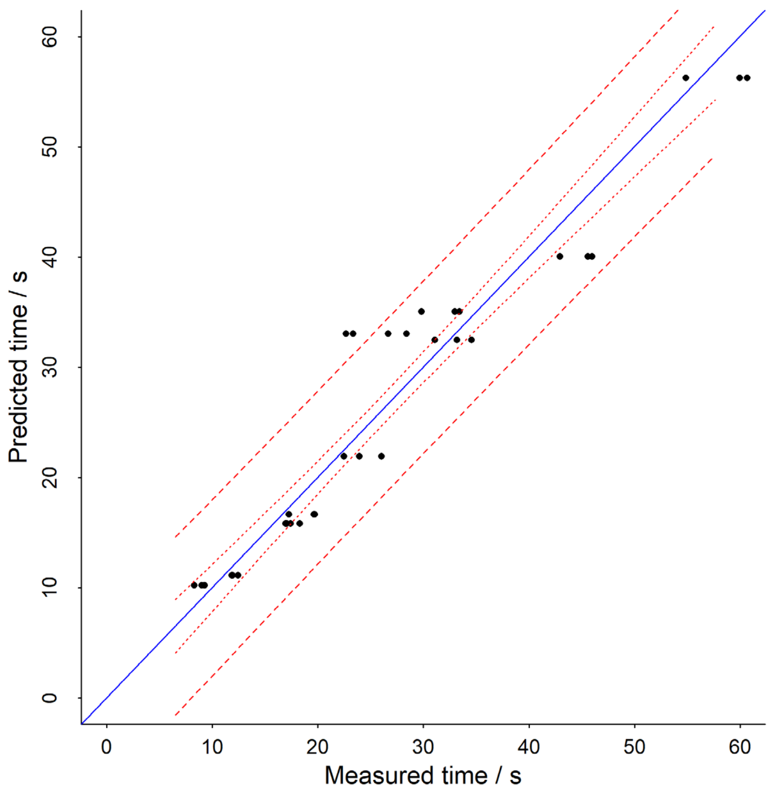
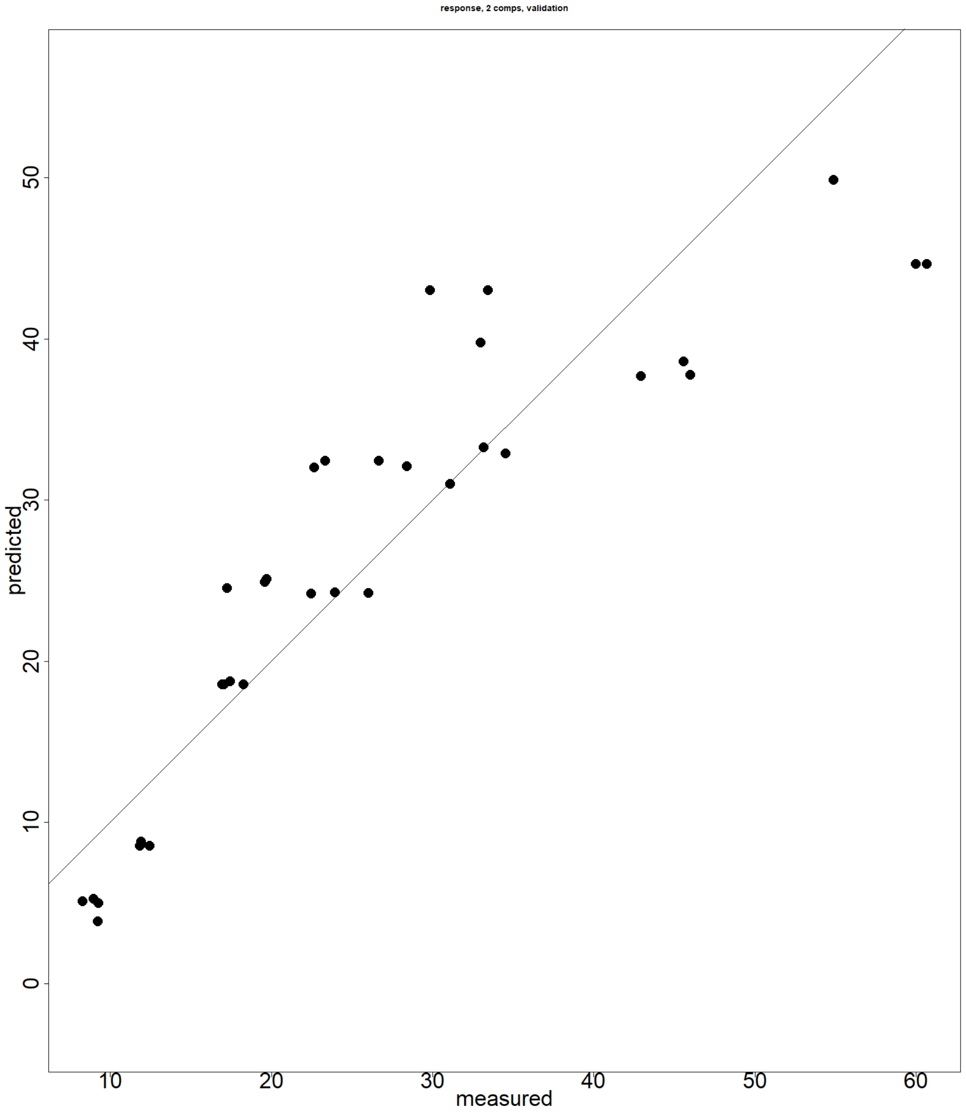
How PSD controls espresso

Using X50 and Q100 to predict extraction time



PLSR model from whole PSD



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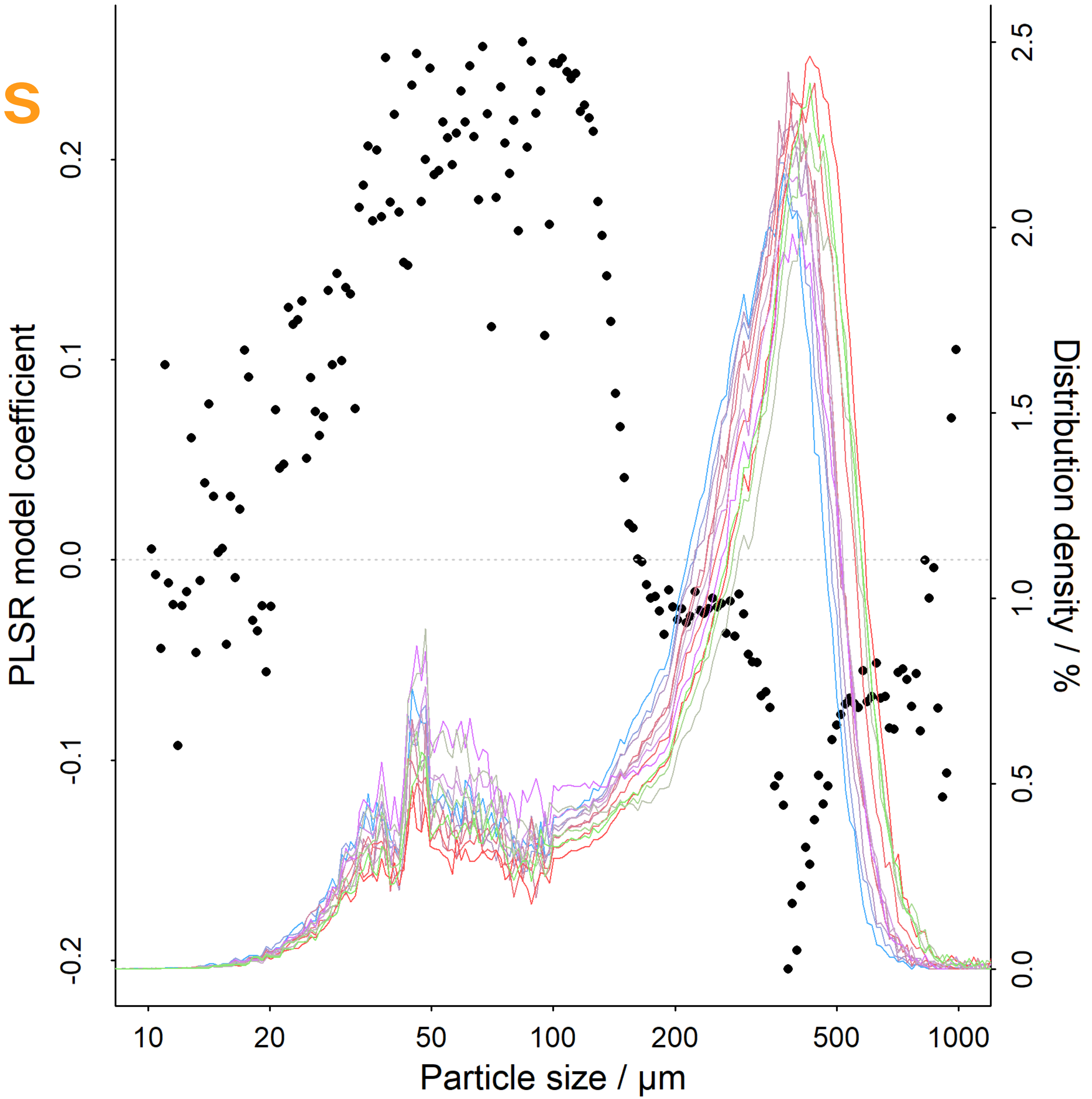
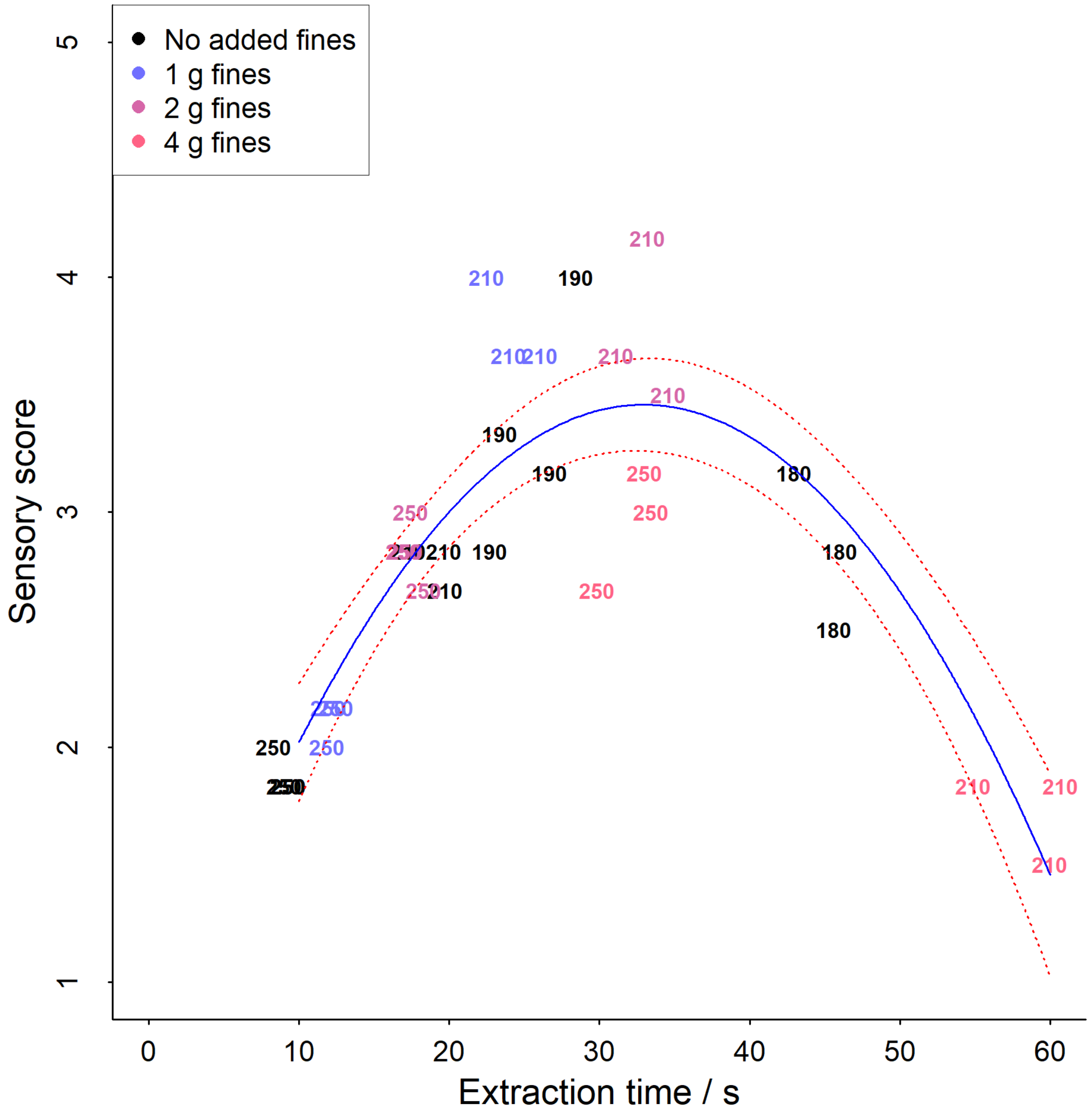
How PSD controls espresso

Model coefficient values tell us if and increase is positively or negatively correlated.

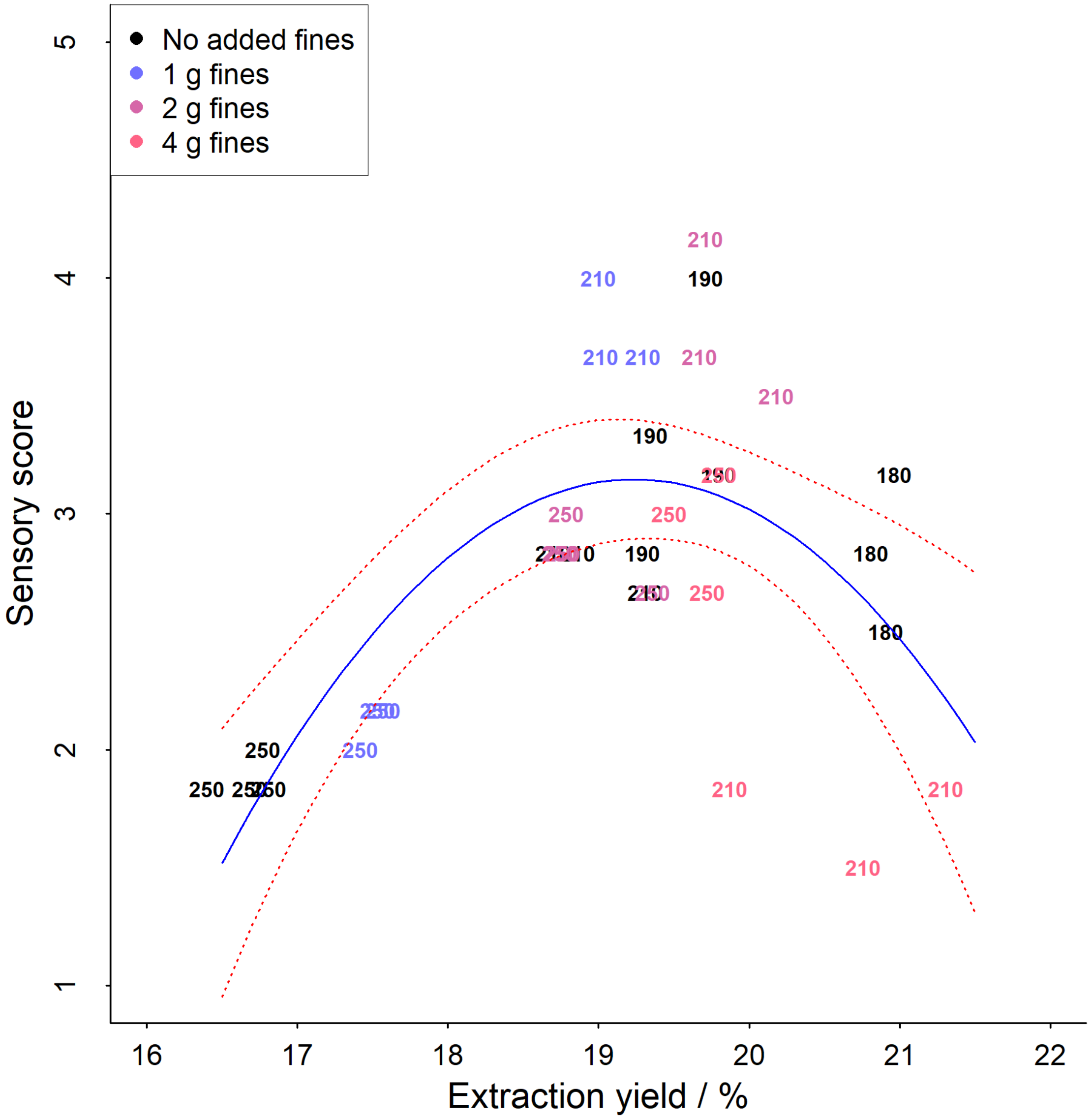
- More fines – longer extraction
- More larger particles at the high-end size – shorter extraction



Sensory

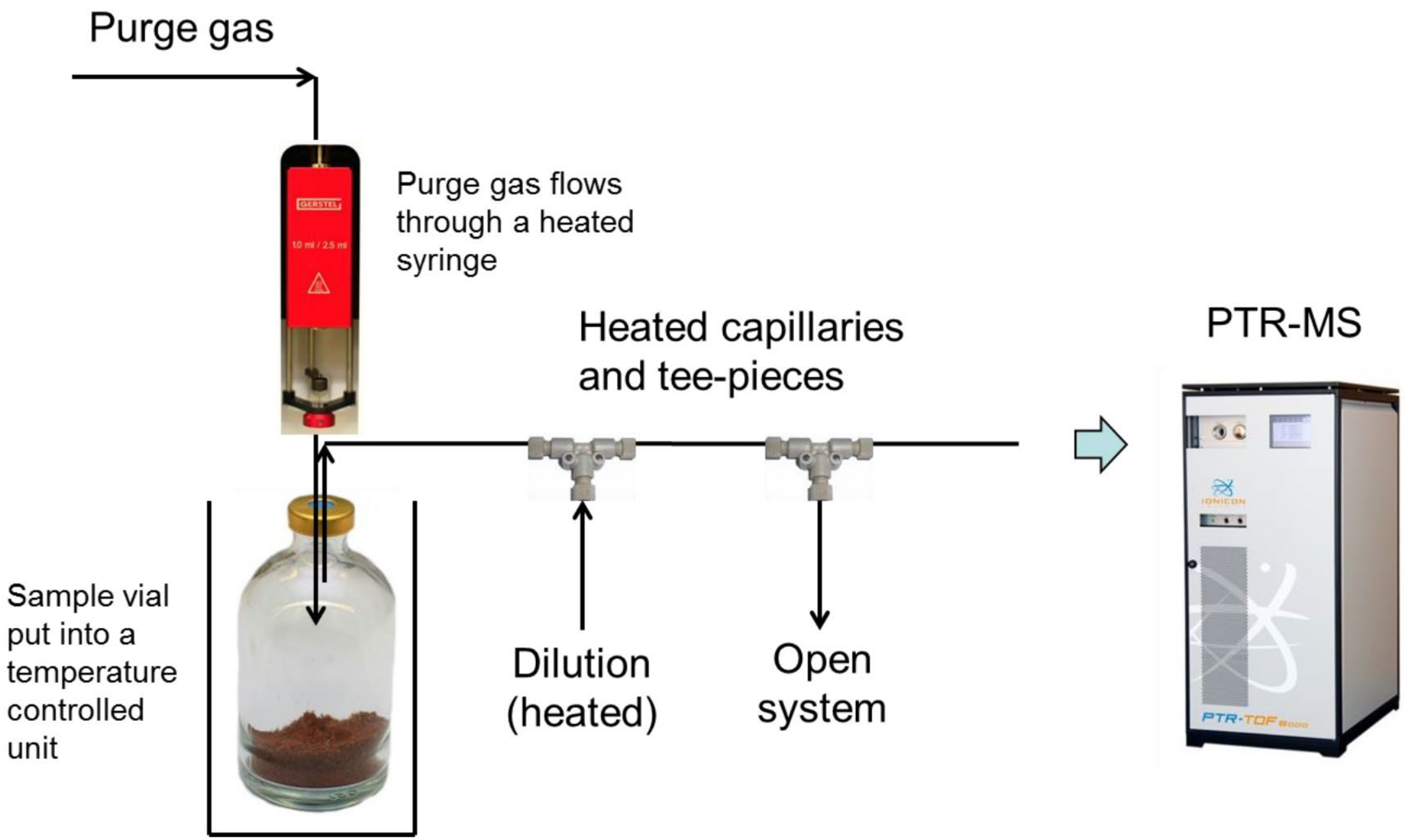


No added fines
1 g fines
2 g fines
4 g fines
Sensory score
Extraction time / s



No added fines
1 g fines
2 g fines
4 g fines
Sensory score
Extraction yield / %

Aroma analysis



Espresso extracts were frozen and then thawed and heated to 50.0 °C to simulate drinking temperature

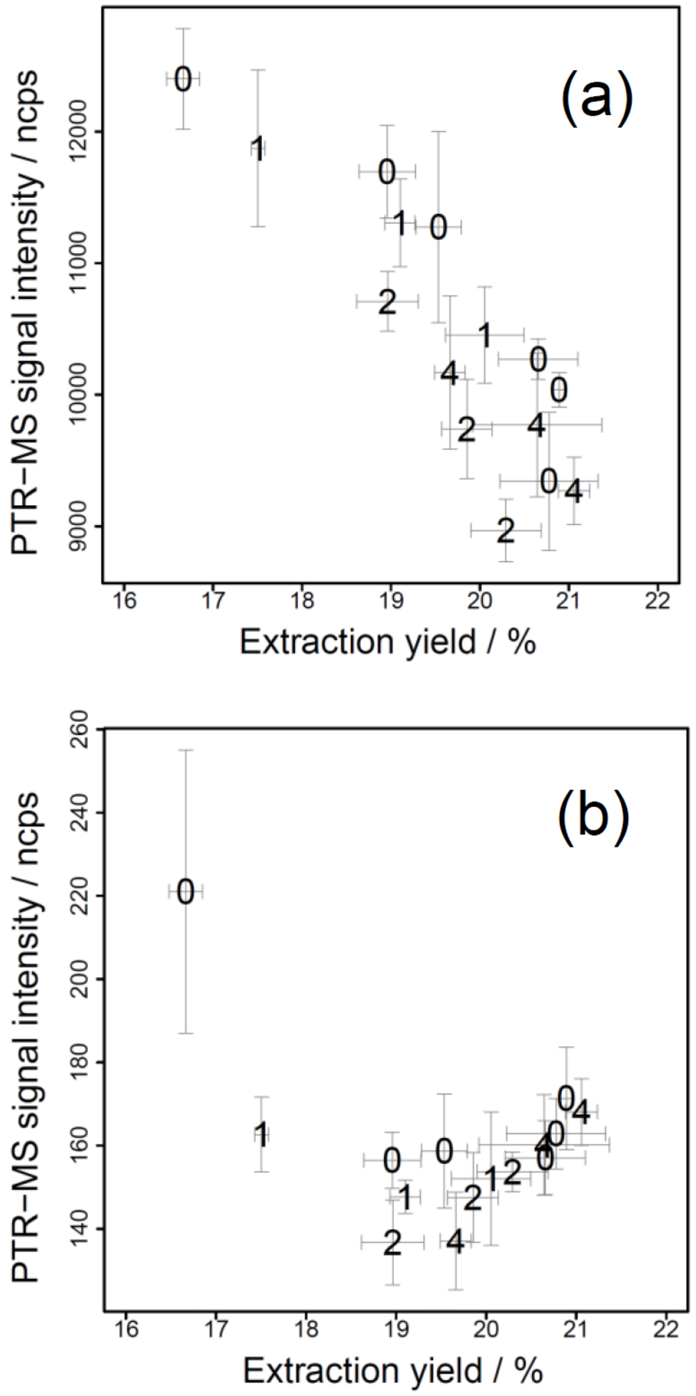
Aroma composition

More yield – less highly volatile aroma

Decrease followed by increase

Group A (example Fig. 6a) compounds that concentration continuously decrease with increasing extraction yield. Selected PTR-MS peaks showing this behavior are (experimental m/z): 31.020, 33.036, 45.034, 47.013, 59.050, 61.028, 68.046, 69.032, 73.063, 75.044, 82.058, 87.037, 87.074, 89.055, 101.054, 113.052, 115.066, 127.080.

Group B (example Fig. 6b): compounds that show an initial decrease in VOC quantities for fastest extracting samples (with lowest yield), a minimum at around 19.5% yield and a subsequent increase at higher yield: experimental m/z, 111.039, 121.068, 125.061, 131.072, 135.091, 137.108, 149.107. A subset of Group B showed an initial decrease in PTR-MS signal intensity until yield 19.5% and then no changes at higher yield: 80.045, 97.025, 99.037, 107.047, 109.069, 117.044.



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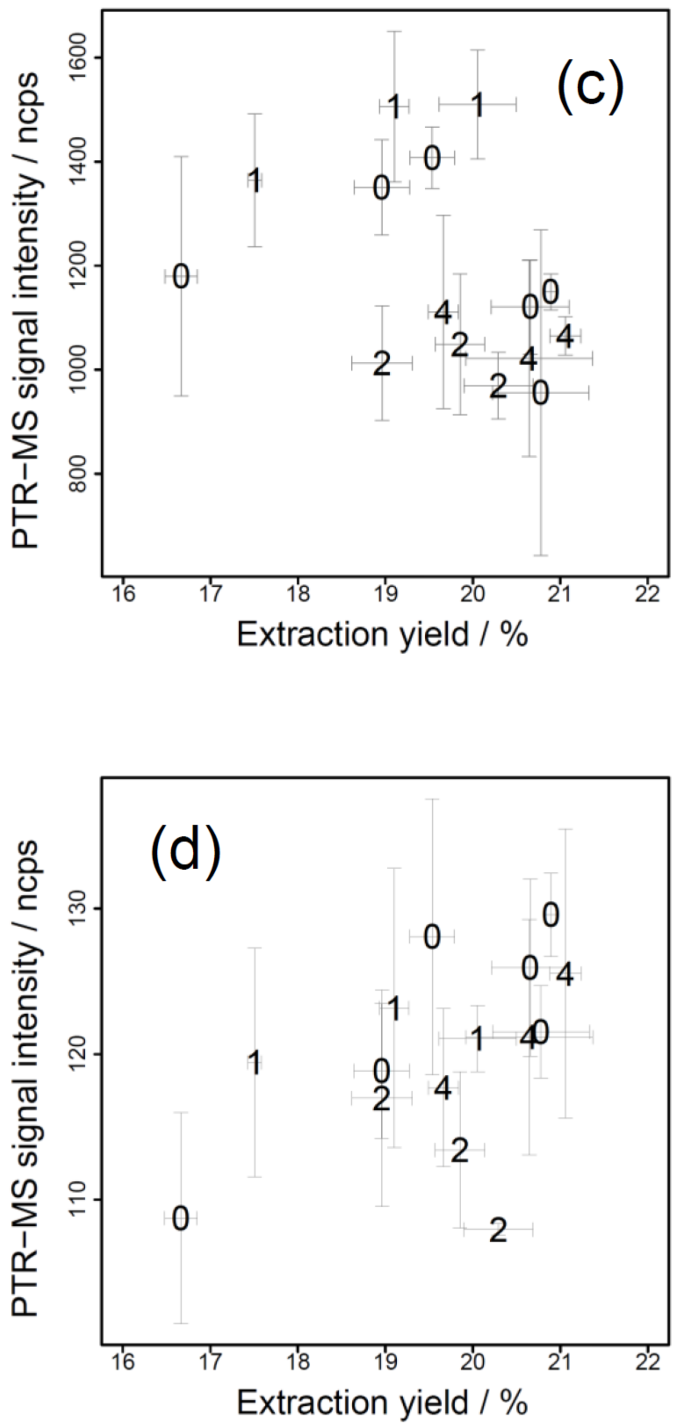
Aroma composition

No clear trend

Increasing trend for medium volatile compounds

(PTR-MS method didn’t measure low volatile aroma)

Group C (example Fig. 6c): compounds that show no clear trend: experimental m/z 55.054, 57.033, 57.069, 63.027, 71.046, 83.046, 85.058, 103.067, 110.055, 123.087.
Group D (example Fig. 6d): compound that shown an increase in headspace concentration with increasing yield: experimental m/z 127.034.



Conclusions

- We demonstrated that share of fines can be adjusted by adding a fines fraction

- The addition of fines did not drastically change the extraction dynamics

- Extraction time can me well modelled with PSD data
- Non-targeted PSD data analysis of whole PSD shows more fines slow the extraction.

- Sensory optimum could be achieved also with relatively high fines (but not adding 4g)

- Aroma composition of highly volatile VOC with regards to yield was not found to be linear.

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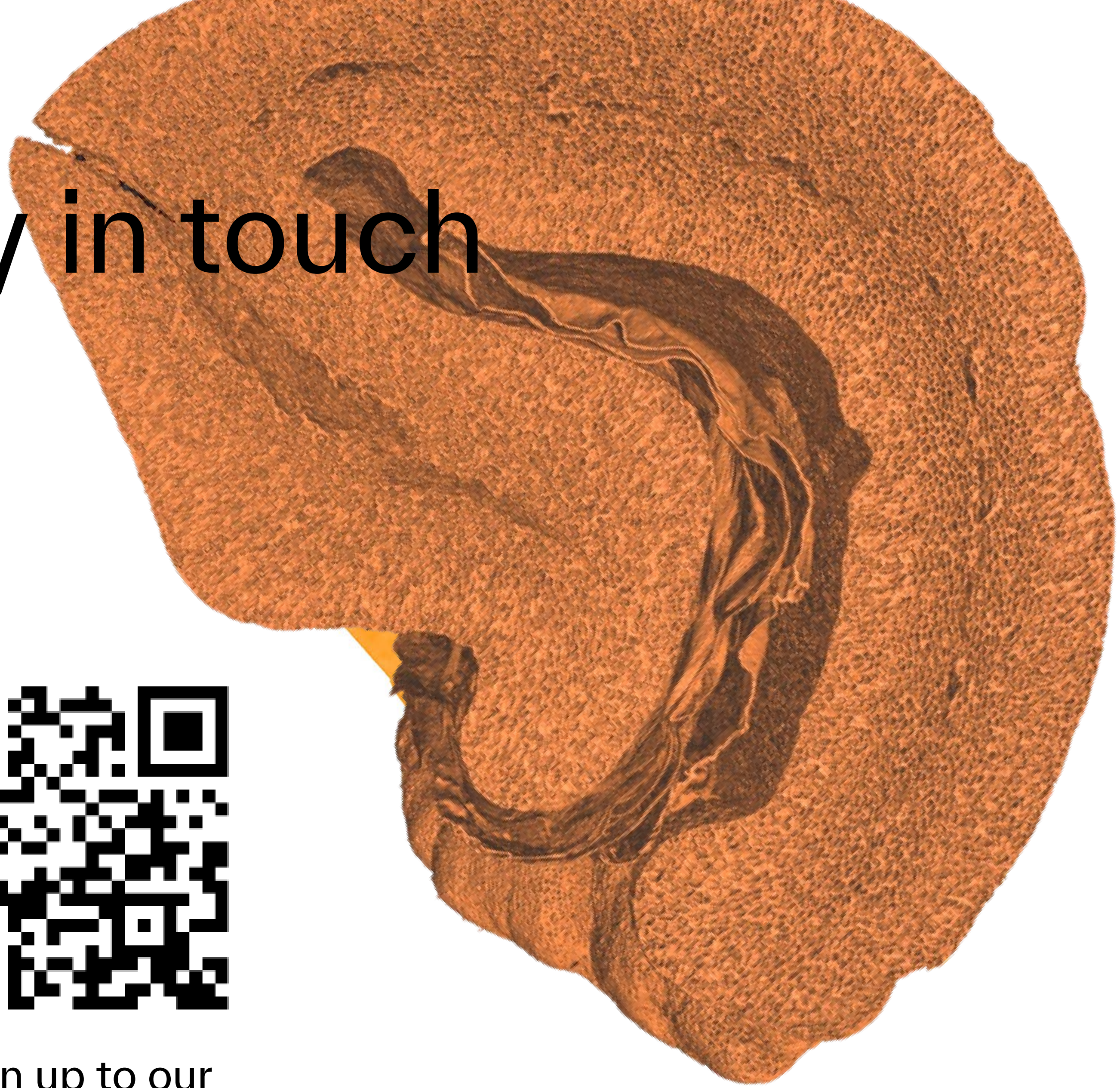

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