# ARTIFICIAL INTELLIGENCE FOR EVALUTION OF QUALITY IN FRUITS RIPENING.

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**Abstract**—In agricultural science, the quality analysis of fruits and vegetables were classified with differentiating color, shape, size and texture and further type of disease by human vision. However, it is crucial to analysis by the normal traditional method. The maturation phase in fruits is a crucial stage, leading to increased tenderness, sweetness, and palatability, driven by the acceleration of metabolic processes. During maturation, ethylene ($C_2H_4$), a gaseous plant hormone known as a phytohormone, plays a pivotal role. It facilitates the softening of the fruit's skin and converts complex polysaccharides into simpler sugars. However, ripe fruits become delicate and susceptible to damage, making handling and transportation challenging. Therefore, it is essential to carefully monitor the ripening process under controlled conditions, including temperature and humidity. Analytical techniques are required to assess the ripening process, which is the focus of researchers' efforts. The key aspect of this research is utilizing ethylene gas levels, ranging from 10 to 100 ppm, to induce fruit ripening, which can be detected and analyzed using alternative term. Image processing techniques and Artificial Neural Networks (ANN) algorithms are utilized. Furthermore, in the maturation process of vegetables, they achieve their desired flavor, quality, color, palatability, and other textural attributes. Apples, pears, bananas, and mangoes are among the fruits that emit ethylene during ripening. Ethylene is known to be responsible for texture changes, softening, color alterations, and other ripening-related processes. The monitoring of the ripening process involves employing image analysis supported by various AI methods. Our analysis involves image preprocessing, segmentation, and feature extraction steps, followed by further analysis using other artificial intelligence methods, to swiftly identify the ripening process and monitor ethylene gas concentrations in the ripening chambers to prevent overripening. The application of various algorithms to climacteric fruits yields highly accurate and efficient outcomes, facilitating prompt moderation and ensuring a short shelf life, thereby posing challenges in transportation and storage. These results benefit farmers and consumers by providing timely assistance in appropriate decision-making.

**Keywords**— The ripening process of fruits and vegetables encompass ethylene gas, agricultural science, fruit quality analysis, image processing, Artificial Neural Networks (ANN), phytohormones, texture softening, flavor development, and controlled environment. Temperature and humidity control are crucial factors influencing ripening processes, while ethylene plays a pivotal role in inducing color changes. Advanced techniques like image processing and ANN algorithms aid in ethylene gas detection, facilitating precise monitoring of ripening stages andensuring optimal produce quality.

## 1. INTRODUCTION

In the human it is necessary to create awareness towards health and fitness, fruits which supply a number of vital nutrients essential to body. The ripening of fruits is a crucial stage that significantly enhances their palatability, sweetness, softness, and both physiological and commercial value. Throughout the developmental phase, fruits attain proper size, weight, texture, color, aroma, and flavor. Ripening entails the acceleration of various metabolic processes, ultimately governed by enzymatically regulated and catalytic mechanisms. Globally, around 370 million metric tons of fruits are produced annually, constituting approximately 8% of the total fruit production worldwide. India stands as the second-largest fruit producer globally, particularly leading in banana and mango production compared to other fruits (Dhawan and Singh, 2015). Ethylene ($C_2H_4$), a gaseous plant hormone, predominantly regulates the ripening process. Studies have shown that the phytohormone ethylene controls the expression of genes involved in fruit ripening, thereby modulating the activity of various enzymes crucial to the ripening process. As the enzymes act on the fruit to soften the skin and converts the complex polysaccharides into simple sugars.

Generally, Ethylene, a natural plant hormone, plays a crucial role in the ripening process of fruits. Fruits are categorized into two main types based on their response to ethylene: climacteric and non-climacteric fruits. Climacteric fruits undergo a ripening phase post-harvest where they continue to ripen, marked by an increase in ethylene emission and respiration rate. As a result, these fruits become soft and delicate, making them unsuitable for long-distance transportation. Hence, climacteric fruits like Mango, Banana, Papaya, Guava, and Sapota are typically harvested when they are still hard and green, and then ripened closer to the consumption areas. In some cases, ethylene is artificially applied in small doses to accelerate the ripening process under controlled conditions of temperature and humidity. This practice ensures that the fruits reach their optimal ripeness level by the time they reach consumers, enhancing their flavor and texture. Non-climacteric fruits, in contrast to their climacteric counterparts, produce only small amounts of ethylene and do not undergo further ripening post-harvest. Examples include Oranges, Watermelons, Grapes, and Pomegranates. Unlike climacteric fruits, non-climacteric fruits do not exhibit a characteristic increase in respiration or carbon dioxide production. However, ethylene can still be utilized with non-climacteric fruits as a de-greening agent. This process breaks down chlorophyll pigment in the peel, allowing yellow or orange carotenoid pigments to become more prominent, enhancing the fruit's appearance. In today's competitive agricultural and food market, the quality of fruits and vegetables is of paramount importance. Traditionally, fruit quality has been assessed based on human observation of texture, shape, and color. However, this method becomes impractical and error-prone when dealing with large sample sizes. Therefore, researchers are increasingly exploring alternative methods for effectively detecting the ripening process. Accurately identifying the ripening stage is crucial as it is closely linked to internal fruit properties such as sweetness and firmness, and it aids in determining the optimal storage time before consumption. Thus, there is a need for non-destructive and efficient techniques to assess fruit ripeness, ensuring high-quality produce reaches consumers. To accurately assess the properties of fruits like bananas and mangoes, traditional analytical techniques are often employed, which are both time-consuming and destructive. These methods involve chemical reagents and lengthy sample preparation procedures, limiting their applicability to only a few samples and failing to capture the full range of physiochemical variability in large batches. Therefore, there's a growing need for rapid, intelligent, and non-destructive techniques in this domain. Automatic image processing tools, leveraging intelligent techniques, offer a promising alternative. These tools are particularly valuable in ensuring productivity, quality standards, and reliability in fruit products. In the initial stage, the accuracy of fruit ripeness assessment heavily relies on advanced preprocessing segmentation algorithms. Machine learning-based classifiers, such as Support Vector Machines, Hidden Markov Models, and Artificial Neural Networks, undergo intensive training phases to achieve higher recognition rates. Ultimately, the integration of automated fruit grading with Artificial Intelligence and sensor-based technologies like image sensors holds significant potential. Non-contact image sensing technology, coupled with robust computing and decision-making processes, offers an automated, non-destructive, and cost- quality assessment in the agricultural industry.

## 2. LITERATURE REVIEW

A simple technology practiced is to keep unripened and ripened fruits together inside an air tight container Since already fruits would have released ethylene so that ripening will be faster A common practice in fruit ripening involves placing unripened and ripened fruits together in an airtight container to expedite ripening, leveraging the ethylene released by already ripe fruits. However, an alternative method involves enclosing fruits in an airtight room and inducing ripening through smoking, which produces acetylene gas. Yet, this approach often results in uneven color and flavor in the fruits, along with lingering smoke odors that compromise product quality. Another method entails using paddy husk or wheat straw over a week to facilitate ripening. Alternatively, mature fruits can be dipped in a 0.1 percent ethrel solution, dried, and spaced apart without touching. Additionally, a mixture of ethrel and sodium hydroxide pellets can be placed in an open vessel near unripe fruits to accelerate ripening.In India, calcium carbide has been historically used for ripening, despite being banned due to its toxic nature, containing traces of arsenic and phosphorus. When dissolved, calcium carbide generates acetylene, mimicking ethylene's ripening effects. However, acetylene exposure poses health risks, particularly to the nervous system, by reducing oxygen supply to the brain. The safest and globally accepted method involves using ethylene gas under specific temperature and humidity conditions. Nevertheless, even this method has drawbacks, including variations in ripening rates due to factors like fruit maturity, temperature, humidity, airflow, ethylene concentration, and carbon dioxide levels, which if excessive, can lead to fruit spoilage. Monitoring the ripening process is crucial to prevent over-ripening, which can diminish the fruit's mineral content and secondary metabolites. Therefore, an effective method for measuring ethylene and carbon dioxide levels, potentially through fruit color analysis, is proposed. Additionally, implementing image processing tools for accurate ripening stage classification of different climacteric fruits upon harvest is essential for quality control and efficient distribution. Despite the benefits of ethylene-induced ripening, handling ripened fruits during transport poses challenges, as they become fragile and prone to damage. Conventional methods for chemical analysis of fruits are costly, require sophisticated instruments, and skilled analysts, emphasizing the need for simpler, more accessible techniques (Karthika et al., 2017).Utilizing image processing tools for precise ripening stage classification of various climacteric fruits upon arrival is essential in fruit ripening processes, as ethylene gas is naturally released during respiration, accelerating the ripening process. However, a significant challenge arises during transportation, where ripened fruits become fragile and prone to damage, potentially compromising their quality. Traditional methods for chemical analysis of fruits are both complex and costly, requiring skilled analysts, which can be impractical. Manual sorting of fruits like bananas and mangoes is labor-intensive and time-consuming, leading to biases and errors that impact growers' profitability. there's a pressing need for reliable, rapid, and accurate automatic detection techniques to assess fruit maturity. Fruit maturity plays a pivotal role in determining storage life and ripening quality, crucial for ensuring marketability and consumer satisfaction. Accurate maturity assessment not only aids in adhering to trade regulations and devising effective marketing strategies but also optimizes labor and resource utilization.

Thus, implementing automated detection methods is crucial for enhancing efficiency and profitability in the fruit industry.

The parameters as follows related to maturity of fruits

- **Color:**Color is typical varies with different variety. This can be measured, in various fruits classes that is dark, medium, light green color of fruits. This app will allows light green color for lower quality and medium color for medium fruit and darker fruit for higher quality
- **Size**: It measures diameter, size by (x,y) coordinators. Fruits size is determined by maximum diameter of fruits. It will be measured as center of the origin
- **Shape**: It can be measured for aspect ratio, roundness of the fruit
- **Data**: Some of the images of fruit were collected to check the fruits quality system

**Fig. 1 Mango ripening in air tight Rice Bin and Straw bed**

Mango holds significant global importance and is utilized in various culinary applications such as mango pulp juice, ice cream, pickles, and candies, necessitating precise ripening stages for optimal use (Rahul Pralhad Salunkhe and Aniket Anil Patil, 2015). Originating from the Indo-Burma region, mango is a prominent tropical fruit. Recent data reveals that India boasts the largest mango plantation area globally, spanning 2.46 million hectares (Balyan et al., 2015). Furthermore, India leads in mango production, yielding 14.8 million metric tons (MMT), contributing to 51% of the world's total mango production (28.8 MMT). However, despite its significant production capacity, India ranks fourth among mango-exporting nations. Domestically, mango cultivation dominates fruit production, occupying around 35% of cultivated land. Mangoes contribute 21% to India's total fruit yield, trailing closely behind citrus fruits. Banana, a globally consumed fruit, holds a significant position as the fourth most important food crop worldwide, alongside staples like rice, wheat, and maize. However, disparities in banana production and export among countries stem from challenges related to the fruit's perishable nature and a lack of standardized quality control measures, hindering its international marketability (Patil and Rawale, 2012). The cultivation of bananas serves as a crucial source of livelihood and economic security for millions of people worldwide.The quality of banana fruit, crucially determined by the maturity of banana bunches at harvest, directly influences its flavor, ripening process, and overall market value. Harvesting bananas prematurely may result in a lack of flavor and inadequate ripening, whereas delaying harvest can lead to overripening and fruit splitting (Patil and Rawale, 2012). Guava (Psidium guajava L.), another widely cultivated tropical and subtropical fruit crop in India, is renowned for its nutritional value, particularly its high vitamin C content and gelatinous texture. Despite being the fifth most cultivated fruit crop in India, following banana, mango, citrus, and papaya, guava cultivation covers approximately 0.26 million hectares and yields 3.66 million tons annually, with an average productivity of 13.7 MT/ha (Saxena and Gandhi, 2014). The quality of guava is influenced by factors such as color, size, and shape, with skin color serving as a significant indicator of maturity, transitioning from dark green in its juvenile stage to yellow when fully ripe.In banana cultivation, harvesting at the appropriate maturity stage is crucial to meet market demands. Various morphological changes, including peel color transition from dark green to pale green, disappearance of angularity, and alterations in finger length and diameter, are used as maturity indices to classify banana bunches into three categories: unripe, ripe, and overripe fruit (Muchui et al., 2010). During the early stages of ripening, bananas synthesize secondary compounds such as alkaloids and tannins as a defense mechanism against infections, contributing to a bitter and astringent taste in underripe fruits. As bananas mature, their skin transitions from green to yellow as storage cells expand and fill with water, sugars, starches, organic acids, vitamins, and minerals. Consequently, starch and acid levels decrease, while sugar content increases, and alkaloids and tannins diminish, leading to a sweeter taste in ripe bananas.Moreover, as bananas continue to ripen, changes in aroma, acid, and protein composition occur, accompanied by a softening of fruit texture as cell walls break down. These transformations culminate in bananas reaching optimal ripeness, making them tender and flavorful, ready for consumption. The efficient ripening process is globally achieved through meticulous control of factors such as humidity, temperature, time, airflow, and ethylene concentration (Fatma et al., 2018). In the agricultural sector, image processing has emerged as a valuable tool for assessing fruit quality, albeit in its nascent stages of practical application. Image analysis, particularly focusing on texture, offers insights into changes in intensity values, providing valuable information about both color and physical structure.The utilization of image processing technology began with citrus fruits, where it was employed to quantify the ratio of ripe to unripe fruits on trees prior to harvesting (Molto et al., 1992). Subsequently, this approach was extended to other fruits like strawberries and papayas, aiming to distinguish matured fruits, achieving accuracies ranging from 80% to 100% (Bato et al., 2000; Riyadi et al., 2007). In the case of bananas, computer vision systems have been implemented to identify seven ripening stages based on color, including the detection of brown spots, and texture information, achieving an impressive accuracy of 98% (Quevedo et al., 2008). Notably, full-ripened bananas exhibit dark spotting, a characteristic evaluated through fractal texture analysis using Fourier techniques. In the case of climacteric fruits, such as bananas, even small amounts of ethylene, along with appropriate temperature and humidity conditions, are adequate to initiate the ripening process. However, non-climacteric fruits, like grapes, watermelon, and citrus fruits, do not respond to ethylene treatment as they are typically harvested when fully ripe (Swati Khandarkar and Vijay Wadhankar, 2018).Advancements in technology have led to the preference for color image segmentation over grayscale images in fruit analysis. Color images offer more detailed information, higher capacity, and faster processing speeds, making them more suitable for segmentation and analysis (Ojeda-Magana et al., 2010).As bananas ripen, various biochemical changes occur, transforming the fruit from an underripe, bitter, and astringent state to a ripe, sweet, and flavorful condition. The transition from green to yellow in banana skin signifies the expansion of storage cells, which absorb water, sugars, starches, organic acids, vitamins, and minerals. This process results in a decrease in starch and acid content, an increase in sugar content, and the disappearance of alkaloids and tannins as the fruit reaches its late stage of maturity. Concurrently, changes in aroma, acid, and protein composition occur, leading to a softening of fruit texture as cell walls break down. Ultimately, these transformations render the banana ripe and suitable for consumption.

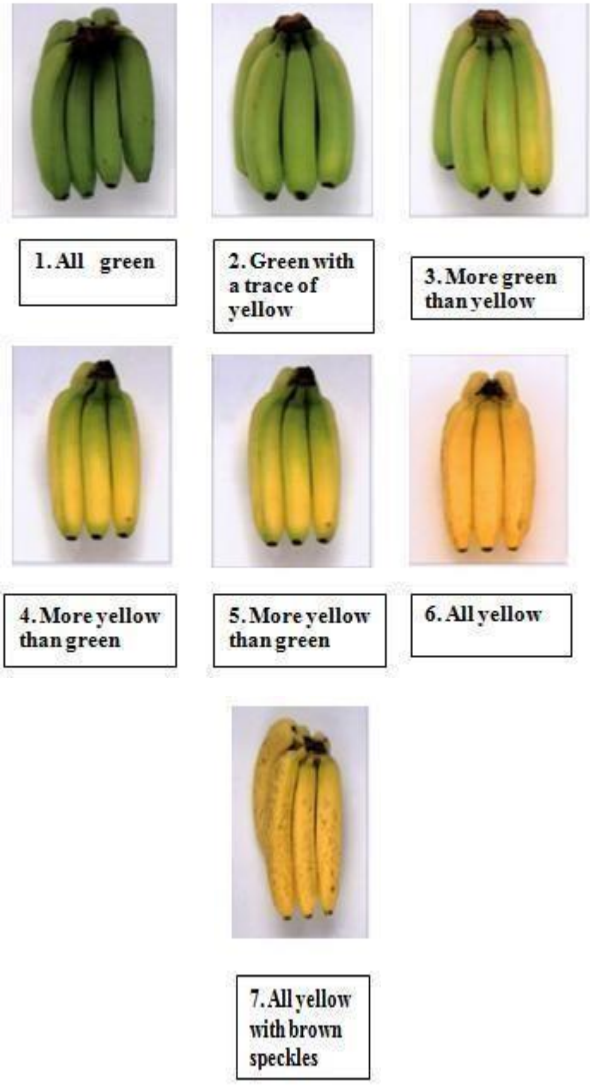



**Fig. 2. Color chart of banana fruits in various stages**

Efficient ripening processes worldwide rely on meticulously controlled factors such as humidity, temperature, time, airflow, and ethylene concentration (Fatma et al., 2018). In the agricultural sector, image processing is gradually gaining traction, especially in assessing fruit quality from images (Quevedo et al., 2008). The utilization of image processing stems from its ability to reveal texture changes throughalterations in intensity values, providing valuable insights into color and physical structure.Initially applied to citrus fruits for counting ripe and unripe fruits on trees before harvesting (Molto et al., 1992), image analysis has since been extended to various fruits like strawberries and papayas, achieving high accuracies of around 80-100% in sorting matured fruits (Bato et al., 2000; Riyadi et al., 2007). In the case of bananas, computer vision systems have been employed to identify seven ripening stages based on color, including brown spots and texture information, with an impressive accuracy of 98% (Quevedo et al., 2008). This underscores the potential of image processing techniques in post-harvest fruit analysis and market trading.In the case of guava, the ripening process involves enzyme activities such as PME, PG, cellulose, and B-galactosidase, with variations observed during different ripening stages (Selvaraj et al., 1998). Skin shading emerges as a promising non-destructive method for assessing guava ripeness and storage quality. Similarly, in palm oil fruit grading, color vision inspection is utilized to assess ripeness stages, with specific color attributes indicating different ripeness levels (Choong et al., 2006). Studies focus on correlating fruit ripeness stages with oil content, highlighting the importance of ripeness in oil yield.Enhanced control of transport conditions, facilitated by Wireless Sensor Networks, has significantly improved transport quality for agricultural products. However, managing various tasks within the system, especially regarding information flow and temperature and humidity monitoring during transport, presents challenges (Fig. 1.7). Temperature emerges as a critical variable to measure, particularly in the transport of dry agricultural products, underscoring the importance of efficient monitoring and control mechanisms.

## Aim and Objectives

- Developing a fruit ripening quality monitoring system utilizing fruit images analyzed through color image processing.
- Assessing the brightness values of individual fruit samples and implementing online monitoring to dynamically adjust the flow of ethylene gas, ensuring an effective ripening process while also evaluating maturity quality through $CO_2$ determination.
- Conducting pre-processing procedures to facilitate segmentation and eliminate noise and background errors from the acquired images.
- Employing artificial intelligence techniques to analyze the pre-processed images and estimate the ripeness of the fruits accurately.

**Preprocessing** - Preprocessing of fruit images represents a critical initial phase essential for enhancing image quality by removing noise. The elimination of impulse noise from digital images has been a focal point of numerous research endeavors, drawing significant attention from scholars (Mélange et al., 2011; Hao et al., 2012). Various methods have been proposed to address this issue, often incorporating filters such as the weighted median filter and switching median filter (Manikandan et al., 2004; Kalavathy and Suresh, 2011). Directional image vectors have also been utilized during denoising, employing vector directional filters to effectively reduce noise while preserving edges (Hsu and Chen, 1993). A novel approach involves the application of an adaptive operator, derived from differences between the current pixel and the output of the Center Weighted Median (CWM) filter, demonstrating efficacy in suppressing various types of impulse noise, including salt and pepper noise, across different noise ratios. Additionally, during noise removal, efforts are made to detect and preserve edges using techniques such as Laplacian edge detection (Zhang and Karim, 2002). These preprocessing methods collectively aim to improve the quality and reliability of fruit images, laying a solid foundation for subsequent image analysis tasks.

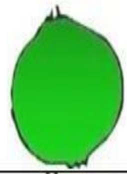
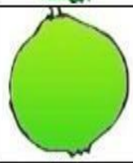
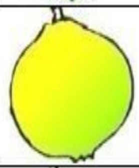
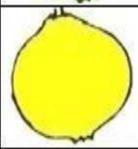
**Segmentation -** The segmentation process stands as a pivotal step in image analysis, facilitating pattern recognition and subsequent feature extraction. It involves dividing images into distinct regions, a task that becomes challenging with poor-quality images. Segmentation techniques are broadly categorized into threshold-based, edge detection, histogram-based, region-based, and watershed transformation methods. Among these, the Fuzzy C-Means (FCM) method is widely utilized due to its ability to preserve information and robust characteristics, albeit with sensitivity to noise and artifacts. To address this limitation, methods have been proposed that leverage detected edges or histogram analysis to refine segmentation results.For instance, Mazouzi and Batouche (2008) introduced a method that extracts all region boundaries from an image, labeling adjacent regions and iteratively continuing this process to produce segmented results. Arifin and Asano (2006) proposed a similarity measure based on inter-class variance for merging clusters, while Yu and Wang (2007) utilized a two-dimensional FCM algorithm to handle noise suppression and intensity variation. Xiong et al. (2021) demonstrating its efficacy in identifying plant species and diagnosing plant diseases. This underscores the broad application prospects of deep learning algorithms in various domains, including speech and image recognition, offering significant advancements in accuracy and efficiency.

**Feature Extraction and Color Features -** Once the segmentation process is complete, the next step involves feature extraction, a fundamental aspect of low-level image processing. While automated feature extraction from digital images traces back to the seventies, advancements in technology have led to improved processing capabilities and enhanced access to commercial imagery. Feature extraction and selection rely on mathematical computations and manipulation of image features to achieve high efficiency, robustness, and invariance (Lichun et al., 2009). Repeatability, a crucial property of detectors, ensures consistency in feature detection(Padmavathi, 2012).Numerous approaches, including principal component analysis, minimum noise fraction transform, discriminant analysis, decision boundary feature extraction, non-parametric weighted feature extraction, wavelet transform, and spectral mixture analysis, have been employed for feature extraction to reduce data redundancy. These techniques is to identify and extract hidden features within an image to enhance classification performance. However, selecting the most relevant feature extraction method is crucial for effective fault detection in image processing.In the following section, the analysis will focus on the color and texture features of fruits, as color represents one of the most important aspects of images. The initial step in color feature extraction involves segmentation, where the choice of color space is vital. Various color spaces have been utilized in literature for segmentation and feature extraction studies (Stanchev et al., 2003). The convolutional knowledge gained from image analysis processes provides valuable insights into further exploration of fruit defect and ripening detection techniques.

## 3.METHODOLOGY

The ripening process of fruits poses a significant challenge due to various factors involved, including initial fruit maturity, temperature, air flow, humidity, and the presence of ethylene and carbon dioxide ($CO_2$) gases in the ripening storage room. It is crucial to monitor these factors closely to ensure optimal ripening conditions. However, an excess level of $CO_2$ (>5%) can result in the deterioration of fruits and vegetables, highlighting the importance of maintaining balanced gas levels during ripening.To monitor the ripening process effectively, an infrared camera is employed to capture the gradual transition of fruits from green to yellow, which signifies the ripening progression. Subsequently, the recorded video is processed by converting it into individual frames. These frames are then analyzed, and features are extracted to estimate the levels of ethylene and $CO_2$ gases present during the ripening process.This process involves sophisticated image processing techniques to identify and isolate relevant features from the images, enabling accurate estimation of gas levels. By utilizing advanced technology and analytical methods, it becomes possible to monitor the ripening process in detail and ensure optimal conditions for fruit ripening while mitigating the risk of spoilage due to excessive $CO_2$ levels.

**Parameters for condition monitoring of ripening**

| S.No | Image of the Guava fruits | Condition | Temperature required for Ripening in °C | Ethylene gas Required for ripening in PPM | Humidity % |
|---|---|---|---|---|---|
| 1 |  | Immature green | 25 | 100 | 95 |
| 2 |  | Mature green | 22 | 95 | 93 |
| 3 |  | Intermediate | 20 | 50 | 92 |
| 4 |  | Fully Ripe | 10 | 10 | 90 |

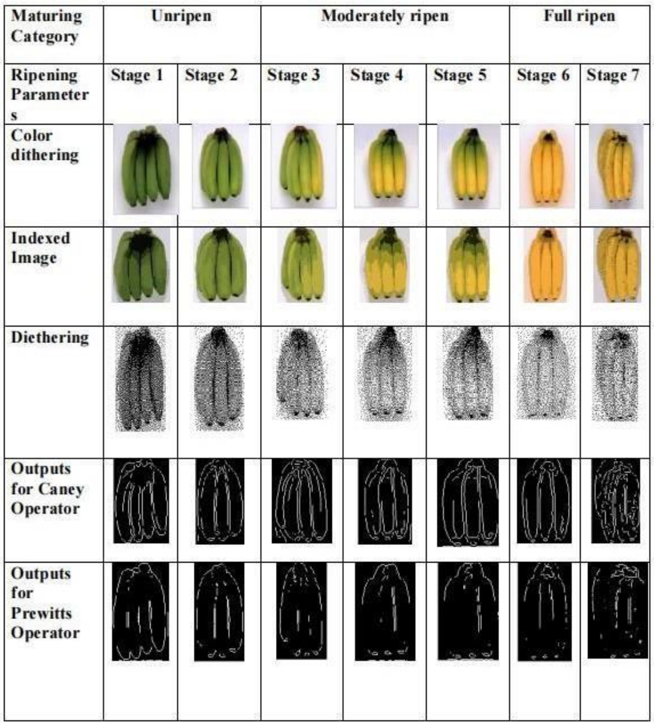
**process**

In the fundamental particle aggregation calculation, the inertial factor plays a crucial role in determining the balance between exploration and exploitation. When is small, the algorithm tends to prioritize local search, allowing particles to focus on exploring their immediate neighborhoods more intensively. This enhances the algorithm's ability to exploit promising areas in the search space. However, the downside is that particles may struggle to explore new regions efficiently, leading to a slow convergence rate as they approach the optimal solution. Conversely, when the inertia factor $\omega$ is large, the algorithm favors global exploration.

This facilitates a faster exploration of the solution space, enhancing the algorithm's ability to locate the global optimum. However, this may come at the expense of local search capability, as particles may overlook promising areas within their local neighborhoods.In practice, finding the optimal value for involves striking a balance between these competing objectives.

## 4.CONCLUSION

The analysis of features such as texture, color, intensity variation, mean, variance, and standard deviation extracted from fruit images serves as a representation of the underlying patterns present in various directions within the image. These features are indicative of changes occurring in the fruit, which can be correlated with the amount of ethylene gas present in the ripening room, specifically for bananas and mangoes.




**Outcomes after Dithering and filtering process (Banana)**

However, the ultimate goal is to accurately determine the concentration of ethylene gas. To achieve this, a normalization process is applied to each feature value, dividing it by the maximum value of that particular feature. This normalization formula helps mitigate computational complexities, ensuring that the inputs of the four features are scaled appropriately for analysis. Subsequently, a testing algorithm is employed to infer the ripening state and ethylene concentration from the fruit image. This algorithm utilizes the ultimate weights obtained after training, enabling feedforward control of ethylene gas concentration.

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