

Research Article

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Use of maturity traits to identify optimal harvestable maturity of banana *Musa* AAB cv. “Embul” in dry zone of Sri Lanka

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Abstract: Banana is a climacteric fruit and perishable in nature having relatively high postharvest losses. Harvesting banana at a perfect maturity stage can reduce the quantity of losses during post-harvest handling. There is no identified optimal harvestable maturity time line available for local banana cultivars in Sri Lanka. Therefore, this study focused on use of maturity traits to identify optimal harvestable maturity for harvesting banana in the dry zone of Sri Lanka. Changes of fruit weight, length of banana fruits, fruit pulp weight, luminosity (L^*), red-green (a^*), yellow (b^*), hue angle and chroma for skin of banana, total soluble solid (TSS) content, pH value and starch content of banana fruit pulp, respiration rate, and ethylene production of banana fruits during the developmental continuum were measured from seven days after flowering (DAF) to senescence. Data were statistically analyzed using one way-ANOVA at 95% confidence level. Results revealed that physical parameters such as length and weight of banana fruits were steadily increased in time. Chemical parameters such as TSS, pH and starch content of banana fruit pulp were significantly differed with the maturation. Fruit physiological parameters including ethylene production and respiration rate were significantly different with DAF. In conclusions, optimum maturity for the distant markets was observed in range of 77–84 DAF. Maturity

stage from 84 to 104 DAF is better for the local/immediate consumption, and afterwards it can be recommended for the fruit processing firms.

Keywords: physical maturity, chemical parameters, physiological maturity, postharvest handling

1 Introduction

Bananas and plantains (*Musa* spp.) have played an important role in the history of human civilization. It has been reported that bananas were among the first few plants to be domesticated from the beginning of the settled agriculture (Simmonds 1962). Southeast Asia and Western Pacific region have been identified as the native place of modern bananas and plantains, as inedible, seed bearing, diploid ancestors can still be found in the natural forest vegetations. *Musa acuminata* is a wild native species to Southeast Asia. It is the progenitor of modern edible bananas, along with *Musa balbisiana* (Wong et al. 2001). Bananas were first cultivated around 8,000 B.C. (Bora 2011).

Bananas have achieved a greater importance as a cash or subsistence crop in regions away from their primary centers of origin. The banana trade, which was developed in tropical America around middle of the nineteenth century, is remarkable to note. The fruit had been exported from West Indian islands and Central American countries to markets in North America. This trade developed rapidly with the introduction of refrigerated shipment (Robinson and Sauco 2010). A small number of triploid cultivars of *M. acuminata* have been used in this trade. When considering plantains, 73% of the world crop is grown and consumed in West and Central Africa. Triploid crosses between *M. acuminata* and *M. balbisiana* are the cultivars that are widely used in the banana trade (Robinson 1996).

Under Sri Lankan context, banana (*Musa* spp.) is the most widely cultivated and consumed fruit (Wasala et al.

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2014). It is also an attractive perennial fruit crop for farmers due to high economic gains throughout the year. Therefore, rice fields have been converted to grow banana, as it gives more economic benefits, requires relatively less water and less input, and gives higher returns than rice. The net profit of banana growers has gone up about four times in comparison to rice cultivation. In addition, banana (*Musa* spp.) is grown in more than 120 countries worldwide and has been ranked second in world fruit production (Lassois *et al.* 2010). It is a vital source of income, employment, and export revenue for many developing countries in Latin America, the West Indies, Southeast Asia and Africa (Lassois *et al.* 2010). National annual production of banana is 730,000 metric tons, it was recorded from 44,578 ha banana cultivation throughout the country (Hirimburegama *et al.* 2004). There are said to be almost 1,000 varieties of banana in the world, which sub-divide into about 50 groups, Sri Lanka boasts 29 varieties, the greater number of which appear to be indigenous to the country (Hirimburegama *et al.* 2004).

Most of the cultivars of banana are hybrids and most of the edible cultivars are triploid (Hirimburegama *et al.* 2004). Mysore ('Embul' AAB group) is the most popular banana cultivar in Sri Lanka due to its high yielding and good keeping qualities during postharvest life. Additionally, this banana cultivar can be cultivated in most agro-ecological zones in Sri Lanka. The life span of banana crop mainly depends upon the level of crop management. Some growers in Sri Lanka harvest only the first bunch of the crop and no suckers are allowed to grow for subsequent crops (Sirisena and Senanayake 1997). The banana crop becomes ready for harvesting within 11–12 months from planting. First ratoon crop would be ready by 8–10 months from the harvesting of the main crop, and second ratoon by 8–9 months after the second crop (Hurlston 1991).

The first step in the postharvest life of the product is the moment of harvest. For most fresh produce, harvest is manual. Therefore, picker is responsible for deciding whether the produce has reached the correct maturity for harvest. The maturity of harvested commodities has an important influence on their storage life and quality, and may affect the way they are handled, transported, and marketed (Kitinoja and Kader 2015). An understanding of the meaning and measurement of maturity is therefore central to postharvest technology (Watada *et al.* 1984). Mature is best defined as having completed natural growth and development. Producers, handlers and quality control personnel make maturity measures. A maturity index should be measurable rather than

subjective, consistently related to the quality and post-harvest life of the commodity for all growers, districts, and years, non-destructive and based on common characteristics (Kitinoja and Kader 2015).

Therefore, banana is a climacteric fruit and perishable in nature having relatively high postharvest losses of about 20–30% (Ekanayake *et al.* 2001). Due to these circumstances, postharvest loss of banana can be seen as prominent characteristics in local markets of Sri Lanka. Currently, there are no maturity indices available for the Sri Lankan banana cultivars. Therefore, this study focused on assessing maturity traits for banana, *Musa* AAB cv. 'Embul' in dry zone of the Sri Lanka for distance and local market with special reference to physical parameters such as changes of fruit weight, length, pulp weight, luminosity (L^*), red-green (a^*), yellow (b^*), hue angle and chroma for skin of banana and chemical parameters such as total soluble solid content, pH value and starch content of the banana and fruit physiological parameters including respiration and ethylene production behavior from primordial initiation to senescence.

2 Materials and methods

2.1 Study site description

The research was carried out at a well establish semi-commercial banana plantation situated at Keralogama, Eppawalla, Anuradhapura (8°11'24" N, 80°22'26" E, 120 m above sea level), North Central Province (NCP) (dry zone) of Sri Lanka, and Postharvest Technology Laboratory, University College of Anuradhapura, University of Vocational Technology, Sri Lanka. The dry zone covers predominantly the northern and eastern part of the country. The dry zone receives a mean annual rainfall of less than 1,750 mm with a distinct dry season from May to September.

2.2 Experimental design and sample collection

All pre-harvest practices of this banana plantation were carried out according to the instruction given by the Department of Agriculture, Sri Lanka. Based on the simple random sampling method, ten banana plants showing floral primordial initiation with synchronic maturity (same age) were labeled. Periodically, banana fingers were harvested

from the second hand middle area with the help of sharp knife. Then, the cutting end at the second hand middle area was disinfected with 70% ethanol to minimize fungal infection. After collecting the sample, banana fingers were separately kept in poly propylene bag with label and quickly transported to the Postharvest Technology Laboratory.

To use maturity traits to identify optimum harvestable maturity for *Musa* AAB cv. 'Embul', chronological, physical, chemical and physiological features were employed at the laboratory with standard methods described by the Kader (1992).

Length of the fruit, peel color, fruit diameter, and weigh of the fruit, peel weight and pulp weight were measured. Total soluble solid content (TSS), pH, and iodine test were assessed on banana pulp. In addition to that, respiration rate and ethylene production were measured to identify harvestable maturity of banana, *Musa* AAB cv. 'Embul.'

2.2.1 Measurement of fruit weight

Weight of the individual fruits at different maturity stages were determined by using digital scale, and mean value of ten fruits were calculated.

2.2.2 Measurement of fruit length and diameter

Length and diameter of the fruits was measured using venire caliper, and mean value of ten fruits were calculated.

2.2.3 Measurements of the fruit peel color

Color was measured by using a Konica Minolta portable colorimeter (CR-400, Japan). A standard white tile ($Y = 93.9$, $X = 0.3125$, $Z = 0.3191$) was used to calibrate the instrument and L^* , a^* and b^* values were directly taken from the colorimeter. Overall color change ($\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$) was calculated based on measured L^* , a^* and b^* values (Jayathunge et al. 2015).

2.2.4 Measurement of the total soluble solid content

Total soluble solid content was measured using a digital refractometer (ATAGO, PAL-01, Tokyo). Distilled water was used to calibrate the instrument and total soluble

solid content of the pulp was directly taken from the refractometer (Ranganna 1986). TSS content was determined using the Brix scale and readings were recorded (AOAC 1990).

2.2.5 Measurement of the fruit pulp pH

pH of the fruit pulp was measured using a digital pH meter (Thermo Orine, 420A⁺, USA). Standard buffer solution was used to calibrate the instrument, and pH of the pulp was directly taken from the pH meter (Nielsen et al. 2010). Ten banana fingers were collected from second hand middle region of the ten banana bunches at a time with same age and same cultivar under similar treatments to extract fruit pulp for pH measurement based on the simple random sampling technique. This process was continued with a week interval from the fruit set.

2.2.6 Measurement of ethylene production during fruit development

Samples of fruit were immediately transported to the postharvest technology laboratory from the field. After that, weight of the sample was measured by using digital scale and transferred to seal airtight container at 20°C. After two hours, the concentration of ethylene in the container was measured using an ICA 56 ethylene meter (International Controlled Atmosphere Ltd. Instrument Division, UK) according to the manufacturer's instructions with an accuracy up to 0.1 ppm, within a time of 15 s, at a flow of 0.8 L min⁻¹ (Response sample flow, 0.8 L min⁻¹). Finally, based on the result, ethylene production was measured in ppm (Kheiralipour et al. 2008); Ethylene production was measured until senescence.

2.2.7 Measurement of respiration rate during fruit development

Samples of fruit were immediately transported to the postharvest technology laboratory from the field. After that, weight of the sample was measured by using digital scale and transferred to seal container. After one hour, the concentration of CO₂ in the container was measured by using a Dual Gas Analyzer (International Controlled Atmosphere Ltd. Instrument Division, UK) according to the manufacturer's instructions (Saltveit 2015). Finally, based on the result, respiration rate was measured until senescence, as mg CO₂ per kg per hour.

2.3 Statistical analysis

Data was statistically analyzed using one way-ANOVA at 95% confidence level, and mean separation was done according to the Fisher LSD method.

Ethical approval: The conducted research is not related to either human or animal use.

3 Results

In general, weight of the banana fruit increased significantly ($p < 0.05$) during the developmental continuum showing sigmoid behavior (Figure 1). A week after flowering weight per fruit was 10 g/fruit. It reached above 50 g fruit weight at 84 DAF and maximum weight (82 g/fruit) was obtained at 110 DAF. Figure 2 reveals that length of the samples varied significantly ($p < 0.05$). At the initial stage (7 DAF), length and diameter of the fruit was recorded as 6.6 and 0.65 cm, respectively. Maximum length (13.25 cm) and diameter (3.82 cm) of the fruit was recorded at 110 DAF. However, at 84 DAF fruit, length was 11.29 cm (diameter 3.39 cm), showing a slight significant difference with maximum length and diameter, compared to the initial stages of development.

Total Soluble Solid (TSS) content of the samples varied significantly ($p < 0.05$) among the samples during developmental continuum. At the initial stages TSS of the samples was comparatively low (Brix 9.71). TSS content gradually increased with time and reached it maximum

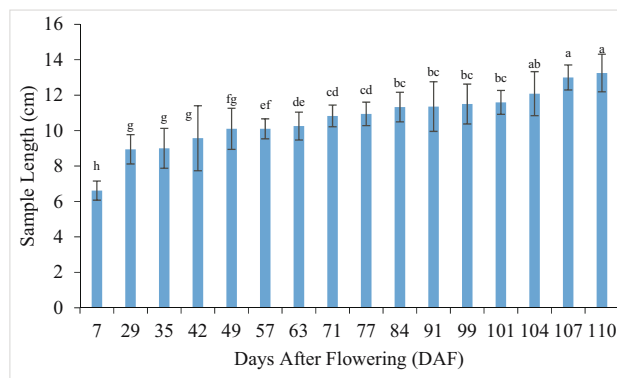


Figure 2: Changes of length during developmental continuum of banana fruit. *Bars (means values) that do not share the letter/s are significantly different according to the Fisher LSD.

of 19.20 Brix at 110 DAF. However, Brix value of 15.04 TSS content was recorded at 84 DAF (Figure 3).

Pulp weight of the banana fruit samples varied significantly ($p < 0.05$) among the samples during developmental continuum. Pulp weight gradually increased with development, it ranged from 5.28 g (7 DAF) to 61.5 g (110 DAF) (Figure 4).

Luminosity (L^*), red-green (a^*), yellow (b^*), hue angle and chroma for skin of banana fruits varied significantly ($p < 0.05$) among the samples during developmental continuum as mentioned in the Figure 5.

Figure 6, describes the pH values of the banana fruit pulp that varied significantly ($p < 0.05$) among the samples during developmental stages. pH values of the banana fruit pulp were slightly acidic (pH range from 6.0 to 5.8) up to 84 DAF, thereafter pH decreased to 5 at the 91 DAF, however up to 104 DAF pH ranged was recorded in-between

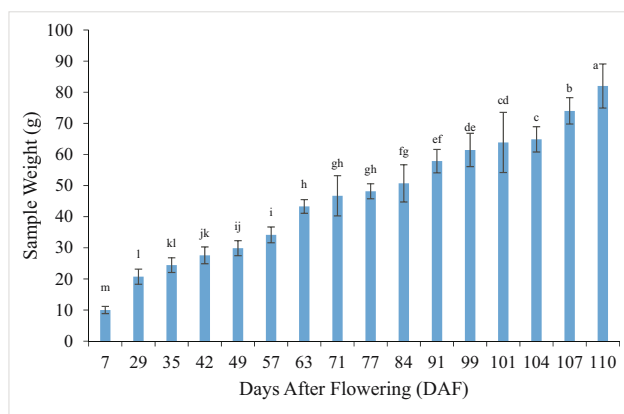


Figure 1: Changes of fruit weight during developmental continuum of banana fruits. *Bars (means values) that do not share the letter/s are significantly different according to the Fisher LSD.

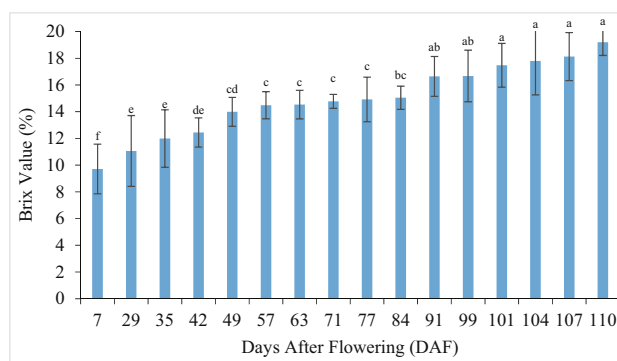


Figure 3: Changes of Total Soluble Solid content during developmental continuum of banana fruit. *Bars (means values) that do not share the letter/s are significantly different according to the Fisher LSD.

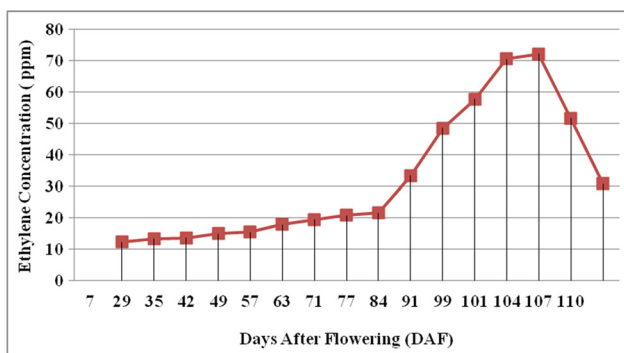


Figure 8: Changes of ethylene production of banana fruits during the developmental continuum.

fruit weight and pulp weight of the samples increased during the developmental continuum showing sigmoid behavior (Figures 1 and 4) but length and TSS of the samples increased during the developmental continuum with decreasing rate (Figures 2 and 3).

The pH value of the banana fruit pulp showed that slightly acidic nature (pH 5.8) at the initial developmental stages, but gradually pH value was decreased up to 3.2, revealing a very acidic nature. The pH, TSS, carbohydrate and protein contents are possible physico-chemical and nutritional maturity indices. According to Zhang and McCarthy (2012), characterization of the intricate process of maturity and ripening poses a challenge to fruit farmers and processors as well as scholars. The pH, TSS, protein and carbohydrate contents vary as fruit mature (Carrari *et al.* 2006; Faurobert *et al.* 2007; Gautier

et al. 2008; Matsuda *et al.* 2010), making these parameters indispensable maturity indices.

As mentioned in Figure 9, there is a correlation in between changes of internal and external maturity traits during the developmental continuum of banana fruits from floral primordial initiation to senescence. In general, farmers do harvesting; they do not have idea of the internal chemical changes of fruits. Therefore, maturity indices need to be developed based on the external changes in size, shape, length, diameter and peel color, but it should be correlated with internal quality changes. Figure 9 clearly indicates the level of starch disappearance along with the maturation process. Fifth stage in Figure 9 indicates that conversion of starch to sugar, showing physiological maturity. However, determination of respiration rate and ethylene production can make consistent determination of physiological maturity.

The measurement of respiration is very important because it provides a window through which we can determine the metabolic activity of plant tissues. During aerobic respiration, stored food (e.g., carbohydrates, fats, proteins) are combined with oxygen from the atmosphere to produce carbon dioxide, water and the energy needed to maintain plant cells and tissues, and quality of the commodity (Saltveit 1999). Respiration rate of banana fruits started with comparatively higher rate at the beginning (Figure 7). During the initial level of development of biological material cell division and elongation can take place. Therefore, these biological processes need more



Figure 9: Developmental continuum of banana fruits from floral primordial initiation to senescence.

energy for these activities, which can be the main reason for higher respiration rate at initial days of fruit development. However, with time, respiration rate went reducing up to its minimum level, and it was recorded at 84 DAF. After that, respiration rate drastically increased with increasing rate up to 104 DAF.

Autocatalytic plant hormone “ethylene” governs the ripening process of almost all of the fruits. It is highlighted that, two hundred genes are activated during ripening process of a fruit. De-greening, dissociation of latex, conversion of starch into sugar, development of aroma and improved firmness are the some of functions carried out by ethylene hormone. (Klee and Giovannoni 2011). Historically, fruits have been categorized into two classes of behavior with respect to ethylene physiology and respiratory pattern. In the first type, as fruit progresses towards edibility, the respiratory rate increases followed by a decline as fruit senesces. This is known as the climacteric rise. In climacteric fruits like banana, they produce small concentration of ethylene hormone up to physiological maturity after fruit set and beyond sudden increase in the hormone, concentration can be observed to its maximum, and then declines before fruit rots intervene and lead to a renewed output.

In contrast, at the initial development stages ethylene concentration or ethylene production is at low level (Figure 8). Production of ethylene is an autocatalytic process. Therefore, at initial cell division and cell elongation period we were able to see, comparatively low ethylene production in banana fruits. However, with time, ethylene production increased up to its maximum level by 104 DAF, and started to decline onwards as mentioned by the Klee and Giovannoni (2011).

Color is the first feature of quality evaluated by a person (Markovic et al. 2018). Color is the natural pigment in fruits. Fruits color changes at different stage of maturity and ripeness. The color is the main important factor attracting the consumer to a production as premise to create a good market. Consumers need fresh and very good flavor fruits. They firstly select the fresh fruits using its appearance. Fruits external color is used as an indicator of ripeness of fresh fruits. The color meter can be used for determination of fruits and vegetable color (Barrett et al. 2010). Previous studies including that of Carvalho et al. (2005) demonstrated that L^* value decreases as tomatoes ripen and turn red because carotenoid synthesis and loss of green color reduces fruit brightness. Caron et al. (2013) describe tomato as a climacteric fruit and assert that harvesting at the light red stage would give the productive and commercial sectors

greater flexibility for its management. Similarly, to Caron et al. (2013), by 84 DAF we were also able to see the changes of banana peel light green color with changes in the surface gloss, or feel waxiness in banana peel and well grown fruits with fullness.

Similar to our experimentation, Abdullah et al. (1986) conducted a research with eighty banana plants, which were tagged and after fruits were harvested. Then these fruits were transported to the laboratory. This researcher sampled each fruits bunch, these bunches were divided in to three portions, such as upper, middle and lower and checked the physical, chemical, and sensory evaluation factors such as, weights of the sample, diameter, pulp weigh, pH value of pulp, TTA, starch content, total sugar content. Those result revealed that banana could be harvested 10–13 weeks after flower emergence. Results of our research revealed that banana possess all necessary maturity characteristics by 84 DAF.

In conclusion, maturity trait for harvesting banana *Musa* AAB cv. “Embul” in dry zone of Sri Lanka, days after flowering (DAF) can be used as a potential maturity trait. Banana cultivar Embul can be harvested 77–84 DAF (11–12 weeks) for distant markets to avoid ripening during transport. In contrast, maturity stage 84–104 DAF is better for the local/immediate consumption and afterwards it can be recommended for the fruit processing firms. However, environmental and agronomic factors such as temperature and manure/fertilizer application have key influence on flowering behavior of banana.

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Author contribution: Authors equally contributed for the conceptualization, data curation, formal analysis, investigation, projects administrations supervision, validation, visualization and writing – original draft.

Conflict of interest: The authors state no conflict of interest.

Data availability statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

- [1] Abdullah H, Aipun MZ, Rohaya MA. Maturity indices of banana (*Musa Sapientum* CV. Berangan). *MARDI Res Bull.* 1986;11(3):237–42.
- [2] Bora C. *History of bananas.* New York: Springer; 2011. p. 147–59.
- [3] Caron VC, Tessmer MA, Mello SC, Jacomino AP. Quality of mini tomatoes harvested at two maturity stages and kept chilled in three packages. *Hortic.* 2013;31:279–86.
- [4] Carrari F, Baxter C, Usadel B, Urbanczyk-Wochniak E, Zanol MI, Nunes-Nesi A, et al. Integrated analysis of metabolite and transcript levels reveals the metabolic shifts that underlie tomato fruit development and highlight regulatory aspects of metabolic network behavior. *Plant Physiol.* 2006;142:1380–96.
- [5] Carvalho W, Fonseca MEN, Silva HR, Boiteux LS, Giordano LB. Estimativa indireta de teores de licopeno em frutos de genótipos de tomateiro via análise colorimétrica. *Hortic.* 2005;23:819–25.
- [6] Barrett DM, Beaulieu JC, Shewfelt R. Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: desirable levels, instrumental and sensory measurement, and the effects of processing. *Crit Rev Food Sci Nutr.* 2010;50(5):369–89.
- [7] Ekanayake EMDSN, Samarasinghe WLG, Randeni RAVK. An unrecorded banana cultivar from Sri Lanka. *Annu Sri Lanka Dept Agric.* 2001;3:37–43.
- [8] Faurobert M, Mihr C, Bertin N, Pawlowski T, Negroni L, Sommerer N, et al. Major proteome variations associated with cherry tomato pericarp development and ripening. *Plant Physiol.* 2007;143:1327–46.
- [9] Gautier H, Diakou-Verdin V, Bénard C, Reich M, Buret M, Bourgaud F, et al. How does tomato quality (sugar, acid, and nutritional quality) vary with ripening stage, temperature, and irradiance? *J Agr Food Chem.* 2008;56:1241–50.
- [10] George WL. *Official methods of analysis.* 15th edn. Washington; DC USA: Association of Official Analytical Chemist; 1990.
- [11] Hirimburegama WK, Dias WKG, Hirimburegama K. Banana improvement through gamma irradiation and testing for banana bract mosaic virus in Sri Lanka. *FAO corporate document repository;* 2004. [Online]. [Accessed on 12.08.2019] Available from: <http://www.fao.org/docrep/007/ae216e/ae216e09.html>
- [12] Hurlston EF. *Sri Lanka banana production and post-harvest technology manual.* Mahaweli Authority of Sri Lanka; 1991. p. 3–5.
- [13] Markovic I, Markovic D, Ilic J, Simonovic V, Veg E, Šiniković G, et al. Application of statistical indicators for digital image analysis and segmentation in sorting of agriculture products. *Tehnički Vjesn.* 2018;25(6):1739–45.
- [14] Jayathunge KGLR, Grant IR, Linton M, Patterson MF, Koidis A. Impact of long-term storage at ambient temperatures on the total quality and stability of high-pressure processed tomato juice. *Innov Food Sci Emerg Technol.* 2015;32:1–8.
- [15] Kader AA. *Postharvest technology of horticultural crops.* 2nd edn. California, USA: University of California Davis. Division of Agriculture and Natural Resources; 1992.
- [16] Kheiralipour K, Tabatabaefar A, Mobli H, Rafiee S, Sharifi M, Jafari A. Some physical and hydrodynamic properties of two varieties of apple (*Malus domestica* Borkh L.). *Int Agrophys.* 2008;22(3):225–9.
- [17] Klee HJ, Giovannoni JJ. Genetics and control of tomato fruit ripening and quality attributes. *Annu Rev Genet.* 2011;45:41–59.
- [18] Kudagamage C, Chandrasiri GWJ, Razmy AMZ. Analysis of long-term trends in banana sector of Sri Lanka. *Ann Sri Lanka Dept Agric.* 2002;4:21–32.
- [19] Lassois L, Jijakli MH, Chillet M, De Lapeyre de Bellaire L. Crown rot of banana- pre harvest factors involve in postharvest disease development and integrated control methods. *Am Phytopathol Soc Plant Dis.* 2010;94(6):648–58.
- [20] Kitinoja L, Kader AA. *Measuring postharvest losses of fresh fruits and vegetables in developing countries.* Oregon, USA: The postharvest education foundation; 2015. ISBN 978-162027-006-6.
- [21] Cantwell M. *Dept plant sciences, melon quality and ripening. Fruit ripening and ethylene management workshop.* UC Davis: Postharvest Technology Center; 2015. [Online]. [Accessed on 16.08.2019] Available from: <http://postharvest.ucdavis.edu/>
- [22] Matsuda R, Kubota C. Variation of total soluble protein content in fruit among six greenhouse tomato cultivars. *Int J Hortic Sci.* 2010;45(11):1645–8.
- [23] Saltveit M. *Department of plant sciences. Measuring respiration.* UC Davis: Postharvest Technology Center; 2015. [Online]. [Accessed on 20.08.2019] Available from: <http://postharvest.ucdavis.edu/>
- [24] Saltveit M. Effect of ethylene on quality of fresh fruits and vegetables. *Postharvest Biol Technol.* 1999;15:279–92.
- [25] Nielsen DR, Yoon SH, Yuan CJ, Prather KL. Metabolic engineering of acetone and meso-2,3-butanediol biosynthesis in *E. coli*. *Biotechnol J.* 2010;5(3):274–84.
- [26] Ranganna S. *Handbook of analysis and quality control for fruit and vegetable products.* New Delhi, India: McGraw-Hill; 1986. p. 124–5.
- [27] Robinson JC. *Bananas and plantains.* Cambridge, UK: CAB International; 1996.
- [28] Robinson J, Saucó VG. *Bananas and plantains.* 2nd edn. UK: CABI Publishing; 2010.
- [29] Simmonds NW. *Evolution of the bananas.* London: Longmans, Green & Co; 1962.
- [30] Sirisena JA, Senanayake SGJN. Changes in growth and yield characteristics of *Musa* Cv Mysore (“Embul” banana) with increasing the age of the crop. *J Natn Sci Foun Sri Lanka.* 1997;25(3):159–68.

- [31] Wasala WMCB, Dharmasena DAN, Dissanayake TMR, Thilakarathne BMKS. Physical and Mechanical Properties of Three Commercially Grown Banana (*Musa acuminata* Colla) Cultivars in Sri Lanka. *J Trop Agric.* 2012;24(1):42–53.
- [32] Wasala WMCB, Dharmasena DAN, Dissanayake TMR, Gunawardena CR. Postharvest losses, current issues and demand for postharvest technologies for loss management in the main banana supply chains in Sri Lanka. *J Postharvest Technol.* 2014;2(1):80–7.
- [33] Watada AE, Herner RC, Kader AA, Romani RJ, Staby GL. Terminology for the description of developmental stages of horticultural crops. *J Hortic Sci.* 1984;19:20–1.
- [34] Wong C, Kiew R, Loh JP, Gan LH, Set O, Lee SK, et al. Genetic diversity of the wild banana *Musa acuminata* Colla in Malaysia as evidenced by AFLP. *Ann Botany.* 2001;88:1017–25.
- [35] Zhang L, McCarthy MJ. Measurement and evaluation of tomato maturity using magnetic resonance imaging. *Postharvest Biol Technol.* 2012;67:37–43.