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DOCTORAL DISSERTATION

TEXTURE RELATIVITY AND THE INFLUENCE OF ITS DISTINGUISHING CHARACTERISTICS ON COFFEE BEAN ROASTING PROFILES IN CORRELATION WITH THE SENSORY QUALITY OF SPECIALTY COFFEE

KRZYSZTOF BARABOSZ, M.Sc. Eng.

SUPERVISOR:
DOMINIKA MATUSZEK, D.Sc., Ph.D. Eng.

ASSISTANT SUPERVISOR:
ŁUKASZ BIŁOS, Ph.D. Eng.

OPOLE, 2025

ABSTRACT

In the Specialty coffee segment, great emphasis is placed on consistency and the highest quality of flavour, but the natural variability of the raw material (variety, growing conditions, post-harvest processing method) makes achieving this goal difficult. During the roasting process, coffee beans undergo complex physicochemical changes that influence the sensory profile of the brew. The literature lacks comprehensive studies linking measurable textural characteristics of beans with roasting process parameters and sensory evaluation.

The aim of this doctoral dissertation was to examine the relationship between selected physicochemical properties of *Coffea arabica* beans (moisture, water activity, hardness, porosity, surface topography), the roasting process (temperature profile, development phase length, heat input rate), and the sensory quality of the coffee.

Three main hypotheses were formulated:

1. There is a statistically significant relationship between the physicochemical parameters of Arabica coffee beans and the roasting process.
2. The textural and topographic properties of coffee beans after the roasting process correlate with the sensory attributes of the infusion.
3. The post-harvest processing method (natural vs. washed) significantly influences changes in bean properties during and after the roasting process.

To confirm or refute the hypotheses, a series of tests were conducted, divided into four groups (studies):

1. Analysis of the roasting profiles of washed and natural coffees roasted at constant heater power (73%), airflow (75%), drum speed (63 rpm), and development time (53 s).
2. Analysis of the effect of ten different development times (5 s, 15 s, 30 s, 45 s, 60 s, 75 s, 90 s, 105 s, 120 s, 135 s) on texture characteristics at constant heater power (73%), airflow (75%), and drum speed (63 rpm).
3. Analysis of the effect of the roasting process for three different development phases (1 s (FC), 75 s, 180 s) on texture and topography parameters, with constant parameters of heater power (73%), airflow (75%), and drum speed (63 rpm).

4. Analysis of the effect of the roasting process for three different heater power settings (Fast: 88%, Regular: 73%, Slow: 66%) on texture and topography parameters, with constant parameters of development time (75 s), airflow (75%), and drum speed (63 rpm).

The study included measurements of water activity and moisture content before and after roasting, single-bean hardness tests (texture analyzer), micro-computed tomography to determine internal porosity, 3D surface profilometry (Sq, Sz parameters), and colour measurements. Sensory quality was assessed using the standard cupping method (Specialty Coffee Association protocol) for aroma, flavour, acidity, body, and overall assessment by a panel of experts. The post-harvest processing method was shown to determine the roasting process: dry-processed (natural) beans reached the first crack approximately 20 seconds later than wet-processed (washed) beans. Natural beans lost more mass over time and generated fewer cracks, and after roasting, they were characterized by a lower hardness than washed beans. Extending the development phase time (from 5 seconds to 135 seconds) resulted in an increase in the final temperature (from approximately 210 to 225°C), greater mass loss (from 10 to 17%), and increased cracking. Longer expansion also caused darkening of the color (decrease in the *L parameter value) and a significant reduction in the mechanical hardness of the beans. Roasting speed, which relates to the heating power used, also proved significant. Too high power (Fast profile) led to rapid cracking and uneven flavour development, while too low power (Slow profile) resulted in the loss of volatile aromatic notes. Correlations were found between textural parameters and sensory quality. More porous and brittle beans, resulting from dark roasting, released aromas more quickly, increasing flavour intensity, which was characterized by a distinct bitterness. Harder, less porous beans (lighter roasts) retained distinct acidity and aroma complexity.

In summary, the research confirmed the significant impact of the beans' physical properties on the roasting process and coffee flavour characteristics. Key factors (water activity, post-harvest processing method, time-temperature profile) were identified that determine bean texture, which in turn affects extraction and sensory perception. The results were used to test the hypotheses. It has been shown that changes in the coffee bean structure (hardness, porosity, topography) correlate with the quality of the brew, and these relationships can be represented using simple equations. The presented results and observations expand our knowledge of the mechanisms of coffee roasting. The quantitative description of the relationship between the microstructure of roasted beans and their flavour represents an innovative approach. From a practical perspective, recommendations for Specialty coffee roasters are formulated, and the implementation of new sensory tests combining physicochemical parameters and proprietary diagnostic indices: WOC and WSUM, with the most sensitive sensory attributes (aroma, acidity, body, balance). This work points the way to integrating process engineering with sensory evaluation towards a more predictive, scientific approach to coffee roasting, which will translate into a better and repeatable product in the cup.