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Project Title: Raspberry-Pi Based System For Real Time Poultry Egg Quality Assessment Using Convolution Neural Network. An Affordable Computer Vision Solution for Small-Scale Poultry Farmers in Tanzania

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Abstact*: The poultry industry in Tanzania plays a crucial role in food security and economic stability, yet it remains hindered by inefficient manual methods for egg quality assessment. Traditional techniques such as candling are labor-intensive, prone to human error, and economically unsustainable for small to medium-scale farmers. To address these challenges, this project proposes the development of EggFresh AI an intelligent, computer vision-based system for the automated detection and sorting of rotten eggs in real-time. The system utilizes a Raspberry Pi microcomputer integrated with a high-resolution camera, LED lighting array, and servo-controlled sorting mechanism. By applying machine learning algorithms, specifically a Convolutional Neural Network (CNN) model trained on locally sourced egg images, the system classifies eggs as fresh, questionable, or rotten with a target accuracy exceeding 95%[1]. A user-friendly web dashboard provides real-time monitoring and analytics, enabling farmers to track quality metrics and system performance. This project emphasizes affordability, scalability, and local relevance, aiming to reduce post harvest losses, enhance food safety, and improve operational efficiency for Tanzanian poultry producers. By leveraging accessible technology and adaptive AI, EggFresh AI seeks to bridge the gap between high-cost industrial automation and the practical needs of local farmers, contributing to the digital transformation of agriculture in Tanzania.*

Keywords: Egg freshness evaluation; Non-destructive detection technologies; Spectroscopic analysis; computer vision; Egg quality.

1.0 INTRODUCTION

The poultry industry represents one of the most vital agricultural sectors in Tanzania, contributing significantly to national food security, employment, and economic development. Eggs, in particular, serve as an accessible and nutritious source of protein for millions of Tanzanians, supporting both rural livelihoods and urban consumption. However, the sector faces persistent challenges in maintaining consistent product quality, especially during post-production stages such as sorting, grading, and packaging. Traditional methods of egg quality assessment primarily manual candling, where eggs are held against a light source to inspect internal defects remain prevalent across small and medium-scale farms[2][1]. These methods are not only labor-intensive and time-consuming but are also highly susceptible to human error, inconsistency, and inefficiency.

In Tanzania, where the majority of poultry operations are smallholder or medium-scale enterprises, the economic and operational constraints are pronounced[1]. Farmers often lack access to affordable, automated grading technologies, forcing reliance on manual processes that reduce throughput, increase labor costs, and compromise product quality. Studies indicate that manual inspection methods miss between 5% to 15% of defective or rotten eggs, leading to financial losses for producers and posing serious public health risks to consumers. Furthermore, the absence of reliable and scalable quality assurance mechanisms limits market access, reduces competitiveness, and hinders the growth potential of local poultry value chains.

Recent advancements in computer vision and artificial intelligence offer transformative opportunities to address these challenges. Globally, vision-based systems have been successfully deployed in agri-food sectors for quality inspection, sorting, and classification tasks. However, their adoption in Tanzania remains limited, particularly in affordable and locally adaptable forms. This gap presents both a need and an opportunity for innovation—specifically, the development of a cost-effective, accurate, and user-friendly automated system tailored to the context and constraints of Tanzanian poultry farmers[3].

In response to this need, this study proposes the design and implementation of "EggFresh AI" an intelligent, computer vision-based system for the automated detection of rotten eggs[3]. The system integrates hardware components such as a Raspberry Pi microcomputer, a high-resolution camera, and a servo-controlled sorting mechanism with software built on machine learning algorithms. By training a convolutional neural network (CNN) on a locally curated dataset of egg images, the system aims to classify eggs in real-time with high accuracy, thereby replacing error-prone manual inspection with consistent, automated decision-making.

This project aligns with Tanzania's national development agendas, including the Agricultural Sector Development Program (ASDP II) and Vision 2025, which emphasize

technological innovation, value addition, and food safety. It also supports Ruaha Catholic University's commitment to "Quality Education for Development" by engaging students in applied research that addresses real-world challenges. Through the development of EggFresh AI, this study seeks not only to enhance operational efficiency and food safety within the poultry industry but also to demonstrate the practical applicability of emerging technologies in solving local agricultural problems.

1.1 Background of the Study

The poultry industry is a significant contributor to food security and economic growth in Tanzania and many developing nations. Egg production, in particular, provides a vital source of protein and livelihood for millions. However, maintaining consistent egg quality remains a major challenge, especially during the sorting and packaging stages. Traditional quality control methods, such as manual candling where eggs are held against a light source to inspect interior defects are labor-intensive, time-consuming, subjective, and prone to human error [10]. These inefficiencies lead to economic losses for producers and pose serious health risks to consumers if rotten eggs enter the supply chain [11].

Advancements in computer vision and machine learning offer transformative potential for automating and enhancing agricultural processes. Globally, these technologies are being adopted for quality inspection in food production, yet their application remains limited in Tanzania's poultry sector, particularly for small and medium-scale enterprises (SMEs) that cannot afford expensive industrial grading equipment [6][13]. This study, therefore, proposes "EggFresh AI," an intelligent, affordable, and accurate system designed to automate the detection of rotten and defective eggs using computer vision and artificial intelligence, tailored to the local context and resource constraints[4][7][8].

1.2 Problem Statement

The poultry industry in Tanzania, particularly small and medium-scale egg producers, faces significant inefficiencies and risks due to its reliance on traditional manual methods for egg quality inspection, primarily candling. This labor-intensive process is slow, costly, and highly prone to human error and inconsistency, resulting in the misclassification of high rate of defective or rotten eggs. These undetected spoiled eggs not only cause economic losses for farmers but also pose serious public health risks to consumers. Moreover, existing automated grading systems are prohibitively expensive and inaccessible to local producers, creating a critical gap for an affordable, accurate, and scalable technological solution to ensure egg quality, enhance food safety, and improve the economic sustainability of the sector. There is a clear need for an accurate, cost-effective, and scalable automated solution to ensure egg quality, enhance food safety, and improve the economic viability of poultry farming in Tanzania.

1.2 Objectives of the Study

1.2.1 Main Objective

To design, develop, and implement an affordable and intelligent computer vision-based system for the automated detection and sorting of rotten eggs in real-time.

1.2.2 Specific Objectives

i. To design and construct a low-cost, functional imaging chamber prototype for capturing high-quality egg images.

ii. To develop and train a machine learning model using a curated dataset of egg images to classify eggs as fresh, questionable, or rotten with a target accuracy of at least 95%.

iii. To integrate the detection model with a real-time physical sorting mechanism (e.g., conveyor gates) to separate defective eggs automatically.

iv. To develop a user-friendly software dashboard for system monitoring, control, and visualization of quality analytics (detection statistics, trends).

v. To test, validate, and document the system's performance in a controlled environment simulating real poultry farm conditions.

1.3 Significance of the Study

This project holds substantial value for multiple stakeholders:

i. For Poultry Farmers (SMEs): Provides an affordable automation tool to reduce Labor costs, minimize product loss, and ensure consistent, high-quality output.

ii. For Consumers: Enhances food safety by significantly reducing the chance of rotten eggs reaching the market.

iii. For the Tanzanian Economy: Supports the growth and professionalism of the Agri-tech sector, increases export potential through improved quality standards, and reduces post-harvest losses.

iv. For Academic & Research Community: Contributes to the body of knowledge on applying computer vision in African agricultural contexts and provides a replicable model for other perishable goods inspection.

v. For RUCU: Aligns with the university's mission of providing "Quality Education for Development" by fostering innovation and practical, technology-driven solutions to local industry problems.

1.4 Scope of the Study

Within Scope:

i. Focus Product: White and brown chicken eggs.

ii. Detection Parameters: Freshness/spoilage (based on visual cues like cloudiness, blood spots, yolk displacement) and crack detection.

iii. System Components: Hardware prototype (imaging chamber, conveyor, computing unit), software (CV/ML model, dashboard), and integration for real-time sorting.

iv. Target Users: Small to medium-scale poultry farms and cooperative collection centers.

v. Testing Environment: Controlled lab tests and potential pilot testing with a collaborating local farm.

Out of Scope:

i. Detection of fertilized eggs or embryo development.

ii. Analysis of nutritional content or chemical composition.

iii. Integration with large-scale, high-speed industrial processing lines (beyond prototype scale).

iv. Development of a commercial-grade, waterproof, or dustproof industrial housing.

2.1 Literature review: introduction

This chapter presents a review of existing literature and technological works related to egg quality assessment, computer vision applications in agriculture, and automated sorting systems [4]. The purpose is to establish the theoretical and empirical foundation for the EggFresh AI project, identify current technological capabilities, and pinpoint the research gap that this study aims to fill, particularly for the Tanzanian context [18][19].

2.2 Theoretical Review

This project is theoretically anchored in Computer Vision Theory, Machine Learning Principles, and Digital Image Processing Frameworks, which together provide the foundational basis for automated visual inspection systems. It draws from Convolutional Neural Network (CNN) architectures inspired by biological visual cortex models to enable hierarchical feature extraction from egg images, transforming raw pixel data into meaningful classifications of freshness, defects, or spoilage. The system also integrates Pattern Recognition Theory to distinguish between visual cues of egg quality, such as cloudiness, blood spots, or cracks, and applies Statistical Learning Theory to optimize model accuracy and generalization from limited datasets. Furthermore, the project is informed by Human-Computer Interaction (HCI) principles to ensure usability and accessibility, and aligns with Appropriate Technology Theory to ensure the solution remains affordable, sustainable, and contextually relevant for small to medium-scale poultry farmers in Tanzania.

2.3 Empirical Review

Several studies have demonstrated the efficacy of computer vision for egg quality inspection:

i. Gunes et al. (2020) developed a system using image processing to detect blood spots and cracks, achieving over 92% accuracy using histogram and edge detection techniques on images captured in a controlled light setting[3].

ii. Patel & Patel (2019) implemented a Convolutional Neural Network (CNN) model to classify egg freshness based on yolk buoyancy and air cell size visible in candled images, reporting an accuracy of 96.8%[3].

iii. A 2021 study in the *Journal of Food Engineering* compared manual candling against a vision system using a Raspberry Pi and OpenCV, finding the automated system was 30% faster and reduced human error-related defects by 12%.

iv. Research by Zhang et al. (2022) highlighted that the most reliable visual indicators for spoilage include egg white cloudiness, yolk position stability, and the presence of blood or meat spots, which can be effectively captured with proper backlighting.

2.4 Related Works

Commercial and research-grade systems exist but have limitations:

a) Industrial Grading Machines: Companies like MOBA and Sanovo offer fully automated lines capable of grading 100,000+ eggs per hour. However, their high cost ($20,000–$100,000+) and complexity make them unsuitable for SMEs.

b) Research Prototypes: Numerous academic prototypes (e.g., using Arduino with cameras) prove feasibility but often lack robust sorting mechanisms, real-time performance, or user-friendly interfaces for farm use.

c) Mobile Applications: Some apps claim to check egg freshness using smartphone cameras, but their accuracy is questionable and they do not offer integrated physical sorting.

2.5 Research Gap

The literature reveals a significant gap between high-cost industrial solutions and low-fidelity academic prototypes. There is a lack of a low-cost, integrated, and practically viable system that combines accurate computer vision detection with a simple, effective sorting mechanism, specifically designed for the scale, budget, and operational environment of small to medium poultry farms in developing countries like Tanzania. Furthermore, most studies use ideal lab conditions; testing and validation in more realistic, resource-constrained settings are limited.

Project Approach

This project will adopt a Design Science Research (DSR) approach combined with Agile development principles. DSR is suitable as it focuses on the creation and evaluation of an innovative artifact (the EggFresh AI system) to solve a recognized problem. The Agile methodology will allow for iterative development, with cycles of prototyping, testing with potential users (e.g., local farm staff), and refinement based on feedback.

3.2 Research Project Methods

The project will employ the following methods and techniques:

1. Hardware Development:
   a. Components: Raspberry Pi 4 (computing unit), high-resolution USB camera, LED backlighting array, a small conveyor belt system, and servo motors for sorting gates.
   b. Design: CAD software (e.g., Fusion 360) will be used to design the imaging chamber for uniform, shadow-free illumination.
2. Software & Algorithm Development:
   a. Computer Vision: OpenCV library for image pre-processing (filtering, segmentation).
   b. Machine Learning: TensorFlow/Keras framework to build and train a CNN model. Transfer learning using a pre-trained model (e.g., MobileNetV2) will be explored for efficiency.
   c. Programming: Python will be the primary language for the entire software stack.
   d. User Interface: A local web-based dashboard built with Django for real-time monitoring and control.
3. Data Collection & Model Training:
   a. A dataset of at least 2,000 labelled images (fresh, rotten, cracked) will be created using the built prototype under consistent lighting.
   b. The dataset will be split (70% training, 15% validation, 15% testing) for model development and evaluation.
4. System Integration & Testing:
   a. The trained model will be deployed on the Raspberry Pi.
   b. The detection algorithm's output will be linked to the GPIO pins controlling the servo-based sorting mechanism.
   c. Performance will be measured by accuracy, precision, recall, F1-score, and sorting speed (eggs per minute).

3.3 Area of the Study

The project's design, development, and primary testing will be conducted within the ICT laboratories and libraries of Ruaha Catholic University, Iringa, Tanzania. Collaboration will be sought with a local poultry farm in the Iringa region for the purpose of data collection (image capturing of their eggs) and potential pilot testing of the final prototype in a real-world setting.

3.4 Ethical Considerations

i. Data Integrity: All egg images collected will be for research purposes only. No farm-specific data will be disclosed publicly without consent.
ii. Safety: The prototype will be designed with necessary safety covers to prevent electrical or mechanical hazards during operation.
iii. Academic Integrity: All sources of information and code libraries will be properly cited. The work will be original, and any collaboration will be acknowledged.

Beneficence: The project aims to create a beneficial tool for local farmers. If successful, plans for knowledge sharing and potential low-cost technology transfer will be considered.

Conclusion

The EggFresh project represents a timely and innovative response to critical challenges facing Tanzania's poultry industry. By leveraging accessible computer vision and machine learning technologies, the project aims to transform traditional, error-prone manual egg inspection into an automated, accurate, and efficient process. The proposed system directly addresses key pain points for small and medium-scale poultry farmers including high labor costs, inconsistent quality control, product losses, and food safety concerns while remaining affordable and adaptable to local conditions.

Through the development of this intelligent detection system, the project contributes to multiple development objectives: enhancing food security by improving product quality, supporting economic growth through reduced post-harvest losses, promoting technological innovation in agriculture, and providing practical learning opportunities in applied computer science. The integration of hardware prototyping, software development, and real-world testing offers comprehensive educational value for RUCU students while delivering tangible benefits to the agricultural community.

The successful implementation of EggFresh AI has the potential to serve as a model for appropriate technology adoption in Tanzania's Agri-tech sector, demonstrating how emerging technologies can be adapted to address specific local challenges. Beyond immediate applications in egg quality control, the methodologies and lessons learned could inform similar innovations for other agricultural products,

contributing to broader digital transformation in Tanzania's food systems.

As Tanzania continues to pursue agricultural modernization and value addition, projects like EggFresh AI exemplify the strategic intersection of technology, entrepreneurship, and sustainable development. By bridging the gap between academic research and practical industry solutions, this initiative supports RUCU's mission of providing "Quality Education for Development" while making meaningful contributions to national development goals.

Ultimately, the EggFresh AI project embodies a forward-looking approach to problem-solving that combines technical innovation with contextual understanding, creating solutions that are not only technologically sophisticated but also practically relevant, economically viable, and socially beneficial for Tanzanian communities.

3.5. Recommendation

This project should begin with a camera-only MVP before integrating additional sensors, utilizing pre-trained models like MobileNetV2 to accelerate development, and adopting a modular design for ease of maintenance and future upgrades. It is recommended to pilot-test the system on 2–3 local poultry farms in Iringa to gather practical feedback, develop a bilingual Swahili/English interface for accessibility, and establish a WhatsApp-based support channel for users. Academically, the project should publish a locally sourced egg image dataset to support further research, involve students from both ICT and Agriculture departments for interdisciplinary input, and document all processes thoroughly for replicability. For sustainability, a tiered pricing model should be offered to accommodate different farm sizes, partnerships formed with poultry cooperatives and standards bodies like TBS, and grant funding sought from local innovation programs such as COSTECH to ensure affordability and scalability while complying with Tanzania's Data Protection Act and advocating for policy support to make the technology accessible to smallholder farmers.

3.6. Estimated costs for the project prototype are summarized below:

figure 2. (Budget constraints for the project).

Item Category	Specific Item	Estimated Cost (TZS)
Hardware	a. Raspberry Pi 4 Kit	150,000/=
	b. USB Camera (High Rens)	120,000/=
	c. LED Light Panel	50,000/=
	d. Conveyor Belt & Motor	100,000/=
	e. Structural Materials (Wood)	20,000/=
Software & Misc	a) Development Tools (Open Source)	
	b) Internet & Cloud Credits (for training)	100,000/=
TOTAL		540,000/=

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