International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Investigating Advanced and Innovative Non-Destructive Techniques to Grade the Quality of Mangifera Indica.

CH. V. K. N. S. N. Moorthy[1], Mukesh kumar Tripathi*[2], Nilesh Pandurang Bhosle[3], Vishnu Annarao Suryawanshi[4], Priyanka Amol Kadam[5], Suvarna Abhimunyu Bahir[6]

Submitted: 22/08/2023 **Revised:** 12/10/2023 **Accepted:** 25/10/2023

Abstract: This paper comprehensively investigates various internal and external features to grade the mango. We have utilized different machine learning techniques and models to predict the quality of the mango fruit. One significant countenance of this paper is also to explore the Distinctiveness, robustness, and effectiveness of the existing state-of-the-art feature extraction techniques. We also investigate various aspects of destructive and non-destructive methods for the collection of data analysis. Near-infrared (NIR) based evaluation of mango fruit's internal quality is also an open challenge nowadays. The images of the same fruit under different lighting directions in visible light are negatively correlated. In contrast, closely correlated fruit images of the same individual are produced by Near-infrared imaging. Moreover, Near-infrared imaging is more advantageous for indoor and cooperative users. This concludes that Near-infrared (NIR) is very effectively used in several applications as a feature.

Keywords: *Non-destructive, Near-infrared, quality grading, machine learning*

1. Introduction

The quality of mango fruit depends on the broad internal and external features. The quality parameter such as size, shape, color, mass, and volume are classified as an external feature [1]. The sizes of mangoes are a crucial parameter for outward appearance because the quality of mangoes is mostly graded by size variability. The estimation of outside rate dependent on size is, in reality, progressively complex because of the sporadic size and shape. The meaning of size is removed depending on its highlights, strikingly the length, the distance across, and the width.

[1]*Department of Mechanical Engineering, Vasavi College of Engineering, Hyderabad, India,*
Email: krishna.turbo@gmail.com,
orcid.org/0000-0001-7209-8017
[2] *Department of Computer Science & Engineering, Vardhaman College of Engineering, Hyderabad, India,*
Email: mukeshtripathi016@gmail.com
orcid.org/0000-0001-5031-8947
[3]*Department of Information Technology, Trinity Academy of Engineering, Pune, India,*
Email: bhoslenp@gmail.com
orcid.org/0000-0002-4517-4261
[4]*Department of Electronics and Telecommunication, Trinity Academy of Engineering, Pune, India,*
Email: vishnusam2007@gmail.com
orcid.org/0003-0648-2330
[5]*Department of Computer Engineering, Trinity Academy of Engineering, Pune, India,*
Email: priyamahadik2007@gmail.com
orcid.org/0009-0008-7178-6174
[6]*Department of Computer Engineering, Trinity Academy of Engineering, Pune, India,*
Email: suvarna.bahir1@gmail.com
orcid.org/0009-0007-1424-7361

Color is also one of the most adaptable parameters in recognition of the external quality of mango. The recognition of the outside feature, the surface region for shading assurance, is estimated at the skin or external surface of the mango fruits. The visual evaluation is straightforward, insisting that different components mainly rely upon the progressions of brightening and lighting. A few disadvantages are utilizing the traditional strategy, even though basic color estimations can be obtained directly from the dataset image. The primary color measurement typically estimates the image surface that is identical and systematic. If the surface area has various colors, the estimations should be imitated for a couple of readings to achieve the scattering aid of the concealing surface of the image sample. In this situation, color estimation of the image surface is a tough assignment for the experiment of enormous volume and non-homogeneous state of the natural product. Accordingly, the requirement for creating fast and non-destructive color estimation is exceptionally needed for the exact color dissemination of agricultural development.

Disease is another critical parameter for the external quality review of mango fruit. The disease that ordinarily influences mango fruit includes over-ripeness and bruises [2]. Despite the undeniable decay of mango, non-destructive strategies offer an answer for assessment of external characteristics to distinguish kinds of deformities for the taking care of procedures of mango. The indication of superficial imperfections could influence the quality and cost of mango fruit. However, grading mangoes by the external parameter is challenging due to the mango fruit's illumination, shape variability, and ripeness condition.

2. Internal Quality Parameters for Mango

Consumer preference based on quality and cost of agricultural product depends on internal attributes. Attributes like Total Acidity, Dryness, Firmness, Maturity, and Un-maturity are some essential features broadly classified as internal parameters [3] used to grade the quality. The combination of all these Physical, biochemical, and physiological attributes is used to grade the quality of mango fruit [4]. The internal attributes of mango change practically every day. Due to this, it is more complicated for a consumer to estimate the grade of the mango at purchase time. Due to this, there is need for all internal and external attributes to be associated in the such a way that size, shape, colour, weight, texture, TAC, SSC should divulge the inclusive the quality of mango fruits.

During the ripening process, consideration changes in the bio-chemical of mango fruit by cause of temperature. At different temperature stages, mango fruits' physicochemical attributes vary according to the time and number of days. Many researchers [5] have shown that at 20 °C temperature, physiological loss in weight is less compared to a higher temperature at 25 °C. The loss is more insoluble solid content (SSC), titratable acidity (TA), and total acidity at 25 °C. The survey found that for the one-week duration, 25 °C temperatures yield the best quality of mango, whereas the best quality of mango fruit for the long term, such as more than ten days, 20 °C temperature maintains the best quality of mango to grade.

Many authors [6] has as worked on identifying the biochemical parameter of mango fruits. The biochemical composition varies with the cultivar—the range of bio-chemical pieces with parameters. Mostly 85 % moisture is present in unripe mango. The Carbohydrate range is between 11.6 % to 24.3 %. The content for TSS biochemical is between 12 % and 23 %, and the range between 8.7 % and 17.9 % is the range of total sugar. Vitamin A is between 6375 and 20750 per 100 grams, whereas Vitamin B, Vitamin C, and Nicotinic acid are 40, 0.3, and 50.0 per 100 grams. The author [7] show in their research that a sugar component shows symmetric increment at a ripe state. Initially, the sugar value is less at the unripe stage, but the sugar component was found to be gained in maturity. The range of moisture in ripe mango is very similar to unripe mango, with a value of 78.9 % to 82.8 % per 100 g.

The author [8] discuss the presence of bio-accessible B-carotene content in different variety of mango, such as 'Badami,' 'Raspuri', 'Malgo,' 'Malika,' 'Totapuri' and 'Neelam.' The highest bio-accessible B-carotene content in the 'Malika' variety is 0.89/100 g, followed by 'Badami' and 'Raspuri' varieties with 0.79/100 g and 0.79/100 g, respectively. The 'Totapuri' and 'Neelam' variety has an average presence of carotene content with values 0.48/100 g and 0.45/100 g, respectively. 'Malgo' verity of mango has less B-carotene content with a value of 0.18/100 g. A few more parameters can affect the quality of mango at the ripping stage, such as Temperature, Controlled and modified atmosphere, Ionizing radiation, and Chemicals. TAC, SSC, and TA internal parameters is most essential to grade the quality of mango. It is preposterous to expect to check for inward harm in every mango because of the inadequate technique, which relies upon visual appearance. This may bring about less financial profit for mango fruit. Hence, early recognition is essential in deciding the mango's internal quality since the deformity's seriousness affects financial worth. Consequently, the capacity of non-destructive methods to recognize internal features is desirable to decrease the crumbling of influence mango.

3. Physical Parameters of Ripened Mango Cultivars Grown in India

In India, a variety of mango is cultivated from March to June. Weight, Length, Width, Volume, and specificity are critical physical parameters of the ripened mango. ‘Totapuri’ variety [9] has the highest length, 128.88 mm, whereas ‘Keasr,’ ‘Alphonso,’ and ‘Samarbahist Chausa’ has an average length with the value of 95.6 mm, 94.6 mm, and 93.7 mm, respectively followed by ‘Mallika’, ‘Fazli,’ ‘Chausa,’ ‘Dashehari’ with value 14.52 mm, 13.65 mm, 10.88 mm and 10.32 mm respectively. The lowest length with values of 7.55 mm, 8.44 mm, 8.54 mm, 9.00 mm, and 9.04 mm for respective varieties of mango such as ‘Alphonso’, ‘Gulabkhas’, ‘Himsagar’, ‘Bombai,’ ‘Langra’. The width of all varieties of mango is in a similar pattern. The value of width does not vary too much. ‘Mallika’ and ‘Alphoso’ variety mango has the largest width, whereas ‘Samarbahist Chausa’ has a low width of 57.0 mm.

‘Mallika’ variety of mango has the highest width and volume with values of 382.23 g and 373.33, respectively, followed by the ‘Fazli’ and ‘lagra’ varieties. ‘Samarbahist Chausa’ variety has less weight and volume, with values of 173.33 g and 93.7 ml, respectively, compared to other mango varieties. This table also shows the specific gravity of various mango product which varies 1.095 to 1.022. The report [9] says that mango fruit weight varies during cultivation. The weight and heaviness of organic products might depend on various internal and external features during the ripening stage. Whereas minimum carotenoid content is present in ‘Alphonso’ and ‘Fazil varieties of mango with a value of 2.65 mg/100 and 1.82 mg/100, respectively. Different mango varieties produce carotenoid content, which varies due to β-carotene, lycopene, lutein and zeaxanthin. Identification for ripening of fruits depends upon the presence of Treatable Acidity content. It is also dependent on prevailing environmental conditions. It is likewise subject to ecological conditions. The variety in the causticity in various mangoes could be because of their heterogeneous attributes. This abnormality in ascorbic acid could be characteristic of the environment. The higher level of ascorbic corrosive may be because of the unending combination of glucose 6-phosphate during the development and advancement of mango fruit, which is viewed as the forerunner. The expansion in ascorbic corrosive substances is most likely due to the reactant impact of development substances on the biosynthesis of ascorbic caustic from sugars.

4. Non-Destructive Measurement

A non-destructive estimation is the assessment of materials in terms of shape, biochemical, and qualities without crushing their usefulness, just as the framework highlights. The conventional approach to identifying the inner attributes of fruit needs a destructive technique using apparatus, strategies, and training professionally, which brings about high examination costs. All this author says that [10] new advancements to keep track of fruit quality changes during the post-harvest taking care of chain are quickly being presented, particularly those dependent on non-destructive evaluation strategies. Hence, non-destructive methods allow supplanting the standard reference strategy, including the traditional methodology. Right now, non-destructive methods are utilized in mechanical applications to guarantee the practicability of a given item or framework. Non-destructive methods are significant in deciding the dependability of different applications, remarkably in assessing the quality parameters of fruits. These efficient and non-ruinous strategies can benefit by furnishing definitive attributes to acquire better quality mango items and advancing utilization of mangoes with better well-being benefits.

5. Infrared Based Spectroscopy

The author [11] has used VIS-NIR spectroscopy with a robot gripper for mango quality grading. They have also presented the framework which describes the working model of spectroscopy in robot gripper. The author [12] has also utilized the near-infrared reflection spectroscopy to acquire the spectra. The range of NIR spectroscopy is between 400 to 700 nm. The spectra were taken after each 10 nm space. In this, the value has been taken ten times for a single range of spectra, and the average value is taken for further calculation. Figure 1 shows the block diagram of spectroscopy with another component such as a detector, sample holder, laptop, etc. For the experimental purpose, the author has collected the mango data sample. This sample was kept at 24+1 0c before the measurement of spectra. In this, it is observed that raw spectra have very high dimensions. Further, in the pre-processing step, the noise will be removed from raw spectra by applying weight regression coefficients. Lastly, internal parameters such as TSS, TA, and firmness will be analysed in a PLS model for the calibration stage and the RPI method to predict the condition of the mango.

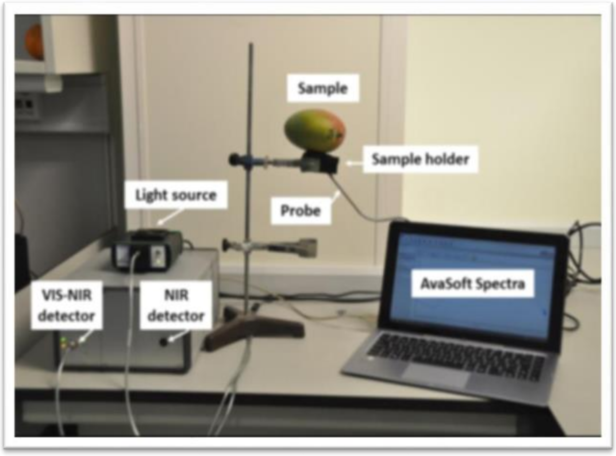

Fig 1: Block diagram of NIR spectrometer for internal quality assessment of mango.

The author presents a framework based on electrical impedance spectroscopy to identify maturity levels to assess mango quality [13]. In this, 'Tommy Atkins' variety of mango has been utilized in the experiment. The data sample was washed and kept at different degrees of temperature for 15 days before the experiment.

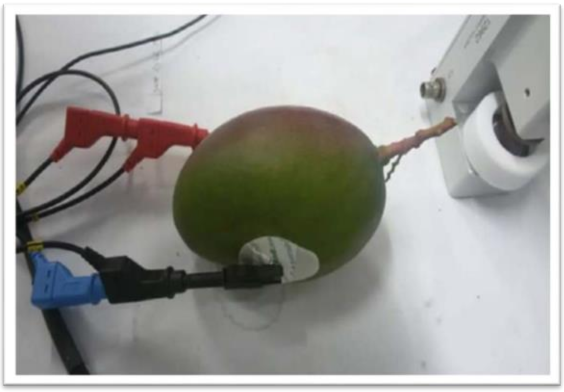

Fig 2: Framework of electrical impedance spectroscopy to identify the maturity

The connection of all components to extract the spectra is shown in Figure 2. The electro-mechanic universal machine with TESC software is utilized for mechanical tests. With this, the mango sample was connected by two electro nodes. Finally, the maturity of mango can be obtained by calculating fitting results divided by mango fruit diameter. The author [14] presents an NIR spectral framework with a combination of an NIR spectrometer and a tool for mango fruit positioned, as shown in Figure 3. In this, internal parameters such as Dry matter (DM), TA, SSC, and ripeness will be reviewed to grade the quality of mango fruit. At last, MLR and PLS regression model is used to analyze the data. The outcomes show that NIR is a promising strategy to explore the relationships of biochemical parameters of the same mango product at various formative stages. With this recently created technique, a pattern estimation of value changes during fruit product improvement dependent on inspecting different mango samples is never again required.

Some author, for example, [15], have enclosed in their research the full range utilizing spectroscopy in mangoes, even though reviews using color arranges are increasingly expected, for example, [16]. The application of non-destructive measurements for quality assessments is summarized in Table 1.

Table 1: Application of non-destructive measurements for quality assessments

Application	Parameter	Data analysis	Reference
VIS-NIR	TSS, TA	PLS	[11]
NIR spectroscopy	TSS, TA	RPI	[12]
Impedance spectroscopy	Maturity	Bulk Resistance	[13]
Hyperspectral imaging system	TSS, TA, Firmness	General linear model	[14]
NIR spectral	DM, TA, SSC	Multiple linear regression	[15]
NIR spectroscopy	Dryness maturity	Linear regression model	[16]

Over the past few years, X-ray has given a quality-based 3D image of objects with various materials, making a difference in separating low-and high-density materials. To fulfill this intention, the author [17] has studied the physical properties of cucumber fruit. The physical properties such as density, porosity, moisture content, and Firmness is estimated for seven continuous days different temperature. Respectively, X-ray techniques are applied to the sample to collect the 3D –image. Further segmentation method was performed to obtain the average gray value of the pixel. Finally, by using regression techniques, the change in fruits is analyzed. They have also expressed that in higher temperatures of 25 oc, the average value grayscale decreases, whereas increment is observed in the internal porosity parameter.

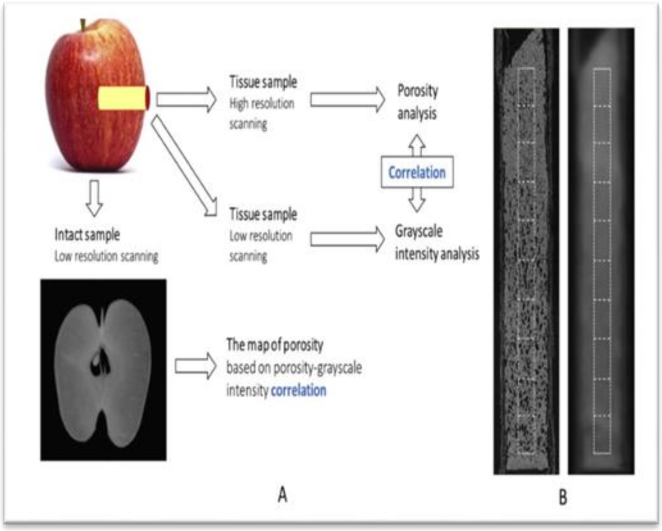

Fig 3: Framework for experiment by X-ray

In their study, authors [18] evaluated the porosity in fruits and vegetables by applying X-ray CT. They also presented the framework where an X-ray machine scanned an image sample. This machine has ranged between 746 mm to 1085 mm with 120 KV. Further, two tissue sample with high and low resolution is analyzed. The resulting image with a dashed line in Figure 3 represents the relation between porosity and gray level intensity.

6. Machine Vision

Machine vision is a part of an engineering expert skill in consolidation with optical and mechanical properties, electromagnetic, and image processing methods. Machine vision frameworks are progressively faster regarding sample image assessment when analyzing acoustic and vibration techniques. The improvement of the application has increased a lot of enthusiasm for the quality assessment of agricultural products. The volume estimation is essential for fruit to decide the size per specific grading evaluations [19]. At the present stage, the principle worries in this machine vision explore the capacity of machine vision to classify the agriculture product regarding quality parameters. Till now, research has dealt with the primary practice of quality assessment with methods for machine vision frameworks. But, just a couple of the present works discussed the physicochemical and biochemical presence in the image sample [20].

In a computer vision-based system, each image is represented in some particular color space. Many color spaces are available in image processing. Some common color space is RGB color space, HSI color space, L* a* b* color space, etc. [21]. For example, the RGB color space is frequently utilized in exacting R G B individually of mango fruits, which contains the three wavelengths with the composition of red, green, and Blue. As we know, RGB color space is hardware-based. Color changes have been done by the standard color value of the particular image that can be identical to a human person in HSI color space [22]. The machine vision framework plays a vital role in detecting color, texture, shape, and illumination. Identifying disease or external damage is ongoing with further, more challenging tasks. Particularly since the present measurement relies upon the high discrepancy of disease. For instance, the exactness of the machine vision framework to assess the external part of food products depends upon a few elements, including the cultivar, planting area, and postharvest treatment of fruits [23].

The author [24] has presented a computer vision approach to improve productivity. This system comprises a camera, frame grabber, and sample holder component. In this, image samples are kept on a sample holder. This image holder is connected to the camera, which captures the image and forwards it to the next stage, where the image is collected in frame format using the frame grabber component. The system is connected by wired with all members of the proposed framework. They have analyzed the review of various fruits and vegetables. Image processing techniques mostly do the quality analysis of fruits and vegetables. This technique consists mainly of four steps: the first step is to do pre-processing to remove unwanted noise, the second segmentation process to extract the background of the image sample, feature extraction to extract the parameter responsible for the quality, and finally, applying classifiers to detect the proposed system's performance.

The author [25] first prepared the image acquisition chambers to grade the mango quality. A design framework was presented by the author [26]. The layout of the system is helpful for fruit grading. This module combines components such as conveyor belts, fruit placers, image-capturing chambers, fruit sorting strips, and sorting bins. In this back propagation neural network (BPNN) is utilized at the classification stage to sort the fruit based on respective quality. 80.0 percent accuracy rate is achieved by the proposed system for grade II fruit, whereas 71 percent accuracy for grade I and 66 percent for grade III date fruit has been achieved. The author presents a framework of computer vision for mango grading [27]. Author [28] also presents the Machine Vision system for the quality determination of mango. This framework consists of components such as Conveyed assembly, Electric power drive, Fruit samples, Illumination unit, Light sources, Camera, Control unit, Computer, Frame grabber software, and Variable-frequency control. For the experimental purpose, the author collected two different categories of mango, 'Nam Dokmai' and 'Maha Chanok'.

Further, all sample images of mangoes were segmented by the Gamma Curve Fitting method. All the backgrounds extracted from the mango image are processed in the next step, where the color of each mango sample is calculated by the first Quadrant method. They have utilized the L* a* b* color space. Finally, in the calibration model, both mango 'Nam Dokmai' and 'Maha Chanok' categories are classified by static methods such as Mean and standard derivation. The grading of mangoes is done based on three different types: ripe, unripe, and overripe. The author presents an artificial intelligence-based structure for sorting mangoes [29]. Their study briefly described the role of image processing and AI in sorting the mango. The present model helps capture the image of the mango. Next, the segmented process and all features are extracted to obtain a segmented image of the mango based on color, mass, and volume features. Finally, ANN-based regression method quality grading has been done. The proposed system has produced 80 percent accuracy rates for sorting mangoes. A hardware and software-based model system is explored to sort a mango by the author [30-32]. They have utilized a conveyor belt, AC motor controller, webcam, sensor, and serial combination board. In this model, mango samples are kept on conveyor belts that pass through a webcam device to capture the image. Then, the image is segmented by Threshold techniques. The dilatation and erosion method is applied to the respective segmented image to remove the unwanted noise or shadow. This dilatation and erosion operation plays a vital role in improving the performance of the proposed system. Further, the size of the mango sample is based on the caliber determination method. This method extracts the pixel value of images based on the weight of the respective image.89.5 The proposed system achieves a percentage of accuracy rate. The quality of mango fruit significantly relies on numerous parameters, such as ripe, unripe, overripe, texture, shape, color, and other factors at harvesting time.

Table 2: Application of machine vision for fruit grading

Application	Pre-processing	Feature Extraction	Data Analysis	Accuracy in %	Reference
Sorting of mango	Ostu Threshold	Colour and Size	Fuzzy rule	94.97	[19]
Grading of date Fruit	Binary Threshold	Shape, Size	BPNN	80	[20]
Grading of mango	Binary Threshold	Mass	Statics analysis	97	[21]
Sorting of mango	Gamma curve fitting	Color	Coefficient of determination	98	[22]
Sorting of mango	Convolution Filter	Color, Mass	ANN	80	[23]

Grading of Mango	Threshold - Techniques	Size	Caliber model	89.5	[24]
Grading of Mango	HSI	Texture	Neural Network	93.33	[25]
Grading of Mango	Binaries adaptive	Color, shape	PCA	92	26]
Classification of mango	Ostu Threshold - Techniques	Region and Boundary	Bayes classifier	90.01	[27]
Sorting of mango	Threshold - Techniques	Mass and volume	Regression model	91.76	[28]

Object recognition and classification is an essential application in computer vision systems. The framework presented by the author [33] consists of four parts. Firstly, the mango image is segmented Ostu Threshold- Techniques. Next, the feature is extracted by using Region and Boundary descriptors. Finally, a 90.01 percent accuracy rate is achieved by applying Bayes classifier. A similar type of framework is presented by the author [34]. They must grade the mango by regression model based on mass and volume features. The proposed system produces a 91.76 percent accuracy rate for grading mangoes.

7. Advantages and Disadvantage of Non-Destructive Method

Non-destructive methods have been designed as a typical instrument for estimating and examining fruit grading. For mango, a few non-destructive methodologies are accessible for quality assessment depending upon the reason. In observation with the destructive strategies, non-destructive methods are driving as far as quick observation, simple installation, and persistent estimation of food quality grading on different categories of fruits [35]. However, the expense of accessories for the non-destructive strategies is moderately high and subsequently frustrates the research community of the non-destructive applications in the food industry. The fundamental advantages and drawbacks of non-destructive methods in the grading assessment of mangoes are depicted in Table 3. All the given non-destructive methods have their express points of interest and downsides from the standard methodology or the perspective of the researchers. Indeed, even though the applications of non-destructive strategies are open, the most generally utilized method in the quality assessment of mango quality is the spectroscopy strategy. These methodologies are often accessible for quality grading in the food industry and agricultural field.

Table 3: Advantages and disadvantage of non-destructive method.

Application	Advantages	Disadvantage
Infrared based spectroscopy	Provide robust model for quality grading assessment.	Bio-chemical composition in a single spectrum and image acquisition process is quite slow.
X-Ray	Highly accurate in analysis the internal feature	Considerably large, complex and costly
Raman spectroscopy	Detection of different biochemical and physical parameter simultaneously	Low sensitivity and Heating problem
Machine vision	Efficient extraction of Pesticide residues.	Not suitable for extensive processing scale.

The capacity of spectroscopic strategies to be non-intrusive, target, and quick when correlated with the traditional approach is fundamental in the execution of the grading system of mango. This is because of the development of an online recognition framework that can handle manual labor. Furthermore, the method offers great quality horticultural produce for business purposes. Still, compiling the spectral information without utilizing multivariate techniques is challenging since the data is assessed concerning the framework's accuracy. The machine vision framework for evaluating the quality of fruits relies upon the viability of the standard reference technique during the design advancement of the calibration model. Then again, the impediment of infrared spectroscopy for assessing fruit product quality is costly and complex for the online quality grading system. The significant challenge for enhancing the non-destructive method is to grade the quality of mango based on internal and external parameters. There is a crucial need to build up a quick, objective, and dependable framework that can be utilized to detect natural fruit perceptive to external and internal disease precisely**.**

8. Machine Learning in Food Industries

With the rapidly expanding populace worldwide, the requirement for high-quality food with less utilization of agricultural land is increasing. Computer vision would guarantee the expansion of food production by using a robotized, efficient, and non-destructive technique. In recent years, impressive outcomes have been accomplished in various areas of horticulture products. These accomplishments are incorporated with machine learning strategies on a computer vision-based approach that adapts color, texture, shape, and spectral investigation from the image of the data set. Regardless of having numerous utilizations of various machine learning techniques, the present review focus on linear, non-linear, and statistical machine learning techniques and computer vision framework in food industries.

The author [36-38] has introduced a framework by NIR spectroscopy. In their study, non-infrared spectroscopy is utilized to assess the internal features of mangoes. In the material and method procedure, the first drying procedure is completed. Further, NIR with a range of 400-2500 nm is used to obtain spectra, and destructive techniques are used for biochemical parameters. Additionally, Analysis of variance (ANOVA) is implemented to analyze the data. High dimension and noise are present in mango spectra, so dimension reduction algorithms Principal component analysis (PCA) is utilized. This PCA model is developed based on root mean square (RMSEC) in calibration and Root Mean Squared Error cross-validation (RMSEC) value in the validation. Further, the ANOVA-simultaneous component analysis (ASCA) method analyzed the improved spectra with a significant effect with a value of 47.5 percent.

An author [39] introduces a methodology to assess the quality of mangoes during the ripening process stage. Initially, one hundred mango images were acquired. The image processing technique is applied for pre-processing and background subtraction. Next, The first function-based feature extraction algorithm is utilized to extract the feature from the segmented image. Then, information gain is estimated, which gives information about the complete information carried with an image. Also, the ranked search method ranks the attributes of images belonging to information gain. Finally, in the training and testing phase, C4.5 algorithms were implemented in association with 10-fold cross-validation to improve the performance of the proposed system. The overall 96 percent accuracy rate is achieved using C4.5 algorithms.

Maturity is one of the critical indicators of the quality of fruit. During the ripening process, Dry Matter (DM) content is utilized to show the maturity level of mango fruit. The author [40] has proposed a robust and effective approach to recognize spectral images and assess the maturity level of mango fruit. First, data are acquired by NIR spectral, and labeling is done manually. They have implemented classification and regression modeling to detect the mango and evaluate the quantity of DM. Partial least squares discriminant analysis (PLS-DA) is a variant of PLS used for the reduction process. Both classification and regression methods unitize the reduction process spectral data. For the classification CNN, based architecture is proposed, which is based on two convolutional layers and two fully connected layers without padding operation. The result shows that for the PLS model, R2 =0.580 and RMSE =1.168, whereas the CNN-REG model has R2 =0.639 and RMSE =1.081 and the CNN-COMB model R2 =0.631 and RMSE =1. 094. One major limitation of the proposed system is the issue of illumination under natural light.

An author [41] presents a novel approach based on Mango Net deep segmented architecture to detect and count the mangoes from the tree. Further, the mango image is identified in the semantic segmented yield utilizing shape-based associated object identification. Next in the training phase, 11094 patches obtain from 40 image and in the testing phase, four test images generated 1,500 image patches. In the result section, the performance of mango Net architecture and FCN variant architecture is compared on the same data. The mango Net architecture has produced 73.6 percent accuracy, whereas a 51 percent accuracy rate is achieved by FCN architecture. The outcomes illustrate, that the proposed strategy for identification is invariant to scale, lighting, difference, and impediment contrasted with model. The results show the capability of Deep CNN-based strategies for mango yield estimation.

An author [42] has presented a hyperspectral imaging system to estimate moisture content. In the experiment section, the first drying process will be completed, and then NIR spectroscopy will extract the value of the internal parameter. Visible-near infrared is applied for spectra having a wavelength range between 400 to 1000 nm, and second Near-infrared (Vis-NIR) is implemented having a wavelength range between 880 to 1720 nm. Once this process is finished, the moisture content in mango is estimated by destructive methodology. Finally, the PLS model builds the relationship between spectra and harmful moisture content. Results show that in mango samples in the spectral wavelength range between 400-1000 nm, the accuracy rate is 43.70 %, whereas an 87.15 % accuracy rate has been achieved with NIR-based spectra wavelength range between 880 to 1720 nm. The author proposes a framework based on the firmness attribute of mango [43]. In their work [44], both destructive and non-destructive methodology is implemented to evaluate the internal quality of mango. Vis-NIR extracts the spectra with a wavelength range between 400-1050 nm [45]. Further, the PLS model builds the relationship between spectra and internal parameters [46]. Finally, genetic algorithms are utilized [47] to estimate the firmness level of mango fruit. Mango fruit image is a combination of different internal biochemicals, and sometimes [48], it is difficult to estimate the parameter based on a regression model. These challenges [49] can be avoided by using NIR spectroscopy and applying machine learning techniques.

9. Problem Identification

On the basis of the comparative analysis of various recent state-of-the art methods, we found the following research gaps to be addressed by the research work reported in this paper:

- Categorization of mango fruits based on computer vision technique is a challenging task. There are two kinds of fruit categorization: one is to recognize specific categories of fruit, and the other is to classify different fruit classes. However, a traditional approach based on image processing is not good enough to produce a reasonable accuracy rate. It is identified as one of the research gaps for the recognition problem.
- Most of the research for image recognition has focused on descriptor techniques with classification accuracy as a performance metric. To improve performance, we will implement a deep convolutional neural network and compare the state of the art using various performance metrics.
- Proper and efficient grading is essential for increasing productivity in the agricultural industry. Many processes exist for grading, yet need further updates to enhance the fruit quality. Mango is one of the most exported fruits regarding the volume and value of production. Manually grading mangoes is labor- intensive, inefficient, and prone to errors. It is also pointed out one of the research problems where the automated grading system is required to explore to enhance the processing time and minimize the error.
- The quality of fruit depends on internal parameter, which is affected by temperature during the ripening process and storage period. Till now, there is no such effective and robust mechanism to evaluate the quality of mango based on internal features. We identify quality evaluation is one of the research gaps that need to be addressed by applying linear and non-linear regression models as a straightforward, quick, and non-destructive alternate for assessing mango quality.
- It has been demonstrated through numerous practical applications that computer vision frameworks are scientific and powerful tools to evaluate the fruits based on external parameters. Still, they need to grade the internal quality based on internal parameters. Moreover, most existing destructive methods could more effectively evaluate mango fruit's inner quality. It is also pointed out that one of the research problems where distinctive and robust near-infrared spectroscopy must be explored to grade the quality of mango based on internal quality attributes with machine learning techniques.

10. Conclusion

In this paper, we surveyed mangoes' internal and external parameters to grade the quality based on their properties. We additionally analyze the non-destructive measurement to evaluate the internal parameter; further, various method of pre-processing spectra is discussed. Finally, the role of machine learning techniques in the food industry is briefly examined. Literature review and analytical comparison have been made among recent state-of-the-art internal and external features applying destructive and destructive, based on which the five most challenging research gaps are identified that need to be addressed.

Reference:

[1] C. S. Nandi, B. Tudu, and C. Koley, “A machine vision technique for grading of harvested mangoes based on maturity and quality,” IEEE Sens. J., vol. 16, no. 16, 2016, doi: 10.1109/JSEN.2016.2580221.

[2] V. E. Nambi, K. Thangavel, and D. M. Jesudas, “Scientia Horticulture Scientific classification of ripening period and development of colour grade chart for Indian mangoes (Mangifera indica L .) using multivariate cluster analysis,” Sci. Hortic. (Amsterdam)., vol. 193, pp. 90–98, 2015, doi: 10.1016/j.scienta.2015.05.031.

[3] Tripathi, M.K. and Maktedar, D.D., 2018. A Framework with OTSU’S Thresholding Method for Fruits and Vegetables Image Segmentation. International Journal of Computer Applications, 975, p.8887.

[4] Tripathi, M.K. and Maktedar, D.D., 2016, August. Recent machine learning based approaches for disease detection and classification of agricultural products. In 2016 International Conference on Computing Communication Control and automation (ICCUBEA) (pp. 1-6). IEEE.

[5] Y. Ding, L. Wang, Y. Li, and D. Li, “Model predictive control and its application in agriculture: A review,” Computers and Electronics in Agriculture, vol. 151. 2018, doi: 10.1016/j.compag.2018.06.004.

[6] S. C. N. Aleixos and F. A. A. Torregrosa, “Optimized computer vision system for automatic pre-grading of citrus fruit in the field using a mobile platform,” no. 45, 2013, doi: 10.1007/s11119-013-9324-7.

[7] A. K. Bhatt and D. Pant, “Automatic apple grading model development based on back propagation neural network and machine vision , and its performance evaluation,” 2013, doi: 10.1007/s00146-013-0516-5.

[8] M. Shamili, “The estimation of mango fruit total soluble solids using image processing technique,” Sci. Hortic. (Amsterdam)., vol. 249, no. October 2018, pp. 383–389, 2019, doi: 10.1016/j.scienta.2019.02.013.

[9] V. Mohammadi, K. Kheiralipour, and M. Ghasemi-varnamkhasti, “Detecting maturity of persimmon fruit based on image processing technique,” Sci. Hortic. (Amsterdam)., vol. 184, pp. 123–128, 2015, doi: 10.1016/j.scienta.2014.12.037.

[10] Mohapatra, S. Shanmugasundaram, and R. Malmathanraj, “Grading of ripening stages of red

banana using dielectric properties changes and image processing approach," Comput. Electron. Agric., vol. 143, no. 382, pp. 100–110, 2017, doi: 10.1016/j.compag.2017.10.010.
[11] X. Chen, Z. Li, Y. Wang, and J. Liu, "Effect of fruit and hand characteristics on thumb – index fi nger power-grasp stability during manual fruit sorting," Comput. Electron. Agric., vol. 157, no. January, pp. 479–487, 2019, doi: 10.1016/j.compag.2019.01.032.
[12] K. Hameed, D. Chai, and A. Rassau, "A comprehensive review of fruit and vegetable classification techniques," Image Vis. Comput., vol. 80, 2018, doi: 10.1016/j.imavis.2018.09.016.
[13] Tripathi, Mukesh Kumar, and Dhananjay D. Maktedar. "Optimized deep learning model for mango grading: Hybridizing lion plus firefly algorithm." IET Image Processing 15, no. 9 (2021): 1940-1956.
[14] X. Li et al., "Postharvest Biology and Technology SSC and pH for sweet assessment and maturity classi fi cation of harvested cherry fruit based on NIR hyperspectral imaging technology," Postharvest Biol. Technol., vol. 143, no. May, pp. 112–118, 2018, doi: 10.1016/j.postharvbio.2018.05.003.
[15] Tripathi, M.K. and Maktedar, D.D., 2021. Detection of various categories of fruits and vegetables through various descriptors using machine learning techniques. International Journal of Computational Intelligence Studies, 10(1), pp.36-73.
[16] Bhargava and A. Bansal, "Fruits and vegetables quality evaluation using computer vision: A review," Journal of King Saud University - Computer and Information Sciences, 2018.
[17] M. K. Tripathi and D. D. Maktedar, "A role of computer vision in fruits and vegetables among various horticulture products of agriculture fields: A survey," Inf. Process. Agric., no. xxxx, 2019, doi: 10.1016/j.inpa.2019.07.003.
[18] Q. Kou, D. Cheng, L. Chen, and Y. Zhuang, "Principal curvatures based local binary pattern for rotation invariant texture classification," Optik (Stuttg)., vol. 193, p. 162999, Sep. 2019, doi: 10.1016/j.ijleo.2019.162999.
[19] Channapattana, Shylesha V., Srinidhi Campli, A. Madhusudhan, Srihari Notla, Rachayya Arkerimath, and Mukesh Kumar Tripathi. "Energy analysis of DI-CI engine with nickel oxide nanoparticle added azadirachta indica biofuel at different static injection timing based on exergy." Energy 267 (2023): 126622.
[20] G. P. Moreda, J. Ortiz-Cañavate, F. J. García-Ramos, and M. Ruiz-Altisent, "Non-destructive technologies for fruit and vegetable size determination - A review," J. Food Eng., vol. 92, no. 2, pp. 119–136, 2009, doi: 10.1016/j.jfoodeng.2008.11.004.
[21] F. S. A. Sa'ad, M. F. Ibrahim, A. Y. Md. Shakaff, A. Zakaria, and M. Z. Abdullah, "Shape and weight grading of mangoes using visible imaging," Comput. Electron. Agric., vol. 115, pp. 51–56, 2015, doi: 10.1016/j.compag.2015.05.006.
[22] Tripathi, Mukesh Kumar, and Dhananjay D. Maktedar. "Internal quality assessment of mango fruit: an automated grading system with ensemble classifier." The Imaging Science Journal 70, no. 4 (2022): 253-272.
[23] K. Utai, M. Nagle, S. Hämmerle, W. Spreer, B. Mahayothee, and J. Müller, "Mass estimation of mango fruits (Mangifera indica L., cv. 'Nam Dokmai') by linking image processing and artificial neural network," Eng. Agric. Environ. Food, vol. 12, no. 1, pp. 103– 110, 2019, doi: 10.1016/j.eaef.2018.10.003.
[24] Chiranjeevi, Kasa, Mukesh Kumar Tripathi, and Dhananjay D. Maktedar. "Block chain technology in agriculture product supply chain." In 2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS), pp. 1325-1329. IEEE, 2021.
[25] K. Schulze, M. Nagle, W. Spreer, B. Mahayothee, and J. Müller, "Development and assessment of different modeling approaches for size-mass estimation of mango fruits (Mangifera indica L., cv. 'Nam Dokmai')," Comput. Electron. Agric., vol. 114, pp. 269– 276, 2015, doi: 10.1016/j.compag.2015.04.013.
[26] M. Fashi, L. Naderloo, and H. Javadikia, "The relationship between the appearance of pomegranate fruit and color and size of arils based on image processing," Postharvest Biol. Technol., vol. 154, no. April, pp. 52–57, 2019, doi: 10.1016/j.postharvbio.2019.04.017.
[27] Tripathi, Mukesh Kumar, Dhananjay Maktedar, D. N. Vasundhara, CH VKNSN Moorthy, and Preeti Patil. "Residual Life Assessment (RLA) Analysis of Apple Disease Based on Multimodal Deep Learning Model." International Journal of Intelligent Systems and Applications in Engineering 11, no. 3 (2023): 1042-1050.
[28] Y. Gurubelli, M. Ramanathan, and P. Ponnusamy, "Fractional fuzzy 2DLDA approach for pomegranate fruit grade classification," Comput. Electron. Agric., vol. 162, no. March, pp. 95–105, 2019, doi: 10.1016/j.compag.2019.03.036.
[29] Nyalala et al., "Tomato volume and mass estimation using computer vision and machine learning algorithms: Cherry tomato model," J. Food Eng., vol. 263, no. April, pp. 288–298, 2019, doi: 10.1016/j.jfoodeng.2019.07.012.
[30] V. O. Ayodele, O. M. Olowe, C. G. Afolabi, and I. A. Kehinde, "Identification, assessment of diseases and agronomic parameters of Curcuma amada Roxb (Mango ginger)," Curr. Plant Biol., vol. 15, no. October, pp. 51–57, 2018, doi: 10.1016/j.cpb.2018.10.001.

[31] M. Moalemiyan, A. Vikram, and A. C. Kushalappa, "Detection and discrimination of two fungal diseases of mango (cv. Keitt) fruits based on volatile metabolite profiles using GC/MS," Postharvest Biol. Technol., vol. 45, no. 1, pp. 117–125, 2007, doi: 10.1016/j.postharvbio.2006.08.020.

[32] Tripathi, M.K., Neelakantapp, M., Kaulage, A.N., Nabilal, K.V., Patil, S.N. and Bamane, K.D., 2023. Breast Cancer Image Analysis and Classification Framework by Applying Machine Learning Techniques. International Journal of Intelligent Systems and Applications in Engineering, 11(3), pp.930-941.

[33] H. Cen, Y. He, and M. Huang, "Measurement of soluble solids contents and pH in orange juice using chemometrics and vis-NIRS," J. Agric. Food Chem., vol. 54, no. 20, pp. 7437–7443, 2006, doi: 10.1021/jf061689f.

[34] Tripathi, M.K., Reddy, P.K., Neelakantappa, M., Andhare, C.V., Shivendra "Identification of mango variety using near infrared spectroscopy", Indonesian Journal of Electrical Engineering and Computer Science this link is disabled, 2023, 31(3), pp. 1776–1783.

[35] S. Wibowo, C. Buvé, M. Hendrickx, A. Van Loey, and T. Grauwet, "Integrated science-based approach to study quality changes of shelf-stable food products during storage: A proof of concept on orange and mango juices," Trends Food Sci. Technol., vol. 73, no. November 2017, pp. 76–86, 2018, doi: 10.1016/j.tifs.2018.01.006.

[36] B. T. PETER BUTZ, CLAUDIA HOFMANN, "Recent Developments in Noninvasive Techniques for Fresh Fruit and Vegetable internal quality analysis," J. Food Sci., vol. 70, no. 9, pp. 131–141, 2005.

[37] E. J. N. Marques, S. T. De Freitas, M. F. Pimentel, and C. Pasquini, "Rapid and non-destructive determination of quality parameters in the 'Tommy Atkins' mango using a novel handheld near infrared spectrometer," Food Chem., vol. 197, pp. 1207–1214, 2016, doi: 10.1016/j.foodchem.2015.11.080.

[38] Shivendra, Chiranjeevi, K. and Tripathi, M.K., 2022. Detection of Fruits Image Applying Decision Tree Classifier Techniques. In Computational Intelligence and Data Analytics: Proceedings of ICCIDA 2022 (pp. 127-139). Singapore: Springer Nature Singapore.

[39] M. A. Hossain, M. M. Rana, Y. Kimura, and H. A. Roslan, "Changes in biochemical characteristics and activities of ripening associated enzymes in mango fruit during the storage at different temperatures," Biomed Res. Int., vol. 2014, 2014, doi: 10.1155/2014/232969.

[40] P. P. S. Gill, S. K. Jawandha, N. Kaur, and N. Singh, "Physico-chemical changes during progressive ripening of mango (Mangifera indica L.) cv. Dashehari under different temperature regimes," J. Food Sci. Technol., vol. 54, no. 7, pp. 1964–1970, 2017, doi: 10.1007/s13197-017-2632-6.

[41] D. Thinh, J. Uthaibutra, and A. Joomwong, "Effect of Storage Temperatures on Ripening Behavior and Quality Change of Vietnamese Mango Cv . Cat Hoa Loc," Interntional J. Bio-Technology, vol. 3, no. 3, pp. 19–30, 2013.

[42] Tripathi, M.K., 2023. Neutrosophic approach based intelligent system for automatic mango detection. Multimedia Tools and Applications, pp.1-23.s..

[43] G. Kansci, B. B. Koubala, and I. L. Mbome, "Biochemical and physicochemical properties of four mango varieties and some quality characteristics of their jams," J. Food Process. Preserv., vol. 32, no. 4, pp. 644–655, 2008, doi: 10.1111/j.1745-4549.2008.00204. x.

[44] Vasundhara D.N., Seetha M., Comparative analysis of spatial image classification techniques using rough-sets, International Journal of Geoinformatics, 14 (4), pp. 39 – 45, (2018).

[45] N. V. Sailaja, M. Karakavalasa, M. Katkam, D. M, S. M and D. N. Vasundhara, "Hybrid Regression Model for Medical Insurance Cost Prediction and Recommendation," 2021 IEEE International Conference on Intelligent Systems, Smart and Green Technologies (ICISSGT), Visakhapatnam, India, 2021, pp. 93-98, doi: 10.1109/ICISSGT52025.2021.00029.

[46] Vasundhara D.N., Seetha M., Accuracy assessment of rough set based SVM technique for spatial image classification, International Journal of Knowledge and Learning, 12 (3), pp. 269 – 285, DOI: 10.1504/IJKL.2018.092318, 2018.

[47] D. N. Vasundara and M. Seetha, "Implementation of hybrid RS-ANN for spatial image classification," 2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), Chennai, India, 2016, pp. 1-5, doi: 10.1109/ICCIC.2016.7919722.

[48] Vijaya Saraswathi, R., Vasundhara, D.N., Vasavi, R., Laxmi Deepthi, G., Jaya Jones, K. (2022). Face Detection and Comparison Using Deep Learning. In: Reddy, A.B., Kiranmayee, B., Mukkamala, R.R., Srujan Raju, K. (eds) Proceedings of Second International Conference on Advances in Computer Engineering and Communication Systems. Algorithms for Intelligent Systems. Springer, Singapore. https://doi.org/10.1007/978-981- 16-7389-4_49

[49] Brahmananda Reddy A., Vasundhara D.N., Subhash P., Sentiment research on twitter data, International Journal of Recent Technology and Engineering, 8 (2 Special Issue 11), pp. 1068 – 1070, DOI: 10.35940/ijrte.B1181.0982S1119, 2019

[50] Ali Ahmed, Machine Learning in Healthcare: Applications and Challenges , Machine Learning Applications Conference Proceedings, Vol 1 2021.

[51] Morzelona, R. (2021). Human Visual System Quality Assessment in The Images Using the IQA Model Integrated with Automated Machine Learning Model . Machine Learning Applications in Engineering Education and Management, 1(1), 13–18. Retrieved from http://yashikajournals.com/index.php/mlaeem/article/view/5