FreshPick: An IoT-Based System for Classifying and Selecting Fresh Fruits for Market Distribution

Mahdi Shamsa
Dept. of Computer Science and Engineering,
University of North Texas,
Denton, USA
mahdishamsa@my.unt.edu

Laavanya Rachakonda
Dept. of Computer Science,
University of North Carolina Wilmington,
Wilmington, USA
rachakondal@uncw.edu

Saraju P. Mohanty
Dept. of Computer Science and Engineering,
University of North Texas,
Denton, USA
saraju.mohanty@unt.edu

Elias Kougianos
Dept. of Electrical Engineering,
University of North Texas,
Denton, USA
elias.kougianos@unt.edu

***Abstract*—Currently, consumers identify markets to obtain necessary goods. Certain retailers offer consumers a comprehensive range of necessities, including apparel, gadgets, frozen food, etc. Fruits are considered vital commodities that should be available in supermarkets. Supermarkets enter into arrangements with large farms to acquire fruits for customer distribution; however, does the quality of the supplied fruits meet consumer satisfaction? Store owners compensate for fruits based on both quantity and quality. This challenge necessitates a system to classify the health of fruits to inform markets of the percentage of high-quality produce. This research proposes a system that classifies agricultural products by training on harvested fruits and predicting their health status. The precision of the outcomes depended on a Convolutional Neural Network (CNN) model utilizing a dataset comprising approximately 13,000 images depicting both fresh and rotten fruits.**

***Index Terms*—Smart Healthcare, Smart Agriculture, Machine Learning, Food Quality**

I. Introduction

Consumer satisfaction holds the highest priority for merchants. A disappointing experience with a store's products often leaves consumers with a lasting negative impression. Given its importance, merchants strive to maintain consumer satisfaction—regardless of the cost. Among organic foods, agricultural products originating from natural resources are the most perishable and can spoil quickly in stores. This sensitivity is often due to the absence of preservatives applied by farmers, presenting a challenge that store owners must address. Moreover, the demand for fresh fruits is expected to rise with a continuously growing population. Hiring individuals to manually classify fresh and rotten fruits increases expenses for farm owners and may not yield satisfactory results [4]. Even with the implementation of Artificial Intelligence (AI), both fresh and rotten fruits are often harvested together by machines [21].

The most common approach farmers use today for harvesting crops involves using specialized equipment. This enables markets to supply consumers with the necessary quantity of fruits. However, consumers increasingly seek markets that offer higher-quality produce. As a result, there is ongoing competition among market owners to deliver the best-quality fruits, given that fruits are considered one of the healthiest dietary sources [16]. Animals and birds often affect crops, which can damage agricultural productivity and reduce crop quality [14]. Continuously offering consumers lower-quality fruits can erode their loyalty and trust. The inconsistency in consumer expectations drives them to seek alternative markets that guarantee higher quality. On the other hand, employing workers to harvest and assess fruit quality adds operational costs for store owners [11], [15]. Raising fruit prices based on quality alone negatively impacts consumers' budgets. Therefore, store income will remain unstable until this issue is effectively addressed.

The significant increase in consumer fruit consumption necessitates that store owners continuously verify the quality of harvested fruits. This study introduces a system called FreshPick, designed to monitor fruit harvesting on farms by capturing images using a camera, as shown in Fig. 1.

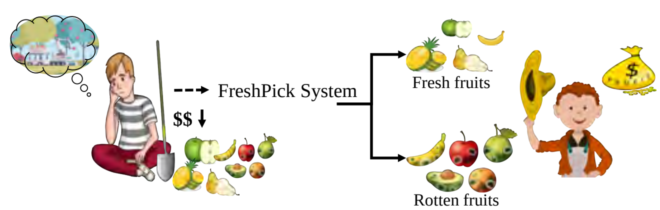

Fig. 1. Motivation Behind FreshPick System

Statistics on fruit consumption in the United States indicate that over half of the population consumes fruits, as detailed below:

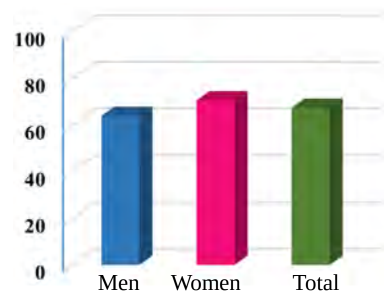

Fig. 2. Any Fruit Consumption Statistics [1]

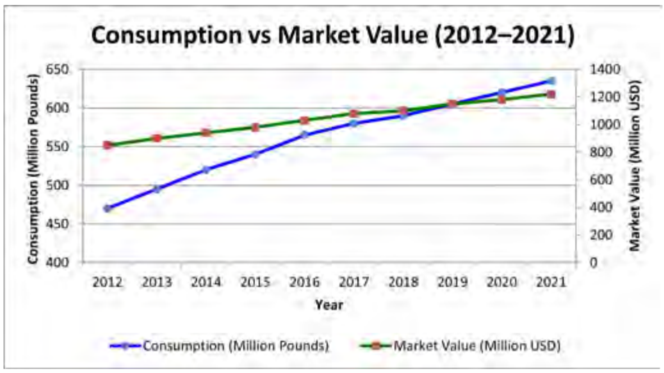

Fig. 3. Consumption Vs Market Value [18]

- According to [1], more than two-thirds of adults (men and women over the age of 20) consume 67.3% of fruits, as shown in Fig. 2.
- Per capita consumption of fresh fruit in the U.S. in 2022 was 116.21 pounds, as indicated in Fig. 3 [18].
- In 2022, 45% of store sales were for fresh fruit, as shown in Fig. 3 [17], while the total market value of fruits and vegetables in the U.S. increased from USD 4,446 in 2011 to USD 65,000 in 2023 [13].

The rest of this paper is organized as follows: Section II presents the proposed contribution of the FreshPick system. This section discusses the core concept of the application by identifying the problem, proposing the FreshPick-based solution, and highlighting its significance. Section III reviews related work by comparing existing systems with FreshPick. In Section IV, the architecture and novel methodology of FreshPick are described, including an algorithm detailing the system's processes and benefits for end users. Section V presents the experimental setup, validation steps, the dataset used, and model training results. Finally, Section VI concludes the paper with a summary of the FreshPick application and outlines potential directions for future research.

II. Proposed Contribution of the FreshPick System

FreshPick is a system that quantifies fruit production within the crop to inform farmers about the quality of their yield. The system is trained on these collected images to classify and determine whether the fruits are fresh or rotten. Based on the system's classification, a yield formula [9], Eqn.1 is applied to calculate the percentage of fresh fruits. As a result, store owners can determine appropriate pricing for farmers according to the outcome of the yield calculation.

$$YP = \frac{RF}{TDF} \tag{1}$$

where YP in equation 1: Yield Products Percentage, RF in equation 1: Rotten Fruits, TDF in equation 1: Total Detected Fruits. It has been designed to provide services at three specific stages. The initial phase involves farmers, where FreshPick assists in promoting agricultural products to suppliers and retailers at fair prices. The next stage focuses on food suppliers, enabling them to pay exactly what the harvest is worth, which contributes to reduced fruit prices for merchants. This price reduction indirectly benefits consumers in the third stage by allowing them to purchase fruits at lower costs. The FreshPick system supports this process by classifying fruits as either fresh or rotten, thereby eliminating spoiled produce from the supply chain.

A. Problem Addressed

Annual per capita fruit consumption continues to rise, as illustrated in 3. Preventing the sale of spoiled fruits while ensuring the availability of fresh produce remains a challenge for market owners striving to achieve customer satisfaction. The practice of purchasing crops—both fresh and rotting fruits—at a fixed price from farmers presents a problem that requires an effective solution. Approximately one-third of food in the United States, equivalent to 1.4 billion tons, is wasted globally [2]. Market owners and suppliers should not bear the full cost of harvested produce that includes spoiled items. Exclusively purchasing fresh fruits would help reduce procurement costs, enhance the quality of fruits available in stores, and make them more affordable for consumers. Additionally, quantifying the yield and percentage of freshly harvested fruits can assist farmers in identifying the causes of fruit decay, enabling earlier detection and reducing overall crop waste.

B. Proposed Solution Through FreshPick

The paper addresses the assessment of crop pricing by proposing the FreshPick system as a solution. The FreshPick system assists farmers in evaluating crop quality and determining the value of their produce. In addition, it supports suppliers and retailers by promoting fair transactions and helping prevent overpayment for substandard crops. FreshPick serves as an effective tool for quantifying the total yield, classifying fruits, and reporting the percentage of freshly harvested produce.

C. Significance of the Proposed Solution

This study introduces a state-of-the-art approach that assists farmers, suppliers, market owners, and consumers in ensuring the delivery of fresh fruits and determining their associated value. In 2016, farms in the United States experienced a loss of 6.7 billion pounds of fruit [20], which impacted the cost of fruits acquired by suppliers and retailers, contributing to economic inflation. To help reduce this substantial loss, FreshPick enables rotten fruits to remain on the trees rather than being harvested. This strategy is beneficial in two ways. First, FreshPick reduces the impact of decaying fruits on natural recycling processes and helps improve soil health [12], as rotting fruit can degrade soil vitality. Second, leaving rotten fruits on trees attracts birds and insects, which helps protect healthy fruits by diverting attention to the spoiled ones. FreshPick functions as an effective monitoring system by capturing images of harvested fruits, identifying them, and classifying them as either fresh or rotten. This process contributes to minimizing waste and can play a role in mitigating global economic inflation.

III. STATE-OF-THE-ART LITERATURE

Classifying fruits as either rotting or fresh is not considered a challenge for researchers. A thorough examination of prior research in this domain will guide the researcher in identifying various fruit classification systems previously addressed by others. Two essential questions must be asked after the system's design:
Q1. What is the accuracy of the results?
Q2. Did the author address the exact problem that was resolved?

One proposed system utilized CNN technology to categorize fruits as either fresh or rotten by first detecting the fruits and then classifying them. The system achieved an accuracy of 90%; however, it did not include a camera for capturing images, requiring users to manually collect and upload images for classification. Moreover, it does not clearly address the specific problem it aims to solve. Additionally, the system is not fully automated [10].
Q1. Accuracy is 90%
Q2. No.
Another approach detects rotten fruits either by taking images or by measuring emitted gases using an MQ2 sensor. However, using the MQ2 gas sensor to assess fruit health could result in inaccurate outcomes, as it detects "alcohol and hydrogen in air." On the other hand, methane—which indicates decay—is typically released in anaerobic environments, which are rare. This system focuses on harvested fruits in storage, indicating their readiness for market or customer distribution. It is also not fully automated [8].
Q1. Accuracy 99.1%.
Q2. No.
Another system uses CNN to ascertain the freshness of fruits by distinguishing between rotten and fresh ones. However, the author did not include any images of rotten fruits, which is a central element of the system. Although additional sensors are mentioned in the conclusion, they are not discussed in the methodology or diagrams. While this system is fully autonomous, it does not make any decisions [7].
Q1. Accuracy 99%
Q2. No.
Another author introduced a system rich with detailed information and images explaining its functionality and application. This system was designed to assist users at home after purchasing fruits. The core problem arises when fruits rot on farms or in stores and are then brought home, potentially leading to spoilage of other fruits in the consumer's kitchen. As the adage goes, "one bad apple spoils the bunch." The system emits a beep sound to notify users of spoiled fruit, but it remains unclear how this notification is triggered. This system is fully automated [19].
Q1. Accuracy 99%
Q2. No.
Another system was developed to classify fruits as either fresh or rotten using models like VGG16, DenseNet, MobileNetV2, ResNet50, and InceptionV3. This complex framework achieved an accuracy of approximately 90%. However, implementing such a technique on farms with large harvests may increase time consumption and the risk of system glitches. If consumers rely on this approach, they might end up eating rotten fruit before being alerted. Using a single, highly accurate model would save time and energy [3].
Q1. Accuracy 90%
Q2. No.
Regarding the systems previously mentioned, the evaluation was based on two essential questions. Identifying a real-world problem adds value to any research study. While the authors of these related works have developed promising systems, many failed to focus on the core issue their systems were intended to solve. In contrast, the current research aims to address three distinct user categories within the FreshPick system: farmers, suppliers, and consumers, in both financial and health-related contexts. Economically, FreshPick seeks to protect farmers from losses and help consumers avoid purchasing spoiled produce. Medically, it aims to prevent consumers from unknowingly consuming rotten fruits.

IV. PROPOSED NOVEL METHODOLOGY

A. Methodology

Currently, the emphasis on technology has simplified system design. If systems are not created and intended to address and resolve a specific issue, they become ineffective. This paper addresses the issue of selling fruits without regard for their quality. To solve this, a system known as FreshPick is introduced. It collects images of fruits, evaluates their quality and health through a trained model, and categorizes them into two classes: rotten and fresh, based on the system's observations. FreshPick assists suppliers in assessing the condition of harvested fruits and adjusting their prices accordingly, using the previously described yield calculation formula.

At the same time, this approach helps farmers improve crop management and supports consumers in finding fresh produce in supermarkets. As shown in Fig. 4, the process begins with the automated harvesting of fruits via a picking tractor. The system then evaluates the captured fruit images and classifies them. A report is generated to inform the farmer and supplier about the detected fruit quality. This streamlines the packing

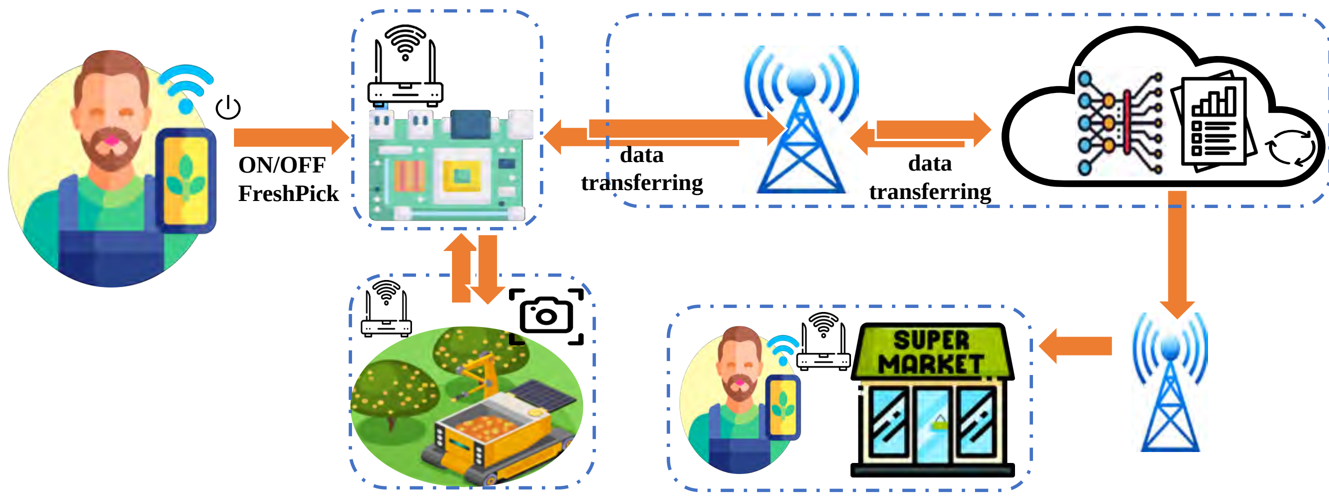

Fig. 4. Architecture of the Proposed FreshPick System

and distribution process to vendors, as described in Algorithm 1.

Algorithm 1 FreshPick Object Detection Methodology

Require: Ultrasonic Sensor, Object Caption OC, Deep Learning DL, Report.
Ensure: Running or Sleepy Mode is chosen by the farmer.

```
Ultra Sonic starts sensing the objects
if Ultra Sonic sensed the object distance changing then
    Ultra Sonic notifies the system that an object is passing
    The system turns on the camera
    The system takes a OC
    Internal system takes OC and introduces it to DL Model
    DL receives the captured object
    Deep Learning Model uses OC as an input
    The model classifies the object in OC
    The model outputs the quality of the reaped fruits
    if The fruit is rotten then
        leave it in the tree
        DL sends a signal to the internal system
        The internal system adds one to the Rotten Fruits
        value RF in the yield formula
    else
        Directs the fruit to the fresh container
        Adds one to the Total Reaped Fruits TDF value in
        the yield formula
        FreshPick calculates the percentage of the reaped
        fruits based on the Yield Products YP percentage
        Generate a report and send it to the farmer and
        supplier
    else
        Ultrasonic Sensor is sensing
    end if
end if
```

B. The End User

Typically, in technology, system designers regard the end user as an essential system component. The proposed system categorizes the end user into three levels. The initial phase involves farmers. FreshPick assists farmers in enhancing the quality of their agricultural produce. The second stage is suppliers, which is the emphasized stage. Suppliers obtain assistance from FreshPick for expense optimization. This indicates that suppliers are paying only for the actual value of the produce. The final step involves consumers, who are at a preliminary phase and may gain advantages from FreshPick. FreshPick assists consumers in acquiring fresh fruits from stores by guaranteeing the removal of rotten fruits post-harvest by FreshPick.

V. Experiment and Validation of the Proposed FreshPick System

A. Model (software)

FreshPick is a system designed to assist users in identifying and classifying fruits into two categories: fresh and rotten. It combines object detection and classification techniques, both of which are essential components of computer vision methodologies. In such systems, the accuracy of the classification results—alongside the efficiency of the process—is a critical performance metric. To achieve high accuracy, FreshPick was developed using a Convolutional Neural Network (CNN) architecture [5], trained on a substantial dataset of approximately 13,000 images of fresh and rotten fruits.

The quality of the dataset is equally important as the model architecture. The dataset used in FreshPick provided rich visual diversity and was instrumental in achieving high classification performance. The training was conducted on a system equipped with an Intel Core i5 processor, 16 GB of RAM, and a 512 GB Solid-State Drive (SSD)—sufficient resources to train and evaluate the CNN effectively.

As shown in Fig. 5, the model achieved a training accuracy of 95% and a validation accuracy of 98%, indicating strong generalization.

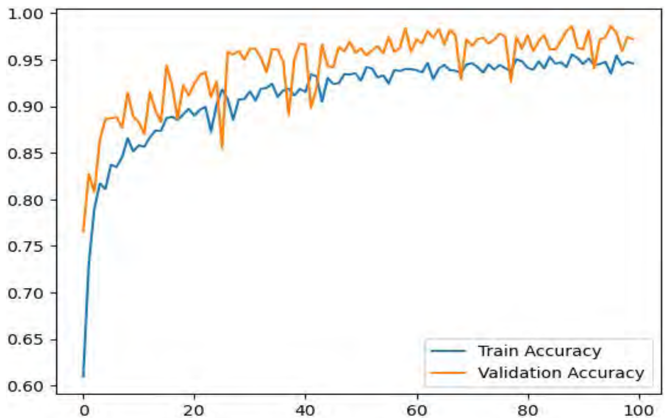

Fig. 5. Performance of Train and Validation Accuracy of the Proposed FreshPick Classification Model.

Furthermore, as illustrated in Fig. 6, the system exhibited low loss values—0.03 for training and 0.01 for validation—highlighting the model's robustness and minimal overfitting.

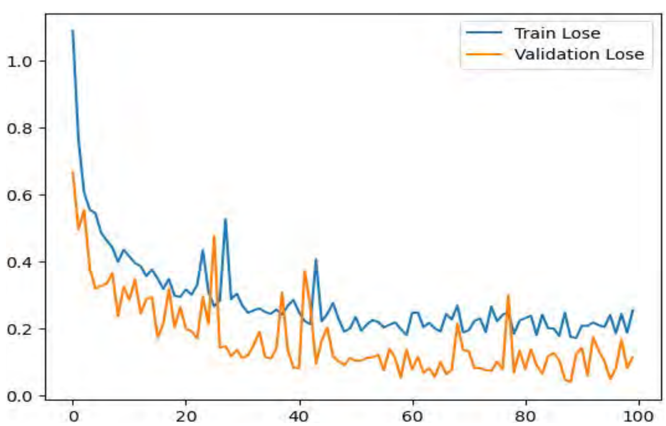

Fig. 6. Performance of Train and Validation Lose of the Proposed FreshPick Classification Model.

These consistent results between training and validation demonstrate that the FreshPick model was successfully trained and optimized.

B. Dataset

System designers aim to achieve optimal outcomes to support the credibility of their work by presenting impressive results. These outcomes depend on various factors, one of the most critical being the quality of the dataset used for training. For this purpose, FreshPick utilized the "Fruits Fresh and Rotten for Classification" dataset [6] to distinguish between fresh and rotten fruits. The dataset comprises a total of 11,392 labeled images, distributed as follows:

- Apple (2014 images):
  A- 1,000 images of fresh apples.
  B- 1,014 images of rotten apples.
- Banana (1,835 images):
  A- 916 images of fresh bananas.
  B- 919 images of rotten bananas.
- Orange (1,918 images):
  A- 957 images of fresh oranges.
  B- 961 images of rotten oranges.

The dataset's diversity and volume contribute to achieving high classification accuracy. The model's strong performance reflects the dataset's quality, which is characterized by the following attributes:

- Resolution:
  - Images are 46*46 pixels.
- Format:
  - Red, Green, and Blue RGB color images in Joint Photographic Experts Group JPG format.
- Split:
  - Roughly a 70/30 train/test split.
- Balance:
  - Classes are fairly well-balanced between fresh and rotten.

Integration of this comprehensive dataset with the learning capabilities of Convolutional Neural Networks (CNN) allowed the development of the FreshPick model with high confidence and robust performance as represented in Table I.

VI. Conclusion and Future Research

This paper introduces FreshPick, an IoT-based system for real-time fruit quality assessment in smart agriculture. FreshPick supports both farmers and suppliers in achieving their objectives by providing accurate information about the quality of harvested fruits. It enables farmers to monitor the condition of their produce, while allowing suppliers to assess the true value of the crops. By enhancing transparency, FreshPick promotes fairness in transactions between farmers and suppliers. Its implementation can lead to a reduction in fruit prices by eliminating the costs associated with spoiled produce. Additionally, FreshPick serves as an effective tool for early detection of factors contributing to fruit spoilage, helping farmers take preventive action.

For future work, the FreshPick system can be improved by using a higher-quality dataset with more images and integrating advanced technologies to enhance accuracy and performance. Moreover, FreshPick could be extended to monitor fruit conditions at consumers' homes, addressing the rare but possible scenario of fruit spoilage after purchase.

References

[1] N. Ansai and E. A. Wambogo, "Fruit and vegetable consumption among adults in the united states, 2015–2018," National Center for Health Statistics, Hyattsville, MD, NCHS Data Brief 397, 2021.

[2] W. W. Fund, "What farmers found when they measured fresh produce left in the field," https://www.worldwildlife.org/stories/what-farmers-found-when-they-measured-fresh-produce-left-in-the-field, 2024, accessed: May 11, 2024.

TABLE I
NOVELTY OF FRESHPICK VS. EXISTING SYSTEMS

Authors	Year	ML Model Type	Q1	Q2	Automation
Aditi Mohite , et al. [10]	2024	Detection	90%	No	Not Fully Automatic
M.Meenalochani Meenalochani, et al. [8]	2024	Classification	99.1%	No	Not Fully Automatic
Mukund Kulkarni, et al. [7]	2022	None	99%	No	Semi Automatic
Athulya Thulaseedharan, et al. [19]	2022	Classification	99%	No	Semi Automatic
Tuğçe Göksu , et al. [3]	2023	None	90%	No	NA
FreshPick (Current paper)	2025	Classification	97%	Yes	Fully Automatic

[3] T. Göksu, Z. Kaya, and S. Sahmoud, "Classification of fruit images as fresh and rotten using convolutional neural networks," in *3rd International Conference on Computing and Information Technology (ICCIT)*, 2023, pp. 297–301.

[4] M. A. Hamim, J. Tahseen, K. M. I. Hossain, N. Akter, and U. F. T. Asha, "Bangladeshi fresh-rotten fruit & vegetable detection using deep learning deployment in effective application," in *3rd International Conference on Computer Communication and Artificial Intelligence (CCAI)*, 2023, pp. 233–238.

[5] IBM, "What are convolutional neural networks?" https://www.ibm.com/think/topics/convolutional-neural-networks, accessed: Dec. 7, 2024.

[6] S. Kalluri, "Fruits fresh and rotten for classification," https://www.kaggle.com/datasets/sriramr/fruits-fresh-and-rotten-for-classification/data, 2018, accessed: Nov. 7, 2024.

[7] M. Kulkarni, A. Chaudhari, S. Shegokar, K. Rudrawar, S. Joshi, S. Tibile, and I. Tayade, "Fruit freshness detection using cnn," in *International Conference on Futuristic Technologies (INCOFT)*, 2022, pp. 1–5.

[8] M. Meenalochani, B. S. Aboorvaa, and S. Srinivasan, "A novel standalone internet of things enabled device for detection of rotten fruits in cold storage systems," in *5th International Conference on Smart Electronics and Communication (ICOSEC)*, 2024, pp. 798–803.

[9] B. Meister, "On murphy's yield formula," *IBM Journal of Research and Development*, vol. 27, no. 6, pp. 545–548, 1983.

[10] A. Mohite, R. Joshi, S. Kunjir, and M. Kodmelwar, "Deep learning-based fruit recognition and quality assessment: A convolutional neural network approach," in *ASU International Conference in Emerging Technologies for Sustainability and Intelligent Systems (ICETSIS)*, 2024, pp. 589–593.

[11] L. Rachakonda, "Transforming agriculture: A mini-review of IoT innovations and their impact," in *IFIP/IEEE 32nd International Conference on Very Large Scale Integration (VLSI-SoC)*, 2024, pp. 1–6.

[12] L. Rachakonda and S. Stasiewicz, "Sanasolo 2.0: Edge-based monitoring and management of soil fertility using IoT," in *IFIP/IEEE 32nd International Conference on Very Large Scale Integration (VLSI-SoC)*, 2024, pp. 1–6.

[13] M. Shahbandeh, "Market value of fruits and vegetables in the united states from 2011 to 2023," https://www.statista.com/statistics/961451/us-fruits-and-vegetables-market-size/, 2024, accessed: May 11, 2024.

[14] M. Shamsa, L. Rachakonda, S. P. Mohanty, and E. Kougianos, "qcrop: An IoT-based framework to enhance crop productivity in smart agriculture," in *IFIP/IEEE 32nd International Conference on Very Large Scale Integration (VLSI-SoC)*, 2024, pp. 1–6.

[15] ——, "Secfarm: An IoT application framework to aid farmers with a secured farm system," in *SATC 1st IEEE Conference on Secure and Trustworthy CyberInfrastructure for IoT and Microelectronics (SaTC2025)*, 2025, pp. 1–5.

[16] J. L. Slavin and B. Lloyd, "Health benefits of fruits and vegetables," *Advances in Nutrition*, vol. 3, no. 4, pp. 506–516, Jul 2012, pMID: 22797986; PMCID: PMC3649719.

[17] Statista, "Fruit consumption statistics & facts," https://www.statista.com/topics/1475/fruit-consumption/topicOverview, 2024, accessed: May 11, 2024.

[18] ——, "Per capita consumption of fresh fruit in the united states from 2000 to 2022," https://www.statista.com/statistics/257127/per-capita-consumption-of-fresh-fruit-in-the-us/, 2024, accessed: May 11, 2024.

[19] A. Thulaseedharan and A. Choudhary, "Camera-based automated quality assessment of fruits for a smart home," in *IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI)*, 2022, pp. 1–5.

[20] USDA, "Food-loss quantities and rates for retailers differ among fresh fruits," https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=92910, 2019, accessed: Dec. 5, 2024.

[21] Y. Xu, X. Liu, X. Cao, C. Huang, E. Liu, S. Qian, X. Liu, Y. Wu, F. Dong, C. W. Qiu, J. Qiu, K. Hua, W. Su, J. Wu, H. Xu, Y. Han, C. Fu, Z. Yin, M. Liu, R. Roepman, S. Dietmann, M. Virta, F. Kengara, Z. Zhang, L. Zhang, T. Zhao, J. Dai, J. Yang, L. Lan, M. Luo, Z. Liu, T. An, B. Zhang, X. He, S. Cong, X. Liu, W. Zhang, J. P. Lewis, J. M. Tiedje, Q. Wang, Z. An, F. Wang, L. Zhang, T. Huang, C. Lu, Z. Cai, F. Wang, and J. Zhang, "Artificial intelligence: A powerful paradigm for scientific research," *Innovation (Camb)*, vol. 2, no. 4, p. 100179, 2021, pMID: 34877560; PMCID: PMC8633405.