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# STUDY ON THE EFFECT OF HARVEST AGE ON PHYSICAL CHARACTERISTICS, REDUCING SUGAR CONTENT, AND VITAMIN C CONTENT OF CUCUMBER FRUITS (Cucumis sativus L.)

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## ABSTRACT

*The study was conducted to determine the physiological maturity stage of the F1 hybrid cucumber cultivar Amata 765 cultivated at An Huu commune, Dong Thap province, thereby providing a scientific basis for harvesting to ensure optimal fruit quality. Physiological and biochemical methods were employed to analyze changes in selected parameters - including fruit length, diameter, reducing sugar content, and vitamin C content - during fruit growth and development from fruit set to maturity. Results revealed that day c post-pollination represents the ideal stage for cucumber fruit development and quality, at which fruit dimensions approached maximum values (length a cm, diameter b cm), while vitamin C and reducing sugar contents reached peak levels before exhibiting a slight decline thereafter. Consequently, harvesting at this precise timing is essential to maximize both yield and nutritional value of the fruit.*

***Keywords:*** *Cucumber, physical properties, chemical composition, harvest time.*

## 1. Introduction

Cucumber (*Cucumis sativus* L.), a member of the Cucurbitaceae family, is a fruit vegetable with a long history of cultivation and is currently grown widely around the world. It is commonly consumed fresh or processed and is valued for its cooling properties; it is used in salads and pickled products and serves as a rich source of vitamins and minerals. Cucumber has also been reported to possess medicinal properties, such as alleviating jaundice, and is appreciated for its characteristic aroma and crisp texture (Kaur & Sharma, 2022). In Vietnam, the cultivation area of cucumber has been continuously expanding due to stable market demand and high economic returns for growers (Cuong et al., 2023).

A notable characteristic of cucumber is its high adaptability, allowing it to grow on various soil types and to be successfully cultivated under both traditional farming practices and modern greenhouse systems (Mallick, 2022). Fruit morphology varies considerably among cultivar groups. While East Asian cultivars are favored for their long fruits, the North American fresh market prefers smooth fruits of medium size (20–30 cm). In contrast, processing cultivars (for pickling) in North America and Europe are characterized by short fruits (5–15 cm) with a rough surface. Modern cultivation trends have also seen the development of parthenocarpic cucumber cultivars for greenhouse production, including two main types: long-fruited cultivars (30–40 cm) and Beit Alpha/Mediterranean types (12–15 cm) (Grumet et al., 2022).

In addition, cucumber is a fruit vegetable with high nutritional and medicinal value, containing approximately 95–96% water, very low calories, and serving as a source of dietary fiber, vitamins (particularly vitamins K, C, and B-complex), and minerals such as potassium and calcium. Numerous studies have reported that cucumber is rich in bioactive phytochemicals, including polyphenols, cucurbitacins (with anticancer properties), flavonoids, and carotenoids. As a result, cucumber exhibits various health-promoting properties, such as antioxidant, anti-inflammatory, and antimicrobial activities, as well as benefits in blood glucose and blood pressure regulation. Notably, these bioactive compounds have been shown to support cardiovascular health, improve skin health, enhance digestion, and offer potential in preventing certain chronic diseases. The nutritional composition and levels of bioactive compounds in cucumber can vary depending on cultivar, cultivation conditions, harvest time, and processing methods. Therefore, owing to its diverse composition and significant health benefits, cucumber is regarded as an important natural functional food in the human diet (Uthpala et al., 2020).

Harvest timing has a direct impact on physiological maturity and the overall quality of cucumber fruits. Harvesting too early results in underdeveloped fruits characterized by incomplete crispness, bland flavor, and substandard commercial size. Conversely, delayed harvesting leads to soft and spongy fruit tissues, hardened seeds, and reduced edibility due to excessive changes in cellular water content (Burrows, 2021). Bitterness may develop as a result of cucurbitacin C accumulation, a naturally occurring triterpenoid compound that increases when fruits become overmature or when plants experience environmental stress (Fan et al., 2024). These changes are closely associated with pectin degradation, alterations in cell wall structure, and a reduction in turgor pressure within parenchyma cells, ultimately affecting both sensory attributes and nutritional quality of the fruit (Paniagua et al., 2014).

This study aims to evaluate the effects of different harvest ages on the physical characteristics and chemical composition of cucumber fruits cultivated in An Huu, Dong Thap province. Through the analysis and comparison of relevant parameters, the study seeks to provide a scientific basis for determining the optimal harvest time to ensure high fruit quality. The findings are expected to have not only theoretical significance but also practical value, assisting growers and agro-processing enterprises in improving production efficiency and minimizing postharvest losses.

## 2. Materials and Methods

### 2.1. Plant Material

The cucumber (*Cucumis sativus* L.) cultivar used in this study was the F1 hybrid Amata 765, originating from Thailand and imported by Trang Nong Company Limited.

### 2.2. Research Methods

#### *2.2.1. Experimental Design*

Cucumber fruits were cultivated in An Huu commune, Dong Thap province, to ensure uniformity in climatic conditions, soil characteristics, and cultivation practices. Harvesting was conducted at five different stages: 7, 9, 11, 13, and 15 days after pollination (DAP). Fruits were harvested in the morning between 7:00 and 9:00 a.m. and were clearly labeled according to their harvest age.

After harvesting, samples were placed in cushioned baskets and transported to the laboratory within 4 hours for analysis of the selected parameters.


**Figure 1.** Cucumber fruits harvested at different times.

*2.2.2. Analytical Methods*

The monitored parameters and analytical methods applied in this study are described as follows.

**Morphological and Physical Parameters**

**Fruit length and diameter (cm):**

Fruit length and diameter were measured using a micrometer caliper with a precision of 0.01 mm and converted to centimeters. Fruit length was measured from the blossom end to the stem end, while fruit diameter was measured at the widest part of the fruit. Results were averaged from 5–10 fruits per sample (Anders et al., 2019).

**Fruit volume (cm³):**

Fruit volume was determined using the water displacement method. Fruits were wiped dry and immersed in a graduated glass cylinder (250–500 mL) containing a known initial volume of water ($V_1$). The increased water volume ($V_2$) was recorded, and fruit volume was calculated using the formula:

$$\mathbf{V = V_2 - V_1}.$$

Results were averaged from 5–10 fruits per sample (Huynh et al., 2020).

**Fruit weight (g):**

Fruit weight was measured using an electronic analytical balance with a precision of 0.01 g (manufactured in Japan). Fruits were dried, placed directly on the balance pan, and recorded once the reading stabilized. Mean values were calculated from 5–10 fruits per sample (Kator et al., 2018).

**Fruit firmness (kg/cm²):**

Fruit firmness was measured using a penetration-type firmness tester with a measuring range of 0–5 kg and a division of 50 g. Fruits were fixed in position, and a conical probe with a diameter of 3–5 mm was inserted into the midsection of the fruit to a depth of 5–8 mm. The maximum force (kg) required to penetrate the fruit tissue was recorded as the firmness index. Each fruit was measured at three symmetrical positions, with 5–10 fruits per sample, and the average value was calculated (Wang et al., 2020).

**Biochemical Parameters**

**Reducing sugar content (%):**

Reducing sugar content was determined using the Bertrand method, based on the reduction of $Cu^{2+}$ ions in Fehling's solution. Samples were extracted with hot water, filtered, neutralized, and titrated with Fehling's solution until the blue color of $Cu^{2+}$ completely disappeared. The reducing sugar content was calculated using the Bertrand conversion table. Each sample was analyzed in triplicate, and the mean value was reported (Trong et al., 2019).

**Vitamin C content (mg/100 g):**

Vitamin C content was determined using the DCPIP (2,6-dichlorophenol indophenol) titration method based on the procedure described by Pham et al. (2024). A 0.10 g sample was extracted with 20 mL of 4% oxalic acid and centrifuged at 10,000 rpm for 30 minutes. The supernatant was used for analysis. A mixture of 10 mL of sample extract and 10 mL of 4% oxalic acid was titrated with DCPIP solution (denoted as $V_2$) until a light pink color persisted for at least 90 seconds.

The control sample consisted of 5 mL of a 100 ppm standard ascorbic acid solution mixed with 10 mL of 4% oxalic acid. The volume of DCPIP consumed for the control was recorded as $V_1$.

Vitamin C content (mg/100 g) was calculated using the following equation:

$$Vitamin\ C = \frac{0.5 \times V_2 \times 20}{V_1 \times 10 \times 0.1}$$

Where:

**- $V_1$ (mL):** Volume of DCPIP used to titrate the control sample (equivalent to 0.5 mg ascorbic acid);

**- $V_2$ (mL):** Volume of DCPIP used to titrate the sample extract;

**- m (g):** Sample weight (0.1 g).

### 2.3. Data Analysis

Experimental data were processed and statistically analyzed using Microsoft Excel 2016 and Statgraphics Centurion XV.I software. Differences among treatments were considered statistically significant at a probability level of 5% ($p < 0.05$).

## 3. Results and discussion

### 3.1. Effect of Harvest Time on Morphological and Mechanical Properties of Cucumber Fruits

During fruit development, cucumber fruits exhibited distinct changes in morphological traits and mechanical properties, as presented in Table 1.

**Table 1.** Effect of harvest time on morphological and mechanical properties of cucumber fruits

| Harvest time (days) | Length (cm) | Diameter (cm) | Volume ($cm^3$) | Fruit weight (g/fruit) | Firmness ($kg/cm^2$) |
|---|---|---|---|---|---|
| 7 | $12.33 \pm 0.11^c$ | $1.60 \pm 0.10^c$ | $67.33 \pm 0.05^c$ | $73.12 \pm 0.05^c$ | $2.63 \pm 0.15^c$ |
| 9 | $14.46 \pm 0.05^b$ | $2.96 \pm 0.05^b$ | $90.66 \pm 0.11^b$ | $90.76 \pm 0.05^b$ | $3.60 \pm 0.10^a$ |
| 11 | $15.53 \pm 0.05^a$ | $3.03 \pm 0.05^{ab}$ | $108.00 \pm 0.05^a$ | $101.46 \pm 0.11^a$ | $3.63 \pm 0.05^a$ |
| 13 | $15.56 \pm 0.05^a$ | $3.13 \pm 0.05^a$ | $108.35 \pm 0.05^a$ | $101.66 \pm 0.11^a$ | $3.73 \pm 0.05^a$ |
| 15 | $15.53 \pm 0.15^a$ | $3.13 \pm 0.05^a$ | $108.33 \pm 0.11^a$ | $101.61 \pm 0.15^a$ | $3.33 \pm 0.01^b$ |

Values are means of three replicates. Within a column, values followed by different letters indicate significant differences at $p < 0.05$.

Data from Table 1 indicate that fruit length and diameter increased rapidly from 7 to 11 days after pollination (DAP). This growth was primarily driven by active cell division followed by cell expansion. From 13 to 15 DAP, fruit size reached a plateau and remained relatively stable, with length and diameter attaining near-maximum values of 15.53 cm and 3.03 cm, respectively, at 11 DAP. This stage marks the transition from active growth to the onset of fruit maturation (Grumet et al., 2022).

In addition to size changes, fruit volume and weight were closely associated with water accumulation and dry matter deposition. According to Abiodun and Adeleke (2010), during the early stages of fruit development, water content and soluble solids are relatively low; however, as fruit growth progresses, increased water uptake and solute accumulation lead to a rapid increase in both volume and weight. Upon entering the ripening stage, biochemical changes such as the hydrolysis of structural polysaccharides-particularly pectin-alter cell wall structure, causing fruit volume to stabilize or slightly decline (Brummell, 2006). Fruit weight increased markedly up to 11 DAP and then remained nearly constant, reflecting a reduction in growth rate and the dominance of physiological ripening processes. This trend indicates a physiological shift from active growth to maturation, during which dry matter synthesis decreases while respiration and intracellular transformations predominate, thereby slowing or terminating further weight gain (Ando et al., 2012).

Fruit firmness is an important mechanical parameter reflecting the integrity and state of pectin within the cell wall. According to Liu et al. (2018), in immature fruits, cell walls are thick and rich in insoluble pectin, contributing to high crispness and mechanical strength. As fruits progress into the ripening stage, the activity of pectinolytic enzymes-primarily polygalacturonase and pectinesterase-leads to pectin degradation, resulting in reduced firmness and cell-to-cell adhesion. Data in Table 1 show that firmness increased gradually from 7 to 11 DAP, remained relatively stable, and then slightly decreased from 13 to 15 DAP, clearly reflecting the physiological and biochemical changes occurring during cucumber fruit ripening.

Overall, variations in fruit size, weight, and firmness serve as clear indicators of fruit growth and maturation. Based on the combined assessment of these parameters, this study identified 11 days after pollination as the optimal harvest time, at which cucumber fruits exhibited the most desirable quality in terms of size, weight, and firmness.

### 3.2. Effect of Harvest Time on Biochemical Characteristics of Cucumber Fruits

Changes in reducing sugar content and vitamin C content of cucumber fruits at different harvest times are illustrated in Figure 2.

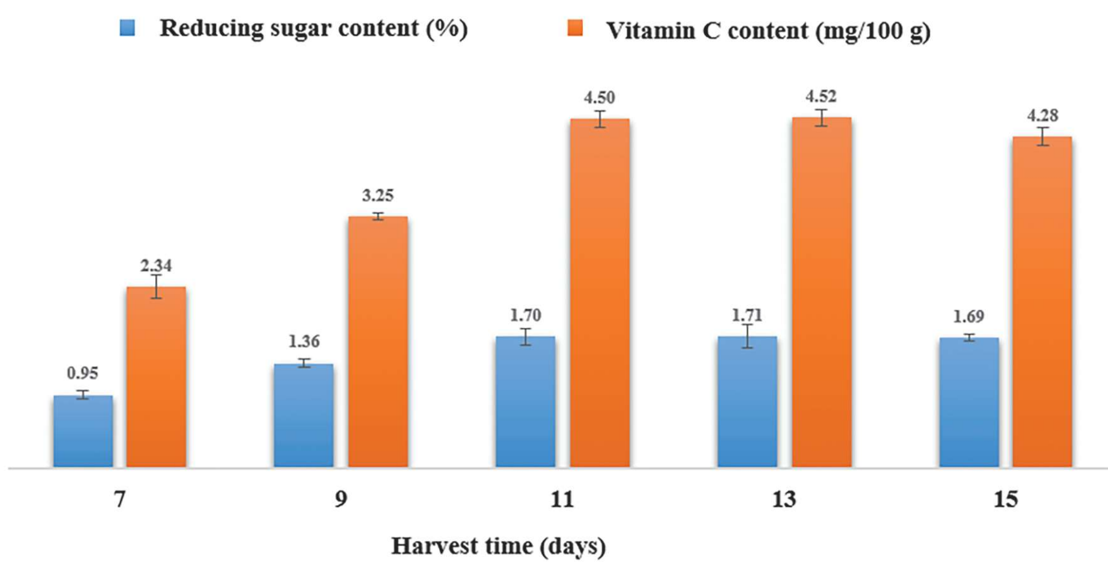


**Figure 2.** Effect of harvest time on biochemical characteristics of cucumber fruits

The results indicated that the reducing sugar content of cucumber fruits increased markedly from 7 to 11 days after pollination (DAP), reaching a maximum value of 1.70% at 11 DAP. This period corresponds to an intense phase of physiological growth in fruit tissues, characterized by the accumulation of soluble carbohydrates in the vacuole, as sugar transport and metabolism are highly active to meet the energy demands of rapid cell expansion and differentiation. This increasing trend in sugar content is consistent with the findings of Patel et al. (2013), who reported a rapid increase in total sugars during the mid-to-late developmental stages of fruits belonging to the Cucurbitaceae family, such as cucumber and zucchini.

However, after 11 DAP, the reducing sugar content tended to stabilize and slightly decline, reflecting a physiological transition from fruit development to maturation. This phenomenon can be attributed to an increase in respiratory activity during the physiological ripening phase, during which reducing sugars serve as substrates for cellular respiration to generate energy (ATP), thereby reducing the level of sugar accumulated in fruit tissues (Wills et al., 1998).

In parallel with changes in reducing sugars, vitamin C content in cucumber fruits also increased significantly during the early stages of development. Specifically, vitamin C concentration increased from 2.34 mg/100 g at 7 DAP to 4.50 mg/100 g at 11 DAP, followed by stabilization and a slight decrease at 13 and 15 DAP. The increase in vitamin C during early fruit development is attributed to the enhanced biosynthesis of ascorbic acid via the Smirnoff–Wheeler pathway, which is the primary route of ascorbate synthesis in plant tissues, particularly in rapidly growing young fruits (Davey et al., 2000).

As fruits enter the physiological ripening stage, vitamin C content tends to decline, reflecting changes in the balance between ascorbate synthesis and degradation. During this phase, ascorbic acid may be oxidized to dehydroascorbic acid or utilized as a substrate in the biosynthesis of ethylene, oxalate, and tartrate, processes that intensify during ripening. This reduction is considered a typical indicator of active metabolic turnover in fruit tissues and is closely associated with changes in the activity of enzymes such as ascorbate oxidase and peroxidase throughout fruit development (Lee & Kader, 2000).

Taken together, the results demonstrate that 11 days after pollination represents the stage at which both reducing sugar and vitamin C contents reach their highest levels, coinciding with maximum fruit size and a stable tissue structure. These findings confirm that 11 DAP is the most appropriate harvest time to optimize sensory attributes, nutritional quality, and storage potential of commercial cucumber fruits.

## 4. Conclusion

Cucumber fruits harvested approximately 11 days after pollination reached near-maximum size while accumulating the highest levels of reducing sugars and vitamin C. Therefore, this stage is considered the optimal harvest time for maximizing nutritional value and commercial quality of cucumber fruits. These findings have important practical implications, providing growers and agricultural enterprises with a scientific basis for determining appropriate harvest timing, thereby improving product quality, reducing postharvest losses, and meeting the quality requirements of both domestic and export markets.

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