Jurnal Kultivasi Vol. 24(3) December 2025
ISSN: 1412-4718, eISSN: 2581-138x

Lestari RW · Kusumiyati · Mubarok S

Comparative analysis of color, texture, and water content in three shallot cultivars at different harvest ages

Abstract. Shallots are a major horticultural commodity with high economic value. The quality of shallots is determined not only by the quantity of the harvest but also by physical characteristics such as bulb color, texture, and water content. This study aims to evaluate the differences in these physical parameters in three popular local cultivars: Brebes, Sumenep, and Tuktuk, harvested at 56, 63, and 70 days after planting (DAP), respectively. This research uses a Randomized Block Design consisting of 9 treatment combinations and analyzed using the SmartstatXL application. Color measurements are conducted using the CIELAB method and converted to CIELCH and RGB for color type identification. The texture of the tuber is measured using the Texture Analyzer MCT-2150W, while the water content is analyzed using the oven method. The study's results demonstrate a negative correlation between bulb texture and water content. Sumenep cultivar showed the lowest water content (77.57%) and highest texture (17.97 N) compared to others. Additionally, each cultivar displays significant color variations that correspond to differences in harvest maturity. The Brebes cultivar tuber changes from dark coffee to dark taupe, the Sumenep cultivar from mocha to beaver, and the Tuktuk cultivar from rose taupe to dark coffee. This means that the color has changed from dull and gray to bright and full. These findings provide practical guidance for determining the optimal harvest timing to preserve shallot quality during postharvest handling.

Keywords: CIELAB · Cultivar · Harvest age · Shallots · Texture · Water content

Submitted: 21 August 2025, Accepted: 29 December 2025, Published: 31 December 2025
DOI: https://doi.org/10.24198/kultivasi.v24i3.66306

Lestari RW[1] · Kusumiyati[2,3]* · Mubarok S[3]
[1] Graduate student in Master of Agronomy, Faculty of Agriculture, Universitas Padjadjaran
[2] Master Program of Agronomy, Faculty of Agriculture, Universitas Padjadjaran, Sumedang 45363, Indonesia
[3] Department of Agronomy, Faculty of Agriculture, Universitas Padjadjaran, Sumedang 45363, Indonesia
*Correspondence: kusumiyati@unpad.ac.id

Lestari RW, Kusumiyati, Mubarok S. 2025. Comparative analysis of color, texture, and water content in three shallot cultivars at different harvest ages. Jurnal Kultivasi, 24(3): 288-297.

Introduction

Shallot (*Allium cepa* var. aggregatum L.) is one of the leading horticultural commodities with high economic value. Market demand for shallots is determined not only by the quantity of the harvest but also by quality in terms of physical attributes including bulb color, texture (Kurniawan et al., 2020), and water content (Kaveri et al., 2015). These parameters are very important as they affect consumer preference, shelf life, and post-harvest processing efficiency. Studies on shallot quality often focus on single physical parameters or individual cultivars, while comparative analyses across cultivars and harvest ages, as well as the interrelationships among key physical traits, remain limited.

The physical quality of shallot can be influenced by various factors, including genetic variation in the form of cultivars and harvest age. In Indonesia, there are various local cultivars with distinct characteristics, including the Brebes, Sumenep, and Tuktuk cultivars. Each cultivar has its own unique characteristics, such as bulb color, bulb texture, and water content, which affect quality and storage durability. According to previous study, the Brebes cultivar is characterized by its uniform shape, bright red color, and harder texture (Kurniawan et al., 2020). The Tuktuk cultivar typically has a rounder shape, good adaptability, and lower dry weight (Wijoyo et al., 2020). Meanwhile, the Sumenep cultivar has a relatively low water content (Kusumiyati et al., 2024) which makes it widely used for fried onions.

Harvest age is a significant determinant of shallots' physical quality in addition to genetic considerations. Shallots with a high water content are typically produced by harvesting them too early, whereas those with a lower water content can be harvested (Ansar et al., 2022). Shallots' texture after harvesting is influenced by their water content. A tougher texture may be the result of low water content (Sukorini, 2024).

Shallot quality can also be assessed by looking at the bulb, especially the color of its skin. Color changes may be influenced by how long shallot skin is exposed to sunlight (Ghazali et al., 2023). Shallots' skin color is associated with the compounds they contain, such as flavonoids, phenolics, anthocyanins, and antioxidants (Vojnović et al., 2025). Therefore, measuring shallot color using CIELAB-based technology can be useful for a variety of purposes, including determining harvest age in the field, setting market standards for product quality, and monitoring the distribution and storage processes.Color parameter measurements using the CIE Lab* and LCh* systems, as well as texture testing, provide an objective picture of the visual and mechanical quality of shallot bulbs.

Shallot bulb quality can be objectively assessed through texture testing and color parameter measurements using the CIE Lab* and LCh* systems. Meanwhile, water content analysis provides important information regarding potential shelf life and weight loss during storage. Nevertheless, there are currently few studies that compare these three quality parameters in-depth while taking harvest age and cultivar genetic factors into account. This study aims to evaluate and compare color, texture, and water content among three local shallot cultivars (Brebes, Sumenep, and Tuktuk) harvested at different maturity stages, to determine the optional harvest age for maintaining posharvest quality. The results of this study are expected to provide information for farmers and industry participants in determining optimal harvesting strategy in different cultivar to maintain the quality of shallots.

Materials and Methods

Time and Location. This experiment was conducted in open fields in Sindanggalih Village, Cimanggung District, Sumedang Regency, West Java, from October 2024 to December 2025. The experimental site was located at an altitude of 746 m above sea level with Latosol and Alluvial soil types and a temperature range of 26-30 ^{0}C (Guswita et al., 2020). The research was conducted at the Horticulture Laboratory, Faculty of Agriculture, Universitas Padjadjaran University from January to March 2025.

Material. The seeds came from farmers in Brebes for the Brebes cultivar, while the Sumenep and Tuktuk cultivars came from Garut, each of which had been stored for at least 2 months. The cultivated land was then fertilized with 20 tons/ha of chicken manure and 2 tons/ha of dolomite. Planting was carried out in open fields using a monoculture system with a planting distance of 15 x 15 cm. Follow-up fertilization used NPK 16:16:16 and KCL at 14, 28, and 42 days after planting.

Experimental Design. The experiment used a Randomized Block Design with different

ISSN: 1412-4718, eISSN: 2581-138x

treatment combinations of three cultivars (Brebes, Sumenep, and Tuktuk) and three harvest ages: 54, 63, and 70 days after planting (DAP). There were 9 treatment combinations, each with 3 replicates, and each replicate consisted of 3 samples, which were then analyzed using the SmartstatXL application with a Scott-Knott post hoc test at a 5% level.

Texture Measurement. Texture measurements refer to the method of Devgan et al., (2019) which has been modified and adapted to the product being tested. Measurement of onion bulb texture was carried out using a Texture Analyzer (Material Testing Machine-2150W from Japan). The tool was calibrated before being used for testing. The probe used was a cylindrical probe with a diameter of 2 mm, a compression mode type, a 50N force sensor and a pressing speed of 300 mm/min. Measurements were carried out by operating the tool connected to the software. The probe will automatically insert into the onion sample being tested. Measurements were carried out at three points: on the right side, left side, and center of the onion bulb. The texture value of the onion bulb is displayed in units of g/force or Newton.

Water Content Determination. To measure water content, a method referring to Ansar et al., (2022) was used. Onion samples were cut into small pieces and weighed 1-4 g. Then, the onion pieces were placed in aluminum foil cups whose weight had been homogenized. The cups were arranged on a baking sheet and then oven-dried for 3 hours at 105 °C. The cups were placed in a desiccator for 10 minutes. The samples were then weighed until they had a constant dry weight. The water content measurement was calculated using the following formula:

$$Water\ content\ (\%) = \frac{fresh\ weight\ -\ dry\ weight}{fresh\ weight}\ x\ 100\%$$

Color Measurement. Color measurement using a reflectant Spectrophotometer (Konica, Minolta, Tokyo, Japan) the values displayed on the device are L*, a*, b*. Sample measurements were carried out at three measurement points, namely on the right, left, and center of the bulb. The color value is then visualized in the measurement of L* (Lightness), a* (green-red color), and b* (blue-yellow color) (Kusumiyati et al., 2018). Furthermore, these values are used to determine C* and H^{o} which are calculated using the equation by Askin et al., (2021):

$$Chroma\ value\ (C\ *) = \sqrt{(a^*)^2} + (b^*)^2$$

$$Hue\ angel\ value\ (H^o) = Tan^{-1}\frac{b^*}{a^*}$$

The Chroma value is used to determine the intensity or brightness of a color. The higher the Chroma value, the higher the color intensity perceived by humans (Pathare et al., 2013). Meanwhile, the Hue value produces an angle whose number determines the color type of an object. The results of the L*, C*, and H^{o} values are then analyzed using the Lch.oklch and Colorxs websites to determine the color type and compare RGB (Red, Green, Blue) and Hex values (Azetsu et al., 2021).

Photographic documentation was conducted using a smartphone camera (Samsung Galaxy A02s, 13 MP; 4128 × 3096 pixels). Photos were capturated under natural daylight without flash, at a distance of approximately 20 cm above the sample at a perpendicular angle. The sample was placed on aluminum foil. The images were saved in JPEG format without post-processing. Each treatment was photographed in three replicates. Shallot color analysis with a digital approach uses a Hexadecimal (Hex) color representation system converted into Red, Green, Blue (RGB) format. The initial data is a color code in the format #RRGGBB, where the character pairs RR, GG, and BB indicate the intensity of red, green, and blue colors, respectively, in the base 16 (hexadecimal) number system (Drofova et al., 2024). Each Hex digit pair consists of a first digit (high) and a second digit (low) (Matumoto et al., 2023). According to the digital color system standard, each Hex code can therefore be interpreted into an RGB value within 0-255 (Yoo et al., 2023)Additionally, the color characteristics of shallots for each cultivar and harvest age are interpreted using the RGB values that were obtained. The hexadecimal to RGB conversion formula is as follows (Mohammadi et al., 2024):

$$Xdec = (Xhigh \times 16) + Xlow$$

X_{dec} = decimal value (0–255)
X_{high} = first digit in Hex (base 16)
X_{low} = second digit in Hex (base 16)
Convertions letters to numbers: A=10, B=11, C=12, D=13, E=14, F=15

Results and Discussion

This research generally demonstrates that the quality of red onion bulbs is impacted by genetic variation manifested in cultivar differences and harvest age. The physical characteristics of the bulbs, such as their color, texture, and water content, clearly show these variations. Each variety has its own characteristics, and the maturity level affects how these characteristics change based on the harvest date. According to the findings, growing red onions that are both market-ready and storage-ready requires selecting the right varieties and timing the harvest.

Table 1. The effect of the combination of shallot cultivars and harvest age on texture and water content

Cultivar + Harvest Age (DAP)	Average Texture (N)	Average Water Content (%)
Brebes + 56 DAP	12.13 a	82.67 d
Brebes + 63 DAP	11.74 a	85.13 f
Brebes + 70 DAP	11.20 a	86.79 g
Sumenep + 56 DAP	12.55 a	80.08 c
Sumenep + 63 DAP	14.93 b	78.91 b
Sumenep + 70 DAP	17.97 c	77.57 a
Tuktuk + 56 DAP	11.13 a	87.97 h
Tuktuk + 63 DAP	12.51 a	86.83 g
Tuktuk + 70 DAP	15.95 b	84.13 e

Notes: Means followed by the same letter indicate values that are not significantly different based on the Scott-Knott test at the 5% level.

Texture and Water Content. The results of the study showed that the water content of shallots has an inverse relationship with texture. Low water content correlates with increased bulb texture. Based on Table 1, the Brebes cultivar has a different pattern from the Sumenep and Tuktuk cultivars, where the longer the harvest age, the more it shows a decrease in texture value and an increase in water content ($r = -0.98$). However, for Sumenep ($r = -1.00$) and Tuktuk ($r = -1.00$), the longer the harvest age, the higher the texture and lower the water content. This indicates a negative correlation between texture and water content, even though the pattern of change in both at harvest age differs between cultivars. The local Sumenep variety, which tends to have a lower water content physiologically, is expected to produce a denser and firmer bulb texture than other cultivars such as Brebes or Tuktuk.

An earlier study by (Mutia, 2019) clearly demonstrated a negative correlation between these two parameters, based on Table 1. found that shallots with an initial water content of 76.69% has a higher level of texture 4.46 N than samples with higher water content (85.25%) has lower level of texture (4.01 N). The lower the initial water content of shallots during storage, the higher their firmness (Mutia, 2019). High water content accelerates the decline in firmness during storage The negative correlation between water content and texture suggests that reduced water content increases bulb firmness due to cell wall dehydration and pectin polymerization, consistent with (Lawal et al., 2025). The drying process, or evaporation of water within the bulb tissue cells, causes the cells to shrink, the pectin structure to harden, and the intercellular layers to fuse, resulting in a harder and stiffer texture.

Color is one of the most important visual quality parameters in post-harvest evaluation of shallots. In this study, color characteristics were analyzed using the CIELAB color space system which consists of three main parameters: L* (lightness), a* (green-red color direction), and b* (blue-yellow color direction). These values were then converted into C* (chroma) and H° (hue angle), and translated into RGB and hex codes for color visualization (Sandoval et al., 2018).

Lighness (L*) Values. The results in Table 2 showed significant that there are significant variations in L* values between cultivars and harvest ages. The highest L* value is found in the Sumenep cultivar at 56 days after planting (54.56), indicating a brighter surface color of the bulb. Meanwhile, the lowest L* value is found in the Brebes cultivar harvested at 63 days after planting (35.62), indicating a darker color. The L* value shows a decrease in the Sumenep and Tuktuk cultivars; on the other hand, the L* value in the Brebes cultivar tends to increase at the 70 DAP harvest age. The increased L* value indicates a fading process of anthocyanin pigments while physiological processes are still ongoing (Sharma et al., 2015).

The a* Values. For all samples show positive numbers indicating a dominance of red color in all treatments. The Brebes and Tuktuk cultivars produced higher a* values compared to the Sumenep cultivar. The highest a* value was found in the Tuktuk cultivar harvested at 56 DAP (20.20), resulting in a stronger red color.

ISSN: 1412-4718, eISSN: 2581-138x

Meanwhile, the lowest a* value was produced by the Sumenep red onion harvested at 56 DAP (9.55), resulting in a fainter red color. The a* value tends to decrease with increasing harvest age. This indicates degradation of red pigments such as anthocyanins (Enaru et al., 2021).

The b* Values. Experiences an increase over the harvest time, showing a tendency to change color towards yellow. The highest b* value occurs in the Sumenep cultivar harvested at 56 DAP (14.05), while the lowest value is in the Brebes cultivar harvested at 56 DAP (4.42). The increase in b* value indicates the occurrence of phenolic oxidation and the formation of yellowish-brown colored compounds during the storage period or differences in harvest timing. (Pathare et al., 2013) and (Sharma et al., 2015).

Chroma (C*) Values. Chroma values integrate changes in both a* and b*, providing an overall indicator of color intensity. The higher C* value observed in the Tuktuk cultivar at 70 DAP (21.88) reflects a combination of relatively high a* values and moderate b* values, indicating sustained pigment saturation despite advancing maturity. Conversely, the lower C* values in the Sumenep cultivar at early harvest stages (17.29) suggest reduced pigment concentration and lower color intensity. These findings indicate that Tuktuk exhibits greater pigment stability during maturation, whereas Sumenep undergoes faster pigment degradation, resulting in diminished color saturation.

Overall, the coordinated changes in L*, a*, b*, and C* values demonstrate that bulb color development is closely linked to physiological maturation and cultivar-specific pigment metabolism. Cultivars with higher water content and softer texture, such as Sumenep at earlier harvest stages, tended to exhibit higher L* and lower a* values, indicating lighter and less intense red coloration. In contrast, cultivars with lower water content and firmer texture, such as Brebes and Tuktuk at later harvest ages, showed darker and more saturated red color. This relationship highlights the interaction between water content, texture, and pigment stability in determining shallot bulb color quality.

Hue Angle (H°) Values. The hue angle (H°) values quantitatively describe color hue based on the relative contributions of a* and b*. The lower H° values observed in the Brebes cultivar (12.76–34.06) indicate dominance of red pigments, whereas the higher H° values in the Sumenep cultivar (27.80–54.89) reflect increased yellow-brown components. These numerical trends are consistent with the RGB and hex color conversions derived from the same CIELAB data, which show color transitions from deep coffee to mocha, deep taupe, and rose taupe depending on the cultivar and harvest age (Table 3).

These color changes are closely related to post-harvest biochemical processes. Degradation of anthocyanin pigments causes the red color to fade, while the Maillard reaction and phenolic oxidation produce yellow to brownish pigment compounds (Sharma et al., 2015). Previous studies have also shown that temperature and humidity during storage significantly influence the direction and intensity of color changes (Demissew, 2018).

Table 2. The effect of the combination of shallot cultivars and harvest age on lightness, a*, b*, chroma, and hue values

Cultivar + Harvest Age (DAP)	L*	a*	b*	C*	H°
Brebes + 56 DAP	37.06 a	20.13 c	4.42 a	20.81 b	12.76 a
Brebes + 63 DAP	35.62 a	17.32 c	6.24 a	18.81 a	20.21 a
Brebes + 70 DAP	43.24 c	15.23 b	10.26 c	18.96 a	34.06 c
Sumenep + 56 DAP	54.56 d	9.55 a	14.05 d	17.29 a	54.89 e
Sumenep + 63 DAP	46.41 c	15.05 b	8.08 b	17.64 a	27.80 b
Sumenep + 70 DAP	44.61 c	13.68 b	13.87 d	19.60 a	45.16 d
Tuktuk + 56 DAP	40.97 b	20.20 c	6.14 a	21.21 b	16.57 a
Tuktuk + 63 DAP	36.92 a	18.40 c	5.93 a	19.41 a	18.02 a
Tuktuk + 70 DAP	37.55 a	19.61 c	8.90 b	21.88 b	25.15 b

Notes: Means followed by the same letter indicate values that are not significantly different based on the Scott-Knott test at the 5% level.

Table 3. RBG, hex, and color type values in various shallot cultivars with different harvest age

Cultivar	Harvest Age (DAP)		
	56	63	70
Brebes	 Deep Coffee RGB (119, 74, 81) Hex (#774a51)	 Deep Coffee RGB (113, 73, 74) Hex (#71494a)	 Deep Taupe RGB (131, 92, 85) Hex (#835C55)
Sumenep	 Mocha RGB (154, 124, 107) Hex (#9a7c6b)	 Deep Taupe RGB (138, 100, 97) Hex (#8A6461)	 Beaver RGB (133, 97, 83) Hex (#856153)
Tuk Tuk	 Rose Taupe RGB (130, 84, 88) Hex (#825458)	 Deep Coffee RGB (117, 75, 78) Hex (#754b4e)	 Deep Coffee RGB (121, 76, 74) Hex (#794c4a)

Color Type Values. Overall, shallot color is influenced by a combination of genetic (cultivar) and physiological (harvest age) factors, as well as post-harvest processes involving pigment degradation and the formation of new compounds. Research on the changes and dynamics of color is important to determine the optimal harvest time. This can lead to the development of a digital quality system through objective and standardized color identification. Color is one of the parameters that serves as an indicator of visual quality in the post-harvest evaluation of shallots. Color transformation indicates visual changes depending on genetic variation and differences in harvest age. The Brebes cultivar shows a transition from deep coffee color to deep taupe at 70 DAP. The Sumenep cultivar tends to produce brighter colors, namely mocha (56 DAP), deep taupe (63 DAP), and beaver (70 DAP). Meanwhile, the Tuktuk cultivar produces rose taupe color (56 DAP) and becomes darker with a deep coffee color at 70 DAP.

Hex and RGB Values. RGB and hex color visualization (Table 4) can help with a digital color quality classification system. Applications for image-based quality standardization, such as automatic sorting and grading in the post-harvest sector, can be developed using this color model as a foundation (Azetsu et al., 2021). The color changes caused by L*, C*, and H° values show that the primary causes of color transformation during growth and storage are biochemical processes like anthocyanin degradation, enzymatic oxidation, and Maillard reactions. Furthermore, the rate of these changes is strongly influenced by temperature and humidity (Chope et al., 2012).

The Brebes cultivar shallot produces a red (R) value in the range of 113–131, indicating moderate to strong red dominance. When the R value is at its lowest point, namely 113 at 63 days after planting, the color appears darker and duller. Conversely, when R increases to 131 at 70 days after planting, the red hue becomes more pronounced and gives the impression of a brighter color. The green (G) value is in the range of 73–92, low values at 56 and 63 days after planting make the color tend to be deep towards red-brown, while the increase in G at 70 days after planting adds a slight greenish nuance that creates a neutral or ashy effect on the red hue. The blue (B) value which ranges from 74–85 also plays a role in brightness, the low B value at 63 days after planting strengthens the depth of the red-brown color, while its increase at 70 days after planting gives the impression of a softer color, shifting towards taupe. These changes indicate fading of red pigments (anthocyanins) and an increased contribution of gray-brown pigments resulting from phenolic oxidation. The Hex color code of the Brebes cultivar shows a clear transition between harvest ages. At 56 days after harvest, the identified color is #774a51, which is categorized as deep coffee, depicting a deep red-brown hue. At 63 days after harvest, the code changes to #71494a, still categorized as deep coffee, but darker and duller due to decreased brightness caused by anthocyanin pigment degradation. Entering 70 days after harvest, the Hex code changes to #835C55, which is categorized as deep taupe. This shift indicates an increase in brightness and a slight shift towards gray-brown, in line with the fading of the red color and the formation of secondary pigments through phenolic oxidation.

Table 4. Conversion results from hex to RGB values

Cultivar	Harvest Age	Hex	R (pair)	Count R	R Decimal	G (pair)	Count G	G Decimal	B (pair)	Count B	B Decimal
Brebes	56 DAP	#774a51	77	(7×16) + 7 = 112+7	119	4A	(4×16) + 10 = 64+10	74	51	(5×16) + 1 = 80+1	81
Brebes	63 DAP	#71494a	71	(7×16) + 1 = 112+1	113	49	(4×16) + 9 = 64+9	73	4A	(4×16) + 10 = 64+10	74
Brebes	70 DAP	#835c55	83	(8×16) + 3 = 128+3	131	5C	(5×16) + 12 = 80+12	92	55	(5×16) + 5 = 80+5	85
Sumenep	56 DAP	#9a7c6b	9A	(9×16) + 10 = 144+10	154	7C	(7×16) + 12 = 112+12	124	6B	(6×16) + 11 = 96+11	107
Sumenep	63 DAP	#8a6461	8A	(8×16) + 10 = 128+10	138	64	(6×16) + 4 = 96+4	100	61	(6×16) + 1 = 96+1	97
Sumenep	70 DAP	#856153	85	(8×16) + 5 = 128+5	133	61	(6×16) + 1 = 96+1	97	53	(5×16) + 3 = 80+3	83
Tuktuk	56 DAP	#825458	82	(8×16) + 2 = 128+2	130	54	(5×16) + 4 = 80+4	84	58	(5×16) + 8 = 80+8	88
Tuktuk	63 DAP	#754b4e	75	(7×16) + 5 = 112+5	117	4B	(4×16) + 11 = 64+11	75	4E	(4×16) + 14 = 64+14	78
Tuktuk	70 DAP	#794c4a	79	(7×16) + 9 = 112+9	121	4C	(4×16) + 12 = 64+12	76	4A	(4×16) + 10 = 64+10	74

Notes: Columns R (pair), G (pair), B (pair) are hex digit pairs for each color value.

In the Sumenep cultivar, a high R value at 56 DAP (154) produces a bright, warm light brown hue. A decrease in R to 133 at 70 DAP makes the color appear more intense and dark. The G value, which was initially 124 at 56 DAP, gives a bright and neutral impression, but when it drops to 97 at 70 DAP, the color loses its brightness and shifts to reddish brown. The B value also shows a similar pattern, from 107 at 56 DAP to 83 at 70 DAP, which eliminates the bluish nuances, making the color warmer and more intense. These changes illustrate the shift from a bright, neutral color to reddish brown due to the degradation of blue/green pigments and the dominance of red-brown pigments during the ripening process. In the Sumenep cultivar, the color at 56 DAP has the code #9a7c6b or mocha, which describes a bright light brown hue. As the harvest age increases at 63 DAP, the code shifts to #8A6461 (deep taupe), indicating a darkening of the color and a shift towards reddish gray. At 70 DAP, the code changes again to #856153 (beaver), indicating a deeper reddish brown color. These changes indicate a loss of brightness due to a decrease in G and B values in the RGB composition, followed by a dominance of red-brown tones due to the degradation of blue/green pigments.

Meanwhile, in the Tuktuk cultivar, the R value is relatively stable at 117–130, maintaining a soft to deep red hue. The lowest R value at 63 DAP makes the color slightly darker, and a further increase at 70 DAP warms the hue. The G value, which ranges from 75–84, is consistently low, so the color remains intense and does not experience much shift in brightness. The B value, which ranges from 74–88, maintains a stable red-gray hue, the highest B value at 56 DAP gives a slightly pale impression, while the lowest value at 70 DAP reinforces the warm and deep impression of the color. This stability of the RGB composition indicates that the Tuktuk cultivar tends to maintain its red-brown character with relatively small changes in intensity, likely due to the pigment's resistance to degradation during ripening.

Overall, the results indicate a clear interaction between genotype and harvest age in determining the physical quality of shallot bulbs. Each cultivar responded differently to increasing maturity, as shown by the contrasting trends in water content, texture, and color parameters. For instance, the Sumenep cultivar consistently exhibited decreasing water and increasing texture with later harvest ages, while Brebes and Tuktuk showed more moderate changes in firmness but stronger shifts in color attributes such as a and hue angle. These findings highlight that cultivar-specific physiological characteristics interact with harvest timing to produce distinct quality profiles. Recognizing this interaction is essential for identifying the most suitable cultivar–harvest age combinations to achieve desired postharvest traits. The Tuktuk shallot cultivar at 56 DAP showed the code #825458 (rose taupe), which exhibits a pale red hue with ash undertones. At 63 DAP, the code shifted to #754b4e (deep coffee), indicating a darkening of the color due to a decrease in light intensity across all RGB values. Interestingly, at 70 DAP, the code changed to #794c4a, still in the deep coffee category, but slightly warmer than at 63 DAP. This reflects the stability of the red-brown hue of this cultivar, with small variations in brightness and color saturation.

Conclusion

This study demonstrates that cultivar and harvest age significantly affect shallot bulb color (L*, a*, b*, C*, H°), texture, and water content. A strong negative relationship was observed between water and texture. Among all combinations, Sumenep harvested at 70 DAP showed the highest texture (17.97 N) with the lowest water (77.57%), indicating superior postharvest firmness and potential for longer shelf life. Brebes and Tuktuk showed stronger red tones (higher a*), while Sumenep 56 DAP exhibited the brightest surface (highest L*). Practically, Sumenep around 70 DAP is recommended when firmness and low water are prioritized, while harvest timing for Brebes and Tuktuk can be adjusted to meet specific color preferences. These findings provide actionable guidance for selecting cultivar–harvest age combinations to maintain shallot quality during handling and storage.

Acknowledgments

The author would like to thank the horticulture laboratory team who helped in completing this manuscript.

ISSN: 1412-4718, eISSN: 2581-138x

References

Ansar M, Bahrudin, Maemunah, Paiman. 2022. Effect of harvest age and storage duration on viability and vigor of shallot (*Allium cepa* L.) tubers. Research on Crops, 23(4): 815–821. doi: 10.31830/2348-7542.2022.ROC-909

Askin B, Yazici SO. 2021. Bioactive Compounds, Antioxidant Potential and Color Properties of Dried Red Pepper (*Capsicum annuum* L.). International Journal of Innovative Approaches in Agricultural Research, 5(2): 158–171. doi: 10.29329/ijiaar.2021.358.1

Azetsu T, Suetake N. 2021. Chroma enhancement in cielab color space using a lookup table. Designs, 5(2). doi: 10.3390/designs5020032

Chope GA, Cools K, Hammond JP, Thompson AJ, Terry LA. 2012. Physiological, biochemical and transcriptional analysis of onion bulbs during storage. Annals of Botany, 109(4): 819–831. doi: 10.1093/aob/mcr318

Demissew A. 2018. Effect of Storage Temperature on Physicochemical Quality Attributes of Fresh Bombay Red Onion Bulb *(Allium cepa* L.*)*. doi: 10.20944/preprints201803.0111.v1

Devgan K, Kaur P, Kumar N, Kaur A. (2019). Active modified atmosphere packaging of yellow bell pepper for retention of physico-chemical quality attributes. Journal of Food Science and Technology, 56(2): 878–888. doi: 10.1007/s13197-018-3548-5

Drofova I, Adamek M. 2024. Color Models in the Process of 3D Digitization of an Artwork for Presentation in a VR Environment of an Art Gallery †. Electronics (Switzerland), 13(22). doi: 10.3390/electronics13224431

Enaru B, Drețcanu G, Pop TD, Stănilă A, Diaconeasa Z. 2021. Anthocyanins: Factors affecting their stability and degradation. In Antioxidants (Vol. 10, Issue 12). MDPI. doi: 10.3390/antiox10121967

Ghazali NS, Mohd W, Ikwan R, Hussin W, Salleh RM, Basir MH, Rozita W, Engah W, Rosali N. 2023. Curing Technique Affects Physicochemical Changes of Shallot. International Journal of Agriculture, 13.

Guswita D, Makhmudi M, Kusmiyati. 2020. Keberdayaan Anggota Kelompok Tani dalam Menerapkan Good Handling Practices (GHP) Padi Sawah di Desa Sindanggalih Kecamatan Cimanggung Kabupaten Sumedang. Jurnal Inovasi Penelitian, 1: 303–316.

Kaveri G, Thirupathi V. 2015. Studies on Geometrical and Physical Properties of CO 4 Onion Bulb (*Allium cepa* L Var. Aggregatum Don.). International Journal of Recent Scientific Research, 6(3): 2897–2902. Retrieved from http://www.recentscientific.com

Kurniawan YR, Hidayat DD, Luthfiyanti R, Andriansyah RCE, Indriati A. 2020. A comparative study on engineering properties of three varieties of shallots. IOP Conference Series: Earth and Environmental Science, 462(1). doi: 10.1088/1755-1315/462/1/012025

Kusumiyati K, Farida F, Sutari W, Mubarok S. 2018. Kualitas Buah Mangga Selama Penyimpanan pada Keranjang Anyaman Bambu dengan Identifikasi Ruang Warna L*,a* dan b*. Kultivasi, 17.

Kusumiyati K, Manurung GP, Hamdani JS. 2024. Growth, yield, and secondary metabolite responses of three shallot cultivars at different watering intervals. Open Agriculture, 9(1). doi: 10.1515/opag-2022-0255

Lawal HM, Salau IA, Sufiyanu S. 2025. Comparative Study on Flavor, Texture, and Quality Preservation in Onion Bulbs (Allium cepa L.) under Two Storage Methods. Greener Journal of Biological Sciences, 15(1): 18–22. doi: 10.15580/gjbs.2025.1.121624195

Matumoto AdO, Gonçalves-Segundo PR. 2023. A Social-Semiotic Approach to Color Analysis in Digital Media: Theory and Practice. Revista de Estudos Da Linguagem, 31(4): 2009–2065. doi: 10.17851/2237-2083.31.4.2009-2065

Mohammadi V, Ansari K, Gouton P, Attig H. 2024. Developing a New Method of Transformation for Obtaining XYZ Color Values from RGB Images for Agricultural Applications. Sensors, 24(23). doi: 10.3390/s24237728

Mutia AK. 2019. Pengaruh Kadar Air Awal pada Bawang Merah (*Allium ascalonicum* L.) terhadap Susut Bobot dan Tingkat Kekerasan Selama Penyimpanan pada Suhu Rendah. Gorontalo Agriculture Technology Journal, 2: 30–37.

Pathare PB, Opara UL, Al-Said FAJ. 2013. Colour Measurement and Analysis in Fresh and Processed Foods: A Review. In Food and Bioprocess Technology (Vol. 6, Issue 1, pp.

36–60). Springer Science and Business Media, LLC. doi: 10.1007/s11947-012-0867-9

Sandoval JRM, Sandoval EM, Rosas MEM, Velasco MMM. 2018. Color Analysis and Image Processing Applied in Agriculture. In Colorimetry and Image Processing. InTech. doi: 10.5772/intechopen.71539

Sharma K, Asnin L, Ko EY, Lee ET, Park SW. 2015. Phytochemical composition of onion during long-term storage. Acta Agriculturae Scandinavica Section B: Soil and Plant Science, 65(2): 150–160. doi: 10.1080/09064710.2014.983151

Sukorini H. 2024. Shallot extension shelf life with fogging and the storage temperature. *BIO Web of Conferences*, *143*, 01010. doi: 10.1051/bioconf/202414301010

Vojnović Đ, Ilin Ž, Kostić A, Adamović B, Kilibarda S, Pezo L, Popović-Đorđević J. 2025. Phytochemical composition, antioxidant potential, and bulb mass of differently colored onions under distinct sowing methods. Quality Assurance and Safety of Crops and Foods, 17(3): 108–126. doi: 10.15586/qas.v17i3.1549

Wijoyo RB, Sulistyaningsih E, Wibowo A. 2020. Growth, Yield and Resistance Responses of Three Cultivars on True Seed Shallots to Twisted Disease with Salicylic Acid Application. Caraka Tani: Journal of Sustainable Agriculture, 35(1): 1–11. doi: 10.20961/carakatani.v35i1.30174

Yoo WS, Kang K, Kim JG, Yoo Y. 2023. Image-Based Quantification of Color and Its Machine Vision and Offline Applications. Technologies, 11(2). doi: 10.3390/technologies11020049