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Effect of Maturity Indices on Growth and Quality of High Value Vegetables

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Abstract

The study took place at Bangladesh Agricultural Research Institute's Olericulture Division's research farm from March 2021 to February 2022 (BARI). In a protected net house, we investigated the impact of five different types of vegetables on various maturation stages, including tomato, broccoli, sweet pepper, cucumber, and netted melon. Vegetables cultivated under protected conditions in a transparent poly-film net house can improve quality, maturity, fruit size, and yield. When fruits and vegetables are picked before they are fully mature, they may stay green for longer, but they may not ripen to a satisfactory color and flavor, resulting in a loss of consumer confidence. Furthermore, because fruit continues to grow until the harvest, immature fruit will be smaller than mature fruit, reducing harvest yield. We tried to determine the right maturation stages in order to avoid product loss during our investigation. The tomato was found to be an appropriate size (6.5 cm length and 6.2 cm diameter), weight (84 g), TSS (4.5 percent), pH (4.3), "turning red", and "tasty" at the week 5 stage, while the broccoli was found to be an appropriate size (12.0 cm length and 13.0 cm diameter), weight (360 g), and "green" color at the week 5 stage. At the week 6 stage, the nettled melon was found to be of appropriate size (15.2 cm length and 14.5 cm diameter), weight (800 g), TSS (10.8 percent), pH (6.3), "net fully developed" on the fruit skin and "much tasty," while cucumber was found to be of appropriate size (8.8 - 10.8 cm length and 2.2 - 2.9 cm diameter), weight (61 - 88 g), TSS (3.8 - 4.1 percent), pH (6.3), "less powdery". As a result, establishing the optimal maturity of our research will benefit both consumers and growers.

Keywords

Maturity Indices, Growth, Quality, High Value Vegetables, TSS, pH, Different Harvest Stages

1. Introduction

In order to acquire high-quality produce and productivity during the off-season, vegetables must be grown in protected environments such as greenhouses or poly net homes [1]. Poly net buildings have the potential to be used economically to grow high-value temperature-sensitive veggies all year. Because of their better productivity and economic feasibility, poly net houses are commonly used for the cultivation of high-value vegetables. Due to the manipulation of the spectra of radiation reaching the crops, protected poly net houses allow for better utilization of sunlight, promoting physiological responses in plant and fruit development, such as leaf area index, chlorophyll and carotenoid content, tissue structure, fruit ripening, physiological disorders, nutritional quality, and so on [2]. Protected, naturally ventilated high-tunnel cultures are ideal for growing high-value crops in the off-season [3]. Plastic tunnels, both high and low, have long been a useful tool for crop diversification and season extension, allowing growers to create a microclimate more conducive to warm-season crops [4] [5]. Because plants are planted more consistently, big gaps between plants and rows are minimized, and light interception is optimized, a higher fruit yield/unit area can be attained in a high-tunnel protected culture than in a field [6] [7]. Poly homes have a yield potential of 1.5 times that of open fields [8]. When compared to the previous year, total fruit yields (t/ha) increased by 113 to 131 percent.

Identifying the correct stage of maturity and harvesting at the appropriate time are critical pre-harvest criteria for getting the most out of the covered net houses. Maturity indices are useful for determining when a certain item should be harvested in order to provide some marketing flexibility and ensure that the consumer receives appropriate eating quality. Maturity is the stage of growth that leads to a consumer's attainment of a specific goal. Physiological maturity: When a plant or a plant part has all of the necessary characteristics to be used (Selvakumar [9]). In a physiological sense, maturity refers to a plant portion or the entire plant reaching the last stage of biological activity. Vegetable quality can be retained for a longer amount of time if gathered at the right time [10]. Harvesting of tomatoes, for example, is done at different times depending on the function of the fruit. Vegetables are typically harvested at various stages of maturity for long-distance sales, local markets, fresh consumption, or consumer preferences. For long-distance marketing, the tomatoes are collected at a ripe green to turning stage. Pink to light-red tomatoes are picked for the local market.

Determination of maturity indices: Maturity can be judged by various means, like: 1) Computational methods [a) Calendar date, b) Days after anthesis/pollination]; 2) Physical methods [a) Increase in size, b) Color development, c) Softening of tissues, d) Seediness, e) Development net-like structure, f) Yellowing and drying of foliage or top, g) Flowering and bolting]; 3) Chemical methods [a) Increase in sugar content, b) Increase in fiber content, c) Increase in sugar: acid ratio]; 4) Physiological methods [a) Respiration rate, b) Ethylene evolution rate]. Thus, farmers ought to schedule the harvesting at optimum maturity periods to ensure

quality and obtain a good market price, followed by the correct handling and packing of fruit [11]. Despite this, most farmers, especially those operating on a small scale, face challenges, among which are the choice of the right varieties, ineffective transport to distant markets, and high perishability of products, exacerbated by harvesting at improper maturity stages due to farmers' limited knowledge of maturity indicators [12] [13]. Non-temperature controlled plastic tunnel net houses can be used due to their low cost and simplicity as they use natural ventilation to reduce temperature [14] [15]. Natural ventilation, however, may not sufficiently reduce the heat load [15].

Determining the best maturity stage is a challenging practice due to the high variability found in crops. Based on technologies available nowadays, the more relevant maturity indices are coloration, sugars and acids content (evaluated as the ratio between both, TSS:acid ratio), and juice content (as a percentage). Maturity indices also depend on the destination markets and the growing regions, therefore, there are no universal or absolute values, and the different producer countries may apply variable maturity standards. The distance to the market and consequently, transportation time is one of the more important parameters to consider when making harvest decisions [16].

There is a scarcity of data on the maturation indicators of many high-value vegetables for qualitative qualities in protected habitats. Because the selected crops, such as tomato, broccoli, sweet pepper, cucumber, and netted melon, are high-value vegetables in Bangladesh, they were chosen for poly net homes to ensure high-quality production. The goal of this study is to calculate the maturity indices for quality vegetable production in Bangladesh. With this in mind, the current study was designed to determine the maturity indices for quality tomato, broccoli, sweet pepper, cucumber, and netted melon production in Bangladesh.

2. Materials and Methods

2.1. Experimental Site

The evaluation site was the research farm of the Olericulture Division, Bangladesh Agricultural Research Institute (BARI) from Mar 2021 to Feb 2022. The field was at 23.9920˚N Latitudes and 90.4125˚E Longitudes having an elevation of 8.2 m from sea level under the agro-ecological zone (AEZ) 28. The farm was situated in the sub-tropical climatic zone and characterized by scanty rainfall during the experimental period. The soil of the experimental field was sandy clay loam in texture having a pH range of around 6.0.

2.2. Air Temperatures and Relative Humidity of the Experimental Area

Under protected conditions, temperatures can be monitored and managed, and better plant growth could be expected. The protected net house condition influenced the air temperature and RH. Data for the temperatures and RH were measured at 12 pm daily during the experimental period. The average minimum

and maximum temperatures varied between 25.8˚C to 36.8˚C, while relative humidity varied between 62.1% to 81.5% in day time (Figure 1).

2.3. Plant Materials

Five types of vegetables, viz., tomato, broccoli, sweet pepper, cucumber, and netted melon, were cultivated in UV stabilized transparent polyethylene film with a 60-mesh insect net house. Different intervals of harvest were followed for different vegetables for this study. Fruit and quality related traits were visually observed and categorized. Fruits were selected randomly from tagged plants and picked to measure fruit length, diameter, average weight, TSS, and pH. Fruits were harvested on different days after flower opening.

2.4. Flower Tagging and Fruit Harvest

Flowers were tagged at anthesis to determine the stage of fruit development, and 10 randomly selected fruits from 10 plants were harvested at specific day intervals according to the vegetable to determine their growth and maturity. At each harvesting date, 10 fruits were used to determine physicochemical properties like fruit length, diameter, weight, TSS, and pH.

2.5. Measurement of Fruit Weight, Length, and Diameter

Fruit weight was determined using a digital electronic balance (Mettler PJ400, Switzerland) after transporting the harvested fruit in a closed plastic bag to the laboratory. Fruit length and diameter were measured with a digital vernire caliper.

2.6. Measurements of Total Soluble Solids (TSS) and pH

The total soluble solids and pH of the juice were determined by using a hand-held Kruss refractometer (Model HR 900, SN 1200793, brix range 0% - 90% at 20˚C, Germany) and a glass electrode pH meter (Delta 320, Mettler, Shanghai), respectively.

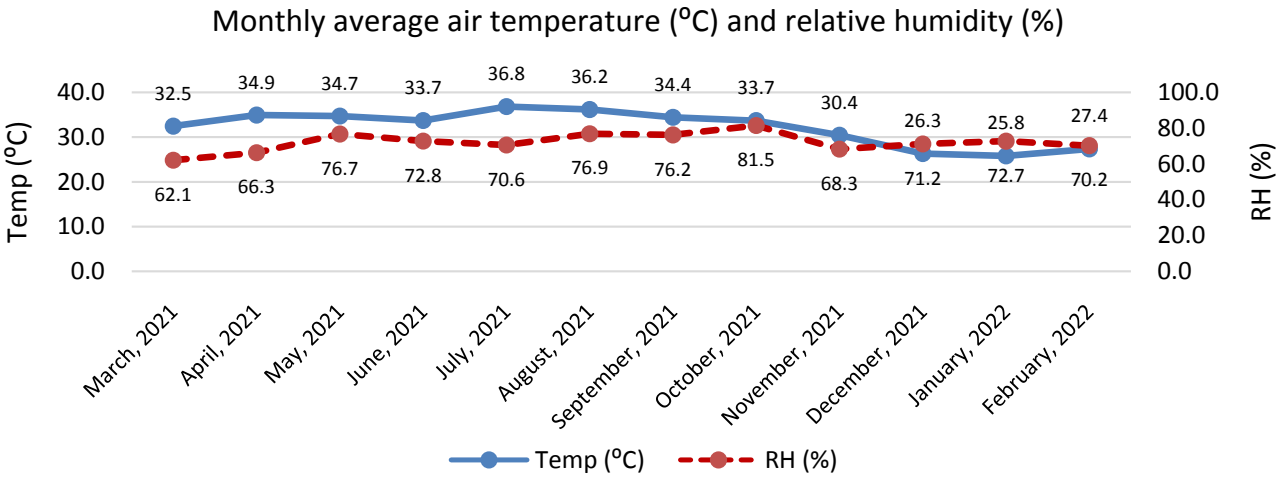

Figure 1. Monthly average air temperature (˚C) and relative humidity (%) at 12 hrs during March 2021 to Feb 2022.

2.7. Evaluation of Sensory Attributes

Sensory evaluation, based on general visual appeal, colour, crispiness, flavor, and taste, was conducted. The scores were: 7 = like extremely; 6 = like very much; 5 = like moderately; 4 = neither like nor dislike; 3 = dislike moderately; 2 = dislike very much and 1 = dislike extremely. Fruit scored above 4 was considered acceptable. Sensory evaluation was performed by a panel of judges consisting of 5 scientific personnel, including both male and female members. Different preferences, as indicated by scores, were evaluated by statistical methods.

2.8. Statistical Analysis

Using the R 3.6.3 statistical software, the data was subjected to analysis of variance (ANOVA).The results showing significant differences were then subjected to mean separation using Tukey's Studentized Range (HSD) Test at $P \leq 0.05$.

3. Results and Discussion

Harvesting at an optimal stage gives the productive and commercial sectors greater flexibility for their management [17]. Climacteric fruits develop their full characteristic flavor, taste, and color during storage if picked during an optimum period. These fruits, harvested at an early stage of maturity, are susceptible to shriveling and mechanical damage and develop poor flavor and taste, despite having a long storage life [18] [19]. Harvesting at an advanced stage of maturity produces fruits that have good taste and flavor but have a short storage life and are not suitable for transporting long distances [20]. The climacteric is a stage of fruit ripening associated with increased ethylene production and a rise in cellular respiration. Alexander and Grierson [21] state that broccoli and netted melon are climacteric fruits, whereas eggplant, cucumber, okra, and sweet pepper are not (they ripen without ethylene and respiration bursts).

3.1. Tomato

Fruits measurement of tomato fruits

Fruit size is a quality parameter used to determine maturity stage at different times of harvest. Generally, at the early stage of growth development, fruits remain small and immature, and at the later stage, the fruits become bigger to attain maturity. An increase in fruit length, fruit diameter, and fruit weight was observed in parallel in this study.

The fruit development curve for tomatoes was determined (**Figure 2**). Following fruit setting, there was a slow increase in fruit diameter and length in the first week. After that, it increased in week 2. Further increases in fruit length and diameter occurred in week 3, reaching a maximum towards the end of week 5 of fruit maturation. The lowest fruit size was at the week 1 stage (1.7 cm and 1.5 cm), followed by week 2, week 3, week 4, week 5 and week 6 (2.4 and 2.1 cm; 3.8 and 3.3 cm; 5.2 and 4.9 cm; 6.5 and 6.2 cm), while the highest fruit size was 6.6 and 6.3 cm at a later stage of harvest (week 6) (**Figure 2**). But this stage is not

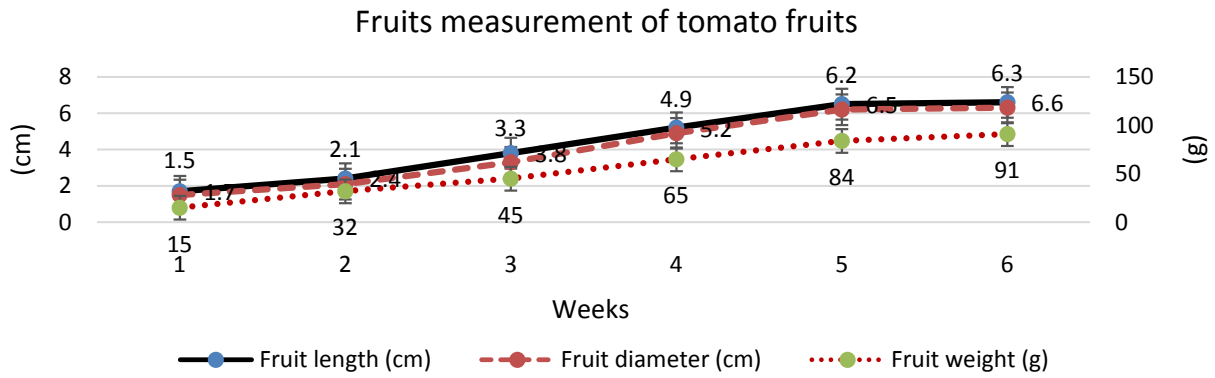

Figure 2. Fruits measurement of tomato fruits at different intervals of weeks.

suitable for fresh consumption; the fresh consumption stage is week 5 (6.5 and 6.2 cm). The changes in fruit diameter and length are expected as tomatoes mature. Zhang and McCarthy [22] stated that tomato ripening is usually associated with a number of variations in the cellular structure and internal structure of the fruit. In addition, the most significant visual changes in the morphological characteristics of the fruit during maturation occur in the size, shape, length, and volume of the fruit as it advances in age [20]. This therefore means that fruit length and diameter are important indices for determining tomato maturity. The fruit weight was gradually increased with the increase of maturity. At the earliest stage (week 1), the individual fruit weight was only 15 g, while the maximum weight (91 g) was at the week 6 stage (**Figure 2**). The weight was increased by 32 g, 45 g, and 65 g at week 2, 3, and 4, respectively. The optimum weight was obtained at the week 5 stage with 84 g.

According to Wu and Kubota [23], tomato fruit enlarge with time after anthesis during the green stage, reach maximum size at around the end of the green stage, and hardly change in size after the breaker stage through the red stage, as demonstrated in this study. Chester [24] and Lovejoy [25] indicated that several tomato varieties are ready for harvest between 6 - 11 weeks following transplanting. This study indicates that fruit development trends are consistent with earlier findings by Robinson [26], Dadzie and Orchard [20], and Mattheis and Fellman [18]. Suryawanshi [27] indicated that tomatoes should be ready for harvest at least 8.5 weeks following transplanting. The variation in times of harvest may be explained by the differences in soil, weather, and pest and disease incidence across study sites.

The Total soluble solids index is a quality parameter used to determine the sweetness, ripeness, and marketability of tomatoes. For the commercial market, tomatoes' TSS should be ≥4% Brix, and below that, tomatoes are not usually suitable. The results (**Figure 3**) revealed that overall mean values of TSS in different stages varied from 3.0 - 4.6 percent. At the earlier stages, viz., week 1 to week 3, they were immature stages, while the TSS was 3.0% to 3.9%, with green color, and the taste was astringent. At the week 4 stage, the TSS was 4.1% and the tomato color breaker stage with a slightly astringent taste. Maximum TSS

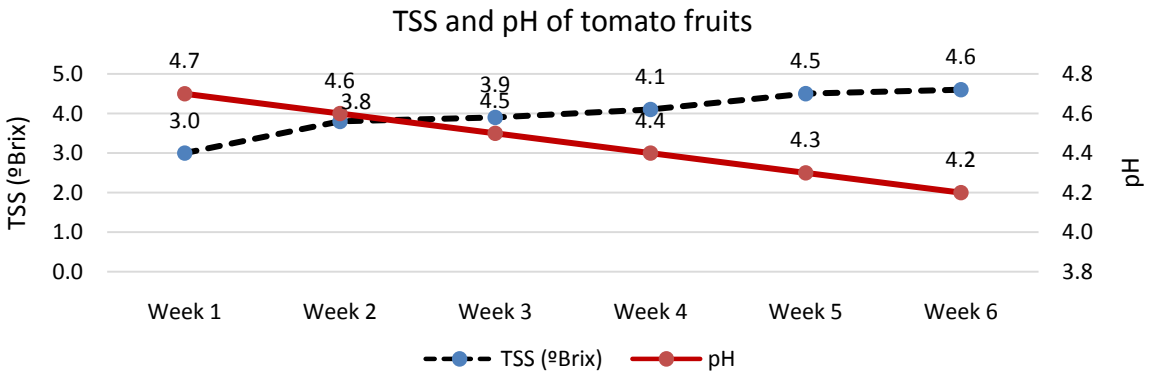

Figure 3. TSS and pH of tomato fruits at different intervals of harvest.

was obtained at week 6 (4.6%), but it was over matured at a fully red colored stage. This stage is better for fresh table purposes, but not for long distance purposes. The second highest TSS value was at the week 5 stage (4.5%), while it was the optimum matured turning red stage, and the fresh eaten taste was slightly good. This stage was better for longer distance purposes, not for fresh table purposes. The optimal harvest TSS values at breaker and red agree with Pinho *et al.* [28] that observed between 4.0 (early harvest) and 6.00 Brix (late harvest) from tomatoes. These results showed a significant difference in TSS content among all stages, which is due to the maturity stage at the time of harvest. The change in TSS with advancement in maturity in this study is attributed to the metabolism of sugar due to increased respiration. The variation in fruit soluble solid content may be due to differences in metabolism and respiration rate between maturity stages. High soluble solids contents are indicators of high sugar content [29]. Fruits are riper, and they contain more flavor volatiles, and these may be useful parameters to predict consumer preference [30]. Harvest at the proper maturity stage is crucial to good eating quality [31].

The pH of fruit did not change appreciably during maturity stages. However, little difference was observed among the maturity stages. The change in pH was consistent with the passage of time, but there was an increasing trend for all stages gradually. The pH values within treatments varied from 4.2 to 4.7 (**Figure 3**). These results coincide with those of Augustin *et al.* [32] and Beaulieu and Lea [33], who reported a similar pattern of pH values (5.25, 6.51, and 6.79) at different maturity stages. There is a slight variation in pH value of fruit harvested at an immature stage as compared to half matured and fully matured fruit that is attributed to low metabolic rate. There was significant variation among all treatments that showed a decline in pH with advancement of maturity. The TSS and pH content vary as fruit matures [34], making these parameters indispensable maturity indices. Therefore, the maturity indices of tomato fruit are morphological features including length, diameter, age, and color and physico-chemical parameters, notably, TSS and pH.

The fruit color of tomato was found to be "light green", "green", "breaker", "turning red" and "red" colored at week 1, 2, 3, 4, 5, and 6 stages, respectively,

while the organoleptic taste was found to be "astringent" at week 1 to week 4, and "slightly tasty" and "tasty" were found at week 5 and week 6 stages, respectively (Table 1).

3.2. Broccoli

Broccoli should be harvested when the head is fully developed, but before the loose head and small yellow flower buds start to open. At harvest, the terminal head should be tight, green, and of an appropriate size. Several smaller side heads (about 1 to 3 inches across) may develop in the axils of the leaves after the central head is removed.

The broccoli head size is a quality parameter used to determine the maturity stage at different times of harvest. Generally, at the early stage of growth development, the head remains small and immature, and at the later stage, the head becomes bigger to attain maturity. An increase in head length, head diameter, and head weight was observed in parallel. The lowest head size was at the 6 days stage (6.2 cm and 6.8 cm), followed by 8 days, 10 days, 12 days and 14 days (9.2 cm and 9.2 cm; 9.8 cm and 11.0 cm; 12.0 cm and 13.0 cm; 13.0 cm and 15.0 cm), while the highest head size was 13.2 cm and 15.5 cm at the later stage of harvest (16 days) (Figure 4). But this stage was not suitable for fresh consumption. The fresh consumption stages were 12 days and 14 days (12.0 cm and 13.0 cm; 13.0 and 15.0 cm).

The head weight and head color were gradually increased with the increase in maturity. At the earliest stage (6 days), the head weight was only 86 g with "dark green" color, while the maximum weight was 420 g at 16 days stage and the color was "green with loose head" (Figure 4 and Table 2). The head weight was increased by 173 g, 221 g, 320 g, and 400 g at 8 days, 10 days, 12 days and 14 days

Table 1. Fruit color and organoleptic taste of tomato at different harvest stages.

Parameter	Qualitative unit	Harvest stage					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Fruit color	Observed color	Light green	Green	Green	Breaker	Turning red	Red
Organoleptic taste	Feeling taste	Astringent	Astringent	Astringent	Astringent	Slightly taste	Tasty

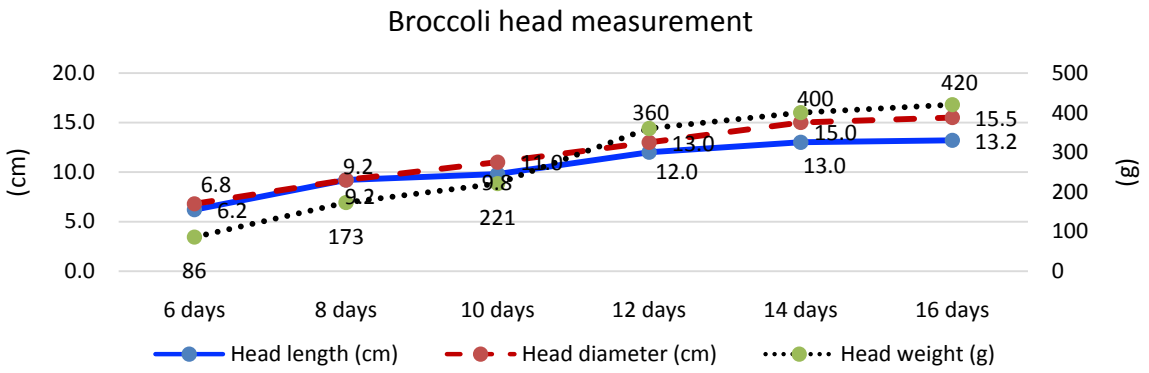

Figure 4. Head measurement of broccoli at different intervals of harvest.

stages, respectively. The optimum head weight was obtained at 12 days with a 360 g "green" colored head, which was found the best quality for edible. No sprouting or looseness was found at this stage. After that, the increase in weight and size occurred in broccoli, but that was not quality due to looseness (**Figure 4**). At 14 days and 16 days stage, the head of broccoli was observed to be "green with slight looseness of head" and "green with loose of head", respectively (**Table 2**).

Harvesting of broccoli heads at the proper stage is a common problem for growers. If heads are picked when immature, they may stay green longer but may not develop to an acceptable size, which may lead to a loss of consumer confidence. Moreover, since head growth continues until harvest, the size of immature heads will be smaller than more mature heads, resulting in a loss of harvest yield. Over matured broccoli heads quickly lose their attractiveness and shininess, and become slimy in texture [35]. Therefore, determining the optimum maturity will benefit both the consumer and the grower. Normally, broccoli head maturity is assessed on the basis of subjective evaluations of visual colour [36], size, and hand pressing to evaluate firmness or days from anthesis [37].

3.3. Netted Melon

Netted melon (*Cucumis melo* L.) characteristics include external color, flesh color, firmness, seed cavity tissue, soluble solid content, flavor, aroma, size, and shape [30] [38], unique flavor, shape, and color, melons generally command high prices. These factors determine eating quality and consumer preference [39], and extended seasons could increase grower income.

The melon fruit remains small and immature at an earlier stage, and at the later stage, the melon fruit becomes bigger to attain maturity. An increase in fruit length, fruit diameter, and fruit weight was observed in parallel in this study. The lowest fruit length and diameter were at the week 1 stage (3.5 cm and 3.2 cm, respectively), followed by week 2, week 3, week 4, and week 5 stages (6.2 and 6.0 cm; 8.4 and 8.0 cm; 10.6 and 10.3 cm; 12.5 and 12.7cm, respectively), while the highest fruit length, diameter were 15.2 cm and 14.5 cm, respectively, at the later stage of harvest (week 6) (**Figure 5**). This stage was the right mature stage. The average fruit weight was gradually increased with the increase in maturity. At the earliest stage (week 1). The fruit weight was only 41 g, while the maximum weight was 800 g at the week 6 stage (**Figure 5**). The fruit weight was increased by 135 g, 244 g, 397 g, and 577 g at week 2, week 3, week 4, and week 5

Table 2. Head color of broccoli at different harvest stages.

Parameter	Qualitative unit	Harvest stage					
		6 days	8 days	10 days	12 days	14 days	16 days
Head color	Observed color	Dark green	Dark green	Dark green	Green	Green with slight loose of head	Green with loose of head

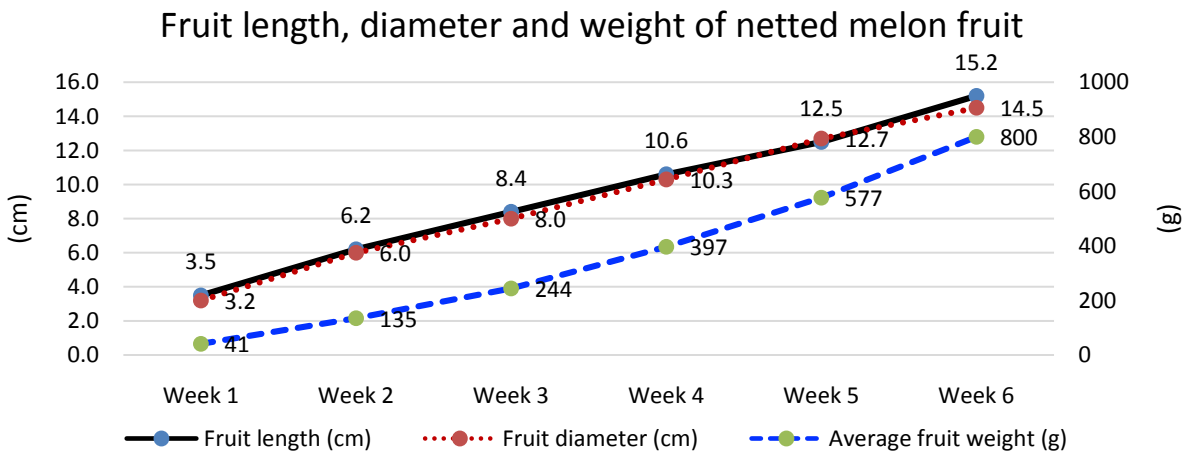

Figure 5. Fruit length, diameter and weight of netted melon fruit at different intervals of harvest.

stages, respectively. The optimum fruit weight was obtained at the week 6 stage with 800 g.

The Total soluble solids index is a quality parameter used to determine the sweetness, ripeness, and marketability of netted melon. For the commercial market, netted melon's TSS should be ≥10% Brix and below that, netted melon is not usually suitable [40] [41]. The findings (**Figure 6**) revealed that the overall mean value of TSS in various stages ranged from 4.5 to 10.8 percent. TSS was 4.5 to 5.3 percent at the earlier stages, namely week 1 to week 4, when the fruit was immature (**Figure 5**). Week 5 stage, the TSS started to increase by 9.2% and it was at its maximum at the week 6 stage, with 10.8%. These results showed a significant difference in TSS content among all stages, which is due to the maturity stage at the time of harvest. Beaulieu and Lea [33] also reported an increase in sugar of 5 - 11 percent during ripening in melon. The change in TSS with advancement in maturity in this study is attributed to the metabolism of sugar due to increased respiration. The deviation in the soluble solid content of fruit might be due to variation in metabolism and respiration rate among maturity stages. High soluble solids contents are indicators of high sugar content [29]. Fruits are riper, and they contain more flavor volatiles, and these may be useful parameters to predict consumer preference [30]. Harvesting of melon at the proper maturity stage (when TSS is about 8% - 10%) is crucial to good eating quality [31]. Since the amount of TSS in fruits usually increases as they mature and ripen, the soluble solids content of the fruit can be a useful index of maturity or stage of ripeness for netted melon.

The pH of fruit did not change appreciably during maturity stages. However, little difference was observed among the maturity stages. The change in pH was consistent with the passage of time, but there was an increasing trend for all stages gradually. The pH values within treatments varied from 5.0 to 6.4 (**Figure 6**). These results coincide with those of Augustin *et al.* [32] and Beaulieu and Lea [33], who reported a similar pattern of pH values (5.25, 6.51, and 6.79) at different maturity stages. A pH of 6.55 occurs at the fruit maturity of melon [42].

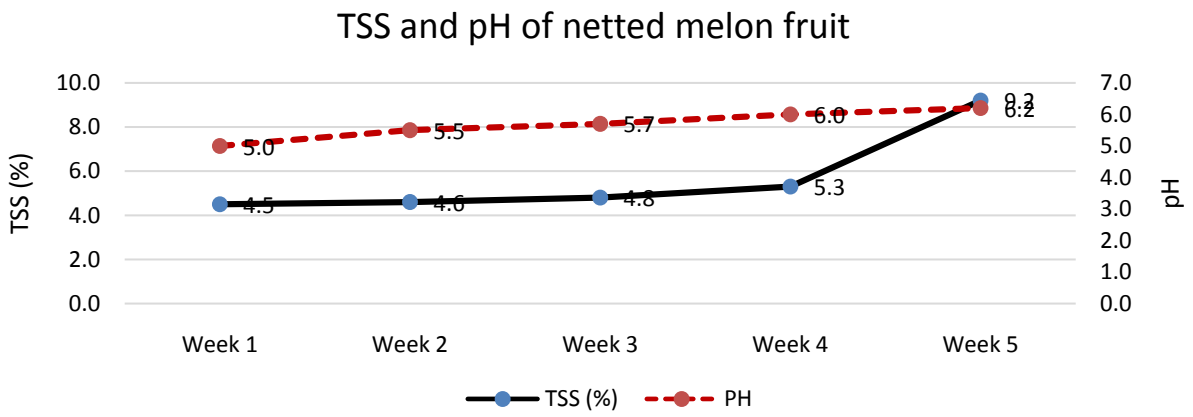

Figure 6. TSS (%) and pH of netted melon fruit at different intervals of harvest.

Cantaloupes had a higher pH than honeydew melons. Sweet melons are unique among fleshy fruits with pH values near neutral [43]. There is a slight variation in pH value of fruit harvested at an immature stage as compared to half matured and fully matured fruit that is attributed to low metabolic rate. There was significant variation among all treatments that showed a decline in pH with advancement of maturity. A pH of 6.5 and high soluble solids content are indicators of high sugar content [29]. Fruits are riper, and they contain more flavor volatiles, and these may be useful parameters to predict consumer preference [30]. The TSS and pH content vary as fruit matures [34], making these parameters indispensable maturity indices. Therefore, the maturity indices of fruit are morphological features including length, diameter, age, and color and physico-chemical parameters, notably TSS and pH.

The net development on the fruit skin of netted melon is a quality parameter used to determine maturity stage at different times of harvest. Generally, at the early stage of growth, the net does not develop well. The net development on fruit skin was gradually increased with the increase of maturity. At the earliest stages (week 1 and week 2), the fruit had a plain surface, while at the mid development stage (week 3), the fruit skin had a "rough surface". The net development starts at week 4, while the full development of the net was observed at week 5 and week 6 stages (**Table 3**). The melon fruits were tasted at different stages of maturity. The fruit had an "astringent taste" during week 1 to week 3, while it was "slightly tasty", "tasty", and "Much tasty" during week 4, week 5, and week 6, respectively. So, from week 5 to week 6 is the appropriate time of maturity to harvest.

Precise determination of netted melon fruit maturity is difficult at harvest. Fruits are harvested at different degrees of maturity, and a proportion of fruits may be immature. Thus, harvesting of netted melon fruits of different maturities at the same time is a common problem, even though fruits may have the same skin color at harvest [44]. If fruits are picked immature, they may stay green longer but may not develop an acceptable colour and flavour upon ripening [45], which may lead to a loss of consumer confidence. Moreover, since fruit growth

Table 3. Net development on fruit skin and organoleptic taste of netted melon at different harvest stages.

Parameter	Unit	Harvest stage					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Net development on fruit skin	Observed color	Plain surface	Plain surface	Rough surface	Net developed	Net fully developed	Net fully developed
Organoleptic taste	Feeling taste	Astringent	Astringent	Astringent	Slightly tasty	Tasty	Much tasty

continues until harvest, the size of immature fruit will be smaller than more mature fruit, resulting in a loss of harvest yield. On the other hand, overripe fruits lose their attractiveness and shininess and become slimy in texture within a very short time [35]. Therefore, determining the optimum maturity will benefit both the consumer and the grower. Normally, netted melon fruit maturity is assessed on the basis of subjective evaluations of visual colour [36] [37] [46], size, and hand pressing to evaluate firmness or days from anthesis [37] [47].

3.4. Cucumber

Cucumber for fresh consumption is one of the most popular vegetables worldwide and is a rich source of vitamins, minerals, and antioxidants [48]. It is estimated that one-third of global production is lost or wasted [49] [50]. These losses occur throughout the value chain, from production and collection, transport and storage, to marketing and distribution to the consumer due to post-harvest management, while improper maturity is one of the factors among all the steps [51]. To facilitate and improve this process, there are easily applicable indicators that allow the selection of proper maturity stages of cucumbers. Therefore, the objective of this study was to demonstrate the proper maturity stages, which can be effective indicators of the probability of marketability of cucumbers.

The cucumber remains smaller in size and immature at an earlier stage, and at the later stage, the cucumber becomes bigger to attain maturity. In this study, the lowest fruit length and diameter were obtained at the day 6 stage (5.2 cm and 1.3 cm, respectively), followed by day 8, day 10, day 12, day 14 stages (6.9 cm and 1.8 cm; 8.8 cm and 2.2 cm; 10.8 cm and 2.9 cm; 13.2 cm and 3.8 cm, respectively), while the highest fruit length and diameter were 14.6 cm and 4.3 cm, respectively, at the later stage of harvest (day 16) (**Figure 6**). The average fruit weight was gradually increased with the increase in maturity. At the earliest stage (day 6), the fruit weight was only 30 g, while the maximum weight was 148 g at the day 16 stage (**Figure 7**). The fruit weight was increased by 45 g, 61 g, 88 g, and 125 g at day 8, day 10, day 12, and day 14 stages, respectively. The maximum fruit weight was obtained at the day 16 stage with 148 g. Cucumber fruits are ready for harvest at the fruit maturity stage of day 10 to day 12 after fruit setting, and it is done at the immature stage of the fruit. In cucumbers, the proper stage of maturity is judged by size and not by the age of the fruit. Cucumbers should be picked when they are 9 - 11 cm long. Another marketable stage is

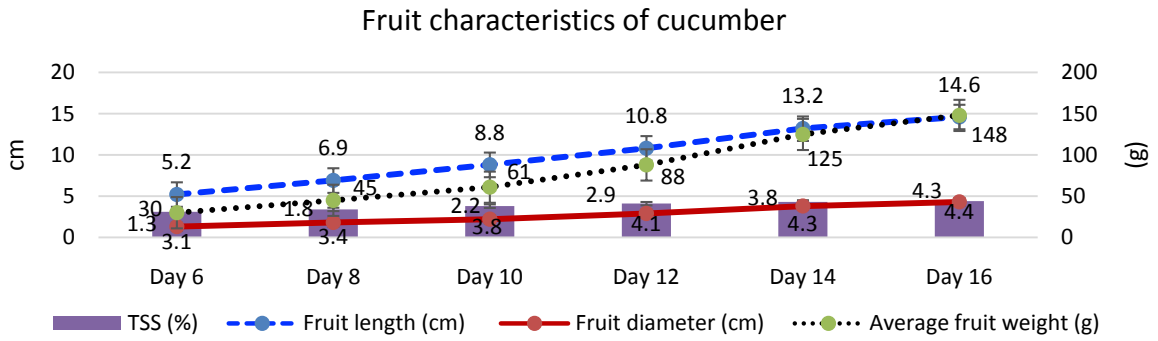

Figure 7. Fruit length, diameter, average fruit weight and TSS of cucumber at different intervals of harvest.

when the spines on fruit become soft and fall down. In general, cucumbers may be picked at any stage of fruit growth, provided yellowish has not started. The fruit should be picked at frequent intervals in order to avoid losses due to oversized or overripe fruits. They are typically picked every 2 to 3 days, depending on variety and weather.

The results (**Figure 7**) revealed that overall mean values of TSS in different stages varied from 3.1 - 4.4 percent. At the earlier stages, viz., day 6 to day 8, were immature stages, while the TSS was 3.1 to 3.4 percent (**Figure 7**). At a moderate stage of harvest, viz., day 10 to day 12 stage, the TSS was 3.8% to 4.1% and the maximum was at day 14 and day 16 stage with 4.3% to 4.4%. These results showed a significant difference in TSS content among all stages, which is due to the maturity stage at the time of harvest. Beaulieu and Lea [33] also reported an increase in sugar from 5 - 11 percent during ripening in melon. The change in TSS with advancement in maturity in this study is attributed to the metabolism of sugar due to increased respiration. The variation in fruit soluble solid content may be due to differences in metabolism and respiration rate between maturity stages. High soluble solids contents are indicators of high sugar content [29]. Fruits are riper, and they contain more flavor volatiles, and these may be useful parameters to predict consumer preference [30]. The TSS is an important postharvest quality attribute of cucumbers. Since the amount of TSS in fruits usually increases as they mature and ripen, the soluble solid content of the fruit can be a useful index of early maturity or stage of ripeness for cucumbers.

The powdery surface and spine development on cucumber fruit is a quality parameter used to determine maturity stage at different times of harvest. Generally, at the early stage of growth, the powdery surface and spine development are well developed. The amount of powdery surface and spine development on fruit skin was gradually decreased with the increase of maturity. At the earliest stages (day 6 and day 8), the powdery surface of fruit and spine development were well developed, while at the mid-development stage (day 10 and day 12), the powdery surface of fruit and spine development were less developed. At later development stages (day 14 and day 16), the powdery surface of the fruit was absent and spine development was very low (**Table 4**). The cucumber fruits were tasted at

Table 4. Powdery surface of fruit and spine development and organoleptic taste of cucumber at different harvest stages.

Parameter	Unit	Harvest stage					
		Day 6	Day 8	Day 10	Day 12	Day 14	Day 16
Fruit skin color	Observed color	Powdery surface with spine	Powdery surface with spine	Less powdery with less spine	Less powdery with less spine	Very less powdery with less spine	No powdery and very less spine
Organoleptic taste	Feeling taste	Less astringent taste	Slightly tasty	Tasty	Tasty	Slightly matured	Over matured

different stages of maturity. The fruit was "less astringent in taste" during the day 6 stage, while it was "slightly tasty" at day 8, "tasty" at day 10 and day 12, and slightly matured and over matured at day 14 and day 16 stages, respectively. So, on day 10 and day 12, the appropriate times of maturity to harvest were set.

Precise determination of cucumber fruit maturity is difficult at harvest. Fruits are harvested at different degrees of maturity, and a proportion of fruits may be immature. Thus, harvesting of cucumber fruits of different maturities at the same time is a common problem, even though fruits may have the same skin colour at harvest [44]. If fruits are picked immature, they may stay green longer but may not develop an acceptable colour and flavour upon ripening [45], which may lead to a loss of consumer confidence. Moreover, since fruit growth continues until harvest, the size of immature fruit will be smaller than more mature fruit, resulting in a loss of harvest yield. On the other hand, overripe fruits lose their attractiveness and shininess and become slimy in texture within a very short time [35]. Therefore, determining the optimum maturity will benefit both the consumer and the grower. Normally, cucumber fruit maturity is assessed on the basis of subjective evaluations of visual colour [36] [37] [46], size, and hand pressing to evaluate firmness or days from anthesis [37] [47].

3.5. Sweet Pepper

Sweet is a non-pungent fruit that is valued for its color, flavor, and nutritional attributes, including ascorbic acid, polyphenolics, and various carotenoids. It comes in a wide variety of colors (ranging from green, yellow, orange, red, and purple), shapes, and sizes, as well as because it has a high content of ascorbic acid, polyphenols, and other antioxidants. Generally, the harvest of sweet peppers is determined by the size, color, and texture of the fruit. Traditionally, the harvest of this fruit is done by reaching physiological maturity when the pericarp becomes thick and the fruit reaches its typical size. However, estimating pepper maturity at the green stage can be difficult, even for fruit with similar physical attributes [44]. The sweet peppers reach their optimum state of maturity for use in the kitchen when they are a solid color. Consumers prefer this fruit at its best stage of maturity, more so than its physical appearance and nutritional content [52]. Dutch researchers specializing in the sensory area, reported that study groups have considered that more ripe sweet peppers are sweeter and have a red

pepper aroma, while those in the green stage were rated for the bitterness and aroma of herbs and cucumber [53]. At the mentioned stage, sweet peppers will progress through the normal ripening process to degrade chlorophyll while simultaneously synthesizing carotenoids. For determining an appropriate harvest time, different attributes like surface colour, fruit firmness, soluble solids content, acid content are used as indicators [44], so that products develop acceptable taste and flavour characteristics as well as maintain structural integrity during subsequent storage and/or shelf life [54] [55].

In our study, the fruit length and diameter of sweet pepper fruits significantly increased with the increase of harvesting time from anthesis (**Figure 8**). The minimum length and diameter of fruits (3.8 and 3.3 cm, respectively) were obtained from harvesting after week 3 of anthesis, followed by week 4 (5.2 and 4.9 cm, respectively), week 5 (9.2 and 6.0cm, respectively), and week 6 (9.5 and 6.2 cm, respectively), while the maximum length and diameter were obtained at week 7 (9.7 and 6.3 cm, respectively). In an experiment, Tadesse *et al.* [44] reported that sweet pepper fruit (cv. Domino) had attained almost 75% of its final length after three weeks of anthesis but continued to elongate at a slower rate until 10 weeks after anthesis.

Sweet pepper fruits under this experiment showed a gain in weight as the harvest time was extended (**Figure 8**). The lighter fruits (58 g) were harvested after week 3 of anthesis, which increased steadily until week 4 (87 g). After this period, fruit weight increased sharply with the extension of the harvesting time until week 5 (131 g). However, the maximum fruit weight of 150 g was obtained after week 7 of anthesis. Rahman *et al.* [56] and Tadesse *et al.* [44] reported that sweet pepper (cv. Domino) fruit fresh weight was linearly increased until eight weeks after anthesis.

Total soluble solids (TSS) are a classical tool to determine the maturity of fruits in the food industry, even though it is a destructive technique. The TSS content consists of 80% - 95% sugars, and the measure of TSS is associated with the dissolved sugars in the cell of juice [57]. The TSS content showed a constant increase as the fruit maturity increased, which could be seen with an increase in color fastness in the sample sweet peppers. The ascending behavior of TSS content is consistent with that reported in the literature [55] (**Figure 9**). The changes in TSS content of sweet pepper fruits with harvesting length. The TSS of fruit samples harvested after week 3 of anthesis was fairly low (3.0%), which was slowly increased with the increase of harvesting time. The TSS content reached a maximum level of 5.1% when fruits were harvested after week 7 of anthesis. The increase in TSS of sweet pepper fruit with maturity is probably a result of increased hexose sugar accumulation during fruit ripening [56], as there is a close positive correlation between the rise in TSS and soluble sugars [58]. The results of the present experiment are in agreement with Rahman *et al.* [56] and Tadesse *et al.* [44], who found that the TSS of sweet pepper increased slightly from 3 to 5% and 5% to 6% during the period 2 to 6 weeks after anthesis, respectively.

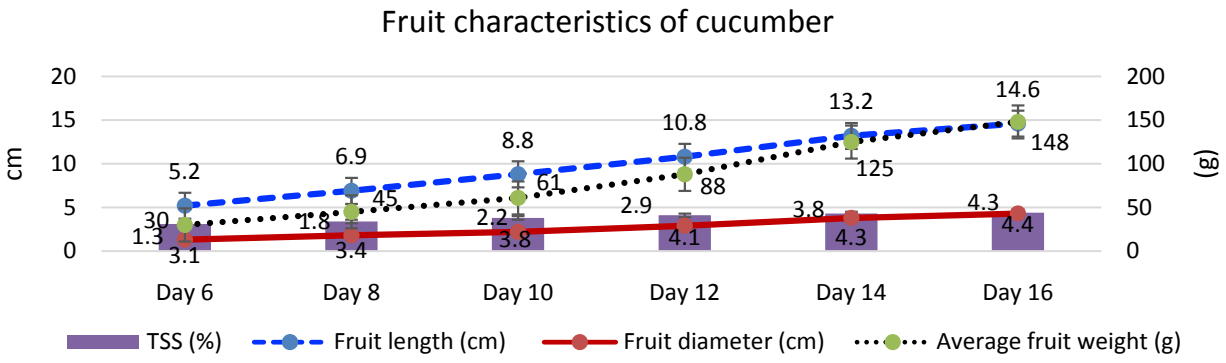

Figure 8. Fruit length, diameter and average fruit weight of sweet pepper at different intervals of harvest Vertical bars indicate standard deviation.

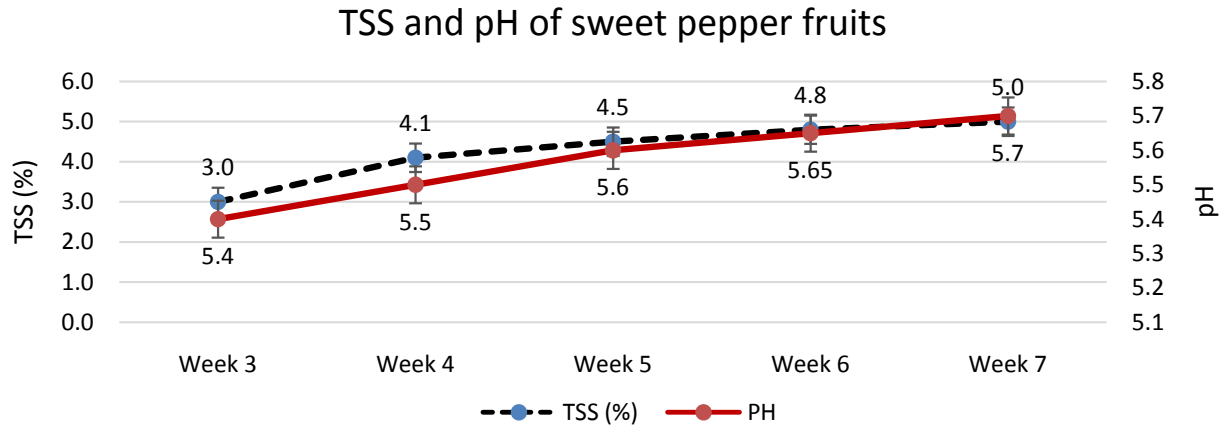

Figure 9. TSS and pH of sweet pepper fruits at different intervals of harvest Vertical bars indicate standard deviation.

Table 5. Fruit color and taste of sweet pepper fruits at different harvest stages.

Parameter	Harvest stage				
	Week 3	Week 4	Week 5	Week 6	Week 7
Fruit color	Green	Green	Shiny green	Shiny green	Less shiny green
Taste	Astringent taste	Astringent taste	Crispy pleasant flavored taste	Crispy pleasant flavored taste	Slightly flavored taste

The changes in pH of sweet pepper fruits as a function of different harvesting times are shown in **Figure 9**. From the results, it was found that the pulp pH of sweet pepper fruit was not affected by different harvest maturity. The pH ranged from 5.40 to 5.70 was found during harvesting from week 3 to week 7, which was not significantly different among harvesting times. Similar results were also found (5.71% to 5.79%) by Rahman *et al.* [56], while Fox *et al.* [59] reported that sweet pepper pH was not affected by different harvesting times, which ranged from 4.9 to 5.1.

The maturity of the sweet pepper fruit was determined by a combination of different attributes. In this study, TSS, surface color change, and firmness were found to be good indicators of sweet pepper fruit maturity. Based on the results

of the present study, sweet pepper fruits reached physiological maturity from week 5 to week 6. At this stage of maturity, the fruit attained 9.2 - 9.5 cm in length, 6.0 - 6.2 cm in diameter, and 131 g - 142 g in weight (**Figure 8**). Besides, fruits were shinier green, crispy, pleasant flavored, and tasty at this stage (**Table 5**).

4. Conclusion

At harvest season, determining the exact maturity of vegetable fruits is tricky. Fruits are collected at various stages of development, with some fruits being immature. As a result, even though fruits may have the same skin color at harvest, collecting fruits of different maturity at the same time is a regular concern. Immaturely chosen fruits may stay green for longer, but they may not ripen to an acceptable color and flavor, resulting in a loss of consumer confidence. Furthermore, because fruit growth continues until harvest, immature fruit will be smaller than mature fruit, resulting in a reduction in harvest yield. Tomatoes were found to be an appropriate size (6.5 cm length and 6.2 cm diameter), weight (84 g), TSS (4.5 percent), pH (4.3), "turning red" and "tasty" at the week 5 stage, while broccoli was found to be an appropriate size (12.0 cm length and 13.0 cm diameter), weight (360 g), "green" color at the day 12 stage in our study. At the week 6 stage, the nettled melon was found to be of appropriate size (15.2 cm length and 14.5 cm diameter), weight (800 g), TSS (10.8 percent), pH (6.3), "net fully developed" on the skin of the fruit, and "much tasty," while cucumber was found to be of appropriate size (8.8 - 10.8 cm length and 2.2 - 2.9 cm diameter), weight (61 - 88 g), TSS (3.8 - 4.1 percent), pH (6.3), "less powdery with less spine" on fruit skin and "tasty" at day 10 - 12 stage. Sweet peppers that were found to be of appropriate size (9.2 - 9.5 cm length and 6.0 - 6.2 cm diameter), weight (131 - 142 g), TSS (4.5 - 4.8 percent), pH (5.6 - 5.65), "Shiny green" fruit color, and "Pleasant flavored taste" at the week 5 - 6 stage lost their attractiveness and shininess, and became slimy in texture within a short time. As a result, determining our study's optimal maturity will help both the consumer and the grower.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Aherne, S.A., O'Sulivan, L., Jiwan, M.A., Daly, T. and O'Brien, N.M. (2010) Content

and Bio-Accessibility of Carotenoids from Sweet Peppers (*Capsicum annum* L.). *Proceedings of the Nutrition Society*, **69**, E509. https://doi.org/10.1017/S0029665110003721

[2] Ilić, Z.S. and Fallik, E. (2017) Light Quality Manipulation Improves Vegetable Quality at Harvest and Postharvest: A Review. *Environmental and Experimental Botany*, **139**, 79-90. https://doi.org/10.1016/j.envexpbot.2017.04.006

[3] Sugani, D. and Varma, L.R. (2014) Quality of Muskmelon (*Cucumis melo* L.) as Influenced by Plant Spacing and Levels of Pruning under Greenhouse. *Progressive Horticulture*, **46**, 121-123.

[4] Lamont Jr., W.J. (1996) What Are the Components of a Plasticulture Vegetable System? *HortTechnology*, **6**, 150-154. https://doi.org/10.21273/HORTTECH.6.3.150

[5] Wells, J.A., and Nugent, P.E. (1980) Effect of High Soil Moisture on Quality of Muskmelon. *HortScience*, **15**, 258-259.

[6] Rodriguez, J.C., Shaw, N.L. and Cantliffe, D.J. (2007) Influence of Plant Density on Yield and Fruit Quality of Greenhouse-Grown Galia Muskmelons. *HortTechnology*, **17**, 580-585. https://doi.org/10.21273/HORTTECH.17.4.580

[7] Vescera, M. and Brown, R.N. (2016) Effects of Three Production Systems on Muskmelon Yield and Quality in New England. *HortScience*, **51**, 510-517. https://doi.org/10.21273/HORTSCI.51.5.510

[8] Patel, B.R., Gohil, K.B. and Veghasiya, P.M. (2003) Response of Gladiator Rose to Fan Pad Cooled Greenhouse under Humid Climate of Novsani. *Proceedings of All India Seminars on Potential and Prospects for Protective Cultivation*, Institute of Engineers, Ahmednagar.

[9] Selvakumar, R. (2014) A Text Book of Glaustus Olericulture. New Vishal Publications, New Delhi.

[10] Kalia, M. (2011) Post Harvest Technology of Vegetables. S.S.S. Printers, New Delhi.

[11] Rajkumar, P., Wang, N., EImasry, G., Raghavan, G.S.V. and Gariepy, Y. (2012) Studies on Banana Fruit Quality and Maturity Stages Using Hyperspectral Imaging. *Journal of Food Engineering*, **108**, 194-200. https://doi.org/10.1016/j.jfoodeng.2011.05.002

[12] Kato, J. (2011) Green House Tomato Growers Root for Market. New Vision. http://www.newvision.co.ug/new_vision/news/1298878/greenhouse-tomato-growers-root-market

[13] Muzaale, F. (2014) Growing Good Quality Tomatoes. Farming Magazine, Daily Monitoronline. 8 January 2014. https://www.monitor.co.ug/Magazines/Farming/Growing-good-quality-%20toma-toes/689860-2137558-4ic69oz/index.html

[14] Maboko, M.M. and du Plooy, C.P. (2008) Effect of Pruning on Yield and Quality of Hydroponically Grown Cherry Tomato (*Lycopersicon esculentum*). *South African Journal of Plant and Soil*, **25**, 178-181. https://doi.org/10.1080/02571862.2008.10639914

[15] Perdigones, A., Pascual, V., García, J.L., Nolasco, J. and Pallares, D. (2005) Interactions of Crop and Cooling Equipment on Greenhouse Climate. *Acta Horticulturae*, **691**, 203-208. https://doi.org/10.17660/ActaHortic.2005.691.23

[16] Lado, J., Rodrigo, M.J. and Zacarías, L. (2014) Maturity Indicators and Citrus Fruit Quality. *Stewart Postharvest Review*, **10**, 1-6.

[17] Caron, V.C., Tessmer, M.A., Mello, S.C. and Jacomino, A.P. (2013) Quality of Mini Tomatoes Harvested at Two Maturity Stages and Kept Chilled in Three Packages.

Horticultura Brasileira, **31**, 279-286.
https://doi.org/10.1590/S0102-05362013000200017

[18] Mattheis, J.P. and Fellman, J.K. (1999) Preharvest Factors Affecting Flavor of Fresh Fruit and Vegetables. *Postharvest Biology and Technology*, **15**, 227-232. https://doi.org/10.1016/S0925-5214(98)00087-8

[19] Beckles, D.M. (2012) Factors Affecting the Postharvest Soluble Solids and Sugar Content of Tomato (*Solanum lycopersicum* L.) Fruit. *Postharvest Biology and Technology*, **63**, 129-140. https://doi.org/10.1016/j.postharvbio.2011.05.016

[20] Dadzie, B.K. and Orchard, J.E. (1997) Routine Postharvest Screening of Banana/Plantain Hybrids. Criteria and Methods. International Network for the Improvement of Banana and Plantain (INIBAP) Technical Guidelines 2. International Plant Genetic Resources Institute IPGRI, Rome.

[21] Alexander, L. and Grierson, D. (2002) Ethylene Biosynthesis and Action in Tomato: A Model for Climacteric Fruit Ripening. *Journal of Experimental Botany*, **53**, 2039-2055. https://doi.org/10.1093/jxb/erf072

[22] Zhang, L. and McCarthy, M.J. (2012) Measurement and Evaluation of Tomato Maturity Using Magnetic Resonance Imaging. *Postharvest Biology and Technology*, **67**, 37-43. https://doi.org/10.1016/j.postharvbio.2011.12.004

[23] Wu, M. and Kubota, C. (2008) Effects of High Electrical Conductivity of Nutrient Solution and Its Application Timing on Lycopene, Chlorophyll and Sugar Concentrations of Hydroponic Tomatoes during Ripening. *Scientia Horticulturae*, **116**, 122-129. https://doi.org/10.1016/j.scienta.2007.11.014

[24] Chester, T. (2004) Tomato Harvest versus Planting Date. Los Angeles County, California. http://tchester.org/analysis/tomatoes

[25] Lovejoy, R. (2016) How Long Does It Take for Tomato Plants to Have Tomatoes? SFGATE, Maine.
http://homeguides.sfgate.com/long-tomato-plants-tomatoes-56430.html

[26] Robinson, J.C. (1996) Bananas and Plantains. 2nd Edition, University Press, Cambridge.

[27] Suryawanshi, V.K. (2014) Sowing Time, Maturity Indices, Harvesting Stages and Time of Vegetables (Part-1). Krishisewa.
http://www.krishisewa.com/crop_system/crops-calendar/430-veg-calendar-1.html

[28] Pinho, L., Almeida, A.C., Costa, C.A., Paes, M.C.D., Glória, M.B.A. and Souza, R.M. (2011) Nutritional Properties of Cherry Tomatoes Harvested at Different Times and Grown in an Organic Cropping. *Horticultura Brasileira*, **29**, 205-211. https://doi.org/10.1590/S0102-05362011000200012

[29] Saftner, R.A. and Lester, G.E. (2009) Sensory and Analytical Characteristics of Novel Hybrid Muskmelon Fruit Intended for the Fresh-Cut Industry. *Postharvest Biology and Technology*, **51**, 327-333. https://doi.org/10.1016/j.postharvbio.2008.09.008

[30] Pardo, J.E., Alvarruiz, A., Varon, R. and Gomez, R. (2000) Quality Evaluation of Melon Cultivars. Correlation among Physical-Chemical and Sensory Parameters. *Journal of Food Quality*, **23**, 161-170. https://doi.org/10.1111/j.1745-4557.2000.tb00203.x

[31] Artes, F., Escriche, A.J., Martinez, J.A. and Marin, J.G. (1993) Quality Factors in Four Varieties of Melon (*Cucumis melo* L.). *Journal of Food Quality*, **16**, 91-100. https://doi.org/10.1111/j.1745-4557.1993.tb00352.x

[32] Augustin, M.A., Osman, A., Azudi, N. and Mohamed, S. (1988) Physicochemical Changes in Muskmelon (*Cucumis melo* L.) during Storage. *Pertanika*, **11**, 203-209.

[33] Beaulieu, J.C. and Lea, J.M. (2007) Quality Changes in Cantaloupe during Growth, Maturation, and in Stored Fresh-Cut Cubes Prepared from Fruit Harvested at Various Maturities. *Journal of the American Society for Horticultural Science*, **132**, 720-728. https://doi.org/10.21273/JASHS.132.5.720

[34] Matsuda, R. and Kubota, C. (20100 Variation of Total Soluble-Protein Content in Fruit among Six Greenhouse Tomato Cultivars. *HortScience*, **45**, 1645-1648. https://doi.org/10.21273/HORTSCI.45.11.1645

[35] Pareek, A. and Trivedi, P.C. (2001) Cultural Values and Indigenous Knowledge of Climate Change and Disaster Prediction. *Indian Journal of Traditional Knowledge*, **10**, 183-189.

[36] Howard, L.R., Smith, R.T., Wagner, A.B., Villalon, B. and Burns, E.E. (1994) Provitamin A and Ascorbic Acid Content of Fresh Pepper Cultivars (*Capsicum annuum*) and Processed Jalapenos. *Journal of Food Science*, **59**, 362-365. https://doi.org/10.1111/j.1365-2621.1994.tb06967.x

[37] Sanchez, V.M., Sundstrom, F.J., McClure, G.N. and Lang, N.S. (1993) Fruit Maturity, Storage and Postharvest Maturation Treatments Affect Bell Pepper (*Capsicum annuum* L.) Seed Quality. *Scientia Horticulturae*, **54**, 191-201. https://doi.org/10.1016/0304-4238(93)90087-7

[38] Miccolis, V. and Saltveit, M.E. (1995) Influence of Storage Period and Temperature on the Postharvest Characteristics of Six Melon (*Cucumis melo* L., Inodorus Group) Cultivars. *Postharvest Biology and Technology*, **5**, 211-219. https://doi.org/10.1016/0925-5214(94)00024-M

[39] Hoberg, E., Ulrich, D., Schulz, H., Tuvia-Alkali, S. and Fallik, E. (2003) Sensory and Quality Analysis of Different Melon Cultivars after Prolonged Storage. *Food/Nahrung*, **47**, 320-324. https://doi.org/10.1002/food.200390074

[40] Burger, Y., Shen, S., Petreikov, M. and Schaffer, A.A. (2000) The Contribution of Sucrose to Total Sugar Content in Melons. *Acta Horticulturae*, **510**, 479-485. https://doi.org/10.17660/ActaHortic.2000.510.75

[41] Paris, H.S., Amar, Z. and Lev, E. (2012) Medieval Emergence of Sweet Melons, *Cucumis melo* (Cucurbitaceae). *Annals of Botany*, **110**, 23-33. https://doi.org/10.1093/aob/mcs098

[42] Villanueva, M.J., Tenorio, M.D., Esteban, M.A. and Mendoza, M.C. (2004) Compositional Changes during Ripening of Two Cultivars of Muskmelon Fruits. *Food Chemistry*, **87**, 179-185. https://doi.org/10.1016/j.foodchem.2003.11.009

[43] Cohen, S., Itkin, M., Yeselson, Y., Tzuri, G., Portnoy, V., Harel-Baja, R., Lev, S., Sáar, U., Davidovitz-Rikanati, R., Baranes, N., *et al.* (2014) The pH Gene Determines Fruit Acidity and Contributes to the Evolution of Sweet Melons. *Nature Communications*, **5**, Article No. 4026. https://doi.org/10.1038/ncomms5026

[44] Tadesse, T., Hewett, E.W., Nichols, M.A. and Fisher, K.J. (2002) Changes in Physicochemical Attributes of Sweet Pepper cv. Domino during Fruit Growth and Development. *Scientia Horticulturae*, **93**, 91-103. https://doi.org/10.1016/S0304-4238(01)00317-X

[45] Boonyakiat, D., Chen, P.M., Spotts, R.A. and Richardson, D.G. (1987) Effect of Harvest Maturity on Decay and Postharvest Life of 'd'Anjou' Pear. *Scientia Horticulturae*, **31**, 131-139. https://doi.org/10.1016/0304-4238(87)90115-4

[46] Lin, W.C., Hall, J.W. and Saltveit Jr., M.E. (1993) Ripening Stage Affects the Chilling Sensitivity of Greenhouse Grown Peppers. *Journal of the American Society for Horticultural Science*, **118**, 791-795. https://doi.org/10.21273/JASHS.118.6.791

[47] Manandhar, J.B., Hartman, G.L. and Wang, T.C. (1995) Anthracnose Development

on Pepper Fruits with *Colletotrichum gloeosporiodes*. *Plant Disease*, **79**, 380-383. https://doi.org/10.1094/PD-79-0380

[48] Patel, C. and Panigrahi, J. (2019) Starch Glucose Coating-Induced Postharvest Shelf-Life Extension of Cucumber. *Food Chemistry*, **288**, 208-214. https://doi.org/10.1016/j.foodchem.2019.02.123

[49] FAO (2013) Food Wastage Footprint: Impacts on Natural Resources: Summary Report. http://site.ebrary.com/id/10815985

[50] FAO (2018) Gender and Food Loss in Sustainable Food Value Chains—A Guiding Note. http://www.fao.org/3/I8620EN/i8620en.pdf

[51] Prusky, D. (2011) Reduction of the Incidence of Postharvest Quality Losses, and Future Prospects. *Food Security*, **3**, 463-474. https://doi.org/10.1007/s12571-011-0147-y

[52] Frank, C.A., Nelson, R.G., Simonne, E.H., Behe, B.K. and Simonne, A.H. (2001) Consumer Preferences for Color, Price, and Vitamin C Content of Bell Peppers. *HortScience* **36**, 795-800. https://doi.org/10.21273/HORTSCI.36.4.795

[53] Luning, P.A., van der Vuurst, D.V.R., Yuksel, D., Ebenhorst-Seller, T., Wichers, H.J. and Roozen, J.P. (1994) Combined Instrumental and Sensory Evaluation of Flavor of Fresh Bell Peppers (*Capsicum annuum*) Harvested at Three Maturation Stages. *Journal of Agricultural and Food Chemistry*, **42**, 2855-2861. https://doi.org/10.1021/jf00048a038

[54] Meredith, F.I., Robertson, J.A. and Horvat, R.J. (1989) Changes in Physical and Chemical Parameters Associated with Quality and Postharvest Ripening of Harvested Peaches. *Journal of Agricultural and Food Chemistry*, **37**, 1210-1214. https://doi.org/10.1021/jf00089a002

[55] Wills, R., McGlasson, B., Graham, D. and Joyce, D. (1998) Postharvest: An Introduction to the Physiology and Handling of Fruit, Vegetables and Ornamentals. CAB International, Wallingford.

[56] Rahman, M.A., Halim, G.M.A., Chowdhury, M.G.F., Hossain, M.A. and Rahman, M.M. (2014) Changes in the Physical and Chemical Properties of Sweet Pepper (*Capsicum annum* L.) during Fruit Growth and Development. *Bangladesh Journal of Agricultural Research*, **39**, 373-383. https://doi.org/10.3329/bjar.v39i2.20446

[57] Osterloh, A., Ebert, G. and Held, W.H. (1996) Handbuch der Lebensmitteltechnologie. Lagerung von Obst und Südfrüchten. Verlag Eugen Ulmer, Stuttgart. https://onlinelibrary.wiley.com/doi/epdf/10.1002/food.19970410315

[58] Mendlinger, S., Benzioni, A., Huyskens, S. and Ventura, M. (1992) Fruit Development and Postharvest Physiology of *Cucumis metuliferus* Mey., a New Crop Plant. *Journal of Horticultural Sciences*, **67**, 489-493. https://doi.org/10.1080/00221589.1992.11516274

[59] Fox, A.J., Pozo-Insfran, D.D., Lee, J.H., Sargent, S.A. and Talcott, S.T. (2005) Ripening-induced Chemical and Antioxidant Changes in Bell Peppers as Affected by Harvest Maturity and Postharvest Ethylene Exposure. *HortScience*, **40**, 732-736. https://doi.org/10.21273/HORTSCI.40.3.732