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The application of convolutional neural networks, LF-NMR and texture analysis for microparticle assessment in evaluating the quality of blackcurrant fruit powders

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ABSTRACT

The dynamic progress in artificial intelligence is transforming food research, especially in optimizing unit operations like drying while ensuring product quality and shelf-life. A promising approach involves using convolutional neural networks (CNNs) to evaluate the quality and homogeneity of fruit powders, focusing on the morphological structure of microparticles. This study applies CNNs alongside low-field nuclear magnetic resonance (LF-NMR) and texture analysis to assess blackcurrant powders. Results indicate that carriers such as maltodextrin, inulin, whey proteins, microcrystalline cellulose, and gum arabic are effective in CNN-based morphological identification. The most favorable outcomes were achieved with a combination of maltodextrin and whey proteins with inulin. The CNN model for the MD50-MD70 sample yielded the lowest mean squared error (2.5741×10^{-4}), confirming its high accuracy in classifying powder microstructures.

OBJECTIVES

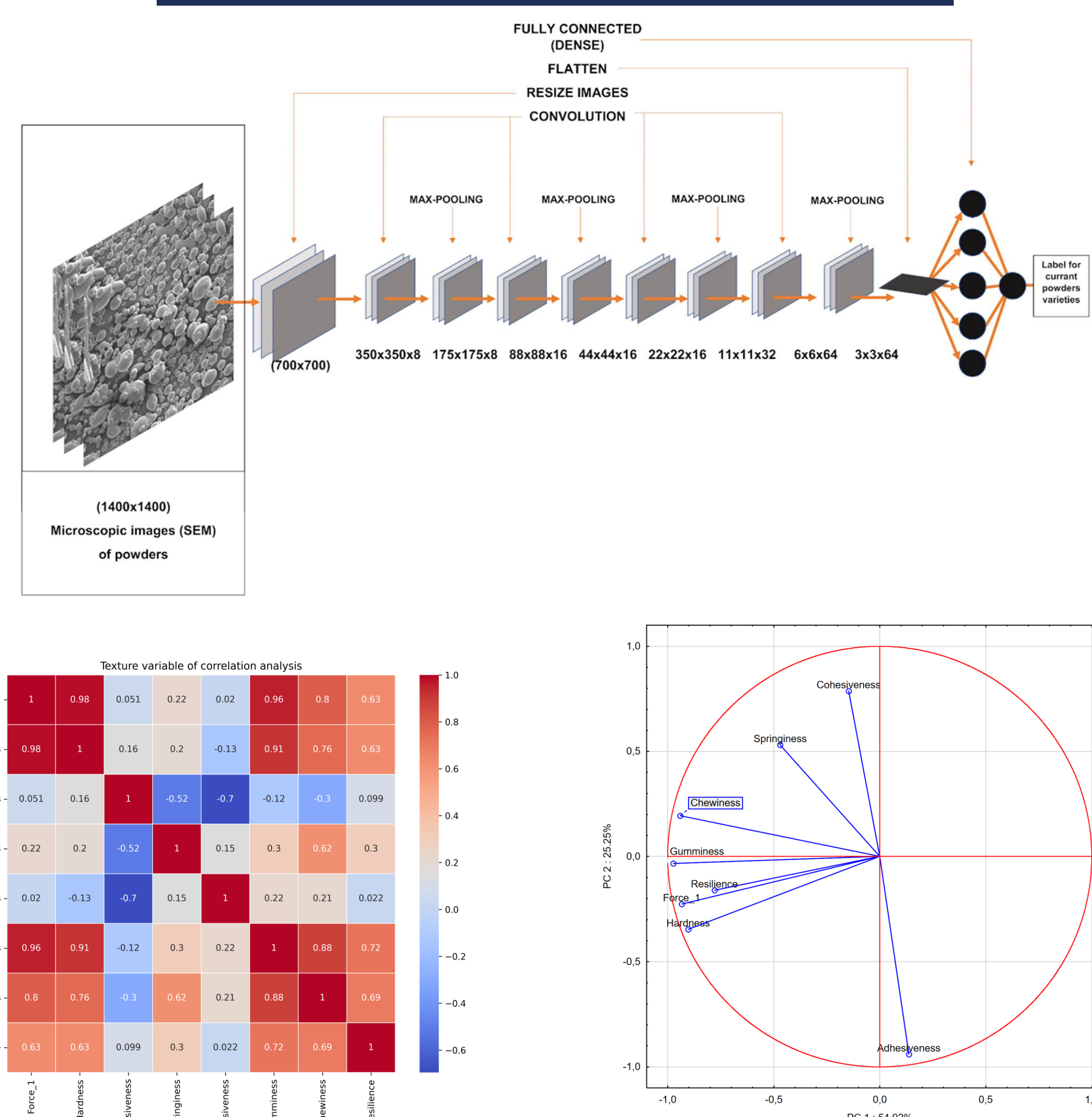
The research aimed to apply advanced AI techniques for optimization and quality control in food processing, specifically focusing on blackcurrant powders. Key points include:

- Utilizing convolutional neural networks (CNN) alongside traditional methods (LF-NMR and texture analysis) to evaluate quality and consistency.
- Assessing the morphological structure of fruit powder microparticles with CNN to enhance food quality analysis.
- Developing a deep learning-based image classification algorithm to analyze SEM images of microparticles.
- Leveraging AI to create alternative solutions for producing high-quality powders, reducing reliance on costly and complex physical methods.
- Optimizing the spray drying process using computer vision for better control of fruit powder morphology.

METHODS

- Material:** Blackcurrant concentrate powders with various carriers (maltodextrin, gum arabic, inulin, whey protein, fiber, microcrystalline cellulose) in proportions of 50% and 30%.
- Structural Analysis:** Scanning electron microscopy (SEM) to obtain images of microparticles.
- Physical (Comparative) Analysis:** Measurement of spin-lattice relaxation time T1 using LF-NMR (low-field nuclear magnetic resonance) and instrumental texture analysis (including hardness, cohesiveness, stickiness).
- Artificial Intelligence (AI):** Development and training of sequential CNN models.

RESULTS



CONCLUSIONS

- Based on the obtained results, it was confirmed that microparticles of blackcurrant powder can be successfully identified using Convolutional Neural Networks (CNNs).
- The best CNN training outcomes were achieved with carriers such as whey protein, inulin, and microcrystalline cellulose (variants W70-IN70 and C70-W70), which yielded the lowest Mean Squared Error (MSE) values. Additionally, the MD50-MD70 model (maltodextrin) also demonstrated an exceptionally low MSE.
- CNNs were able to effectively identify the morphological structure of blackcurrant powders significantly faster and more efficiently than advanced analytical techniques such as LF-NMR and instrumental texture analysis.
- Accurate evaluation of microparticle shape and minimal intermolecular spacing using machine learning represents a key criterion for maintaining a high quality index and uniformity of powders.

REFERENCES

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