Non-Destructive Technologies used for Mango Quality Assessment

Ivane Ann P. Banlawe, Jennifer Dela Cruz

Abstract— Mango is an important agricultural product exported worldwide. Mango fruit quality assessment, since time immemorial, is done manually which makes it time-consuming and labor intensive and people that inspect the quality needed to be expert in the field. Manual assessment of mangoes needed the sample fruit to be destroyed thereby reducing the produce. Non-destructive methods have been developed to solve these problems including the internal assessment of the fruit. This paper presents the non-destructive techniques used in inspecting the fruit quality from its physical structure, internal composition, mechanical damage, diseases and defects and insect infestation. It aims to update of the latest technologies utilized for the mango fruit grading before it is sent out to the market and what can still be explored in this field of post-harvest handling of the said fruit.

Index Terms— fruit grading, Mango, non-destructive methods, quality assessment

I. INTRODUCTION

Mango is a tropical fruit that is widely produced in many different countries. It is considered as a significant export product and has an economical importance [1,2]

As with other fruits, Mango should be harvested at the right time of maturity, because the time of harvest could greatly affect its marketability. Fruit harvested at the proper period would produce a quality product. While those harvested inappropriately could either reach the stalls unripe or over ripe. Unripe mangoes do not taste good while over ripe mangoes could incur disease and spoilage. [3,4,5,6]

Postharvest practices are implemented to be able to control the quality of the mango, this include the temperature, packaging, storage, and the overall fruit grade. Since previous studies proved that external factors affect the ripening behavior of the fruit [4,7,8].

Mangoes, as with any other fruit is prone to damages, these could be mechanical damage while being packed and transported, internal damages such as fruit softening, spongy tissues, decay, disease and pest infestations or in storage environment that causes sap burn, lenticels discoloration and chilling injury. [8,9]

Inspection and assessment methods used to determine the fruit quality of mango are done manually. It requires trained inspectors, time, labor and losses in production since mangoes need to be cut into halves for examination. These sampling tests are based on the shape, size, color, total soluble solids (TSS), acidity, pH, juice, pulp, moisture content, etc. But the results of manual inspection and biochemical analysis cannot be generalized for the fruits since the parameters tested are changing rapidly as the fruit itself matures. [2,3,10,11,12,13,14,15,16]

Non-destructive and automated fruit grading system is seen as a solution for increased accuracy in quality control and lesser losses in production. [13,17]

Image processing was the most explored in the development of the non-destructive technique for mango assessment [18]. And [12] claimed that the method is cheaper and has the advantage of efficiency and objectivity. [11,15,19] and [3] utilized cameras with appropriate lighting conditions that created shadow-free images.

This paper reviewed non-destructive techniques implemented in the assessment of the physical, mechanical, internal composition, disease and infestations that affect the quality of mango fruits.

II. PHYSICAL STRUCTURE

The first quality observed in the fruit is their appearance, since it determines the market value. The visual parameters include shape, size, color and firmness. These features are utilized in non-destructive evaluation of the mango fruit [20,16,8,21].

A. Shape

Reference [22] specified that the shape of mature mangoes suitable for picking are described with fully raised shoulders at their end stem. A study done by [4] measuring the mangoes along defined axis using a Vernier caliper observed a slight increase (0.58 to 0.62) on the cheeks as the fruit matures. While [23] utilized an infrared camera along with a fourier based shape separation method to assess mango shape and attained 92% accuracy. A fuzzy system done by [14] reached 92% accuracy as well, with 2.1 seconds grading time for each mango.

B. Color

Consumers are more particular with the color of the mango and used this as the main key in sorting and selecting the ripe ones [20,24]. Studies have been done in associating the mango quality by its fruit color such as in [4,5,19,25,26,27]. While [28] related the change in mango color to the increase in anthocyanin and carotene pigments and vanishing amounts of chlorophyll.

L*a*b*, HSI and RGB color model for grading mangoes were compared by [29] using the Ellipse strip method for color feature extraction. Results showed that L*a*b* model is more appropriate to be used. Using the L*a*b* model for mango grading, [29] achieved 94% accuracy, [12] tested CIELab color space and reached 98.88% accuracy

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A non-destructive technique using optical fiber sensor and exploiting the reflectance technique was developed and tested by [20]. Results showed a rapid implementation of fruit indexing in approximately 2 seconds and the red system has superior accuracy than that of the blue and green. Fuzzy logic combined with Gaussian mixture model was evaluated by [30].

Other features such as sweetness by evaluation of the hue band using digital refractometer [31] can also be described by evaluating the color of mango.

C. Size

Size is another important factor in mango quality. Consumers and experts measured quality with size [4,15]. Observations made by [4] showed that mango sizes change before ripening and sustains the size up to a few days before decaying.

Fuzzy systems have been explored for grading. [30] achieved 90% accuracy and single mango grading took approximately 50milliseconds. [12] achieved 96.58% accuracy, [32] attained 80% accuracy, [14] achieved 96% accuracy, and [15] implementing CIELab color model has reached 92.37% accuracy.

D. Firmness

Firmness is another enumerated quality for consumers. This quality is affected by transportation and handling of the fruit and it is also attributed to pectic substances inside the fruit and changes in cell wall [5,25,26,33]. It has been found out that firmness does not change until maturity but is reduced rapidly after ripening. [34]

Acoustic transmission velocity was used by [35] to study the firmness depreciation of ripened mangoes.

III. THEORTICAL ANALYSIS AND RESULTS

Mango is a nutritious fruit and is tested by its chemical parameters such as total soluble solids (TSS), acidity, pH, DM, titratable acidity (TA), soluble solids content(SSC), chlorophyll t (Chl t), carotenoids (carot), RPI(ripeness index), SG (specific gravity) and aromatic compounds [1,4,5,7,11,16,25,26,33,36]. These qualities can be affected by external factors such as irrigation and water systems and the pre-harvesting practices done [3,37]

Relationship of the biochemical parameters to the fruit is that, as the fruit ripens, TA decreases [38,39] [40]., pH increases [40,42], SSC is indexed at 9-10% [43], Carotenoid increases [44]. These relationships were used in creating non-destructive tests on mango.

NIR spectroscopy has been studied by [4], [5], [37], [42], [45] and [46] for biochemical predictions. It has been observed by [4] that during development, TSS increases and TA decreases, and SG was dominant among all the parameters and accuracy was 95.8%.

Ultrasonic velocity through ultrasound machine was shown to be related linearly to soluble solids content and was used to clarify the variable sucrose content or titratable acidity of mango juices. [17]

Reflectance spectroscopy was utilized by [36] to measure SSC and pH using PLSR models and best results were in the 1600–1799 nm range of the 2nd derivative spectra.

Reference [19] applied cameras to detect biochemical parameters of mango such as starch, and vitamin C and increases in TSS, pH, total sugars, sugar acid ratio and carotenoid content. [11] affirmed that the technique was cheaper. Reference [11] studied passive reflectance sensing and digital imaging using a digital camera and reported that the two techniques could be used individually or combined for parameter detection.

Computed Tomography (CT) was related by [3] to the X-ray absorption of Mango and established linear relationships between CT number and biochemical properties which makes CT a non-destructive ripeness indicator as also studied by [40,41]. This result could be used for mangoes that remained green even after they are ripe. [3]

IV. MECHANICAL DAMAGE

A good quality mango have firm skin, and without sap injury or bruises [8]. But as discussed earlier, firmness of mango fruit declines as it ripens. [47] reported that 'Manila' mango was one of the most sensitive to having bruises after impact. And the bruises will not appear until the fruit has already reached the market. This could eventually affect the producer since the products are not in good quality. [48]

Since these bruises appear at a later time, postharvest inspection cannot detect its presence. It became a problem for both the producer and the consumers. Traditionally, visual inspection and chemical methods are used to examine the fruit, along with the consideration of the variety and the event of damage [8]. But as the non-detective techniques are being explored, studies of bruises became a part of it. Image processing and dielectric properties were used [2], as well as NIR hyperspectral imaging [48].

Reference [4], [34], [47] and [48] used impact tests for the damage detection and the fruit characteristics were graded based on the acoustic response.

Early detection aimed by [48] was not achieved since the damage was detected three days after the induced impact while [4] achieved 89% of accuracy which was reported to be considerably acceptable for practical application.

V. DISEASE AND DEFECTS

Mango is not safe from infections, two of the most studies physiological disorders of mango include anthracnose and spongy tissue [8]. And if not detected, it could also degrade the fruit quality.

Anthracnose is more common in regions with rainy weather. It is difficult to control the disease through chemical means. Pruning and fungicide applications reduce the infection but cannot eradicate it. Anthracnose damages every part of the mango tree, and more serious is that it can cause the tree not to bear fruit. Its presence is indicated by leaf spot, blossom blight, wither tip, twig blight and fruit rot. [9]

Spongy tissue is a ripening disorder, more closely described as internal breakdown characterized by a white tissue that spoils the fruit pulp and gives it a distasteful flavor. It cannot be seen from the visual appearance of the mango, but is only visible when the fruit is opened. And it is

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interesting that mangoes infested with pulp weevil do not have spongy tissue. [8,9]

Digital X-ray has been utilized as the image source in defect and disease detection and using the appropriate processing algorithms, internal defects can be easily seen. Various non-destructive technique [1,8] have been used to detect diseases in mangoes.

Image segmentation using L*a*b* color model was tested for disease detection by [12] and results showed that the accuracy is based on the image segmentation.

Reference [10] presented a Fuzzy expert system for disease prediction which yielded 97.47% accuracy. And for further investigation, a developed database done by [8] contains 65% of defected mangoes and 35% healthy mangoes.

VI. INSECT INFESTATION

Mango pulp weevil is the commonly researched insect infestation in mango fruit. Its infestation in mango fruit leaves is untraceable because the eggs are deposited on the fruit while it is still young and the grubs enter the fruit through the development of the fruit and will become an adult pulp weevil within two months. No formulated insecticide was available to eradicate the pulp weevil [1,9,13]. Palawan, Philippines has been under quarantine since 1987 because of the mango pulp weevil infestation [49]. And it has also become a threat in Malaysia [13].

Fruit fly is another pest being investigated. The eggs are hatched 2 days after it was deposited, larva emerges 6-8 days until it became a pupa for 10-12 days and becomes an adult that thrives for a few months. Infestation happens when the fruit starts to ripen and external damages can be seen in the fruit caused by the larva and flesh decay. [9]

Digital X-ray was employed to generate sample images used in analysis. [1] classified the infestation as: very lightly, lightly, moderately, severely, uninfested mango. The analysis was done by the identification of percentage affected by the weevil. Reference [13] used AIS algorithm in classification of the infected and uninfected mangoes by the negative selection and reported that AIS is a real-time, rapid and low-cost detection with little improvements on feature extraction of images.

Acoustical methods were also explored by [49]. Two detection methods were developed, the first one is a piezoelectric sensor and the other one utilized stethoscopes connected to pvc tubing with a condenser microphone. But the accuracy reached only 57% due to high electrical noise.

Aside from X-ray, MRI and dielectric properties are also being proposed as infestation detectors, but drawbacks include high cost and low output with high environmental noise [2,50].

Reference [2] utilized dielectric properties of the mango and subjected the method into an artificial neural network. Tests results showed more training needed in order to accurately detect the infestation.

NIR instrument for detecting fruit fly was studied by [51] and later improved sensitivity with Savitzky–Golay smoothing algorithm and Bayesian classifier [52]. And it was the basis of [53] for the NIR hyperspectral imaging for fruit fly detection. Pores were created to induce infestation and results showed that NIR could be possibly used as a more detailed imaging technique for fruit fly detection given sufficient signal absorption.

CONCLUSION

Mango quality has always been an important concern for producers, it is an export fruit and needs to be monitored to be able to deliver quality product to the market. Since the conception of non-destructive techniques for assessment, image processing has advanced many of these techniques for mango quality grading. It has improved X-ray, MRI, NIRS and even digital cameras. But still, non-destructive techniques being studied does not cover the overall Mango fruit grading. The techniques are not yet fully developed, and not yet available to the market, there are still many options to be explored.

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