ISSN 2475-5451

Research Article

International Journal of Diabetes & Metabolic Disorders

Determination Maturity Stages of Iceberg Lettuce Based on Sensory Quality, Color Values and Physiochemical Properties during Cold Storage

Tolcha Techane Alemu[1,2*] and Vu Thi Kim Oanh[1]

[1]*Tolcha Techane Alemu, Department of post-harvest management, Jimma University College of Agriculture and Veterinary Medicine, Ethiopia*

[2]*Vu Thim Kim Oanh, Department of Post- harvest Technology, Vietnam National University of Agriculture, Vietnam*

[*]Corresponding Author
Tolcha Techane Alemu, Department of post-harvest management, Jimma University College of Agriculture and Veterinary Medicine, Ethiopia.

Submitted: 2025, Jan 10; **Accepted:** 2025, Feb 17; **Published:** 2025, Feb 26

Citation: Alemu, T. T., Oanh, V. T. K. (2025). Determination Maturity Stages of Iceberg Lettuce Based on Sensory Quality, Color Values and Physiochemical Properties during Cold Storage *Int J Diabetes Metab Disord, 10*(1), 01- 09.

Abstract

Determining the best maturity stage for vegetables are a challenging practice due to the high variability found in crops. Maturity is the stage of growth that leads to a consumer's attainment of a specific goal. 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. Therefore, this study investigated the effect of maturity stage of iceberg lettuce based on sensory quality, color values and other physicochemical properties. Maturity stage was used as factors with four levels (52, 55, 58 and 61) based on day after planting (DAP). As the plants reached an older stage, the leaf color values in terms of L, a* and b* were decreased. In addition to that the result revealed that, samples harvested at 58 DAP was preserved color values, sensory quality and other physicochemical properties. The experiment concluded that, harvesting iceberg lettuce at optimal maturity stage very important to preserve different quality parameters and samples harvested at 58 DAP suggested for long term storage and also used for marketing purposes.*

Keywords: Maturity Stages, Iceberg Lettuce, Quality

1. Introduction

Fruits and vegetables are valued food because of they play an important role in human nutrition and health too [1]. Iceberg lettuce (Lactuca sativa var. capitata), is one of a member of the Asteraceae family vegetable and widely consumed fresh perishable crop produced on a worldwide scope [2]. The annual global production of lettuce (and chicory) is 27.2 million tons; China, the United States of America, India, Spain, and Italy are the top five producers [3]. Lettuce is also one of the most commonly consumed leafy vegetables worldwide and is available throughout the entire year. Recognized for its nutritional and phytochemical properties, iceberg lettuce holds a prominent place among vegetables [4]. Lettuce, a low-calorie, low-fat, and low-sodium salad vegetable, is rich in fiber, folate, and vitamin C, as well as essential minerals such as iron [5]. Quamruzzaman reported maturity of vegetables can be judged by various techniques and one is maturity stage [2]. The work by depicted the appropriate harvest for lettuce var [6]. Grand Rapids should be at 59 day after planting (DAP) in order to face fewer incidence of browning and maintain good quality.

They furtherly they studied each developmental stage of the plant affected polyphenol oxidase activity. The leaf section of the plant particularly affected polyphenol oxidase especially at 73 DAPS. In addition, at the more mature stages of the leaf, more phenolic substance, ascorbic acid content and pH value were apparent, while Quinone content decreased at advancing leaf age. In addition, as the plants maturity stage increased, the leaf color in terms of L* and b* decreased. Chutichudet also reported out of lettuce harvested at four stages (28, 42, 59 and 73 DAP), lettuce harvested at 28 DAP depicted higher phenolic content (2439.72 g/100 g FW) due to the activity of polyphenol oxidases enzyme is increased [6]. Therefore, iceberg lettuce is highly perishable and requiring attention and special harvesting at optimal maturity stages and properly handling in all stages of supply chain is very important. Quality parameters such as sensory property, physicochemical properties are very important to determine the optimal maturity stage of iceberg lettuce [6-9,4]. However, there is no enough information about time of harvesting iceberg lettuce and

post-harvest quality for different purposes. Hence the aim of this work is to understand the optimum harvesting maturity resulting in better quality and longer marketability of iceberg lettuce.

2. Materials and Methods

The samples (Iceberg lettuce heads) were freshly harvested at their different four stages of maturity in the farm located in Moc Chau district; Son La province, Vietnam. The samples were harvested according to for determination of the optimal maturity stage based on days after planting [6]. After harvesting, the samples were immediately transported to the laboratory of Post-harvest Technology by covering them with low-density polyethylene (LDPE) and put inside carton boxes glued with polyethylene, and then samples were manually cleaned and kept in cool chamber storage at 3±2 ° C with a 95% relative humidity. The damaged leaves of the samples were manually removed.

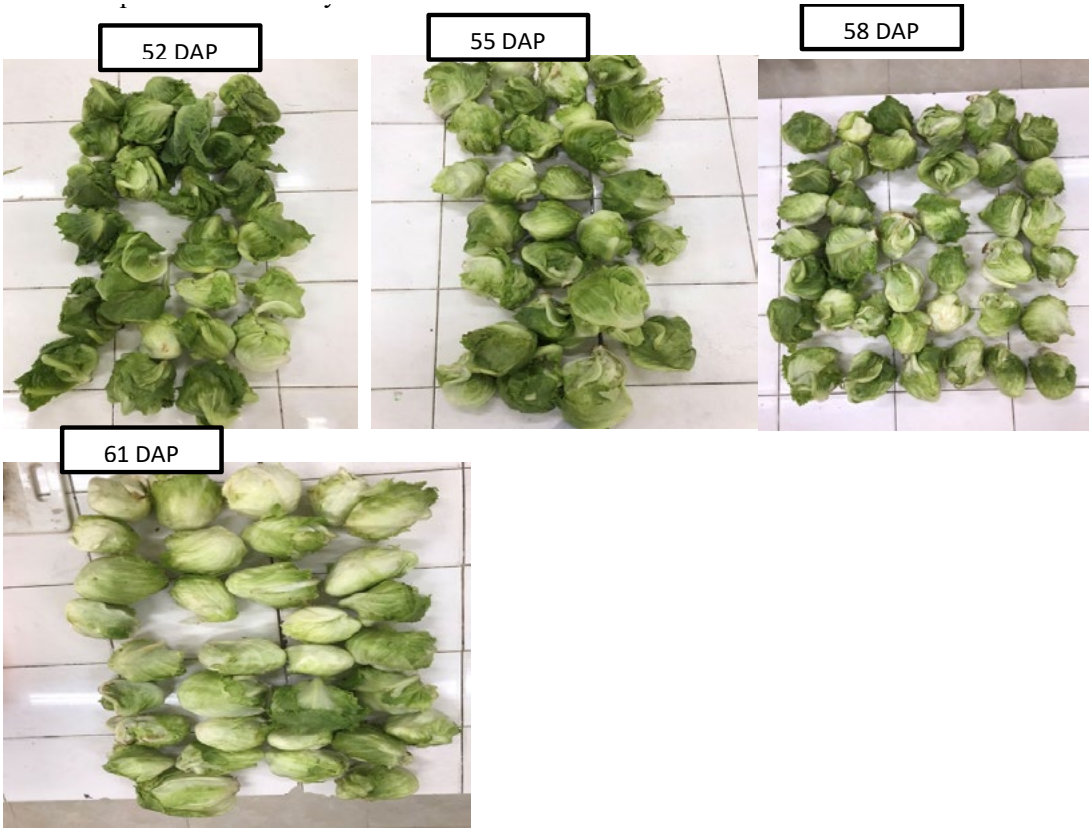

Figure 1: Iceberg Lettuce Harvested at Different Maturity Stages Based on Day after Planting (DAP).

3. Experimental Design

The research work was conducted by using complete randomized design (CRD) using the maturity stages as factors with four levels of stage I (52 DAP), stage II (55 DAP), stage III (58 DAP), and stage IV (61 DAP). Lettuce heads were packed in carton boxes with a layer of LDPE film inside of the boxes and stored in a cooling chamber at 3±2 o C and 95% relative humidity. Quality parameters were analyzed every three days until they were no longer valid. Each parameter was replicated three times.

4. Quality Parameters

4.1. Sensory Evaluation

The sensory analyses of the iceberg lettuce were done using methods [2]. Then, visual qualities, namely color, taste, internal and external morphology, and freshness, were assessed and scored following a 7-point rating scale with 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. For determination of the overall visual quality (OVQ) average of these scale points was used as an estimation of the overall visual quality. Iceberg lettuce scored above 4 was considered acceptable.

4.2. Weight Loss (%)

The weight loss of Iceberg lettuce was determined using the methods described by [10]. Seven (7) heads per levels were used for weight losses determination and were calculated using the below formula:

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

4.3. Color

The color of iceberg lettuce changes was determined by using chroma meter (CR 400 -410 Japan) according to [10]. It was calibrated using the standard white plate (Y= 81.8, × =0.3215, y =0.3392). Three samples pre-replication were used and three readings from left, middle and right part of leaf was taken. The CIE colour values L^* (black = -100 and white = +100), a^* (red)

(- = green and + = yellow) and b* (yellowness) (- = blue and + = yellow) were measured to describe the color of lettuce's leaf. Color changes was quantified as *L*, a*, b** color space where *L**, *light*, *a** indicates green and red color and *b** indicate yellow and blue color.

From values of *L*, a*, b**, the total color difference (*ΔE**) was also calculated using the formula.

$$\Delta E* = \sqrt{(Lo* - L*)^2 + (ao* - a*)^2 + (bo* - b*)^2}$$

L_0*, a_0*, b_0* represent the values at after harvest and *L**, *a**, *b** indicate the reading at any evaluation day.

4.4. Total Soluble Solids (TSS)

Total soluble solid was determined by using digital refractometer (PAL-1, LRO3*2 Tokyo,Japan) according to [7]. Initially the refractometer was calibrated with distilled water and small sample juice of 2-3 drops was placed on the prism of the refractometer and direct reading was taken.

4.5. 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). 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. Each sample extract (1mL) was added to a test tube and 10% 2 N Folin-Ciocalteu reagents (5 mL) was added. Finally, 7% Na_2CO_3 (4 mL) was added to the solution to make a final volume of 10mL and mixed well. The absorbance was measured by using an UV-spectrophotometer (UV-1900i-Shimadzu Kyoto, Japan) at a wavelength of 765 nm. 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:

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

where C total phenolic content mg GAE/g FW, c concentration of gallic acid from calibration curve in mg/mL, V volume of extract in mL, and m is mass of extract in gram.

4.6. Decay Rate

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

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

4.7. 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 ± SD (standard deviation).

5. Results and Discussion

5.1. Sensory Quality

The result of maturity effect on the freshness values of lettuce presented at table 1 below. Freshness was decreased for all maturity stage across storage time due to removal of moisture content. Agüero reported, there was the reduction of vegetables freshness across storage time [6]. Table one below showed samples harvested at 58 DAP maintained its freshness due to it harvest at optimal maturity and preserved it physicochemical properties. Storage time also resulted in substantial degradation in the appearance of lettuce heads, mainly loss of crispness, discoloration and browning development.

	Storage time (days)										
MS	0	3	6	9	12	15	18	21	24	27	30
52	4.7±0.27^{a}	5±0.10^{a}	4.7±0.15^{a}	4.3±0.18^{a}	3.7±0.27^{a}	3.3±0.35^{a}	3±0.20^{a}	2.6±0.35^{b}	1.6±0.15^{a}	1.6±0.15^{b}	1±0.10^{a}
55	5±0.00^{a}	5.3±0.15^{a}	5.3±0.16^{a}	4.7±0.25^{a}	4±0.00^{a}	4.3±0.25^{a}	4±0.21^{b}	2.5±0.37^{bc}	1.3±0.17^{ab}	1±0.10^{a}	1±0.11^{a}
58	5.7±0.25^{a}	5.3±0.17^{a}	5±0.11^{a}	5±0.20^{a}	4.7±0.25^{a}	5±0.21^{a}	4.7±0.25^{c}	2.7±0.36^{b}	2.3±0.23^{b}	2±0.17^{c}	1.7±0.14^{c}
61	6±0.00^{a}	5.7±0.18^{a}	5±0.23^{a}	4.3±0.23^{a}	4±0.0^{a}	4±0.17^{a}	3±0.2^{d}	3±0.33^{a}	1.7±0.16^{ab}	1.6±0.14^{b}	1±0.12^{a}

Table 1: Effect of Stage of Maturity on Freshness of Iceberg Lettuce.

Data are expressed as mean ± SD, each column was analyzed separately; when SD is stand for standard deviation, MS maturity stage. Means that do not share a letter are significantly different, significant ($p < 0.05$), according to Tukey test Comparison; 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.

Table 2 below shows the effect of maturity stages on visual color observation on iceberg lettuce across storage time for one month. The result shows that (Table 2) the value of color sensory evaluation decreased across storage time for all maturity stages. The reduction is due to that fact that removal moisture content and start wilting, enzymatic reaction and due to start of decay. The reduction of color sensory evaluation agrees with the work conducted by [6,](Agüero et al., 2011; Farahanian et al., 2023).

Lee et al. (2018) also reported the same opinion. After three weeks of storage time, samples 55 and 58 DAP insignificantly showed higher values compared to others.

Color

MS	Storage days 0	3	6	9	12	15	18	21	24	27	30
52	6±0.12^{a}	5±0.15^{a}	4±0.0^{b}	4± 0.0^{b}	4± 0.0^{b}	4± 0.0^{b}	3.7±0.52^{a}	3.5±0.0^{a}	1.7±0.35^{b}	1.3±0.0b	1±0.35^{a}
55	5.3±0.25^{a}	5.3+0.17^{a}	5±0.27b^{a}	5±0.0^{ab}	5± 0.0^{ab}	4.7±0.0^{b}	4.7±0.57^{a}	4±0.23^{b}	4±0.30^{a}	2.7±0.18^{ab}	1±0.3^{a}
58	6±0.14^{a}	5.3+0.16^{a}	5.3±0.25^{b}	5±0.05^{ab}	5±0.57^{ab}	5±0.57^{c}	4.7 ± 0.0^{a}	4±0.25^{b}	4±0.31^{a}	4±0.0^{a}	2±0.34^{a}
61	5.7±0.26^{a}	5.3+0.17^{a}	5±0.23^{a}	5±0.07^{ab}	5±0.0^{ab}	5±0.0^{c}	4.00±0.0^{a}	4.3±0.27^{c}	2±0.32b	1.7±0.15^{b}	1.3±0.33^{a}

Table 2: Effect of Stage of Maturity on Sensory Properties of Iceberg Lettuce During Cold Storage at 4 oC and 95% RH Color.

Data are expressed as mean ± SD, each column was analyzed separately; when SD is stand for standard deviation, MS = maturity stage.

Means that do not share a letter are significantly different, significant (P< 0.05), according to Tukey test Comparison Seven hedonic scale: 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.

The result of external morphology was indicated at **table 3** below. According to our results samples external morphology of all maturity stages were reduced across storage time. The reduction of external morphology across storage period was due to severe browning in the midrib bases. These results agree with the opinion of (Agüero et a., 2008). External morphology of samples harvested at 52 and 55 DAP affected due to wilting and moisture removal. The external morphology of 61DAP also damaged due to physiological disorder, russet spot and pinking rib. Mohamed also reported the same explanation for lettuce [11]. 58 DAP showed height value compared to others. This might be due to it harvested at optimal maturity stage and preserved its physiochemical properties and sensory quality.

MS	Days after storage 0	3	6	9	12	15	18	21	24	27	30
52	5.5±0.23a	5±0.27a	4.7±0.15b	4.7±0.15a	4.7±0.25a	4.3±0.0a	4.3±0.0a	4±0.14a	4±0.15a	1.6±0.15a	1±0.10b
55	5±0.24a	5±0.25a	5±0.0b	5±0.0a	5±0.0a	4.3±0.0a	4.3±0.0a	4±0.15a	4±0.17a	1.7±0.16a	1.3±0.14c
58	6±0.22a	5.7±0.24a	5±0.0b	5±0.0a	5±0.0a	4.7±0.17a	4.6±0.05^{ab}	4.3±0.16b	4.3±0.16ab	2.4±0.1b	1.7±0.24ab
61	6±0.21a	5.7±0.26a	5±0.0b	5.0±0.0a	5±0.0a	4.5±0.15a	4.5±0.0b	4±0.0a	4±0.14a	2±0.11ab	1±0.20b

Table 3: Effect of Stage of Maturity on External Morphology of Iceberg Lettuce.

Data are expressed as mean ± SD, each column was analyzed separately; when SD is stand for standard deviation, MS maturity stage.

Means that do not share a letter are significantly different, significant (P < 0.05), according to Tukey test Comparison Data are expressed as mean ± SD, each column was analyzed separately; Means that do not share a letter are significantly different, significant (p < 0.05 According to Tukey test comparison 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.

The result of internal morphology was appeared at **table 4** below. The result showed there was reduction of internal morphology for all levels of maturity stage. Particularly samples harvested at 52 DAP internal morphology reduced due to removal of more moisture content relatively compare with other levels of maturity. Samples harvested at 61 DAP also showed more internal morphology problems due to it harvested at over maturity stage.

This might be due to senescence is the last stage, characterized by natural degradation of the fruit or vegetable. Zhang also reported the same conclusion [12].

	Days after storage										
MS	0	3	6	9	12	15	18	21	24	27	30
52	5.7±0.5a	5.7±0.13a	5±0.14a	4.6±0.15a	4±0.21a	4±0.24a	4±0.0a	3±0.34a	3±0.47b	1.7±0.15a	1.8±0.12a
55	5.3±0.57a	5.3±0.15a	5±0.12a	4.7±0.17a	4.7±0.25^{bc}	3.7±0.25b	3±0.0b	3±0.28a	3±0.54b	1.8±0.17b	1.7±0.15bc
58	6±0.51a	5.3±0.17a	5.3±0.2a	5±0.16a	5±0.27c	4.7±0.23ab	3±0.0b	3±0.31a	2.3±0.43a	2±0.14ab	2±0.17b
61	5±0.56b	5 ±0.16a	5±0.18a	5±0.15a	4.3±0.24b	2.7±0.21a	2±0.10b	2±0.32ab	1.7±0.57c	1.3±0.23b	1±0.16a

Table 4: Effect of Stage of Maturity on Internal Morphology of Iceberg Lettuce.

Data are expressed as mean ± SD, when SD is stand for standard deviation, MS maturity stage.

Each column was analyzed separately; Means that do not share a letter are significantly different, significant (P< 0.05 According to Tukey test comparison 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.

The value of taste sensory properties was indicated at **table 5** below. Sample harvested at 61 DAP revealed higher taste values. This might be due to as stage of maturity increases physiological process increases and resulted high degradation of starch to simple carbohydrates. It also might be due to removal of moisture content. Samples harvested at 52 and 55 DAP revealed lower values of TSS due to present of phenolic compounds and resulted bitter taste. This consistent with the result of [6].

	Days after storage										
MS	0	3	6	9	12	15	18	21	24	27	30
52	2±0.15^{a}	3±0.0^{a}	3.6±1.15^{b}	3.6±0.16^{a}	3.4±0.10^{c}	3 ±0.15^{a}	2±0.20^{b}	2±0.11^{a}	1.3±0.15^{b}	1.3±0.27^{c}	1±0.34^{a}
55	2.7±0.17^{a}	3.2±0.15^{a}	3.5±0.19^{b}	2.6±0.15^{a}	3 ±0.10^{c}	2±0.16^{a}	2.7±0.15^{ab}	2.3±0.17^{a}	1.3±0.16^{b}	1± 0.26^{bc}	1.2±0.33^{a}
58	4±0.18^{a}	4.3±0.1^{a}	4.3±0.17^{b}	4.3±0.17^{a}	4.7 ±0.1b^{c}	5±0.17^{a}	5.7±0.16^{ab}	3.7±0.12^{a}	2.7±0.17^{a}	2.3±0.25^{b}	1.5±0.27^{a}
61	4.7 ±0.00^{a}	5 ±0.16^{a}	5.7±0.18^{b}	5.7±0.16^{a}	6.3±0.15^{a}	6.3±0.14^{a}	6.7±0.16^{a}	3±0.13^{a}	2±0.18^{d}	1.7± 0.28^{a}	1±0.31^{a}

Table 5: Effect of Stage of Maturity on Taste of Iceberg Lettuce.

Data are expressed as mean ± SD, when SD is stand for standard deviation, MS maturity stage.

Each column was analyzed separately; Means that do not share a letter are significantly different, significant (p < 0.05 According to Tukey test comparison 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.

The average over all visual quality of iceberg lettuce was presented at figure 1 below during storage for one month. Samples harvested at 52 DAP showed lower overall visual quality (OVQ) due higher bitter taste, moisture removal and etc. at the end of storage samples harvested at 61 DAP revealed lower OVQ due to decay and russet spot formation. 58 DAP revealed that, highest OVQ due to it harvested at optimal maturity stage and resulted with preserved physicochemical properties and sensory quality too. Hunter reported that, harvested vegetables at optimal maturity stage preserved its quality [8].

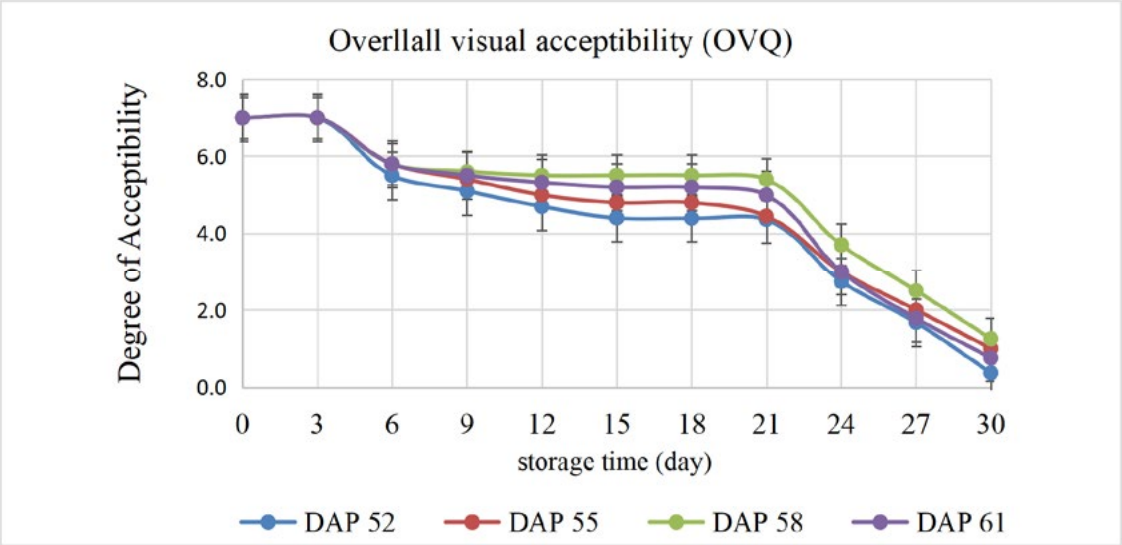

Figure 2: Average Acceptability Maturity Stage of Iceberg Lettuce during Cold Storage.

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. **Table 6, 7 and 8** shows effect of maturity stages on the color values of iceberg lettuce during storage for one month. According to table 6, the L- value was decreased for all maturity stages. For the results on leaf color, it was found that leaf color in terms of L* (lightness) tended to decrease their values with advancing developmental time. The decreased was due to polyphenol oxidases enzymes. The result is agreed with the found of [6]. These results implied that as plant age advances, leaf colour changed toward a less bright green colour. Table 7 also showed reduction of a* value (green-red). This might be due to removal of moister and wilting as well due to enzymatic activity. As maturity stage increase a* value was decreased. The lowest b* (blue-yellow) was decreased for samples harvested at 61 DAP. This might be due to the activity of enzyme. The found of agreed with these results [6].

	storage days										
MS	0	3	6	9	12	15	8	21	24	27	30
52	21.3±0.25a	20.3±0.16a	17.6±0.17c	15.7±0.23a	12.8±0.17a	11.8±0.14a	8.3±0.28a	7.4±0.19a	4.8±0.17a	3.2±0.14a	1.02±0.22b
55	18.5±0.13ab	18.4±0.17ab	16.7± 0.16a	14.4±0.16ab	12.1±0.13ab	10.9±0.6ab	7.2±0.27a	6.7±0.18a	4.4±0.16a	2.3±0.17a	0.4±0.23a
58	18.1±0.19ab	17.5±0.16bc	16.3± 0.2b	12.9±0.15b	11.8±0.12ab	10.8±0.10ab	6±0.26a	5.9±0.2a	4.2±0.11ab	2.1±0.16ab	0.4±0.24a
61	15.5±0.16b	15±0.15c	14.3± 0.2b	12.9±0.11b	10.4±0.11b	9±0.18b	5.8±028a	5±0.11a	2.5±0.14b	0.8±0.12b	0.23±0.21a

Table 6: Effect of Stage of Maturity on L-Value of Iceberg Lettuce During Cold Storage at 4oc and 95% RH.

Data are expressed as mean ± SD, each column was analyzed separately; Means that do not share a letter are significantly different, significant (P< 0.05) according to Tukey test

	Days after storage										
MS	0	3	6	9	12	15	18	21	24	27	30
52	-22.7±0.75^{c}	-22 ±0.5^{d}	- 21.93±0.76^{b}	-20.89±0.14^{b}	-20.54±0.36^{c}	-19.6±0.1^{d}	-14.5±0.1^{c}	-12.5±0.26^{c}	-9.3±0.12^{b}	-5.1±0.25^{b}	-3.6±0a
55	-20.1±0.4^{c}	-19.92±0.3^{c}	-19.8±0.07^{c}	-18.17±0.5^{b}	-15.97±0.24^{b}	-14.1±0.81^{c}	-11.8±0.03^{b}	-9.72±0.28^{bc}	-9.2±0.15^{b}	-4±0.17^{ab}	-0.39±0.23
58	-13.5±0.05^{b}	-12.17±0.8^{b}	-11.7±0.7^{b}	-11.4±0.18^{a}	-11.1±0.4^{a}	-10.4±0.8^{b}	-10.07±0.4^{ab}	-9.15±0.29^{ab}	-8.3±0.3^{b}	-2.7±0.19^{b}	-0.29±0.27^{a}
61	-9.5±0.5^{a}	-9.01±0.6^{a}	-8.35±0.3^{a}	-8.57±0.7^{a}	-8.4±0.84^{a}	-7.7±0.7^{a}	-7.68±0.2^{a}	-6.8±0.6^{a}	-5.4±0.27^{a}	-2.09± 0.18^{ab}	-0.27±0.17^{a}

Table 7: Effect of Stage of Maturity on A-Value of Iceberg Lettuce During Cold Storage at 4oc and 95%RH.

Data are expressed as mean ± SD, each column was analyzed separately; Means that do not share a letter are significantly different, significant (P< 0.05) according to Tukey test

	Days after storage										
MS	0	3	6	9	12	15	18	21	24	27	30
52	14.4±0.16c	9.95±0.29a	9.7±0.1c	9.4±0.24b	8.27±0.29b	8.3±0.25bc	6.5±0.27b	6.1±0.26b	3.9±0.30bc	3±0.23b	2.210±0.16ab
55	22.3±0.15a	21.07±0.26a	20.8±0.26a	19.7±0.22a	17.9±0.24a	14.5±0.19a	12.3±0.28a	9.4±0.280a	8.3±0.26a	7.2±0.24a	4.9±0.18a
58	16.567±0.17b	15.9±0.29a	13.5±0.11b	12.4±0.17b	10.9±0.23b	9.1±0.2ab	7.3±0.29b	6.4±0.10b	5.4±0.27b	6±0.29a	4.4±0.19a
61	8.2±0.27b	5.11±0.18a	3.3±0.23d	3.07±0.11c	2.9±0.17c	2.9±0.21c	2.6±0.25c	2.3±0.25c	1.96±0.3c	1.6±0.26b	1.14±0.15b

Table 8: Effect of Stage of Maturity on B-Value of Iceberg Lettuce during Cold Storage at and 95%RH.

Data are expressed as mean ± SD, each column was analyzed separately; Means that do not share a letter are significantly different, significant (P< 0.05) according to Tukey test, SD is Standard deviation.

Table 9 below shows effect of maturity stage of iceberg lettuce on color change during one month storage at 4oC and 95% RH. The result showed samples harvested at 52 DAP showed highest color change due to removal of moisture. Samples harvested at 61DAP also showed highest color change due to enzymatic reaction and physiological process. The result agreed with the result of who conducts experiment on the same samples [4].

Storage Time (days)	Stages of maturity			
	52	55	58	61
0	-	-	-	-
3	1.24±0.32^{a}	1.6±0.24^{a}	1.6±0.27^{a}	1.97±0.39^{a}
6	2.9±0.25^{b}	4.14±0.27^{ab}	3.85±0.26^{ab}	5.00±0.29^{a}
9	3.5±0.15^{b}	5.31±0.12^{ab}	5.21±0.13^{ab}	6.12±0.10^{a}
12	4±0.11^{b}	8.9±.14^{a}	7.8±0.13^{a}	9.045±0.16^{a}
15	5±0.16^{c}	13.5±0.17^{ab}	12.2±0.19^{b}	14 ±0.18^{a}
18	12.5±0.29^{c}	14.4±0.27^{ab}	15.3±0.32^{b}	20.5±0.26^{a}
21	22.6±0.15^{a}	18.4±0.14^{b}	18.2±0.16^{c}	21.6±0.18^{d}
24	23.5±0.30^{b}	22.7±0.29^{a}	20.96±0.25^{ab}	22.9±0.27^{c}
27	28.7±0.24^{a}	27.03±0.21^{ab}	25.3±0.25bc	26.9±0.18d
30	35.5±0.30^{a}	33.3±0.26^{ab}	28.8±0.34b^{c}	30±0.254^{d}

Table 9: Effect of Stage of Maturity on Color Change of Iceberg Lettuce during Cold Storage at 4oc and 95% RH.

Data are expressed as mean ± SD, each row was analyzed separately; Means that do not share a letter are significantly different, significant (P < 0.05), according to Tukey test comparison.

Figure three below showed effect of maturity stage on weight of lettuce during storage for one month. Our results at **figure 3** showed the highest value of weight was recorded and appeared for samples harvested at 61 DAP after planting. This might be due content of moisture and higher number of leaves or branch formations. The work of Champa on cabbage (Brassica oleracear L.) variety green coronet concurs with this found [13].

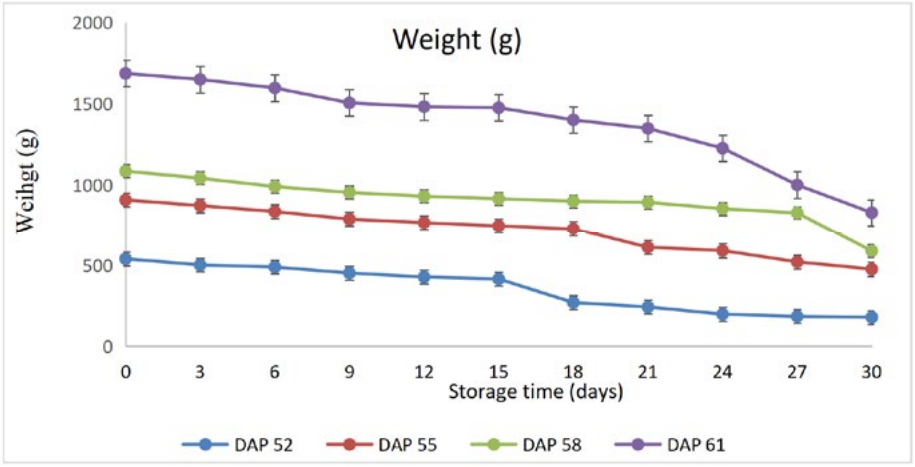

Figure 3: Effect of Maturity Stage on Weight of Iceberg Lettuce; DAP Is Stage of Maturity by Day after Planting.

Figure 4 below revealed the effect of maturity stage lettuce on weight loss across storage time. According to our result the values of weight loss increased across storage time. The result at figure 4 below mentioned showed that, samples harvested at 52 DAP exhibited the highest value. However, samples harvested at 58DAP planting demonstrated lowest value. The highest weight lost at 52DAP might be due to higher removal of moisture content due to smaller number of leaves. It was also due to lower head compactness, a higher rate of transpiration, and increased skin permeability to water vapor. This work concurs with the work conducted by [4].

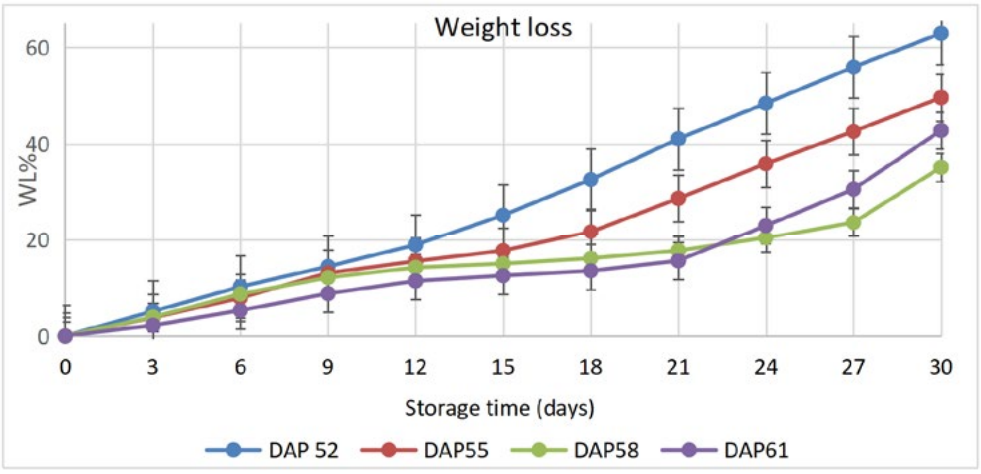

Figure 4: Effect of Maturity Stage of Iceberg Lettuce on Weight Loss.

Table 10 below shows effect of maturity stages lettuce on TSS value during storage time. According to our results, the values of TSS increased across storage time for all maturity stage. The increased TSS was due to the fact that starch change to simple carbs. It also due to physiological process like respiration rates increased with storage time for specific time. The removal of moisture also contributes for increased of TSS values. From our results samples harvested at 61 DAP revealed highest values due to as maturity stage increased sugar content will be up. The work is agreed with the research of [7].

	Storage time (days)										
MS	0	3	6	9	12	15	18	21	24	27	30
52	0.73±0.06^{d}	1.97±0.06^{a}	2.1±0.057^{b}	2.5±0.0^{a}	2.6±0.0^{c}	3.2±0.0^{c}	3.23±0.21^{c}	3.6±0.06^{ab}	3.5±0.153^{b}	3.37±0.21^{ab}	2.8±0.057^{b}
55	1.57±0.06 ^{c}	2.1±0.058^{ab}	2.3±0.0^{a}	2.7±0.4^{a}	2.8±0.0^{b}	3.3±0.12^{bc}	3.43±0.15^{bc}	3.7±0.4^{ab}	3.5±0.15^{b}	3.5±0.17^{ab}	3± 0.45^{b}
58	1.8±0.0^{b}	2.17±0.12^{a}	2.3±0.58^{a}	2.5±0.2^{a}	2.8±0.06^{b}	3.7±0.2^{ab}	3.87±0.06^{ab}	4±0.1b	4±0.1^{a}	3.8±0.153^{a}	3±0.1^{a}
61	1.9 ±0.05^{a}	2.23±0.058^{a}	2.4±0.12^{a}	2.7±0.06^{a}	3.0±0.0^{a}	3.97±0.21^{a}	4.00±0.20^{a}	4.3±0.21^{a}	3.2±0.2^{ab}	3±0.35^{b}	2.73±0.153^{b}

Table 10: Effect of Maturity Stage on TSS Of Iceberg Lettuce During Cold Storage at 4oC and 95% RH.

Data are expressed as mean ± SD, each column was analyzed separately; when SD is stand for standard deviation Means that do not share a letter are significantly different, significant ($p < 0.05$), according to Tukey test Comparison

6. Conclusions

Maturity stage affected sensory quality, color values and physicochemical properties of iceberg lettuce during cold storage. Sensory quality (freshness, color, morphology (external and internal), taste, color values (L, a and b*) and physicochemical properties (weight, weight loss and TSS) are very important to determine the optimal maturity stages of iceberg lettuce. The result of work exhibited and concluded 58 DAP samples maintained quality parameters, extended shelf life and suggested for long distance marketing system [14].

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.

References

1. Oliveira, D. C. R. D., Leal, P. A. M., Honório, S. L., & Soares, E. K. B. (2013). Sensory quality attributes of lettuce obtained using different harvesting performance systems. *Food Science and Technology, 33*, 239-244.
2. Quamruzzaman, A. K. M., Islam, F., Akter, L., & Mallick, S. R. (2022). Effect of maturity indices on growth and quality of high value vegetables. *American Journal of Plant Sciences, 13*(7), 1042-1062.
3. Nakai, J. (2018). Food and Agriculture Organization of the United Nations and the sustainable development goals. *Sustainable development, 22*, 1-450.
4. Tolcha, T. A., & Oanh, V. T. K. (2024). Effect of maturity stages on the quality of cold storage iceberg lettuce (Lactuca sativa var. capitate) for export. V*ietnam Journal of Agricultural Sciences, 7*(1), 2052-2063.
5. Kim, M. J., Moon, Y., Tou, J. C., Mou, B., & Waterland, N. L. (2016). Nutritional value, bioactive compounds and health benefits of lettuce (Lactuca sativa L.). *Journal of Food Composition and Analysis, 49*, 19-34.
6. Chutichudet, B., Chutichudet, P., & Kaewsit, S. (2011). Influence of developmental stage on activities of polyphenol oxidase, internal characteristics and colour of lettuce cv. Grand Rapids.
7. Vargas-Arcila, M., Cartagena-Valenzuela, J. R., Franco, G., Correa-Londoño, G. A., Quintero-Vásquez, L. M., & Gaviria-Montoya, C. A. (2017). Changes in the physico-chemical properties of four lettuce (Lactuca sativa L.) varieties during storage. *Ciencia y Tecnología Agropecuaria, 18*(2), 257-273.
8. Hunter, P. J., Atkinson, L. D., Vickers, L., Lignou, S., Oruna-Concha, M. J., Pink, D., ... & Monaghan, J. M. (2017). Oxidative discolouration in whole-head and cut lettuce: biochemical and environmental influences on a complex phenotype and potential breeding strategies to improve shelf-life. *Euphytica, 213*, 1-16.
9. Firouz, M. S., Alimardani, R., Mobli, H., & Mohtasebi, S. S. (2021). Effect of modified atmosphere packaging on the mechanical properties of lettuce during shelf life in cold storage. *Information Processing in Agriculture, 8*(4), 485-493.
10. Lee, J. S., & Chandra, D. (2018). Effects of different packaging materials and methods on the physical, biochemical and sensory qualities of lettuce. *Journal of Food Science and Technology, 55*(5), 1685-1694.
11. Mohamed, S. J., Rihan, H. Z., Aljafer, N., & Fuller, M. P. (2021). The impact of light spectrum and intensity on the growth, physiology, and antioxidant activity of lettuce (Lactuca sativa L.). *Plants, 10*(10), 2162.
12. Zhang, G., Shen, S., Takagaki, M., Kozai, T., & Yamori, W. (2015). Supplemental upward lighting from underneath to obtain higher marketable lettuce (Lactuca sativa) leaf fresh weight by retarding senescence of outer leaves. *Frontiers in Plant Science, 6*, 1110.
13. Champa, W. A. H., Palipane, K. B., Weerakkody, W. A. P., & Fernando, M. D. (2007). Maturity indices for harvesting of cabbage (Brassica oleracear L.) variety green coronet.
14. Belisle, C. E., Sargent, S. A., Brecht, J. K., Sandoya, G. V., & Sims, C. A. (2021). Accelerated shelf-life testing to predict quality loss in romaine-type lettuce. *HortTechnology, 31*(4), 490-499.