Abstract of the doctoral dissertation of M.Sc. Aleksandra Celejewska entitled "*An Innovative Tool for Assessing the Quality of Cheesemaking Products*"

The doctoral dissertation concerns the development of an innovative tool for assessing the quality of dairy products – ripened cheeses and cheese-like products utilizing measurements of selected electrical parameters as a source of information on the quality and degree of maturity of the examined products. The work is situated within the discipline of management and quality sciences, in which quality management is understood as the design and supervision of production processes, the selection of diagnostic tools, and the making of technological decisions based on measurement data. This approach also includes taking into account the requirements of food quality and safety assurance systems as well as the risk of adulteration resulting from the substitution of milk fat with vegetable fats.

The principal objective of the research was to determine the applicability of the innovative quality assessment tool for monitoring the ripening process and diagnosing qualitative changes in the studied products. An additional aim was to identify the usefulness and limitations of the analyzed tool with respect to the authenticity of matured products. The implementation of the main objective encompassed two research stages (pilot – Stage I and principal – Stage II), within which seven specific objectives were defined, focusing on: (1) the characterization of electrical properties of milk and dairy products, (2) the description of qualitative changes during ripening, (3) the comparison of results obtained using the innovative electrical tool with those of reference methods, and (4) the evaluation of its potential application in quality management and authenticity assessment. Verification of the degree of achievement of these objectives was supported by the formulation of four research hypotheses (H1–H4), reflecting the anticipated relationships between electrical parameters and technological and qualitative indicators of ripened cheeses and cheese-like products.

In Stage I, the electrical characteristics of raw milk, pasteurized milk, and pasteurized milk with palm oil addition were determined based on measurements of selected electrical parameters. Subsequently, the influence of milk fat substitution with palm oil and 28-day ripening on the texture and electrical properties of the studied dairy products was examined. This enabled the evaluation of the suitability of the CPD sensor-based measurement system for rapid, non-destructive assessment of structural changes. In Stage II, the course of qualitative changes during ripening (over 28 days) was characterized, taking into account chemical composition, proteolysis dynamics, color, and texture. Conductivity parameters (Z, G) and capacitance parameters (Cp, Cs) were measured using the CPM sensor and the RCC equivalent model of food products. The data were subjected to statistical analysis (principal component analysis, correlations) and regression modeling to forecast the technological quality of matured products based on electrical parameters.

In the principal research (Stage II), products containing vegetable fat exhibited greater hardness, a more stable structure, reduced dynamics of texture and color changes, and higher values of electrical conductivity and capacitance, which indicates a different character of the interaction between the electric field and the product and a less intensive ripening proces. Comparison of the custom-designed sensors confirmed the superiority of the CPM sensor over the prototype CPD sensor, resulting from the smaller required sample volume and more stable contact with the tested material. Consequently, the CPM sensor provided more reproducible, less interference-prone results and reliable recording of electrical changes across a wide frequency range, enabling the development of useful regression models.

Correlation and PCA analyses indicated that in ripened cheeses, electrical parameters were most strongly correlated with proteolysis indicators and water activity, whereas in cheese-like products they were associated with texture features (particularly elasticity) and color. The regression models developed for matured dairy products (after 28 days) demonstrated significant predictive potential of electrical parameters in assessing technological quality, with greater usefulness observed for ripened cheeses than for cheese-like products. Hypotheses H1–H3, concerning the impact of milk fat substitution with vegetable fat, the greater usefulness of the CPM sensor compared to the CPD sensor, and the existence of statistically significant relationships between electrical and technological parameters, were largely confirmed. Hypothesis H4, concerning the prediction of the quality of matured products based on electrical parameters, was partially confirmed, indicating the need for further verification of the developed models.

From the perspective of management and quality sciences, the obtained results confirm that electrical methods employing the parameters Z, G, Cp and Cs may serve as a valuable complement to classical reference methods in quality control systems. They provide rapid, non-destructive access to information on structural changes during ripening, contributing to the reduction of adulteration risk and the effective monitoring of technological processes and laboratory analysis costs. It should be emphasized, however, that the research was conducted under laboratory conditions, and the proposed tool remains a concept requiring further refinement and validation on an industrial scale, as a potential support for decision-making processes in quality management.