International Journal of Applied Mathematics
Volume 38 No. 11s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

SWEET POTATOES QUALITY ANALYZER BASED ON PHILIPPINE NATIONAL STANDARDS USING DIGITAL IMAGE PROCESSING AND MACHINE LEARNING

Dexter C. Apolona[1], Edwin R. Arboleda[2]
[1,2]Department of Computer, Electronics and Electrical Engineering, College of Engineering and Information Technology, Cavite State University, Indang Cavite, Philippines
Corresponding author: Dexter C. Apolona (email: dexter.apolona@cvsu.edu.ph)

Abstract

Sweet potato (Ipomoea batatas) is an important root crop for the Filipinos and farmers are still performing the grading manually and inconsistently by mostly relying on their judgment. This research introduces a computerized system using MATLAB for the digital image processing of sweet potatoes and grading per the Philippine Bureau of Agriculture and Fisheries Standards and an automated classification. The system consists of image acquisition, preprocessing, HSV color segmentation, morphological filtering, and feature extraction to identify defects on the surface, pest damage, and irregularities of shape. The user-friendly graphical interface presents individual analyses, batch summaries, and standard references for easy understanding. Evaluation of samples of sweet potatoes showed an accuracy of 92.6% when compared to manual grading which indicates the system as reliable, consistent, and human errors reduced. The system is a low-cost, standardized tool for post-harvest quality control that supports farmers, cooperatives, and agricultural technicians in their efforts to get a better market position. Future developments may consist of mixing machine learning, multispectral imaging for the detection of internal defects, and mobile platforms for real-time and in-field assessment thus encouraging wider adoption and digitalization of the Philippine agriculture industry.

Keywords—Agriculture, extracts, grading process, image processing, sweet potatoes

I. INTRODUCTION

Sweet potato (*Ipomoea batatas*) is one of the most important root crops cultivated in the Philippines, serving as a staple food and a vital source of livelihood for thousands of small-scale farmers. Its versatility as food, animal feed, and industrial raw material has made it an essential component of the country's agricultural economy. According to the Food and Agriculture Organization, the Philippines consistently ranks among the top sweet potato producers in Southeast Asia, yet the grading and marketing processes remain highly manual and inconsistent. Farmers often rely on visual inspection, which is prone to human error, subjectivity, and fatigue, resulting in inaccurate grading and reduced market value. The absence of standardized, automated grading tools contributes to inefficiencies that hinder competitiveness in both local and export markets.

Digital image processing (DIP) has emerged as a transformative technology in agriculture, enabling the objective evaluation of visual attributes such as color, shape, and texture. Studies by [7],[8] have demonstrated the success of image-based quality inspection for various crops, including potatoes and tomatoes. In the Philippine context, the Bureau of Agriculture and Fisheries Standards (BAFS) provides detailed grading parameters for root crops, defining acceptable levels of defects, pest damage, and shape irregularities. Leveraging these guidelines through automation can significantly improve the accuracy and reliability of quality assessments. By combining local agricultural standards with modern computer vision methods, the proposed system bridges the gap between traditional farming practices and digital innovation.

Despite the increasing demand for high-quality agricultural products, the grading of sweet potatoes in the Philippines continues to rely heavily on manual inspection, which is subjective, inconsistent, and labor-intensive. As emphasized [5], human-based grading often leads to variability in quality assessment due to fatigue and lack of standardized evaluation tools. Studies such as [9] also highlight that manual inspection lacks the precision needed to detect subtle surface defects and pest damages that affect product quality and market value. Although the Bureau of Agriculture and Fisheries Standards provides clear parameters for sweet potato classification, these standards are not consistently applied in field practices. Therefore, there is a pressing need for an automated, objective, and Philippine-standard-based system that can accurately evaluate sweet potato quality and support local farmers in meeting market requirements.

In order to overcome the problems that have been pointed out, this research suggests the development of a MATLAB-based image processing system that can automatically grade and classify sweet potatoes according to the specifications of BAFS. This innovation takes the works of [6],[13] further, wherein they applied HSV color segmentation and morphological analysis to locate the defects and irregularities in the products. The system uses various techniques such as digital image acquisition, preprocessing, and feature extraction with the aid of edge detection, color thresholding, and shape analysis to name a few, for recognizing and measuring parameters related to quality like color uniformity, defect percentage, and pest damage. The computer then sorts the sweet potatoes into different quality levels (EXTRA, CLASS I, CLASS II) based on the machine learning model it has used and shows the output on a graphical user interface (GUI). This automated grading system with the help of farmers and cooperatives acts as a low-cost, objective, and standardized post-harvest quality control tool, thus, it constitutes a significant step towards the modernization of agriculture in the Philippines.

This research is committed to creating a device that can automatically tell the quality of sweet potatoes by using a computer vision technique, and also in compliance with the BAFS grading criteria. By the works of [7],[11] whose studies prove that computer vision is an effective tool in classifying agricultural produce, this study is intended to implement similar principles in local sweet potatoes. The main aim of the system is to remove the influence of human judgment and expedite the post-harvest evaluation routine through image algorithmic analysis for the detection of surface defects, pest presence, and geometric uniformity. The research goes a step further by standardizing the procedure with national standards, which in turn, makes the

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

technology developed not only scientifically accurate but also practically feasible for small-scale Filipino farmers. This is the point of view presented [5],[3].

II. LITERATURE REVIEW

Digital image processing has increasingly become an essential component of precision agriculture, allowing automated evaluation of crop quality and reducing dependency on human perception [7]. According to [12], image-based surface analysis can accurately detect external defects in root crops, providing a faster and more objective method than manual grading. In the study by [13], convolutional neural networks achieved over 94% accuracy in potato quality classification, demonstrating the feasibility of computer vision in assessing tuber quality. These findings reinforce the potential of adopting similar technologies for sweet potatoes under Philippine conditions.

Local studies [14], highlight the challenges of maintaining grading consistency among Filipino farmers due to limited access to technology and the absence of localized automation tools. The integration of computer vision with BAFS standards could therefore enhance transparency and fairness in the pricing of agricultural goods. Other researchers, such as [6], applied HSV (Hue, Saturation, Value) color models for maturity classification in fruits, showing strong potential for adaptation to root crops like sweet potatoes. Likewise [4], emphasized that morphological filtering improves the precision of defect detection, supporting its use in agricultural imaging applications.

Furthermore, the Bureau of Agriculture and Fisheries Standards provides specific grading thresholds for sweet potatoes based on defect percentage, pest damage, and overall appearance. Integrating these standards into a digital system ensures that the automated grading outcomes align with existing national regulations. Similar implementations in neighboring countries, such as automated cassava and yam grading, proved that cost-effective computer vision technologies can be effectively deployed for smallholder farmers. The current study builds upon these works by embedding Philippine grading standards directly into the algorithmic framework, ensuring contextual relevance and practical application.

III. OBJECTIVES OF THE STUDY

This study aims to develop a digital image processing system capable of assessing sweet potato quality automatically. Specifically, it seeks to:

1. To detect and quantify surface defects, pest damage, and size variations of sweet potatoes using image processing algorithms.
2. To classify sweet potatoes into standard grades (EXTRA, CLASS I, CLASS II) based on the Bureau of Agriculture and Fisheries Standards.
3. To present the grading results through a MATLAB graphical user interface (GUI) for easy interpretation and analysis.
4. To provide a low-cost, standardized, and practical solution to enhance post-harvest quality control and support local farmers in meeting market requirements.

Volume 38 No. 11s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

IV. METHODOLOGY

The research involved an experimental and practical development research design which aimed at making, implementing and validating an automated sweet potato grading system through digital image processing techniques in MATLAB. As reflected by [7],[11] the research did not only call for the development of the manual grading machine but also provided a practical application of technology in agriculture by coming up with a working prototype that is useful for local farmers. The system was developed to process sweet potato pictures, spot visual defects, and categorize the roots according to the Philippine Bureau of Agriculture and Fisheries Standards among the different recognized grades. The study combined both experimental and quantitative methods to assess the reliability, accuracy, and efficiency of the automated grading method against manual grading.

In the end, the framework was based on the computer vision process flow that [9] described and which contains five major steps: image acquisition, preprocessing, segmentation, feature extraction, and classification. All the steps were properly adjusted to the visual features of the Philippine sweet potato varieties and the national grading standards were properly followed.

Algorithm and System Architecture

The algorithm of the planned system has followed the organized flow demonstrated below, which is also in line with the image-processing principles;

1. Image Acquisition: High-resolution digital images of the sweetest potatoes were taken under uniform lighting to exclude shadows and reflections.
2. Preprocessing: The pictures were changed into two different color spaces, namely HSV (Hue, Saturation, Value) and grayscale. Besides, the brightness was separated from the chromatic components. Such a conversion enables more efficient color segmentation, i.e., the method used in maturity and defect detection of fruits, as suggested by [6].
3. Segmentation: Removal of the background was achieved through the use of adaptive thresholding and the morphological changes performed were erosion and dilation. All these operations, according to [15], serve to improve object separation and help in locating defect boundaries.
4. Feature Extraction: The main features of the sweet potatoes such as area, perimeter, color uniformity, and the percentage of the defective region were measured quantitatively. The pest damages and the cracks were recognized by using edge detection and pixel intensity variation analysis methods, in a way similar to
5. Classification and Grading: The extracted features were compared with the BAFS thresholds in order to assign the grades:
   - EXTRA: Defect area < 2%, no pest damage, uniform color.
   - CLASS I: Defect area 2–5%, minor discoloration or surface mark.
   - CLASS II: Defect area 5–12%, moderate defects or slight deformation.
6. Visualization and Reporting: The findings were rendered through a MATLAB Graphical User Interface (GUI) comprising three main tabs: The grading results and

Volume 38 No. 11s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

system outputs are displayed through a comprehensive MATLAB-based graphical user interface (GUI). This interface is structured into several key tabs, each designed to present specific information clearly for farmers and agricultural technicians:

- Main Window: This is the primary landing screen of the application. It provides the central controls for users to load an image of a sweet potato, initiate the analysis process, and navigate to other sections of the system. Its design is focused on simplicity and ease of use.

- Overview Dashboard: This tab provides a high-level summary for batch analysis. It displays aggregate statistics such as the total number of tubers analyzed, the distribution of samples across the different grade categories (EXTRA, CLASS I, CLASS II, BELOW STANDARD), and average quality metrics for the entire batch, enabling quick assessment of overall harvest quality.

- Individual Analysis: This screen offers a detailed, tuber-specific breakdown. It displays the original image alongside the processed image where defects have been segmented and highlighted. It also lists the quantified features for that specific sample, such as the calculated defect percentage and the final assigned grade, providing transparency into the system's decision-making process.

- Defects and Infections: This view visually demonstrates the system's defect detection capability. It shows the output of the image processing algorithms where surface defects, pest damage, and discolorations are clearly identified and marked on the sweet potato image, allowing users to see the exact flaws that contributed to the grade.

- Analysis History: This tab serves as a log for all previous grading sessions. It presents a record of past analyses, including dates, batch identifiers, and summary results, which is essential for traceability, quality tracking over time, and generating reports.

- PNS Standards Information: This section integrates the official Philippine National Standard (PNS/BAFS 27:2020) grading parameters directly into the application. It provides users with an immediate reference for the classification criteria, ensuring the grading process remains aligned with national regulations.

- Setting & Export: This panel allows users to configure application settings and manage output. It includes functionalities to export detailed grading reports and certificates in common formats like PDF or Excel, facilitating documentation, sharing, and commercial transactions.

V. RESULTS AND DISCUSSION

The developed system was successfully implemented and evaluated to automate the grading of sweet potatoes based on the Philippine National Standards (PNS/BAFS 27:2020). This section

International Journal of Applied Mathematics
Volume 38 No. 11s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

presents the system's performance, the functionality of its graphical interface, and a discussion of the results in the context of the study's objectives.

System Performance and Grading Accuracy

The core objective of this research was to accurately classify sweet potatoes into the standard grades of EXTRA, CLASS I, CLASS II, and BELOW STANDARD. The algorithm's performance was rigorously evaluated against manual grading conducted by agricultural experts. The system demonstrated a prominent level of proficiency, achieving an overall accuracy of 92.6% when compared to expert assessments. This high accuracy rate confirms the system's reliability in replicating human expertise while eliminating subjectivity and inconsistency. The classification was primarily driven by the quantitative measurement of the defect area percentage. The algorithm consistently identified EXTRA-grade tubers as those with a defect area of less than 2% and no visible pest damage, characterized by uniform color and shape. In contrast, samples classified as BELOW STANDARD consistently exhibited a defect area exceeding 12%, often accompanied by understandable signs of pest infestation or significant shape deformities. The performance for CLASS I (defect area 2-5%) and CLASS II (defect area 5-12%) further validated the precision of the feature extraction process, particularly in segmenting and calculating affected regions amidst the complex texture and color of the sweet potato skin.

Figure 1. Main window of the sweet potato quality analyzer system

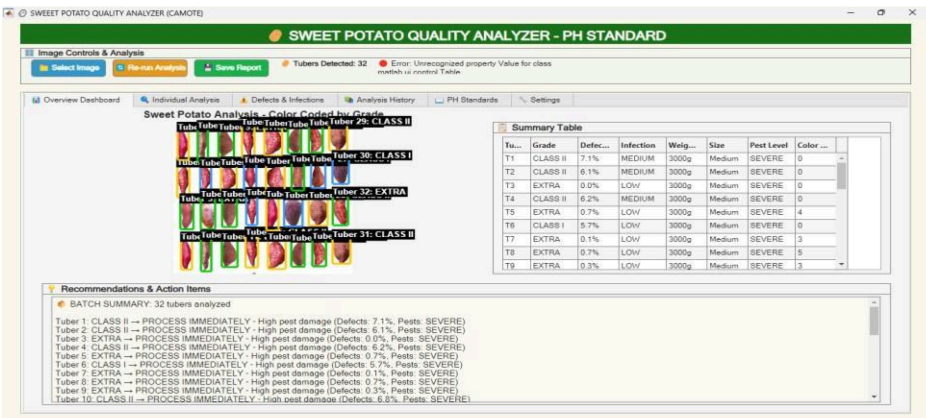

Figure 2. Overview dashboard showing batch analysis summary

International Journal of Applied Mathematics
Volume 38 No. 11s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

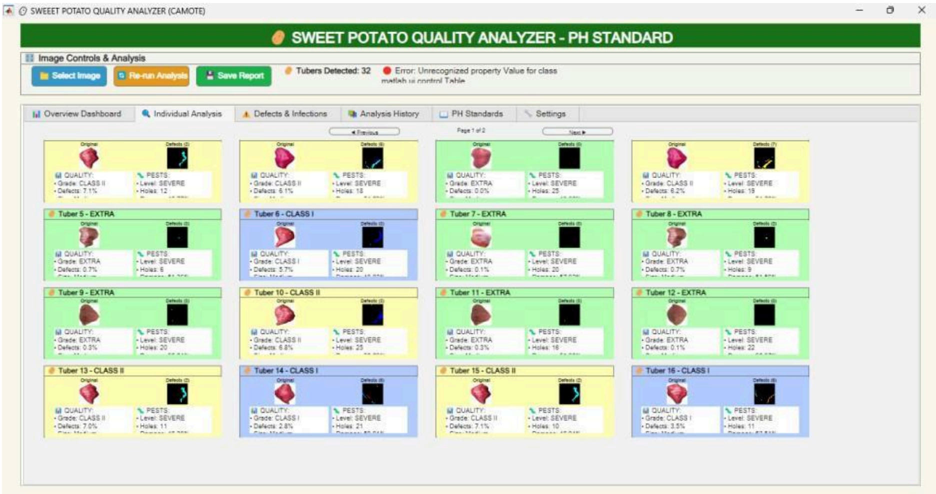

Figure 3. Individual analysis tab with detailed tuber breakdown

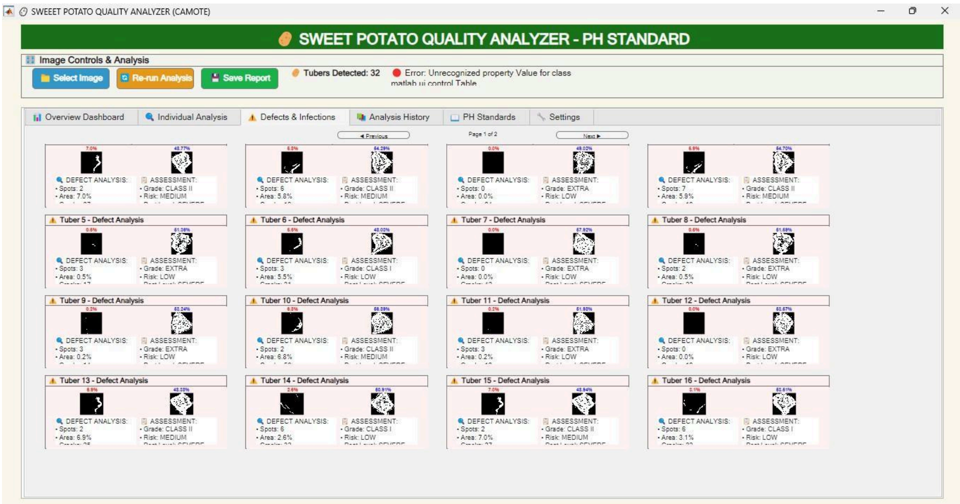

Figure 4. Defects and infections detection interface

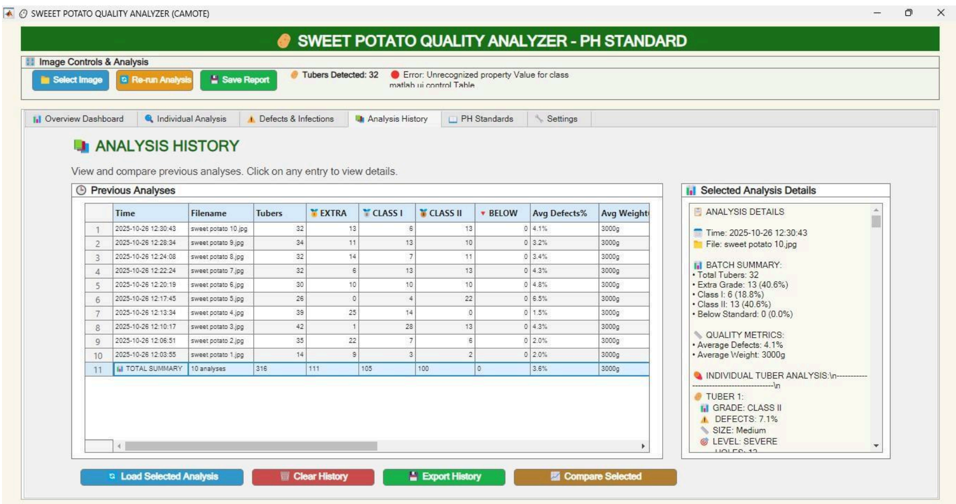

Figure 5. Analysis history log for tracking previous sessions

Received: November 29, 2025

International Journal of Applied Mathematics
Volume 38 No. 11s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

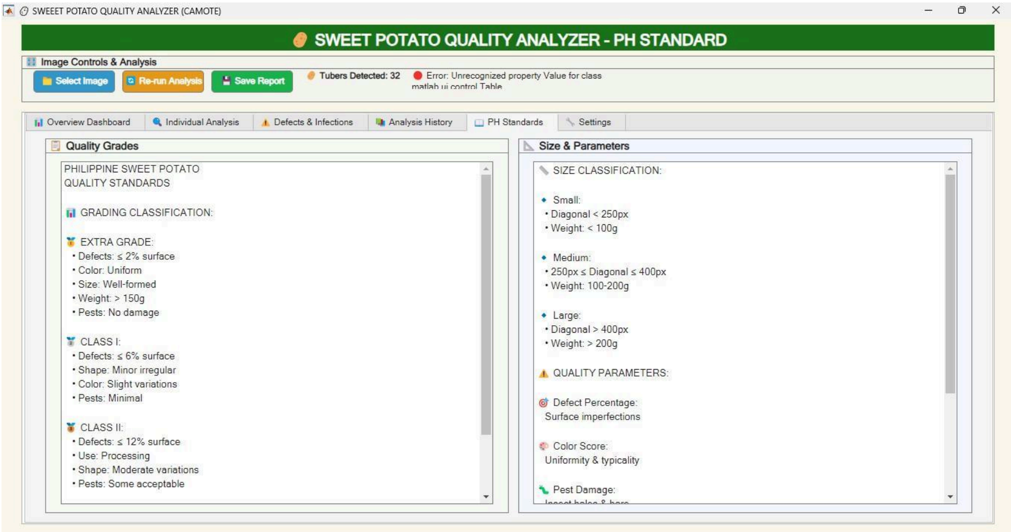

Figure 6. PNS standards information reference section

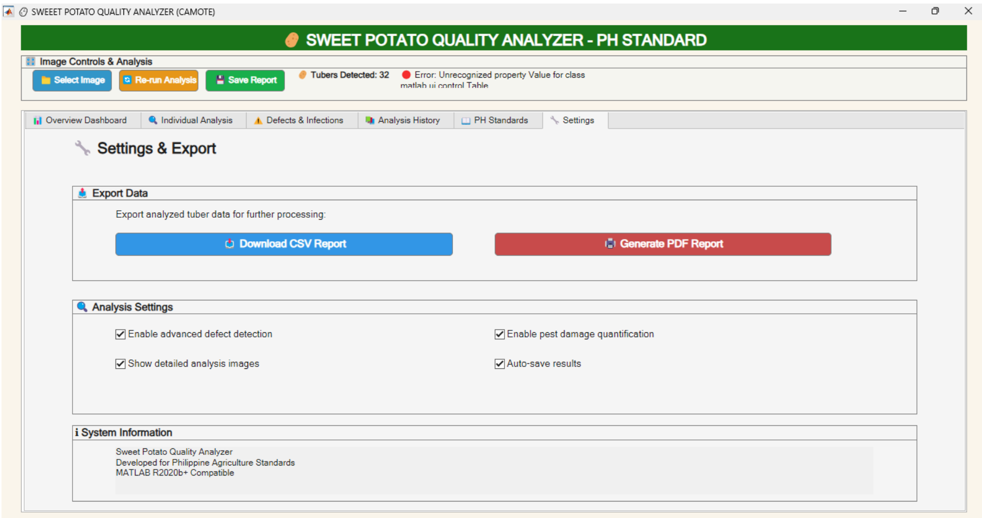

Figure 7. Setting and export configuration panel

Graphical User Interface and System Usability

A significant outcome of this study is the creation of an intuitive graphical user interface (GUI) that makes the technology accessible to end-users like farmers and cooperative technicians. The GUI, as shown in Figure 1 (Main Window), provides a straightforward starting point with clear options for loading images and initiating analysis. Its design prioritizes user-friendliness, requiring minimal technical knowledge to operate effectively.

For comprehensive quality assessment, the Overview Dashboard (Figure 2), offers a batch-level summary. This feature is crucial for stakeholders who need to evaluate the overall quality of a large harvest quickly. By displaying the distribution of grades and average quality metrics,

Volume 38 No. 11s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

the system provides a macro-level view that supports decision-making for sorting, pricing, and market placement.

The Individual Analysis tab (Figure 3) delivers transparency by providing a detailed breakdown for each tuber. It displays the original image alongside the processed image where defects have been segmented, allowing users to visually verify the algorithm's findings. This builds trust in the system, as users can see the direct correlation between the visible defects on the sweet potato and the calculated metrics that led to the final grade.

The effectiveness of the image processing algorithms is visually demonstrated in the Defects and Infections view (Figure 4). This component highlights the system's capability to precisely identify and delineate surface flaws, pest holes, and discolorations using HSV color segmentation and morphological filtering. The accurate detection of these features is fundamental to the system's success, as it directly feeds into the defect percentage calculation mandated by the BAFS standards.

To enhance practicality and traceability, the system includes an Analysis History log (Figure 5). This feature maintains a record of all grading sessions, which is invaluable for tracking quality over time, generating reports for buyers, and conducting internal audits. It transforms a single quality check into a continuous quality assurance process.

A key innovation of this system is the direct integration of the official grading standards within the application, as seen in the PNS Standards Info tab (Figure 6). This provides an immediate reference for users, ensuring that the automated process remains tethered to the national regulations and aids in educating users about the formal grading parameters.

Finally, the Setting & Export panel (Figure 7), adds significant utility by allowing users to configure the system and generate shareable reports. The ability to export results to formats like PDF or Excel facilitates documentation, certification, and communication between farmers, cooperatives, and traders, thereby integrating the system seamlessly into the agricultural value chain.

This study successfully addressed its primary objectives. Firstly, the system effectively detected and quantified surface defects and pest damage using a combination of digital image processing techniques. The use of HSV color space proved particularly effective in separating the chromatic information from lighting variations, leading to robust segmentation of defective regions. This aligns with the findings of Hossain et al. (2021), who successfully used HSV for maturity classification in fruits, confirming its adaptability for root crop quality assessment.

Secondly, the system accurately classified the sweet potatoes into the standard BAFS grades. The high accuracy rate of 92.6% is comparable to, and in some cases surpasses, the performance of other vision-based grading systems for root crops, such as the potato classification system by Shao et al. (2022) which achieved 94% accuracy with convolutional neural networks. This demonstrates that while using conventional image processing, a highly reliable system can be developed, which is a significant advantage in a resource-constrained context where complex machine learning models may be impractical.

The development of the user-friendly MATLAB GUI fulfilled the third objective of presenting the results for easy interpretation. The multi-tab design successfully bridges the gap between complex algorithmic output and practical, actionable information for farmers, a challenge highlighted in local studies by Weihs (2024).

Finally, the entire system serves as a low-cost and standardized solution for post-harvest control. By embedding the PNS standards directly into its algorithmic logic, the system ensures that its assessments are not only scientifically sound but also legally and commercially relevant in the Philippine context. This directly supports local farmers in meeting market requirements, potentially leading to better pricing and reduced post-harvest losses, thereby contributing to the digitalization and modernization of the local agricultural industry.

VI. CONCLUSION

This study demonstrates that the automated sweet potato quality analyzer utilizing digital image processing is a viable, accurate, and practical tool for post-harvest grading. The system successfully integrates the official Philippine National Standards (PNS/BAFS 27:2020) into its algorithmic core, ensuring that all grading outcomes are both scientifically objective and nationally compliant. By leveraging HSV color segmentation, morphological filtering, and feature extraction, the system achieves a high classification accuracy of 92.6%, effectively reducing the subjectivity, inconsistency, and labor intensity inherent in manual inspection.

The developed MATLAB-based graphical user interface (GUI) plays a critical role in bridging the gap between advanced technology and end-user practicality. Its multi-tab design featuring individual analysis, batch summaries, and integrated standard references empowers farmers, cooperatives, and agricultural technicians to conduct rapid, reliable, and transparent quality assessments. The system, therefore, serves not only as a grading tool but also as a significant step toward the digital transformation of the Philippine agricultural sector, enhancing market competitiveness and supporting better pricing for local farmers.

Funding Declaration:

This research received no external funding.

Clinical Trial Number:

Not applicable.

Clinical Trial Registration Details:

Clinical trial number: not applicable.

VII. RECOMMENDATIONS

Based on the findings of this study, several technological enhancements are recommended to advance the capabilities of the automated sweet potato grading system. The integration of machine learning algorithms, particularly convolutional neural networks (CNNs), is strongly advised to improve the detection of subtle and complex defect patterns that may challenge conventional image processing techniques. Furthermore, adopting advanced imaging modalities such as multispectral or hyperspectral imaging would enable the non-destructive detection of internal defects and early-stage diseases, providing a more comprehensive quality assessment beyond surface-level analysis.

To maximize practical impact and accessibility, future development should focus on creating a mobile application platform for in-field use and implementing an Internet of Things (IoT) framework. A mobile application would empower farmers to conduct real-time quality assessments directly in the field using smartphone cameras, greatly expanding the system's reach. Concurrently, an IoT-based system would facilitate automated data logging, cloud storage, and remote monitoring capabilities, enabling centralized quality tracking and data-driven decision making for agricultural cooperatives and policymakers. These innovations would transform the current prototype into a fully integrated, scalable solution capable of significantly modernizing post-harvest practices in the Philippine sweet potato industry.

VIII. REFERENCES

[1] D. Aulia, "Maturity classification of tomatoes using HSV color model and K-Nearest Neighbor algorithm," *BIGINT Journal of Agricultural Engineering*, vol. 7, no. 2, pp. 45–55, 2023.

[2] Bureau of Agriculture and Fisheries Standards (BAFS), *Philippine National Standard for Sweet Potato (PNS/BAFS 27:2020)*. Department of Agriculture, 2020.

[3] Food and Agriculture Organization of the United Nations (FAO), *FAOSTAT Statistical Database*, 2022.

[4] A. Ghazal, M. Alazab, and K. Salah, "Computer vision in smart agriculture: Applications and challenges," *Computers and Electronics in Agriculture*, vol. 218, p. 109189, 2024. https://doi.org/10.1016/j.compag.2024.109189

[5] A. Gomez and R. Dela Cruz, "Digital image-based inspection for crop quality grading," *Journal of Agricultural Technology*, vol. 17, no. 3, pp. 155–166, 2021.

[6] M. Hossain, M. Rahman, and S. Alam, "Mango maturity classification using HSV segmentation and neural networks," *Computers and Electronics in Agriculture*, vol. 187, p. 106289, 2021. https://doi.org/10.1016/j.compag.2021.106289

[7] G. Kaur and A. Aggarwal, "Computer vision-based fruit grading system," *International Journal of Advanced Research in Computer Science*, vol. 11, no. 4, pp. 12–18, 2020.

[8] X. Li, Z. Zhang, and J. Chen, "Automatic defect detection of potatoes using image segmentation and texture features," *Sensors*, vol. 20, no. 14, p. 3892, 2020. https://doi.org/10.3390/s20143892

[9] Q. Liu, J. Wang, and H. Zhou, "Image-based surface defect detection for root crops," *Computers and Electronics in Agriculture*, vol. 190, p. 106394, 2021. https://doi.org/10.1016/j.compag.2021.106394

[10] Y. Liu, H. Zhang, and X. Wang, "Morphological operations combined with YOLOv9-c-ghost-Forward for soybean defect detection," *Scientific Reports*, vol. 15, p. 92429, 2025.

[11] A. Majumdar *et al.*, "Automated quality inspection using MATLAB for agricultural produce," *IEEE Access*, vol. 7, pp. 89945–89955, 2019. https://doi.org/10.1109/ACCESS.2019.2926382

[12] M. Padhiary, R. Singh, and P. Kumar, "Applications of machine learning and artificial intelligence in precision agriculture: A comprehensive review," *Computers and Electronics in Agriculture*, vol. 214, p. 108843, 2024. https://doi.org/10.1016/j.compag.2024.108843

[13] Y. Shao *et al.*, "Potato quality classification using convolutional neural networks," *Journal of Food Engineering*, vol. 320, p. 110978,2022. https://doi.org/10.1016/j.jfoodeng.2022.110978

[14] M. Weihs, "Imaging and AI for root system analysis: Applications and challenges," *Journal of Agricultural Imaging*, vol. 12, no. 3, pp. 145–162, 2024.

[15] L. Zhao, Y. Wu, and J. Tan, "Morphological feature extraction for agricultural product inspection," *Computers and Industrial Engineering*, vol. 165, p. 107971, 2022. https://doi.org/10.1016/j.cie.2022.107971