Effect of Maturity Stages on the Quality of Cold Storage Iceberg Lettuce (*Lactuca sativa* var. capitata) for Export

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Abstract

Iceberg lettuce is one of the most important vegetables economically and nutritionally, but its perishable nature poses challenges for storage and long-distance transportation. This study investigated the effect of maturity stages on the quality of iceberg lettuce for export under cold storage conditions. A completely randomized design with three replications was used to evaluate four maturity stages based on days after planting (DAP): 52, 55, 58, and 61 DAP. The lettuce heads were stored at 3±2°C and a 95% relative humidity, and quality parameters were analyzed every three days until the end of storage. Sensory properties, weight loss, color change, total soluble solids, total phenolics, and decay rates were evaluated. The results showed that maturity stages significantly (*P* <0.05) affected the quality attributes of iceberg lettuce and that harvesting at the optimal stage is very important. Findings from this study confirmed that the quality parameters were preserved for the 58 DAP samples throughout the storage time. They indicated that at three weeks of storage time, the lowest weight loss (5.9%), color change (14.1), and decay rate (8.3%), and the highest sensory analysis (5 scores) and appearance were shown by the 58 DAP maturity stage lettuce. Therefore, harvesting iceberg lettuce at 58 DAP is recommended for long-distance exportation.

Keywords

Iceberg lettuce, maturity stages, quality

Introduction

Iceberg lettuce (*Lactuca sativa* var. capitata), a member of the Asteraceae family, is a widely consumed fresh perishable crop produced on a global scale (Meena & Kulakarni, 2022). Recognized for its nutritional and phytochemical properties, iceberg lettuce holds a prominent place among vegetables. However, its short shelf-life is a result of its high moisture content, which stands at about 95%, and
its rapid biological and physiological reactions (Kim et al., 2016). In the realm of agricultural production, iceberg lettuce plays a pivotal role, serving as a cornerstone of agricultural economies. Notably, in countries such as Vietnam, it is considered a high-value economic crop (Binh et al., 2014). Furthermore, its export potential is significant, boasting competitive advantages in international markets.

Maturity is the stage of growth that is of interest to consumers, and harvesting vegetables at the appropriate time is the most important factor for the determination of general quality and shelf life (Tilahun et al., 2011). Vegetables picked either too early or too late have shorter shelf lives than vegetables picked at the proper maturity stage (Gil et al., 2012). Harvesting lettuce at an inappropriate stage of maturity can also have a detrimental impact on its quality, so harvesting time remains a pivotal consideration in post-harvest handling (Rizzolo & Zerbini, 2012). When iceberg lettuce is harvested at an improper maturity, it becomes susceptible to both mechanical damage and physiological disorders, leading to a fast degradation in quality. Therefore, the maturity stages affect the quality of vegetables, particularly if the vegetables are harvested at an immature stage of maturity; they can become susceptible to shrivelling and mechanical damage, develop poor sensory qualities, and the color, weight, total soluble solids (TSS; good flavor), and phenolics can be negatively affected resulting in a loss of consumer confidence during marketing (Chutichud et al., 2011; Quamaruzzaman et al., 2022). According to Gil et al. (2012), if iceberg lettuce is harvested after reaching the mature stage, it begins developing a bitter flavor and its color changes due to enzymatic activity. Kang et al. (2008) reported that the decay rate is higher in immature lettuce than mature and over-mature ones.

Harvesting vegetables at either an immature or over-mature stage can also result in substantial post-harvest losses and poses challenges for expedited exportation due to elevated air freight expenses. Iceberg lettuce, in particular, experiences a decline in its quality and physicochemical attributes even before it reaches domestic and international markets via marine transport, leading to substantial market quality deterioration (Patil et al., 2017; Ikegaya et al., 2019). Beyond the quality aspect, vegetables harvested at inappropriate maturities complicate various post-harvest handling procedures such as packaging, transportation, and storage, which result in post-harvest losses ranging from 20% to 44% (Faqeerzada et al., 2018). As reported by Eriksson et al. (2012), iceberg lettuce ranks as the third most wasted crop during exportation, primarily due to the issue of harvesting at incorrect maturity stages.

Determining the ideal maturity stage presents a considerable challenge, and the passage of days after planting emerges as a critical factor in identifying this stage. This study provides basic information and insight for growers, consumers, and traders to reduce the post-harvest loss of vegetables like iceberg lettuce with a focus on the harvesting time for export purposes. It also contributes to the development of the export-oriented lettuce industry in Vietnam. Consequently, pinpointing the optimal time for harvesting vegetables is pivotal in ensuring that iceberg lettuce possesses superior quality, extended marketability, and an enhanced shelf-life. Nevertheless, knowledge pertaining to how the maturity stages of vegetables affects the post-harvest quality of iceberg lettuce designated for export remains limited. Therefore, the primary objective of this study was to ascertain the optimal maturity stage for cold-stored iceberg lettuce, with the aim of enhancing its quality and prolonging its marketability for export via sea freight, taking into account the number of days after planting.

**Materials and Methods**

**Plant materials**

Freshly harvested iceberg lettuce heads variety “Saula” (produced by the Enza Company) were obtained from a farm located in Moc Chau district, Son La province, Vietnam. After harvest, the samples were immediately transported to the Laboratory of Post-harvest Technology by wrapping them with low-density polyethylene (LDPE) and packing them inside...
carton boxes glued with polyethylene. Samples were then manually cleaned by using tissues, and damaged leaves were manually removed. Thereafter, cleaned samples free from any damage or defects were kept in a cool chamber storage at 3 ± 2°C with a 95% relative humidity.

**Experimental design**

The experiment was laid out in a complete randomize design (CRD) using the maturity stages as factors with four levels. Lettuce heads were harvested at different maturity stages according to days after planting (DAP): stage I (52 DAP), stage II (55 DAP), stage III (58 DAP), and stage IV (61 DAP). The levels were selected according to Chutichudet et al. (2011) for determination of the optimal maturity stage based on days after planting. Lettuce heads were packed in carton boxes with a layer of LDPE film on the inside of the boxes and stored in a cooling chamber at 3 ± 2°C and 95% relative humidity.

Quality parameters were analyzed every three days until they were no longer valid. Each parameter was replicated three times.

**Determination of quality parameters**

**Sensory evaluation**

The sensory analyses of the iceberg lettuce were carried out following the procedures of Aguero et al. (2011) and Belisle et al. (2021). Then, visual qualities, namely color, taste, internal and external morphology, and freshness, of the iceberg lettuce were assessed and scored following a 9-point rating scale with 9: excellent, 7: good, 5: fair, 3: poor, and 1: extremely poor. The average of these scale points was used as an estimation of the overall visual quality. A score of 5 was considered as the threshold for marketability (Vitti et al., 2005).

**Weight loss**

The weight loss of the iceberg lettuce was determined using the methods described by Lee & Chandra (2018). Seven heads per maturity level were used for weight loss determination. The initial and final weights were measured and then the weight loss (%) was calculated using the formula:

\[
\text{Weight loss} (\%) = \frac{\text{Initial weight (g)} - \text{Final weight(g)}}{\text{Initial fresh Weight(g)}} \times 100
\]

**Color**

The color change of the iceberg lettuce was determined by using a chroma meter (CR 400-410 Japan) according to Lee & Chandra (2018). It was calibrated using a standard white plate (Y=81.8, x =0.3215, y =0.3392). Three samples per replication were used and three readings from the left, middle, and right parts of a leaf were taken. Color change was quantified as the \( L^* \), \( a^* \), \( b^* \) color space where \( L^* \), \( light \_a^* \) indicated the green and red colors and \( b^* \) indicated the yellow and blue colors.

From the values of \( L^* \), \( a^* \), \( b^* \), the total color difference (\( \Delta E^* \)) was also calculated using the formula:

\[
\Delta E^* = \sqrt{(L0 - L)^2 + (a0 - a)^2 + (b0 - b)^2}
\]

where \( L0^* \), \( a0^* \), \( b0^* \) represent the values after harvest and \( L^* \), \( a^* \), \( b^* \) indicate a reading on any evaluation day.

**Total soluble solids (TSS)**

The total soluble solids were determined by using a digital refractometer (PAL-1, LRO3*2 Tokyo, Japan) according to Vargas-Arcila et al. (2017).

**Total phenolic content (TPCs)**

The TPC was determined by Folin-Ciocalteu reagent (FCR) using gallic acid as the standard according to the methods of Singleton (1999). Five grams (5 g) of iceberg lettuce was extracted three times with 25 mL of 99.8% methanol by grinding using a mortar and pestle. Then, the extract was homogenized by a homogenizer (IKA, T25 digital ULTRA-TURRAX) and centrifuged for 10 min at 7000 rpm at 4°C (Centrifuge 5810R, Eppendorf, Hamburg, Germany). Gallic acid solution served as the standard for preparing the calibration curve and was prepared with a 1 mg mL\(^{-1}\) ratio. Various concentrations of gallic acid solutions in methanol (0, 10, 20, 30, 40, and 50 μg mL\(^{-1}\) ) were prepared. Each sample extract (1mL) was...
added to a test tube and 10% 2 N Folin-Ciocalteu reagent (5mL) was added. Finally, 7% Na2CO3 (4mL) was added to the solution to make a final volume of 10mL and mixed well. The absorbance was measured by using a UV-spectrophotometer (UV-1900i-Shimadzu Kyoto, Japan) at a wavelength of 765nm. The total phenolic content of the extracts was expressed as mg gallic acid equivalents (GAE) per gram of sample and calculated by the following formula:

$$\text{TPC (mg GAE/g FW)} = \frac{c \times v}{m}$$

where TPC is the total phenolic content in mg GAE/g FW, c is the concentration of gallic acid from the calibration curve in mgmL-1, v is the volume of the extract in mL, and m is the mass of the extract in grams.

**Decay rate**

The amount of iceberg lettuce damaged during cold storage was calculated according to the methods of Singh et al. (2014) with the formula:

$$\text{Percentage of decayed rates} = \frac{\text{Number of deteriorated}}{\text{Total number of samples}} \times 100$$

**Statistical analysis**

Data were analyzed by using one-way analysis of variance (ANOVA) using Minitab 16 statistical software and MS Excel software. Mean comparisons were done by using Tukey’s multiple comparison test to determine the significance of differences among the treatments at a 95% confidence level. Results were given as mean ± SE (standard error). Each mean was the average of three observations.

**Results and Discussion**

**Sensory quality**

The sensory properties of iceberg lettuce, namely color, taste, morphology (both internal and external), freshness, and overall visual quality (OVQ), were examined. According to **Figure 1**, the OVQ of iceberg lettuce remained constant across all maturity stages until the sixth day of storage, displaying no significant differences ($P >0.05$). However, following the sixth day of storage, the OVQ experienced a decrease across all stages, except for the lettuce harvested at 58 DAP, which did not exhibit a decrease in OVQ until after nine days. This decrease in OVQ could be attributed to reduced freshness resulting from moisture loss and discoloration triggered by enzymatic reactions. This observation agrees with the findings of Farahanian et al. (2023), who reached a similar conclusion. Furthermore, the overall acceptability of the lettuce decreased due to the formation of condensation inside the packaging material, leading to deterioration and rendering the samples unacceptable for commercial markets. Similarly, Lee & Chandra (2018), also reported that the overall visual quality of lettuce decreased during various storage periods.

The decline in the OVQ may have also been attributed to the negative impacts on both the external and internal components of lettuce, derived from defects and increased respiration rates during storage. Aguero et al. (2011) and Hunter et al. (2017) reported similar observations. Similarly, the research conducted by Gil et al. (2012) supports our findings, as it indicated that immature vegetables experience greater water loss, resulting in wrinkling and diminished flavor quality. Quamruzzaman et al. (2022) underscored the importance of harvesting vegetables and fruits at appropriate stages of maturity, as their study suggested that immature produce is prone to shrivelling, mechanical damage, and developing poor color, flavor, and taste resulting in a loss of consumer confidence.

Our results, as shown in **Figure 1**, revealed that throughout all the storage periods, lettuces harvested at 52 DAP exhibited the lowest OVQ, whereas samples at 58 DAP displayed the highest OVQ. This difference could be attributed to the fact that the lettuces harvested at 58 DAP reached their optimal maturity, allowing them to maintain a superior appearance, and have lower rates of wilting and shrivelling, fewer defects, and reduced decay, all while preserving a higher level of freshness compared to the other maturity stages. These findings are consistent with those of Quamruzzaman et al. (2022), who emphasized the significance of optimum maturity indices in influencing the growth and quality of high-value vegetables.
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Importantly, it is worth noting that after 24 days of storage, samples harvested at 61 DAP demonstrated a lower OVQ compared to those harvested at 55 DAP (*P* <0.05). This difference could be linked to the inclination of lettuce harvested at a later stage to develop russet spots, as well as an increased susceptibility to enzymatic browning due to the breakdown of cellular compartmentalization and membrane integrity. In the end, as the evaluation period concluded, samples harvested at 58 DAP consistently exhibited a significantly higher OVQ (*P* <0.05). Overall, the results of this study suggest that the best maturity stage for harvesting iceberg lettuce for cold storage is 58 DAP due to this stage maintains the overall visual quality during storage.

**Weight loss**

*Figure 2* shows the effect of the maturity stages on the weight loss of iceberg lettuce during cold storage. Over the entire storage period, weight loss increased as the moisture content decreased, resulting in reductions in overall weight.

According to Shehata *et al.* (2012), the weight loss increases with the increase in the storage period due to the loss of moisture and dry matter through respiration and transpiration processes. Iceberg lettuce, with its high surface-to-volume ratio, is particularly susceptible to moisture loss, which can lead to wilting and shrinkage as result less appealing to consumers.

During early storage times, the percentage of weight loss was low due to packaging interactions with lower temperature-maintained transpiration process. As Yang *et al.* (2018) emphasized, maintaining low storage temperatures is essential for Chinese cabbage. This strategy effectively reduces the respiration rate of the vegetables and minimizes the loss of moisture and nutrients.

Throughout the storage period, the highest weight loss was recorded in the 52 DAP treatment. This high weight loss could have been derived from several factors, including its lower head compactness, a higher rate of transpiration, and increased skin permeability to water vapor. In contrast, the lowest weight loss was observed for the samples at 61 DAP (*P* <0.05). However,
after a three-week storage period, the 58 DAP lettuces exhibited significantly lower weight loss ($P < 0.05$). This could be attributed to their reduced metabolism, resistance to water loss, and lower respiration rates. Famuyini et al. (2020) reported that the highest values of weight loss for fruits over maturity might be due to the rate of respiration and concentration of CO$_2$ being higher inside the storage system causing toxicity to samples and resulting in unusable samples. The stomata of the 52 DAP sample was very active and had a high surface area to volume ratio, resulting high water loss and contributing to weight loss. This work also agrees with the work of Champa et al. (2007).

The 61 DAP lettuces exhibited significant water loss, likely attributable to the presence of cracks and blemishes, which rendered the heads more susceptible to increased water loss. Water loss is a primary factor in the deterioration of vegetables, as it directly reduces the fresh weight and quality, concurrently hastening the processes of ripening and senescence, thereby shortening their shelf-life. Balaguera-López et al. (2016) further observed that immature vegetables and fruits undergo more pronounced weight loss due to the incomplete development of cuticular waxes on the tissue surface, resulting in enhanced water loss through transpiration.

**Color change**

According to Xing et al. (2022), color serves as one of the crucial quality indicators for assessing the freshness of vegetables particularly for marketing. The effect of maturity stages on color changes ($\Delta E^*$) of iceberg lettuce during cold storage are presented in Figure 3. The results of Figure 3 shows that the color change of iceberg lettuce was significantly ($P < 0.05$) affected by the maturity stage. A gradual increase in color change was observed in all the maturity stages. Previous studies by Lee & Chandra (2018) corroborate these findings and attribute the increase in color change during lettuce storage at 10°C to biochemical and enzymatic activities, such as the formation of browning due to polyphenol oxidases.

Martín-Diana et al. (2008) also noted that prolonged storage periods led to a decrease in the value of fresh-cut lettuce. The heightened color
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**Figure 3.** Effect of maturity stage on the color change of iceberg lettuce during cold storage

changes could likely be attributed to enzymes like chlorophyllase and magnesium decalactase, which reduce the levels of chlorophyll. The reduction in water content in vegetables also results in increased chlorophyllase activity and a subsequent decrease in chlorophyll levels, leading to increased color changes. This observation aligns with the findings of Aguero *et al.* (2008).

The results implied that up to the 15th day of storage, color change was lowest in the 52 DAP lettuce and was significantly affected on the 6th, 12th, and 15th days (*P* <0.05). However, after the 18th days of storage, the 52 DAP lettuce exhibited the highest color change (*P* <0.05) among the examined maturity stages, with no significant differences observed at 27 and 30 days (*P* >0.05). Among the four samples stored for one month, the 58 DAP samples displayed the lowest color change (∆E*) value after two weeks of storage, followed by the 61 DAP samples (Figure 3). The increase in color difference during storage indicated a degradation in the color quality of fresh iceberg lettuce.

These findings are consistent with the works of Hunter *et al.* (2017) who found that immature stages of lettuce have a shorter shelf-life and greater discoloration compared to mature heads of lettuce. However, in contrast, the research of Hilton *et al.* (2009) showed that pinking was more prevalent in over-mature lettuce compared to the tissues of young or mature vegetables, and Kang *et al.* (2008) also reported that over-mature lettuce heads exhibited higher levels of discoloration than mature heads.

**Total soluble solids (TSS)**

**Figure 4** shows the effect of the maturity stages on the TSS of iceberg lettuce during the cold storage period. Total soluble solids increased gradually with the extended storage period, reaching a peak on the 18th day of storage, and then subsequently declined. Significant differences among maturity stages were also observed (*P* <0.05). Gutierrez *et al.* (2008) observed similar increases in TSS for goldenberry fruits at various maturity stages during storage. The results indicated that TSS in iceberg lettuce was highest for the 61 DAP maturity stage up to the 18th day of storage, with significant differences (*P* <0.05) observed among the different maturity stages. Conversely, the lowest TSS contents were recorded for the 52 DAP maturity stage (*P* <0.05) throughout the
storage period. After three weeks of storage, the 58 DAP lettuces exhibited the highest TSS content ($P > 0.05$), while the lowest was observed in the 61 DAP samples at the 30-day storage time point ($P < 0.05$).

The increase in TSS could be attributed to the breakdown of starches and polysaccharides into soluble sugars, whereas the decline could be associated with senescence, starch depletion, and the exhaustion of organic acids. Kaewklin et al. (2018) attributed changes in TSS during the maturation process to the hydrolysis of starches to simple sugars.

Variations in TSS values may arise from differences in chemical processes such as metabolism and respiration rates among maturity stages (Vargas et al., 2017). As noted by Balaguera-López et al. (2016), more mature vegetables tend to accumulate higher TSS. Gutierrez et al. (2008) observed similar patterns in cape gooseberry, where matured fruits displayed higher TSS levels than lower mature ones.

It is worth noting that when iceberg lettuce becomes over-mature, it can develop a bitter taste, leading to a loss of marketability. This underscores the importance of harvesting at the optimal maturity stage for ensuring good eating quality.

**Phenolic compounds**

Figure 5 shows a decreasing tendency of phenolic compounds with the increase of storage duration, with significant differences ($P < 0.05$) among maturity stages. The decrease in phenolic content during storage may have been due to its reduced synthesis and transformation into other substances, as well as the breakdown of cellular compartmentalization with phenolics being oxidized by polyphenol oxidase and peroxidase enzymes to generate brown tannins (Liu et al., 2012; Patay et al., 2016). A slight decrease is supported by the work of Patil et al. (2017) who found phenolic content decreases during the cold storage of lettuce. In the paper of Hunter et al. (2017), levels of phenolic compounds associated with polyphenol oxidase discoloration were shown to be similar in immature, mature, and over-mature lettuce. Islam et al. (2019) also found that the phenolic concentration decreased during storage of romaine lettuce in modified atmosphere packaging at 8°C.

However, the results showed that small differences in the content of phenolic compounds were found among the maturity stages. Wurr et al. (2003) also found similar results in phenolics among mature, immature, and over-mature lettuce heads. According to Figure 5, the highest phenolics (0.39 mg GAE/g FW) were recorded at the 52 DAP stage of maturity at day zero, and the
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Our results agree with the previous work of Chutichudet et al. (2011) who found significant changes in total phenolic content in lettuce at different plant ages, with the highest phenolics at the early stages of development due to mature plants being under oxidative stress as the plant became senescent. Generally, our results imply that total phenolic content tends to decline during the maturity progress of iceberg lettuce and agrees with the results of Zhang et al. (2022) on plums, and Wojdylo et al. (2020) on apples.

Decay Rate

In our results shown in Figure 6, no decay symptoms were found for the first two weeks of storage. However, lettuce decay became apparent in all maturity stages after 18 days due to appearance of symptoms of discoloration, softening, water-logging, and tissue breakdown with the least severe decay observed at stage 3 (58 DAP). The increase in decay seemed to begin from wounded tissue surfaces when accumulated free water from condensation at the bottom of the LDPE film directly contacted the lettuce tissue, leading to decay due to the rapid multiplication of microorganisms. It also might have been due to tissue breakdown as result of the removal of moisture from samples.

As shown in Figure 6, the decay rate was highest in 52 DAP lettuce until 24 days of storage, followed by 61 DAP, and lowest in 58 DAP. This is likely because the 52 DAP lettuces had more stomata than the others, a higher metabolic rate, and a more vulnerable skin structure for water loss and decay. This idea is further supported by the work of Kang et al. (2008).

According to Champa et al. (2007), cabbages harvested at early mature stages are in an actively growing phase with rapid cell division and enlargement. The 52 DAP icebergs had a thin cuticle and epidermal layer, which made them susceptible to damage and disruption of the cuticle, allowing for increased water loss.

However, our results also show that during the evaluation periods of 27 and 30 days, the

Note: Vertical bars represent the standard error of the mean of three replications; bars having different letters are significantly different (P < 0.05) according to Tukey’s multiple comparison test.

Figure 5. Effect of maturity stage on the phenolic content of iceberg lettuce during cold storage

Figure 6. Effect of maturity stage on the decay rate of iceberg lettuce during cold storage
decay was higher in the 61 DAP lettuce due to its higher respiration rate and high susceptibility to splitting, physiological disorders, and pathogens (Figure 6). This work agrees with the results of Moneruzzaman et al. (2008). On the basis of our results, we can conclude that the decay rate was highest in the 61 DAP lettuce, followed by 52 DAP, and lowest in 58 DAP, with significant differences among the maturity stages. The texture of immature iceberg lettuce heads is soft and easily damaged while lettuce heads with optimum maturity have firm heads and maximal storage life (Martínez-Sánchez et al., 2012). This is because multi-leaf lettuce, which is an advanced maturity stage, has higher firmness and longer shelf life than baby-leaf lettuce, which is a less mature stage. Martínez-Sánchez et al. (2008) reported that the rate of deterioration is related to metabolic processes and the respiration rate, which are usually higher in younger leaves.

Conclusions

In this research experiment, the maturity stage at harvest was identified as a critical factor in ensuring the quality of iceberg lettuce, particularly in the situation of exportation. The most suitable maturity stage was found to be 58 DAP for optimal long-term storage with minimal quality deterioration. This stage exhibited the lowest weight loss, minimal color change, the lowest decay rate, and the highest overall visual quality. In conclusion, it is recommended that iceberg lettuce be harvested at 58 DAP for long-distance exportation, which holds benefits for consumers, growers, and traders alike. Furthermore, this study provides invaluable insights into the maintenance of overall vegetable quality and the reduction of post-harvest losses, all within the framework of days after planting. Further study is required to examine many lettuce varieties by using different storage temperatures and relative humidities.

Acknowledgements

The authors are grateful to the students Do Van Son and Vu Van Tung of K64CNTP of Vietnam National University of Agriculture for their participation and technical support in the execution and timely implementation of the experiments. Next, our appreciation goes to the VLIR-UOS project and Post-harvest Technology Department at the Faculty of Food Science and Technology, Vietnam National University of Agriculture.

References


Aguero M. V., Ponce A. G., Moreira M. R. & Roura S. I. (2011). Lettuce quality loss under conditions that favor...
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