Deep Learning-Based Hyperspectral Image Reconstruction from RGB Data for Gluten Detection in Food Products

Adewale A. Oloyede[1], Akinbode A. Adedeji[1]

Department of Biosystems and Agricultural Engineering, University of Kentucky, Lexington, KY, USA,40506

akinbode.adedeji@uky.edu

INTRODUCTION

- Gluten-related disorders affect **1-7%** of the global population.
- Traditional methods of gluten detection and quantification such as ELISA, PCR are **time consuming and required skilled personnel for sample preparation**.
- Although hyperspectral imaging (HSI) can detect and quantify gluten, its adoption is limited by the **high cost, complex design, and low spatial resolution of the HSI equipment.**
- HSI reconstruction from RGB image data bridges this gap by combining **high spatial resolution from RGB data with spectral details from HSI data.**

OBJECTIVE: To use deep learning algorithms to reconstruct hyperspectral images from RGB images for detecting wheat gluten in gluten free flour.

MATERIALS & METHOD

Materials
- Wheat flour (WF): Gluten source
- Corn flour (CF): Gluten free flour

Sample Preparation
- WF was mixed with CF in varying amounts: 0-2.4% (increments of 0.1%) and 2.5-10% (increments of 0.5%)
- For each contamination level, 20g mixture was prepared
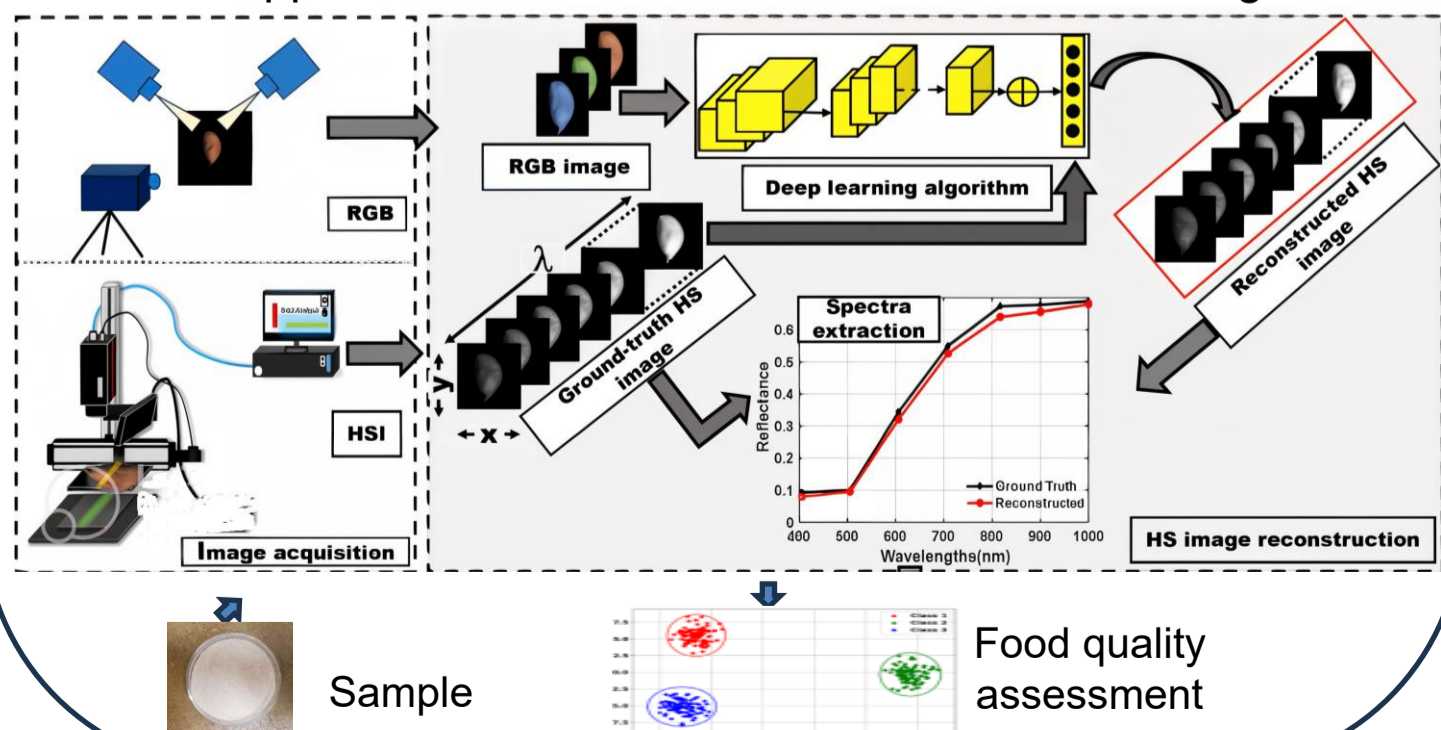
HSI Data Acquisition
- Spectrum range-visible near infrared camera (400-1000nm)

RGB Data Acquisition
- A Samsung Galaxy Tab S9 ultra tablet was used to obtain RGB images

Reconstruction algorithms: EDSR & HRNET

*Approach to HSI Reconstruction from RGB Images

RESULTS & DISCUSSION

Table1: Ground Truth (GT) Label Development

Features selector	No of features	Detection models	Training accuracy (%)	Testing accuracy (%)
Sequential forward selection	10	KNN	100	100
		RF	100	99.4

KNN (K-Nearest Neighbors), RF (Random Forest)

Table 2: Model Evaluation Metrics on Test Set Data for Gluten Detection

Model	MRAE	RMSE	PSNR
HRNET	0.152	0.030	28.06
EDSR	0.204	0.205	30.10

HRNET (High Resolution network), EDSR (Enhanced Deep Super Resolution), MRAE(Mean Relative Absolute Error), RMSE(Root Mean Squared Error), PSNR(Peak signal to noise ratio)
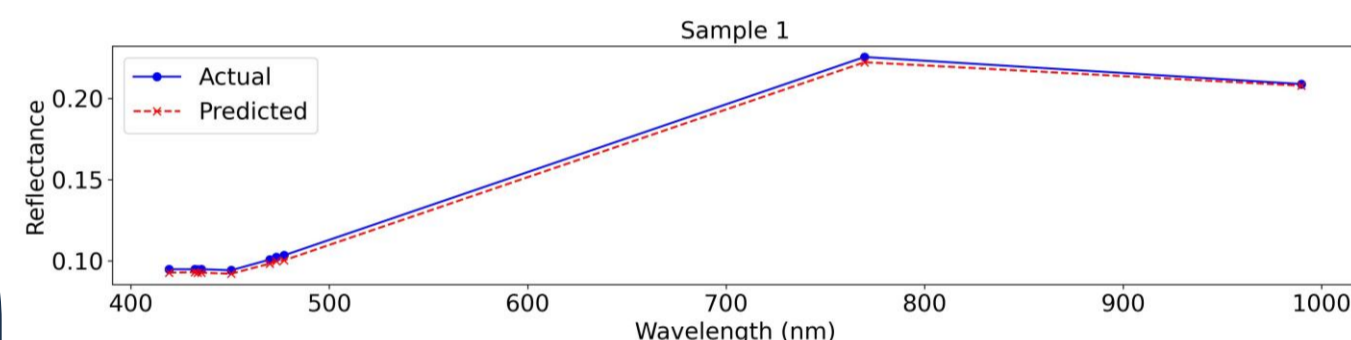

Fig 1: Comparison of reconstructed and GT spectra for gluten detection using EDSR model

Table 3: Models' Performance on the Reconstructed Spectra for Gluten Detection

Model		Detection models	Accuracy (%)	Precision (%)	Recall (%)
HRNET	Training	KNN	92.3	92.9	92.3
		RF	97.0	97.0	97.0
	Testing	KNN	91.8	90.8	91.8
		RF	**94.6**	**94.9**	**94.6**
EDSR	Training	KNN	92.4	93.0	92.4
		RF	96.0	96.0	96.0
	Testing	KNN	91.6	89.8	91.6
		RF	93.1	92.4	93.1

HRNET (High Resolution network), EDSR (Enhanced Deep Super Resolution), KNN (K-Nearest Neighbors), RF (Random Forest)

CONCLUSION

- **HRNET with RF** achieved the highest accuracy, recall, and precision, demonstrating strong overall performance
- Future work: This approach could be applied to test for other gluten contaminant sources.

REFERENCES

* Ahmed, M. T., Monjur, O., Khaliduzzaman, A., & Kamruzzaman, M. (2025). A comprehensive review of deep learning-based hyperspectral image reconstruction for agri-food quality appraisal. *Artificial Intelligence Review*, *58*(4), 96.

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