

Application of principal component analysis in the quality evaluation of size-sorted Idor longan (*Dimocarpus longan* Lour.) in the Mekong Delta, Vietnam

Nguyen Phuoc Mai To

Can Tho University

Minh Trong PHAN

Can Tho University

Thanh Truc TRAN

Can Tho University

Van Muoi NGUYEN

nvmuoi@ctu.edu.vn

Can Tho University

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Abstract

Each bunch of Idor longan (*Dimocarpus longan* Lour.) naturally contains a variation of fruits with different sizes and qualities. Therefore, developing an effective sorting or grading systems is essential to improve postharvest quality, consumer acceptability, and overall fruit utilization. Based on physical measurements, longan fruits were classified into six height-based groups: H1 (0, 2.2] cm, H2 (2.2, 2.3] cm, H3 (2.3, 2.4] cm, H4 (2.4, 2.5] cm, H5 (2.5, 2.6] cm, and H6 (2.6, +∞) cm. The quality evaluation confirmed that this height-based sorting system effectively differentiated fruits, as significant variations in quality attributes were observed among groups. Principal component analysis (PCA) further highlighted distinct quality profiles for each group, supporting the development of specialized utilization strategies. Fruits in the H1 group followed by those in H2 had a higher fruit aril percentage, elevated vitamin C and total phenolic content, suggesting their potential for bioactive-oriented consumption. In contrast, fruits in the H3 to H6 groups shared many similarities, characterized by higher a^* and b^* values for aril color, TSS, TA, and total sugar content, making them more appropriate for storage or industrial processing. Overall, the integration of PCA with conventional physical and biochemical analyses provided a comprehensive understanding of fruit variability, offering a practical framework for efficient sorting and value optimization of Idor longan and other related fruit cultivars.

1. Introduction

Longan (*Dimocarpus longan* Lour.) is a tropical plant belonging to the Sapindaceae family, widely cultivated across Asia-Pacific countries such as China, Thailand, and Vietnam (Nguyen et al., 2017; Tran & Tran, 2019; Tripathi, 2021). The fruit is highly appreciated for its pleasant flavor, rich nutritional profile (Le et al., 2020; Nguyen et al., 2017; Shi et al., 2016; Tripathi, 2021; USDA, 2022) and abundance of bioactive compounds (Shahrajabian et al., 2019; Wang et al., 2020; Yang et al., 2021; Zhang et al., 2018; Zhang et al., 2020; Zhu et al., 2016), which contribute to its long-standing usage in traditional Chinese medicine (Shahrajabian et al., 2019; Zhang et al., 2020). As a non-climacteric fruit, longan ceases ripening once detached from the tree and rapidly deteriorates during storage, typically through pericarp browning and aril shriveling (Jiang et al., 2002; Kader, 2002; Nguyen et al., 2017; Tripathi, 2021). Therefore, the postharvest stability and shelf life of longan depend greatly on its physiological condition at harvest (Le et al., 2020; Nguyen et al., 2017; Shi et al., 2016). Several studies have characterized the quality of longan fruit among different cultivars (Zhang et al., 2018; Zhang et al., 2020), or by harvest date (Le et al., 2020; Nguyen et al., 2017; Shi et al., 2016; Wongchana & Issarakraisila, 2009), and have examined its physical and biochemical properties (Deng et al., 2023; Wang et al., 2020; Yang et al., 2021; Zhang et al., 2018; Zhang et al., 2020). However, relatively little attention has been given to the sorting and grading of longan fruit after harvest, an essential aspect for standardizing quality and improving market value. Size variation is a common feature in longan bunches, where fruits of different diameters and quality levels coexist (De Salvador et al., 2006; Lu et al., 2021; Mikulic-Petkovsek et al., 2016; Pham et al., 2015; Qiao et al., 2023). Unlike berries, which are typically marketed in clusters, longan fruits can be detached from the branch and sold in packages, often consumed individually (Pham et al., 2015; Tran & Tran, 2019; Tripathi, 2021), making size uniformity particularly desirable. In the Mekong Delta of

Vietnam, the Idor longan cultivar has recently gained popularity due to its high yield and consumer acceptance; however, scientific data regarding its postharvest quality and size-related characteristics remain limited (Le & Ngo, 2022; Nguyen et al., 2017; Tran & Tran, 2019).

Fruit size is an important commercial attribute, influencing not only consumer preference but also packaging, transportation, and processing efficiency (De Salvador et al., 2006; Le et al., 2021; Sasikumar et al., 2021; Tiwari, 2019). Moreover, fruit size is often correlated with internal physicochemical parameters and can therefore serve as a proxy for quality differentiation. (De Salvador et al., 2006; Le et al., 2021; Lu et al., 2021; Mikulic-Petkovsek et al., 2016; Tiwari, 2019).

Therefore, this study aimed to establish size-based categories for sorting Idor longan cultivated in the Mekong Delta and to characterize the corresponding physical and biochemical properties. The analysis generated a complex dataset containing multiple variables across fruit size groups (De Salvador et al., 2006; Lu et al., 2021; Mikulic-Petkovsek et al., 2016; Pham et al., 2015). To interpret this dataset, principal component analysis (PCA) was employed, which is a multivariate statistical technique widely used for exploratory data analysis and pattern recognition (Cozzolino et al., 2019; Souza et al., 2024). PCA has been effectively applied in evaluating sensory attributes (Husson et al., 2004; Lawless & Heymann, 2010), chemical and textural characteristics (Bollinedi et al., 2020; Šnirc et al., 2017; Souza et al., 2024; Tornuk et al., 2014), and nutritional quality of food samples (Abdelsalam et al., 2025; Chen et al., 2024; Jaćimović et al., 2023; Quek et al., 2018). By reducing data dimensionality and shifting the focus to a smaller number of principal components that account for the majority of total variance, the PCA can reveal new insights and highlight the most influential features of the dataset (Abdelsalam et al., 2025; Bollinedi et al., 2020; Chen et al., 2024; Husson et al., 2004; Jaćimović et al., 2023; Lawless & Heymann, 2010; Quek et al., 2018; Šnirc et al., 2017; Souza et al., 2024; Tornuk et al., 2014). Its application to size-sorted longan fruits is novel and offers potential as a valuable tool for quality evaluation.

Reliable analysis of the physical and chemical properties of longan fruits provided by this research will be valuable for assessing quality and supporting the development of practical sorting systems (De Salvador et al., 2006; Sasikumar et al., 2021; Tiwari, 2019). Such systems can enhance the value and commercialization of Idor longan cultivated in the Mekong Delta (Le et al., 2021; Sasikumar et al., 2021; Tiwari, 2019). For growers and processors, this contributes to better product standardization, higher market competitiveness, and more targeted use of fruits for either fresh consumption, storage, or other industrial purposes (De Salvador et al., 2006; Le et al., 2021; Tiwari, 2019). Overall, the findings provide useful references for longan quality management and may serve as a model for other tropical fruits.

2. Materials and Methods

2.1. Raw Material Collection and Sample Preparation

Idor longan (*Dimocarpus longan* Lour.) were obtained from an orchard in Ben Tre Province, Vietnam. Fruits were harvest at commercial maturity, approximately 119–126 days after anthesis (Nguyen et al.,

2017; Tran & Tran, 2019) and collected in bunches with stems and leaves intact. The bunches were then placed in perforated nylon bags lined with longan leaves to minimize mechanical damage during transportation.

At the laboratory, individual fruits, which are the typical unit for consumer consumption (Pham et al., 2015; Tripathi, 2021), were separated from the branches, leaving stems approximately 1.5 mm in length. Fruits not meeting the quality requirements of the CODEX STAN 220–1999 standard (Codex Alimentarius Commission, 1999) was discarded. These included fruits that were physically damaged, contaminated, pest-affected, exhibited abnormal pericarp moisture, possessed foreign odors or tastes, showed signs of deterioration, or displayed distinct surface blemishes. The remaining fruits were then washed with running tap water and air-dried at room temperature before further analysis.

2.3. Physical Measurements

A total of 500 fruits (approximately 5.4 kg) was randomly selected from the harvested batch for physical characterization. Fruit weight (m) was measured using a digital balance (Vibra, model DJ-1000 TW, accuracy ± 0.01 g, Japan), while fruit diameter (D) and height (h) were measured using a digital caliper digital (Syntek, 150 mm, accuracy ± 0.01 mm, China). The theoretical volume ($V_{\text{Ellipsoid}}$) of the longan fruit was calculated using the ellipsoid volume formula as follows:

$$V_{\text{Ellipsoid}} = \frac{4\pi}{3} \times \frac{D^2 h}{8}$$

2.1

The color was measured with a digital colorimeter (JZ-600, China) in CIE Lab space.

2.4. Biochemical Analyses

Physical measurements were used to establish the size-sorting ranges for Idor longan fruits. For each size group, 100 fruits (approximately 1.1 kg) was randomly selected for biochemical analysis. The analyses were conducted in five replicates for each of the three major harvest seasons (from January to December, 2024) for 06 sorted groups, resulting in a total of 15 datasets per size group.

The percentage of aril, pericarp, and seed were determined by weighing using a digital balance (Vibra, model DJ-1,000 TW, accuracy 0.01 g, Japan). Titratable acidity (TA), total soluble solids (TSS), and vitamin C content of longan fruit were determined according to the method suggested by Sasikumar et al. (2021). The TSS was measured using a refractometer (Atago, 0–33°Brix, Japan). The TA was determined titration with a standard alkali solution and expressed as a percentage of malic acid (Yang et al., 2021). Vitamin C content was titrimetrically quantified using the indophenol dye method. Total sugar content of longan fruits was determined by the Lane-Eynon titration method following AOAC procedures (Latimer, 2016). Total phenolic content (TPC) was determined by the Folin-Ciocalteu method using gallic acid as the standard (Bastola et al., 2017).

Proximate composition, including moisture, protein, ash, crude fat, and total carbohydrate, was determined according to standard AOAC procedures (Latimer, 2016). Moisture content was determined by oven drying method (Southster NFC-5D, China) at 105°C until constant weight. Protein content was determined using a Kjeldahl apparatus (Velp, DKL 42/26, Italy), where total protein was calculated by multiplying nitrogen content by 6.25. Ash content was measured using a muffle furnace (Nabertherm, NA 250/65, Germany) at 600°C until constant weight. Crude fat was determined using a Soxhlet apparatus (Velp, SER148, Italy) with petroleum ether (boiling range 60–90°C) as the solvent. Total carbohydrate content was estimated by the difference according to standard analysis procedures.

2.5. Statistical Analysis

All data were initially processed in Excel 2019 and statistically analyzed using Statgraphics Centurion 19 software. Analysis of variance (ANOVA) was performed to evaluate differences among mean values of the quality attributes at a 95% confidence level.

Principal component analysis (PCA) was conducted on selected quality attributes that exhibited significant differences among fruit size groups. A covariance matrix was constructed to assess inter-variable relationships, and a scree plot was used to determine the importance of each principal component (Bollinedi et al., 2020; Lawless & Heymann, 2010; Souza et al., 2024; Tornuk et al., 2014). The selected components were then used to generate biplots combining loading and score plots, which visualized both the correlations among quality attributes (as feature vectors) and the distribution of fruit groups. Confidence ellipses at the 95% level were included to represent group variability (Abdelsalam et al., 2025; Husson et al., 2004; Quek et al., 2018; Šnirc et al., 2017). All analyses and PCA visualizations were performed using R software (version 4.4.2) with RStudio interface.

3. Results and Discussions

3.1. Physical Properties of Idor Longan

The Idor longan cultivar is highly valued in the Mekong Delta for its thick, sweet aril and natural resistance to witches' broom disease (Le & Ngo, 2022; Nguyen et al., 2017; Tran & Tran, 2019; Tripathi, 2021). However, a major limitation of this cultivar is the tendency of seeds to germinate prematurely if fruits are left on the tree for extended periods (Nguyen et al., 2017; Tran & Tran, 2019; Tripathi, 2021). Therefore, only fully matured fruits, harvested at approximately 119–126 days post-anthesis, were collected for this study (Nguyen et al., 2017; Tran & Tran, 2019). The physical parameters of the fruits were measured and analyzed to provide baseline data for quality evaluation. The results are presented as a Box-and-Whisker plot in Fig. 1.

The average weight (m) of Idor longan fruit in the Mekong Delta was 10.89 g, ranging from 6.08 to 14.63 g (Fig. 1a). The mean fruit diameter and height were 2.84 cm (range: 2.28–3.27 cm) and 2.46 cm (range: 2.08–2.75 cm), respectively (Fig. 1b). Additional details, including the first quartile, median, and third quartile, are also provided in the corresponding figure. Notably, in all cases, the mean values were close

to, but slightly larger than, the median values, suggesting that the distribution of fruit weight, diameter, and height was approximately normal but slightly positively skewed. These physical characteristics are consistent with the previous reports on Idor longan grown Vietnam, which showed an average fruit weight of 9.51 g and diameter of 27.37 mm (Nguyen et al., 2017; Tran & Tran, 2019). Compared to the Daw cultivar in Thailand (average weight of 9.79 g and a diameter of approximately 3.0 cm) (Wongchana & Issarakraisila, 2009), Idor cultivar demonstrated a comparable fruit weight but exhibits a more rounded morphology. Similarly, it falls within the small-sized category (5–20 g per fruit) typical of Chinese cultivars such as Shixia and Chiliang (Shi et al., 2016; Wang et al., 2020). According to CODEX STAN 220–1999, most of Idor longan fruits belong to the second size category, corresponding to 85–94 fruits per kilogram (Codex Alimentarius Commission, 1999). Variations in fruit shape and size can influence visual appeal, packing efficiency, and consumer preference, as well as postharvest handling practices.

As shown in Fig. 1b, the fruit height of Idor longan was consistently smaller yet close to the diameter, indicating an ellipsoidal shape approaching near-spherical form. Therefore, the theoretical volume ($V_{\text{Ellipsoid}}$) of the fruit was calculated using the ellipsoid volume formula, and the results were presented as a Box-and-Whisker plot (Fig. 1c). Additionally, the results in Fig. 2 showed a strong linear relationship between the weight and theoretical volume of the fruit ($R^2 = 0.9983$), which is consistent with the findings of Shi et al. (2016), who reported a linear relationship between the volume and mass of Shixia longan ($R = 0.9940$). The high coefficient of determination indicates that fruit weight and size are interchangeable and can serve as reliable indices for sorting Idor longan (Tiwari, 2019).

3.2. Establishment of Sorting Criteria for Idor Longan

Sorting by weight or size is a non-destructive and essential step in postharvest handling and quality grading (De Salvador et al., 2006; Le et al., 2021; Sasikumar et al., 2021; Tiwari, 2019). According to CODEX STAN 220–1999 (Codex Alimentarius Commission, 1999), longan fruits can be sized by either the number of fruits per kilogram or by equatorial diameter into five standard size codes. However, measurements of the physical properties of Idor longan (Fig. 1) indicated that these codes were unsuitable, as the fruits are generally smaller and thus could not be effectively categorized using the existing criteria.

In this study, new sorting criteria for Idor longan were proposed. Fruit height —rather than weight or diameter— was selected as the primary sorting index for two main reasons: (i) its distribution most closely followed a normal model (Fig. 1b), and (ii) being consistently smaller than diameter, it facilitates simpler mechanical design and easier scalability for sorting equipment. To align with the established CODEX standard, a 0.1 cm height interval was applied, generating finer sub-groups than diameter-based sizing (Codex Alimentarius Commission, 1999). To ensure adequate representation, only groups containing at least 5% of the total fruit quantity, six groups were proposed: H1 (0, 2.2] cm, H2 (2.2, 2.3] cm, H3 (2.3, 2.4] cm, H4 (2.4, 2.5] cm, H5 (2.5, 2.6] cm, and H6 (2.6, +∞). The external and internal appearance of fruits across the six groups are illustrated in Fig. 3. Given the close relationship between fruit weight and dimensions, other physical parameters of each group can be estimated based on height (Table 1), supporting transitions to other sorting indices when needed. Table 1 also shows that the

percentage of fruits across groups approximately followed a normal curve. This height-based classification system provides more precise sorting for domestic markets while remaining compatible with CODEX grading standards. Such flexibility enables producers to meet both local and export market requirements without compromising compliance.

Table 1
Physical parameters of Idor longan fruits sorted by height

Group	H1	H2	H3	H4	H5	H6
<i>Physical parameter</i>						
Height (cm)	(0, 2.2]	(2.2, 2.3]	(2.3, 2.4]	(2.4, 2.5]	(2.5, 2.6]	(2.6, +∞]
Weight (g)*	(0, 7.39]	(7.39, 8.81]	(8.81, 10.22]	(10.22, 11.64]	(11.64, 13.05]	(13.05, +∞]
Diameter (cm)*	(0, 2.47]	(2.47, 2.62]	(2.62, 2.77]	(2.77, 2.92]	(2.92, 3.07]	(3.07, +∞]
<i>Percentage (%)</i>	6,0	10,0	16.5	28.5	25.5	13.5

3.3. Characteristics of Idor Longan by the Sorted Groups

To evaluate the effectiveness of the proposed system, the physical and biochemical characteristics of fruits within each group were analyzed, as presented in Table 2. Overall, compared to other cultivars, the Idor cultivar is characterized by a high aril proportion (edible portion), accounting for 67.09–72.42% of total fruit weight, whereas other cultivars typically range from 55.9–72.2% (Nguyen et al., 2017; Shi et al., 2016; Tran & Tran, 2019; Wongchana & Issarakraisila, 2009). Its aril also exhibits a similar moisture level (around 80%) and comparable TSS (17.10-19.58°Brix) to other cultivars (12–23°Brix) (Nguyen et al., 2017; Shahrajabian et al., 2019; Shi et al., 2016; Tripathi, 2021; Wang et al., 2020; Zhang et al., 2020). However, total sugar content was slightly lower (61.15–66.43% db) than the reported range (62–90% db) (Deng et al., 2023; Yang et al., 2021), suggesting a moderately sweet flavor. In terms of bioactive compounds, Idor longan contained lower vitamin C (173.5-195.6 mg/100 g DM) and TPC (69.5-155.8 mg GAE/100 g DM) compared with reported averages for longan cultivars (75–820 mg/100 g DM for vitamin C (Le et al., 2020; Nguyen et al., 2017; Shi et al., 2016; USDA, 2022) and 110–660 mg GAE/100 g DM for TPC (Yang et al., 2021; Zhang et al., 2018; Zhang et al., 2020). Nutritionally, the aril was rich in carbohydrates but contained low lipid levels (0.21–0.45% db) (Le et al., 2020; Shahrajabian et al., 2019; USDA, 2022; Yang et al., 2021). This result indicates that Idor longan is a cultivar that combines a high edible portion with balanced sweetness and a considerable level of bioactive compounds.

Table 2
Physical and biochemical characteristics of Idor longan fruits by height-based groups

Group (Sorted by height)	H1 (0, 2.2] cm	H2 (2.2, 2.3] cm	H3 (2.3, 2.4] cm	H4 (2.4, 2.5] cm	H5 (2.5, 2.6] cm	H6 (2.6, +∞] cm
<i>Percentage of fruit parts</i>						
Pericarp (%)	18.24 ± 1.22 ^d	16.66 ± 1.36 ^{bc}	16.89 ± 1.24 ^c	15.88 ± 1.17 ^{ab}	15.54 ± 0.59 ^a	15.24 ± 0.73 ^a
Aril (%)	72.42 ± 1.38 ^e	68.70 ± 2.58 ^b	67.09 ± 2.31 ^a	69.21 ± 1.51 ^{bc}	70.20 ± 1.19 ^{cd}	70.93 ± 0.93 ^d
Seed (%)	9.34 ± 1.38 ^a	14.64 ± 2.33 ^{bc}	16.03 ± 1.29 ^d	14.91 ± 1.27 ^c	14.26 ± 0.94 ^{bc}	13.82 ± 0.44 ^b
<i>Color of pericarp</i>						
<i>L*</i>	47.17 ± 2.22 ^{ab}	47.88 ± 1.98 ^b	46.66 ± 1.56 ^{ab}	47.18 ± 2.49 ^{ab}	47.38 ± 2.37 ^{ab}	45.94 ± 1.79 ^a
<i>a*</i>	14.02 ± 1.11 ^{ns}	14.50 ± 1.44 ^{ns}	14.48 ± 1.51 ^{ns}	14.28 ± 1.34 ^{ns}	14.57 ± 0.90 ^{ns}	13.91 ± 1.04 ^{ns}
<i>b*</i>	16.78 ± 1.54 ^{ab}	16.71 ± 1.87 ^{ab}	17.54 ± 0.94 ^b	16.64 ± 1.76 ^{ab}	17.00 ± 1.33 ^b	15.83 ± 0.93 ^a
<i>Color of aril</i>						
<i>L*</i>	32.16 ± 2.49 ^{ns}	31.27 ± 2.24 ^{ns}	30.64 ± 1.79 ^{ns}	30.79 ± 2.87 ^{ns}	30.66 ± 1.97 ^{ns}	30.57 ± 2.49 ^{ns}
<i>a*</i>	5.83 ± 0.77 ^a	6.02 ± 1.31 ^a	5.96 ± 0.85 ^a	6.76 ± 0.93 ^b	8.87 ± 0.65 ^c	8.29 ± 0.92 ^c
<i>b*</i>	5.94 ± 1.49 ^a	6.38 ± 1.39 ^a	6.74 ± 1.03 ^a	8.45 ± 1.69 ^b	8.41 ± 1.40 ^b	10.24 ± 1.28 ^c
<i>Biochemical content</i>						
Moisture content (%)	81.27 ± 0.38 ^d	80.42 ± 0.60 ^c	79.84 ± 0.36 ^{ab}	79.94 ± 0.50 ^b	79.50 ± 0.68 ^a	79.53 ± 0.75 ^{ab}
TSS, °Brix	17.10 ± 0.67 ^a	17.14 ± 0.30 ^a	18.96 ± 0.31 ^b	18.90 ± 0.67 ^b	19.28 ± 0.25 ^{bc}	19.58 ± 0.76 ^c
TA, %	0.083 ± 0.009 ^a	0.087 ± 0.010 ^a	0.091 ± 0.006 ^{ab}	0.098 ± 0.011 ^c	0.097 ± 0.013 ^{bc}	0.103 ± 0.012 ^{bc}
Note: d.b. – dry basis; GAE – gallic acid equivalent; DM – dry matter; Different letters indicate significant differences (p < 0.05, LSD test); ns – no significant difference.						

Group (Sorted by height)	H1 (0, 2.2] cm	H2 (2.2, 2.3] cm	H3 (2.3, 2.4] cm	H4 (2.4, 2.5] cm	H5 (2.5, 2.6] cm	H6 (2.6, +∞] cm
TSS/TA	212 ± 26 ^b	201 ± 27 ^{ab}	211 ± 16 ^b	194 ± 30 ^{ab}	202 ± 29 ^{ab}	191 ± 20 ^a
Protein (%, d.b.)	4.45 ± 0.51 ^{ns}	4.72 ± 0.54 ^{ns}	4.41 ± 0.42 ^{ns}	4.67 ± 0.53 ^{ns}	4.58 ± 0.49 ^{ns}	4.58 ± 0.60 ^{ns}
Lipid (%, d.b.)	ND	ND	ND	ND	ND	ND
Ash (%, d.b.)	4.03 ± 0.30 ^a	4.07 ± 0.14 ^{ab}	4.04 ± 0.31 ^{ab}	4.09 ± 0.40 ^{ab}	4.18 ± 0.25 ^{ab}	4.24 ± 0.27 ^b
Total carbohydrate (%, d.b.)	91.51 ± 0.72 ^{ns}	91.21 ± 0.49 ^{ns}	91.56 ± 0.54 ^{ns}	91.23 ± 0.52 ^{ns}	91.24 ± 0.48 ^{ns}	91.18 ± 0.52 ^{ns}
Total sugars (%, d.b.)	61.15 ± 2.97 ^a	61.58 ± 4.08 ^a	63.94 ± 4.21 ^b	64.12 ± 1.73 ^b	64.78 ± 1.63 ^{bc}	66.43 ± 3.38 ^c
Vitamin C (mg /100 g DM)	195.6 ± 3.1 ^d	184.3 ± 2.6 ^c	175.0 ± 2.9 ^b	177.1 ± 3.6 ^{ab}	172.4 ± 2.6 ^a	173.5 ± 5.6 ^a
TPC (mg GAE /g 100 DM)	155.8 ± 11.0 ^d	145.0 ± 7.6 ^c	88.8 ± 5.2 ^b	70.5 ± 04.0 ^a	69.5 ± 5.4 ^a	74.1 ± 4.0 ^a
Note: d.b. – dry basis; GAE – gallic acid equivalent; DM – dry matter; Different letters indicate significant differences (p < 0.05, LSD test); ns – no significant difference.						

The analysis results highlighted the differences among the groups, as each group exhibited distinct physical and biochemical characteristics, further confirming that sorting Idor longan fruits by height is effective. In general, a whole longan fruit can be divided into three parts: pericarp, seed, and the edible aril (Fig. 3). Among the sorted groups, H1 exhibited the lowest seed proportion (9.34%) and the highest aril proportion (72.42%), primarily due to the presence of seedless or parthenocarpic fruits, likely resulting from incomplete ovary development during fertilization (Pham et al., 2015). As shown in Fig. 3, seeds in this group are consistently smaller and wrinkled surface compared to those in other groups. In contrast, the H3 group had the lowest aril percentage, while a gradual increase was observed from H3 to H6, reaching 70.93%, which remained slightly below that of H1. Regarding color, the pericarp color exhibited minimal variation among groups (Table 2, Fig. 3), whereas the aril color displayed a noticeable shift from white to yellow with increasing fruit size, as reflected by rising a* and b* values (Table 2).

Significant variations were also found in the biochemical parameters. For the moisture content, group H1 (smallest fruits) had the highest moisture content (81.27%), while the groups H3-H6 (larger fruit) exhibited lower values (79.5–79.9%), which were statistically different from H1. In contrast, TSS and total sugar contents increased with fruit size, reaching 19.58 °Brix and 66.43% db in H6, respectively. No significant differences were found in protein, lipid, or carbohydrate contents (dry basis), except for a slight increase in ash content in H6. Since these values were calculated on a dry basis, variations in moisture content imply corresponding differences in nutrient concentration when expressed on a wet basis. Collectively, these results suggest that larger fruits possess higher sweetness and greater nutritional density. Regarding bioactive compounds, both vitamin C and TPC decreased with increasing fruit size. The smallest fruits (H1) contained the highest levels of vitamin C (195.6 mg/100 g DM) and TPC (155.8 mg GAE/100 g DM), while the larger fruits (H4-H6) exhibited significantly lower values (172–177 mg vitamin C and 69–74 mg GAE/100 g DM), which were also statistically different. This pattern indicates that smaller Idor longan possess higher levels of bioactive compounds and greater antioxidant potential.

The observed differences among groups, particularly between H3 and H6, may be associated with variations in harvest timing (caused by uneven pollination) (Pham et al., 2015; Tran & Tran, 2019), and/or microclimatic conditions during fruit development (De Salvador et al., 2006; Lu et al., 2021; Mikulic-Petkovsek et al., 2016; Pham et al., 2015; Qiao et al., 2023). Several studies have reported that as longan fruits mature, they increase in size and TSS while decreasing in titratable acidity, vitamin C, and TPC, partially aligning with this study's findings (Le et al., 2020; Nguyen et al., 2017; Shi et al., 2016; Wongchana & Issarakraisila, 2009). However, the minimal variation in aril color, TSS/TA ratio (Nguyen et al., 2017; Shi et al., 2016), and protein content (Le et al., 2020) among groups suggests that all fruits had reached maturity, thereby limiting the extent to which harvest timing alone can explain these differences.

In addition, variations in fruit size and composition may reflect microclimatic effects. For example, grape berries grown under lower humidity and higher sunlight conditions tend to be larger and have higher TSS but lower phenolic content (Qiao et al., 2023), with greater sunlight (Lu et al., 2021), or developing from the basal part (near the stem) of the cluster (Mikulic-Petkovsek et al., 2016) were recorded to be larger and exhibited higher TSS content, which is consistent with the findings in this study. However, although the effect of increased sunlight exposure which was linked with larger fruit size and lower phenolic content (Lu et al., 2021) was consistent with present findings, the positional effect, whereby basal fruits exhibit greater weight and higher phenolic levels, contradicts the observations in this study (Mikulic-Petkovsek et al., 2016). Similarly, in apples, smaller fruits grown under high crop loads often show higher TSS, opposing the trend with the present findings (De Salvador et al., 2006). Furthermore, the characteristics of seedless or parthenocarpic longan fruits, primarily found in the H1 group, remain poorly understood. Compared to normal fruits, these fruits may exhibit different physiological development and metabolic activity (Pham et al., 2015). Further research is needed to clarify how fruit developmental processes, together with environmental and microclimatic factors, influence fruit size and quality in the Idor cultivar.

3.4. Application of Principal Component Analysis

To further elucidate the variations in fruit characteristics among the height-based groups (H1 to H6), PCA was applied to evaluate quality attributes and identify the unique features of each group. Eleven dependent variables showed statistically significant differences among groups were included: the percentages of aril, pericarp, and seed; the aril color parameters (a^* and b^*); moisture content; TSS; TA; total sugar content; vitamin C, and total phenolic content. These variables were selected as key indicators of fruit quality for subsequent principal component analysis to distinguish the characteristic profiles of each sorted group.

Figure 4 presents the covariance matrix illustrating the interrelationships among the eleven variables, which are key indicators of longan fruit quality. Blue squares indicate positive correlations, while the red squares signify negative correlations. The number, along with the square area and intensity of the color, reflect the strength of the correlation between each pair (Chen et al., 2024). Overall, a wide range of correlations was observed among the parameters. Notably, strong positive correlations were found between vitamin C and TPC ($R = 0.83$), TSS and aril b^* value ($R = 0.79$), and total sugar and aril b^* value ($R = 0.75$), while negative correlations were noted between pericarp percentage and both aril percentage ($R = -0.83$) and aril b^* values ($R = -0.75$). Additional correlations are presented in Fig. 4. These strong inter-variable relationships confirmed that PCA was appropriate for summarizing and visualizing the underlying structure of the dataset (Bollinedi et al., 2020; Chen et al., 2024; Cozzolino et al., 2019).

A Scree plot (Fig. 5) was generated to determine the importance of principal components. The optimal number of components was identified by locating the “elbow” in the plot, where the variance percentage decreases sharply (Bollinedi et al., 2020). In this study, the “elbow” was observed between the PC2 and PC3 indicated that the first two PC were sufficient to explain the data and the following PC can be discarded. Together, PC1 and PC2 accounted for 73.30% of the total cumulative variance, which satisfies the criterion proposed by Lawless&Heymann (2010) and aligns with previous studies (Souza et al., 2024; Tornuk et al., 2014). The eigenvectors and percentage contributions of each variable to PC1 and PC2 are summarized in Table 3. PC1 was primarily associated with TSS, TPC, vitamin C, and aril b^* , indicating their strong contribution to overall fruit quality, whereas PC2 was mainly correlated with aril and seed percentages, reflecting differences in fruit composition.

Table 3
Eigenvectors of variables and their contributions to the principal components

No.	Dependent variable	Eigenvectors		Contribution (%)	
		PC1	PC2	PC1	PC2
1	Pericarp (%)	-0.3325	-0.1223	11.05	1.50
2	Aril (%)	-0.0024	0.6305	0.00	39.75
3	Seed (%)	0.1946	-0.5306	3.79	28.16
4	a* of aril	0.2759	0.0597	7.61	0.36
5	b* of aril	0.3371	0.2953	11.36	8.72
6	TSS	0.3828	0.0330	14.66	0.11
7	TA	0.2604	0.0006	6.78	0.00
8	Vitamin C	-0.3542	0.2231	12.55	4.98
9	Moisture content	-0.3183	0.1319	10.13	1.74
10	Total sugars	0.2819	0.3633	7.94	13.20
11	TPC	-0.3758	0.1224	14.12	1.50

The selected components were then used to construct a biplot (Fig. 6), which visualized both the correlations among quality attributes as feature vectors (loading plot) and the distribution of fruit groups (score plot). In this biplot, the projection of each vector onto the axes reflects its correlation with the corresponding principal component. Vectors that are longer and closer to an axis contribute more, whereas shorter or more angled vectors contribute less. The angle between vectors indicates the correlation between variables: small angles show strong positive correlations, 90° indicates no correlation, and angles > 90° indicate negative correlations (Bollinedi et al., 2020; Souza et al., 2024). For example, the biplot shows a positive correlation between TSS and aril b* value, and a negative correlation between seed and aril percentages, consistent with the results shown in Table 3.

The biplot (Fig. 6) also includes 95% confidence ellipses to illustrate the variability within each height-based group (Abdelsalam et al., 2025; Husson et al., 2004; Quek et al., 2018; Šnirc et al., 2017). By examining the intersection of these ellipses, additional details beyond those revealed by conventional ANOVA can be observed. Notably, Fig. 6 shows a large difference between the H1, H2 and H3-H6 groups, as their corresponding ellipses did not completely overlap. The H1 ellipses, located in the upper left quadrant, represent fruits with high percentage of aril and pericarp percentage, with greater moisture content, and higher vitamin C levels, which serve as the key characteristics of this group. The ellipse area of H2 group is the largest, indicating the greatest variability in fruits quality. Positioned in between, the H2 ellipse largely overlaps with the H1 and partially with H3 and H6 ellipses, suggesting similar but less

pronounced characteristics compared to H1. In contrast, the ellipses H3-H6 were located on the right side of the plot and overlapped almost completely, indicating that these groups share similar characteristics. Their key traits included a higher seed percentage, increased aril a^* and b^* color values, together with higher TSS, TA, and total sugar contents. Furthermore, from H3 to F6 group, the ellipse areas gradually decreased and shifted toward the upper-right region, suggesting that fruits of greater height exhibited more uniform and stable quality.

3.5. Utilization Strategy

The first point to emphasize is that the act of sorting itself enhances both the acceptability and market value of Idor longan fruits (De Salvador et al., 2006; Le et al., 2021; Tiwari, 2019). Moreover, the results of this study revealed that fruit height correlates significantly with several internal quality traits, suggesting the feasibility of developing specialized utilization strategies for each group. Since the fruit height of longan is consistently smaller than its diameter, simple and practical separation methods can be developed—ranging from manual tools such as a ruler to mechanical options like a rotary drum grader with parallel bars, or even automated image-based sorting systems (Tiwari, 2019). The results can also be converted to other standards based on fruit weight or maximum diameter, when necessary, as shown in Table 1.

The H1 group, consisting of fruits with heights below 2.2 cm (approximately 6.0% of total fruits), contained numerous seedless or parthenocarpic fruits. This group exhibited a high aril proportion, along with elevated vitamin C and TPC, indicating strong potential for bioactive-oriented utilization (Yang et al., 2021; Zhang et al., 2018; Zhang et al., 2020). Its high moisture content, combined with lower sugar and nutritional levels, further enhances its suitability for health-oriented consumption. The subsequent H2 group (2.2–2.3 cm in height, accounting for ~ 10% of fruits) showed similar but less pronounced characteristics compared with the H1 group, suggesting its suitability as a secondary option for bioactive-focused uses. However, owing to their small size, lower yields, and higher variability in quality, fruits from both groups are considered more appropriate for fresh consumption rather than for industrial processing.

The H3-H6 groups, consisting of fruits with heights above 2.3 cm, were characterized by a more yellow aril (higher a^* and b^* values) and higher TSS, TA, and total sugars content, indicating superior eating quality and nutritional levels (Nguyen et al., 2017; Shi et al., 2016). Their higher TSS, lower moisture and TPC contents also suggests improved postharvest stability, making them more suitable for storage and processing (Le et al., 2021; Nguyen et al., 2017). Together, these groups accounted for approximately 84% of all fruits, further supporting their relevance for industrial applications. Although they shared similar general quality profiles, statistical differences were observed among the H3–H6 groups (Table 2), especially in aril percentage, a^* and b^* color values of aril, TSS, and total sugar content. These findings align with the common perception that larger fruits possess higher quality. Therefore, for better and more consistent quality (as indicated by a more yellow aril color, a higher aril proportion, and higher TSS and total sugar contents), consumers and processors may therefore prefer fruits with greater height or larger size.

4. Conclusion

This study demonstrated that Idor longan fruits cultivated in the Mekong Delta can be effectively sorted based on fruit height, which also exhibits strong correlations with key internal quality attributes. Accordingly, height-based grouping provides a practical foundation for developing specialized utilization strategies tailored to different fruit categories. In addition to traditional physical and biochemical assessments characterize fruit quality, the integration of PCA enabled a focused visualization of distinctions among groups, thereby reinforcing the reliability of the proposed classification approach. Collectively, these findings provide valuable insights for optimizing postharvest handling, grading, and utilization of Idor longan, and may also serve as a reference framework for related longan cultivars in future studies.

Declarations

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Competing Interests and Funding

The authors declare no conflict of interests and funding currently.

Author Contribution

NGUYEN Van Muoi and TRAN Thanh Truc designed the conceptualization and methodology. Nguyen Van Muoi supervised the study. TO Nguyen Phuoc Mai and PHAN Minh Trong contributed to investigation and conducted formal analysis. TO Nguyen Phuoc Mai and TRAN Thanh Truc contributed to the manuscript preparation, reading, and approval for publication. TO Nguyen Phuoc Mai: Data curation and Formal analysis, Writing - original draft. PHAN Minh Trong: Data curation and Formal analysis. TRAN Thanh Truc: Conceptualization, Methodology, and Writing – review & editing. NGUYEN Van Muoi: Conceptualization, Methodology and Supervision.

References

1. Abdelsalam K M H, Shaalan A M, AbouEl-Soud G M, El-Dalil M A E, Marei A M, El-Moneim D A, El-Banna A A A, Lamlom S F, Abdelghany A M (2025) Comprehensive quality profiling and multivariate analysis of rice (*Oryza sativa* L.) cultivars: integrating physical, cooking, nutritional, and micronutrient characteristics for enhanced varietal selection. BMC Plant Biol. 25(1): 492. <https://doi.org/10.1186/s12870-025-06438-5>

2. Bastola K P, Guragain Y N, Bhadriraju V, Vadlani P V (2017) Evaluation of standards and interfering compounds in the determination of phenolics by Folin-Ciocalteu assay method for effective bioprocessing of biomass. *Am. J. Anal. Chem.* 8(6): 416–431.
<https://doi.org/10.4236/ajac.2017.86032>
3. Bollinedi H, Vinod K K, Bisht K, Chauhan A, Krishnan S G, Bhowmick P K, Nagarajan M, Rao D S, Ellur R K, Singh A K (2020) Characterising the diversity of grain nutritional and physico-chemical quality in Indian rice landraces by multivariate genetic analyses. *Indian J. Genet. Plant Breed.* 80(01): 26–38.
<https://doi.org/10.31742/IJGPB.80.1.4>
4. Chen L, Chen R, Atwa E M, Mabrouk M, Jiang H, Mou X, Ma X (2024) Nutritional Quality Assessment of Miscellaneous Cassava Tubers Using Principal Component Analysis and Cluster Analysis. *Foods* 13(12): 1861. <https://doi.org/10.3390/foods13121861>
5. Codex Alimentarius Commission (1999) Codex Standard for Longans (CODEX STAN 220–1999). Rome: Food and Agricultural Organization of the United Nations and the World Health Organization.
6. Cozzolino D, Power A, Chapman J (2019) Interpreting and reporting principal component analysis in food science analysis and beyond. *Food Anal. Methods* 12(11): 2469–2473.
<https://doi.org/10.1007/s12161-019-01605-5>
7. De Salvador F R, Fisichella M, Fontanari M (2006) Correlations between fruit size and fruit quality in apple trees with high and standard crop load levels. *J. Fruit Ornam. Plant Res.* 14: 113-122.
8. Deng Y, Lai C, Zhang Y, Zhou P, Liu G, Tang X, Li P, Zhao Z, Zhang M, Wei Z (2023) Effects of pretreatment methods on the physicochemical properties of dried longan (*Dimocarpus longan* Lour.) pulps. *J. Food Sci.* 88(8): 3474–3493. <https://doi.org/10.1111/1750-3841.16675>
9. Husson F, Bocquet V, Pages J (2004) Use of confidence ellipses in a PCA applied to sensory analysis application to the comparison of monovarietal ciders. *J. Sens. Stud.* 19(6): 510–518.
<https://doi.org/10.1111/j.1745-459X.2004.062104.x>
10. Jaćimović S, Kiproviski B, Ristivojević P, Dimić D, Nakarada Đ, Dojčinović B, Sikora V, Teslić N, Pantelić N Đ (2023) Chemical composition, antioxidant potential, and nutritional evaluation of cultivated Sorghum Grains: A combined experimental, theoretical, and multivariate analysis. *Antioxidants* 12(8): 1485. <https://doi.org/10.3390/antiox12081485>
11. Jiang Y, Zhang Z, Joyce D C, Ketsa S (2002) Postharvest biology and handling of longan fruit (*Dimocarpus longan* Lour.). *Postharvest Biol. Technol.* 26(3): 241–252.
[https://doi.org/10.1016/S0925-5214\(02\)00047-9](https://doi.org/10.1016/S0925-5214(02)00047-9)
12. Kader A A (2002) Postharvest technology of horticultural crops. California, USA: University of California Agriculture and Natural Resources.
13. Latimer G W (2016) Official methods of analysis of AOAC International (20th Edition ed.). Rockville: AOAC International.
14. Lawless H T, Heymann H (2010) Sensory evaluation of food: principles and practices (2nd ed.). New York, USA: Springer.

15. Le T B P, To N P M, Nguyen V A, Nguyen V M (2021) The advanced food preservation techniques for increased shelf life of fruits: A review. *Can Tho Univ. J. Sci.* 57 (Special Issue of Food Technology): 32–47. <https://doi.org/10.22144/ctu.jsi.2021.004>
16. Le V D, Ngo N H (2022) Assessment of the current cultivation of Edor longan variety growing on raised bed in Phong Dien district, Can Tho city. *J. Vietnam Agric. Sci. Technol.* 6: 68–73.
17. Le V T, Nguyen N K, Le T L (2020) Physiological and biochemical changes in longan fruit (*Dimocarpus longan* Lour.) cultivated in Vietnam during growth and ripening. *Indian J. Nat. Prod. Resour.* 11(4): 333–339.
18. Lu H-C, Wei W, Wang Y, Duan C-Q, Chen W, Li S-D, Wang J (2021) Effects of sunlight exclusion on leaf gas exchange, berry composition, and wine flavour profile of Cabernet-Sauvignon from the foot of the north side of Mount Tianshan and a semi-arid continental climate. *OENO One* 55(2): 267–283. <https://doi.org/10.20870/oeno-one.2021.55.2.4545>
19. Mikulic-Petkovsek M, Koron D, Veberic R (2016) Quality parameters of currant berries from three different cluster positions. *Sci. Hortic.* 210: 188–196. <https://doi.org/10.1016/j.scienta.2016.07.030>
20. Nguyen T T, Ngo V H, Do O V (2017) Determination of Optimal Harvest Date for Longan cv. 'Edor' in Wet and Dry Season. *Viet. J. Agric. Sci.* 15(6): 826–833.
21. Pham V T, Herrero M, Hormaza J I (2015) Phenological growth stages of longan (*Dimocarpus longan*) according to the BBCH scale. *Sci. Hortic.* 189: 201–207. <https://doi.org/10.1016/j.scienta.2015.03.036>
22. Qiao Z-Y, Zhang Y-H, Zhang X-Y, Zhang L, Shi J-H, Zhou J, Ge J (2023) Effect of microclimates in different slope aspects on quality of 'Chardonnay' grape berries. *Southwest China J. Agric. Sci.* <https://doi.org/10.16213/j.cnki.scjas.2023.4.017>
23. Quek M C, Chin N L, Yusof Y A, Law C L, Tan S W (2018) Pattern recognition analysis on nutritional profile and chemical composition of edible bird's nest for its origin and authentication. *Int. J. Food Prop.* 21(1): 1680–1696. <https://doi.org/10.1080/10942912.2018.1503303>
24. Sasikumar R, Vivek K, Chakkaravarthi S, Deka S C (2021) Physicochemical characterization and mass modeling of blood fruit (*Haematocarpus validus*) – An underutilized fruit of northeastern India. *Int. J. Fruit Sci.* 21(1): 12–25. <https://doi.org/10.1080/15538362.2020.1848752>
25. Shahrajabian M H, Sun W, Cheng Q (2019) Modern pharmacological actions of longan fruits and their usages in traditional herbal remedies. *J. Med. Plants Stud.* 7(4): 179–185.
26. Shi S, Wang W, Liu L, Shu B, Wei Y, Jue D, Fu J, Xie J, Liu C (2016) Physico-chemical properties of longan fruit during development and ripening. *Sci. Hortic.* 207: 160–167. <https://doi.org/10.1016/j.scienta.2016.05.026>
27. Šnirc M, Kral M, Ošťádalová M, Golian J, Tremlová B (2017) Application of principal component analysis method for characterization chemical, technological, and textural parameters of farmed and pastured red deer. *Int. J. Food Prop.* 20(4): 754–761. <https://doi.org/10.1080/10942912.2016.1180532>

28. Souza A S, Bezerra M A, Cerqueira U M F M, Rodrigues C J O, Santos B C, Novaes C G, Almeida E R V (2024) An introductory review on the application of principal component analysis in the data exploration of the chemical analysis of food samples. *Food Sci. Biotechnol.* 33(6): 1323–1336. <https://doi.org/10.1007/s10068-023-01509-5>.
29. Tiwari A (2019) Nondestructive methods for size determination of fruits and vegetables. In *Processing of Fruits and Vegetables* (pp. 203–221): Apple Academic Press.
30. Tornuk F, Ozturk I, Karaman S, Sagdic O, Yetim H (2014) Rheological and some physicochemical properties of probiotic boza beverage fermented with *Lactobacillus casei* Shirota: application of principal component analysis for the characterisation. *Qual. Assur. Saf. Crops Foods* 6(2): 237–247. <https://doi.org/10.3920/QAS2012.0231>
31. Tran V H, Tran S H (2019) Longan and rambutan in the Mekong Delta, Vietnam: A review of technologies to improve flowering and fruit setting. *Can Tho Univ. J. Sci.* 11(1): 7–23. <https://doi.org/10.22144/ctu.jen.2019.002>
32. Tripathi P C (2021) 10. Longan (*Dimocarpus longan* Lour.). In Ghosh S N, Sharma R R (Eds.), *Tropical Fruits* (pp. 384–412). New Delhi, India: Jaya Publ. Co.
USDA (2022). Longans, raw. Retrieved from <https://fdc.nal.usda.gov/fdc-app.html#/food-details/169089/nutrients>
33. Wang J, Guo D, Han D, Pan X, Li J (2020) A comprehensive insight into the metabolic landscape of fruit pulp, peel, and seed in two longan (*Dimocarpus longan* Lour.) varieties. *Int. J. Food Prop.* 23(1): 1527–1539. <https://doi.org/10.1080/10942912.2020.1815767>
34. Wongchana B, Issarakraisila M (2009) Growth and Development of Longan (*Dimocarpus longan* Lour.) fruit cv Daw in Nakhon Si Thammarat Province. *Thai Agric. Res. J.* 27(2): 151–151. <https://doi.org/10.14456/thaidoa-agres.2009.10>
35. Yang E Y, Han Y S, Sim K H (2021) Characterisation of nutritional, physiochemical, and mineral compositions of aril and seed of longan fruit (*Dimocarpus longan* L.). *Int. Food Res. J.* 28(1): 91–101.
36. Zhang R, Khan S A, Lin Y, Guo D, Pan X, Liu L, Wei Z, Zhang Y, Deng Y, Zhang M (2018) Phenolic profiles and cellular antioxidant activity of longan pulp of 24 representative Chinese cultivars. *Int. J. Food Prop.* 21(1): 746–759. <https://doi.org/10.1080/10942912.2018.1425705>
37. Zhang X, Guo S, Ho C-T, Bai N (2020) Phytochemical constituents and biological activities of longan (*Dimocarpus longan* Lour.) fruit: A review. *Food Sci. Hum. Wellness* 9(2): 95–102. <https://doi.org/10.1016/j.fshw.2020.03.001>
38. Zhu S, Zhou B, Liu Q, Wu H, Zheng L (2016) Effect of longan polysaccharides on proliferation and phenotype maintenance in rabbit articular chondrocytes in vitro. *Med. Biol. Eng. Comput.* 54: 607–617. <https://doi.org/10.1007/s11517-015-1352-1>

Figures

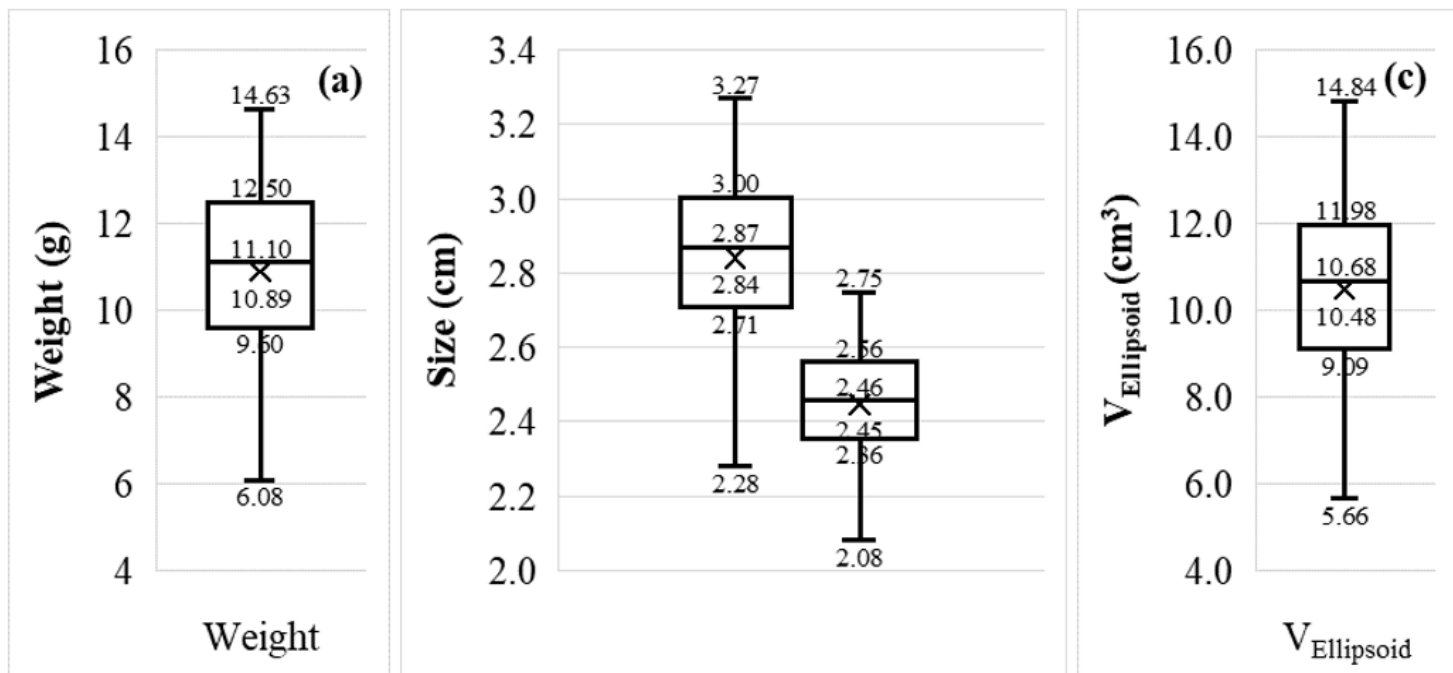


Figure 1

Distribution of weight (a), diameter and height (b), and theoretical volume (c) of Idor longan fruits grown in the Mekong Delta, Vietnam.

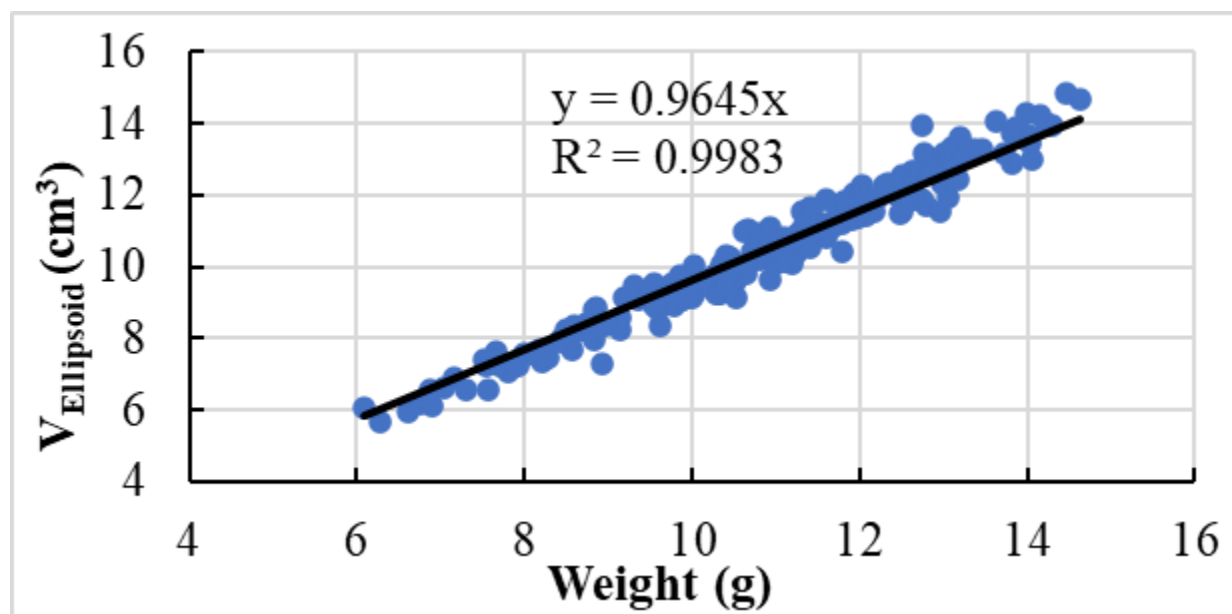


Figure 2

Relationship between weight and the theoretical volume of Idor longan fruits grown in the Mekong Delta, Vietnam.

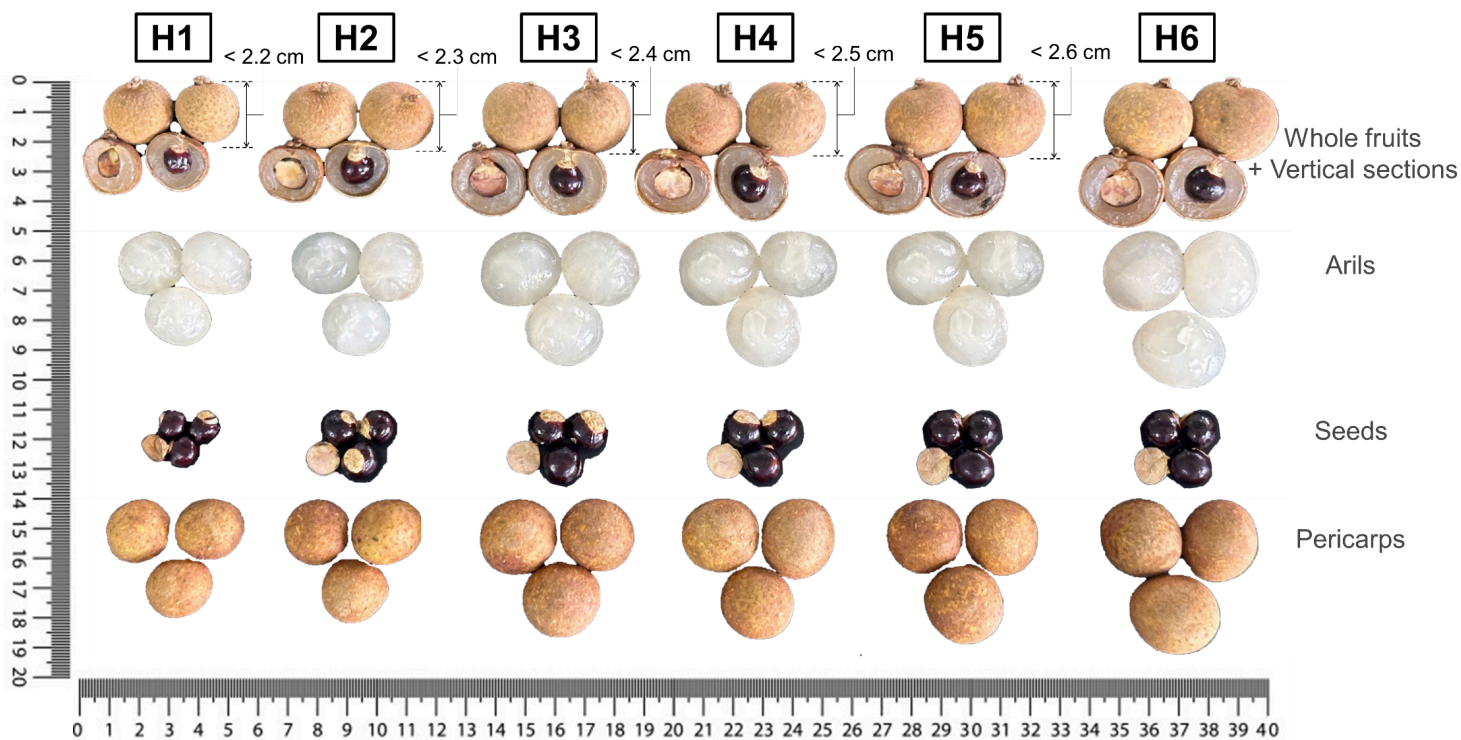


Figure 3

Appearance of 06 height-based groups of Idor longan fruits cultivated in the Mekong Delta, Vietnam.

Note: Groups defined by height: H1(0, 2.2] cm, H2 (2.2; 2.3] cm, H3 (2.3; 2.4] cm, H4 (2.4; 2.5] cm, H5 (2.5; 2.6] cm, and H6 (2.6, +∞] cm

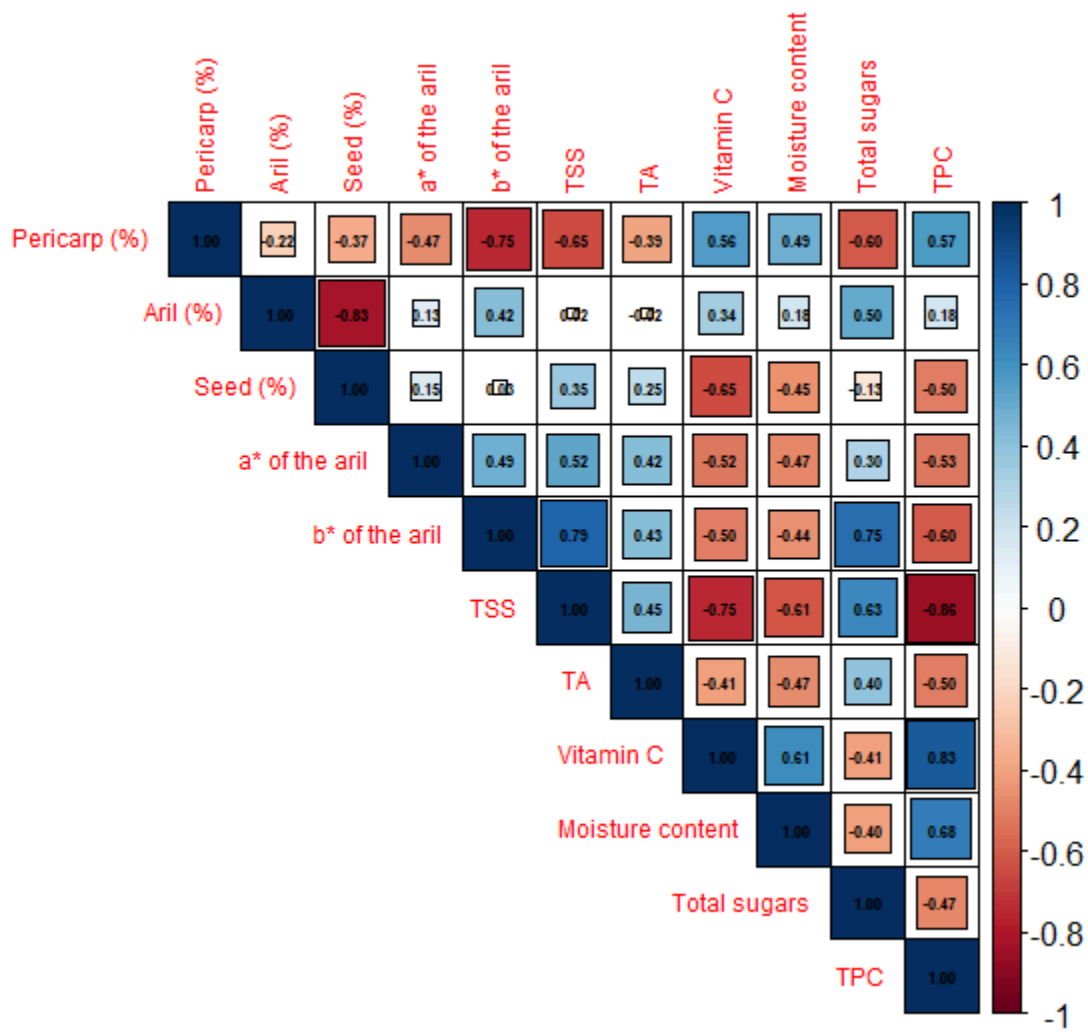


Figure 4

Covariance matrix of the selected variables used in the PCA.

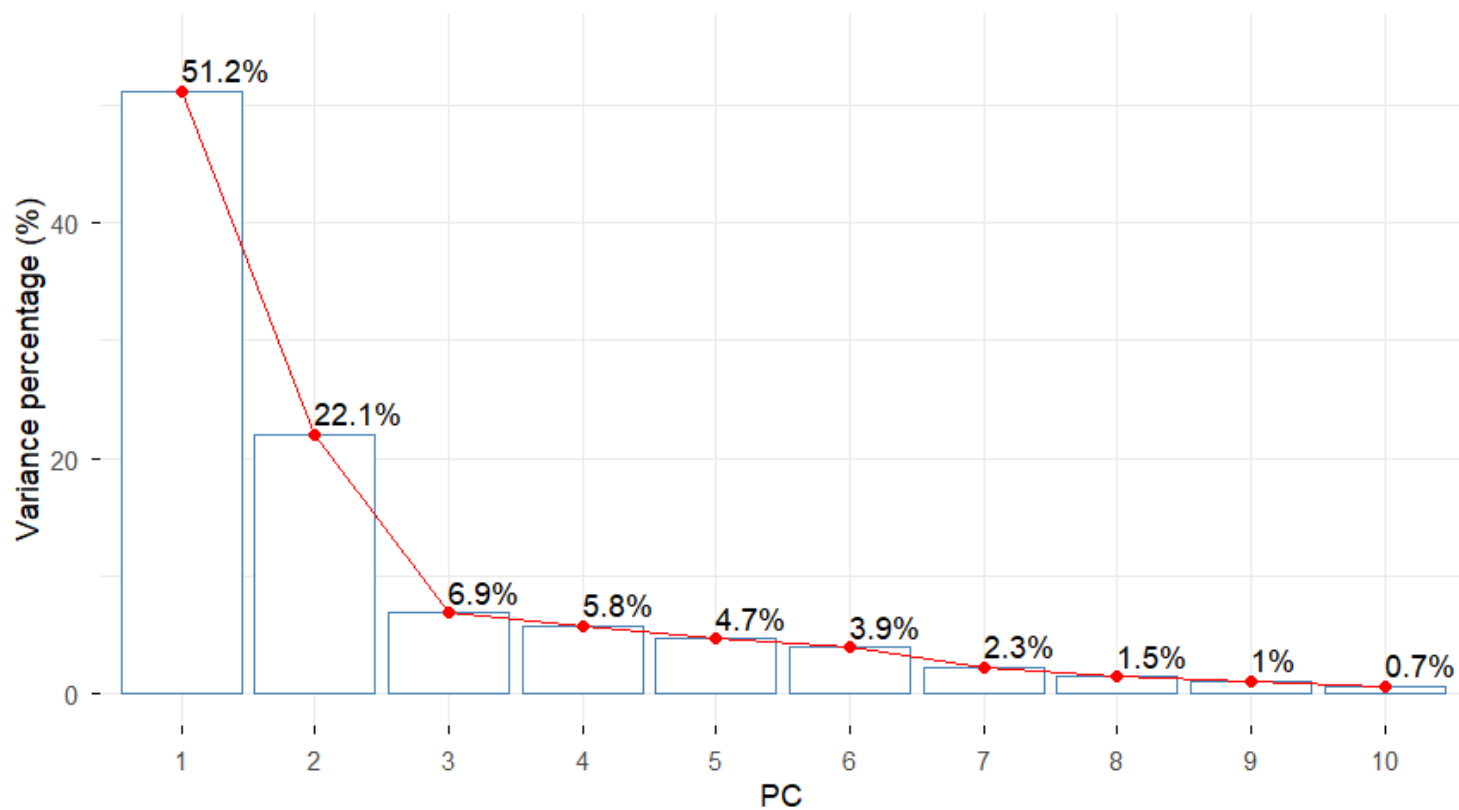


Figure 5

Scree plot of variance percentage by PCs.

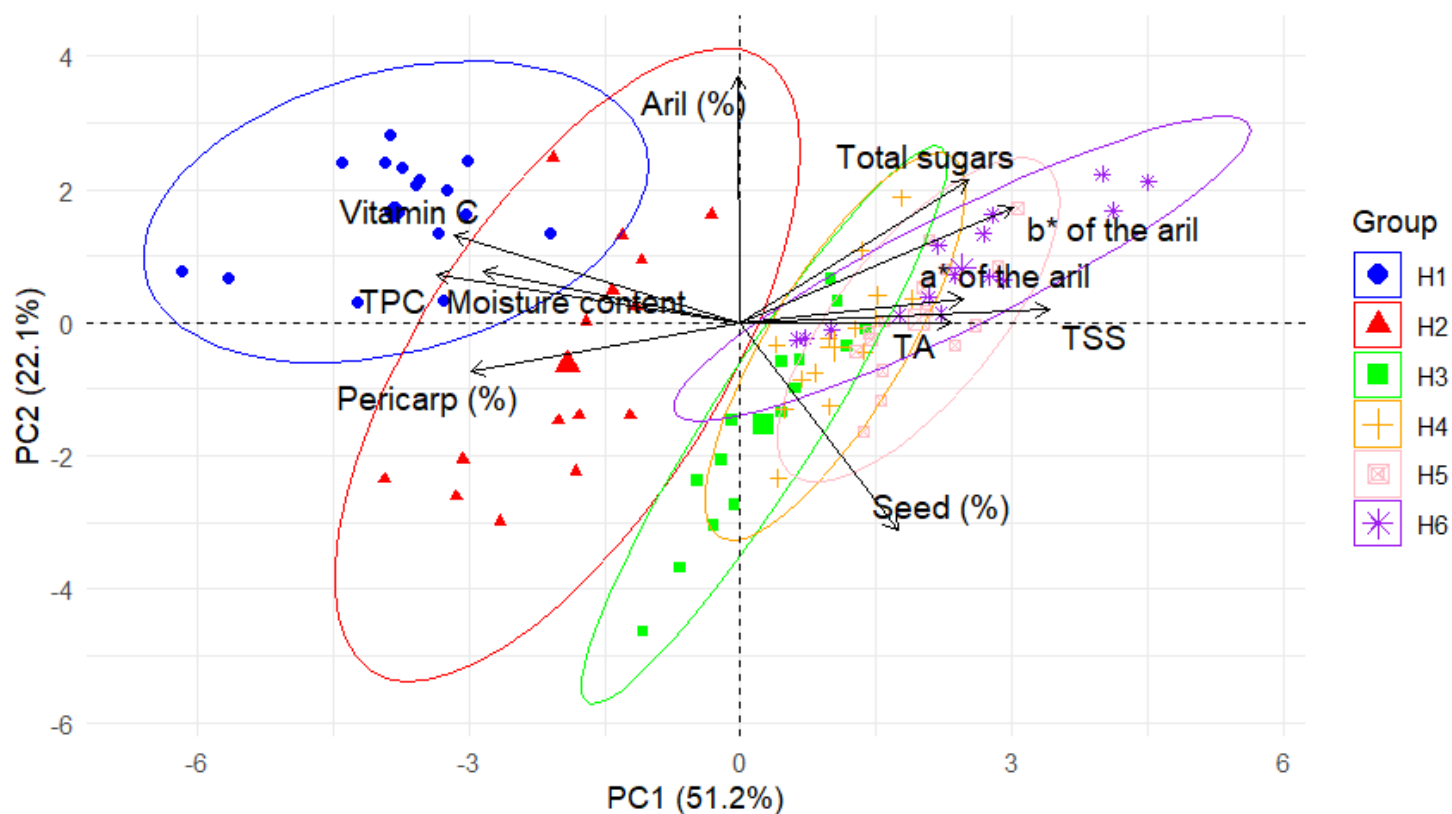


Figure 6

Biplot showing correlations among dependent variables in the coordinate system defined by PC1 (51.2%) and PC2 (22.1%).

Note: Groups defined by height: H1(0, 2.2] cm, H2 (2.2; 2.3] cm, H3 (2.3; 2.4] cm, H4 (2.4; 2.5] cm, H5 (2.5; 2.6] cm, and H6 (2.6, +∞] cm; Ellipses represent each group's dataset with 95% confidence.