Comparison of Coffee Roasting using Hydrogen, Electric and Natural Gas Powered Roasters

Samo Smrke[1], Linda Manthey[1], Nadja Plüss[1], Jaloliddin Khushvakov[1], Sandra Bongers[2]
Dietmar Wißen[2], Sebastian Opitz[1], Chahan Yeretzian[1], Thomas Koziorowski[2]
[1]Coffee Excellence Center, Zurich University of Applied Sciences (ZHAW), Wädenswil, Switzerland
[2]PROBAT SE, Emmerich am Rhein, Germany

Motivation

The transition from fossil fuels to renewable energy sources is reshaping industrial processes, including coffee roasting. While natural gas remains the predominant heat source, electricity is emerging as a viable alternative.[1,2] Hydrogen also presents a promising energy source for roasting. Understanding how roasters powered by these three energy sources influence coffee roasting is essential for ensuring coffee quality and consistency in a decarbonizing industry.

Experimental

Colombian washed Arabica coffee was roasted using three shop roasters powered by electricity, natural gas and hydrogen. Four roast profiles (light/dark and fast/slow combination) were developed to be as comparable as possible. Roasted coffee samples were analysed by colorimetry, particle size distribution (at 3 grind sizes), headspace GC/MS of R&G coffee, organic acids, caffeine and chlorogenic acids in immersion brew (French press), and espresso was extracted at a range of grind size levels. Data were evaluated using both targeted analysis and untargeted analysis by PCA.

Results

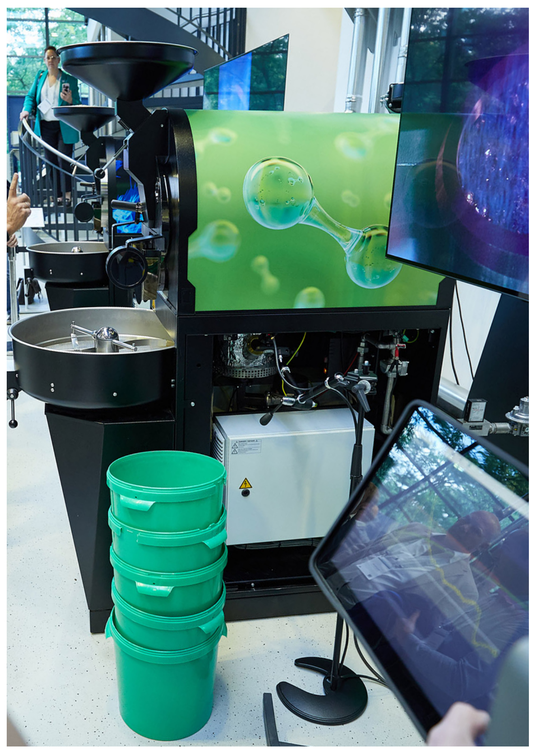
The study demonstrates that coffee can be roasted in nearly identical ways across different heat sources. Despite the distinct physical properties of electric, natural gas, and hydrogen heating systems, nearly identical roast profiles and chemical compositions were achieved. Minor differences were seen in the espresso extraction. The grinder setting of burr spacing to achieve a 25 second extraction were for light slow roast: 142, 146 and 151 um and for light fast roast: 146, 154 and 157 um, for (same order for both fast and and slow), hydrogen, electric and natural gas roasters, respectively.

Conclusion and perspectives

These findings suggest that alternative energy sources can be adopted in coffee roasting without compromising product quality, as evidenced by the highly comparable chemical compositions. Slight differences in espresso extraction were found. Future work will focus on optimizing roast profiles and further investigating the direct transferability of profiles between roasters using different heat sources.

1. Franco, et al. 2018, European Journal of Sustainable Development, 7, 3, 90-98
2. Tsai, et al. 2025, Energies 2025, 18(5), 1018

Hydrogen powered coffee roaster



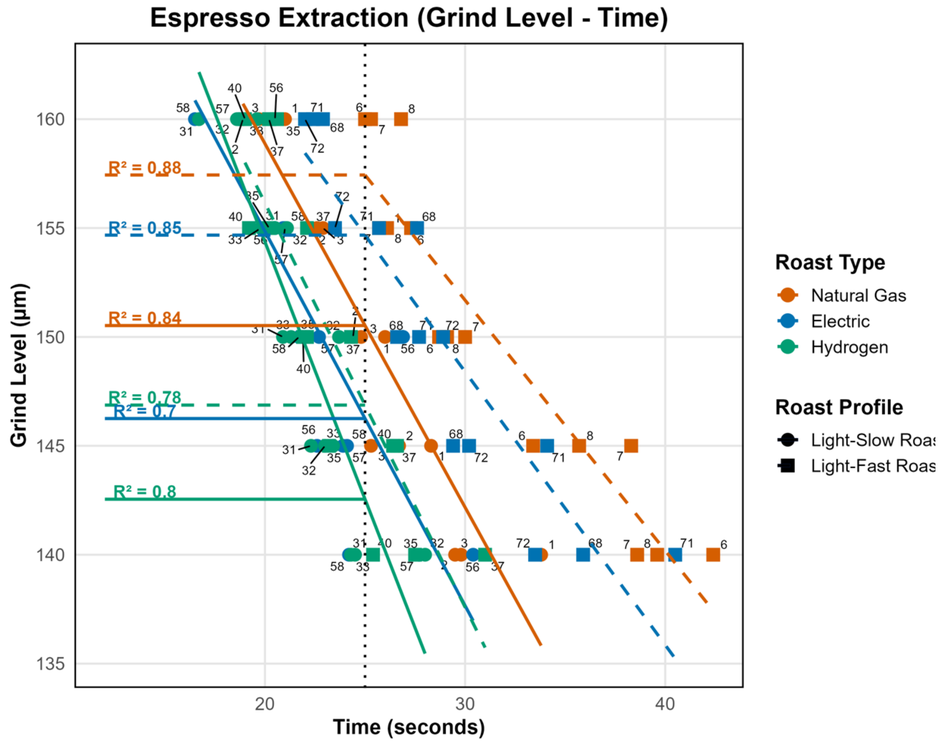


Figure 1 (top): Espresso extraction times at 9 bar when using different setting of the grinder: 140 – 160 µm burr spacing for 3 types of roasters, light roaster coffee (fast and slow roast). Dotted vertical line represent an arbitrarily chosen “optimal” extraction time of 25 second. Each coloured line is a linear fit of the extraction series.

We see slower extraction for both natural gas samples and faster extractions for hydrogen samples.

The trend is the same for both fast and slow samples. This result indicates that the structure properties of the beans were not the same (particle size distribution measurements of the coffees did not show any difference)

Caffeoyl quinic acid analysis

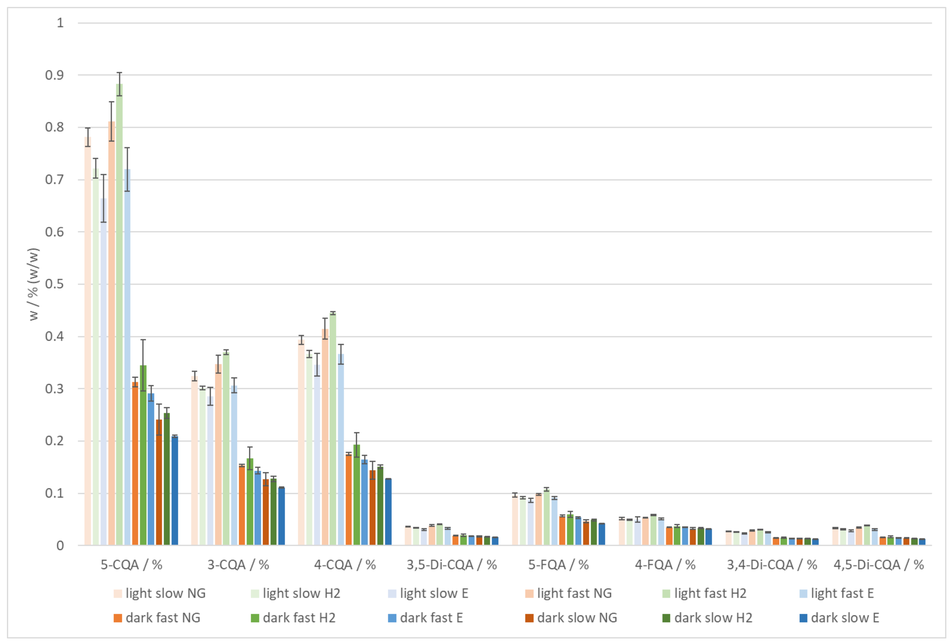


Figure 2 (top): Light fast electric heater and Dark slow electric heater were found to contain lower amounts of 5-CQA.

This indicates that the effective roast profile for the electric heating was not the same as for gas burners. A larger degradation of CQAs at same roast level can generally occur when longer roast development time is used (i.e. time after first crack)

Organic acid analyis

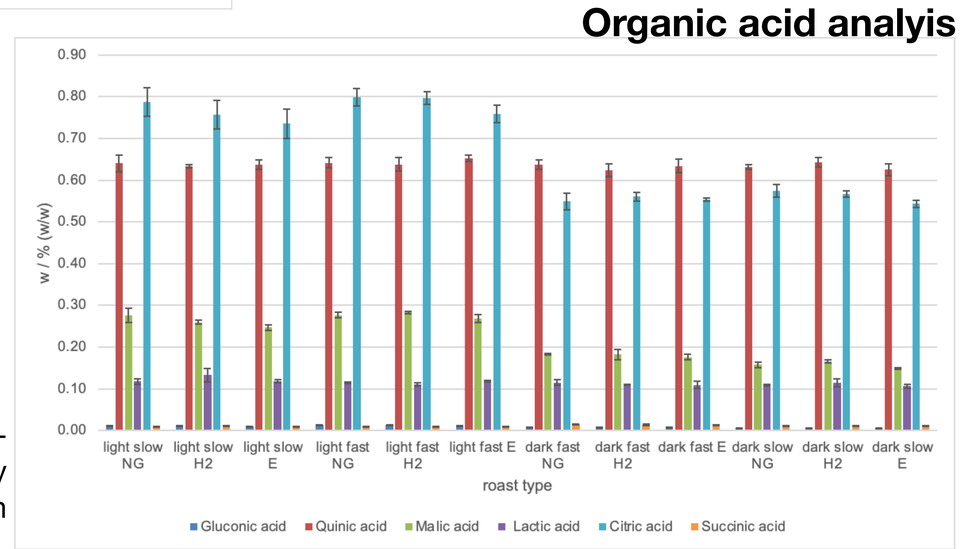
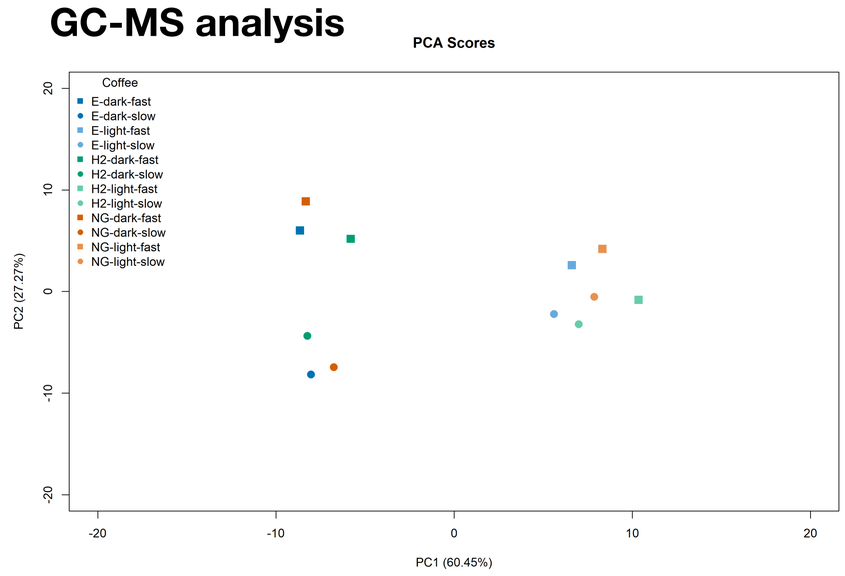


Figure 3 (right): The organic acid composition of roasted beans did not show any differences between samples roasted on

GC-MS analysis



Samples Legend:
E - electric roaster
H2 - hydrogen powered roaster
NG - natural gas powered roaster

Figure 4 (left): PCA analysis of headspace GC-MS results groups well the coffees based on the roast profile applied. At dark roast level the roast time has a bigger differentiation impact as for the light roast.

Based on this analysis no outliers from different roasters sample could be seen and can be concluded: Well known changes in volatile composition of coffee beans as a function of roast profile are significantly larger than any potential changes caused of using different heat application by the roasters.

Roast Profiles Legend:
dark - Colorette 75
light - Colorette 110
fast - 8 min
slow - 14 min