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Morphological Characterization and Nutritional Evaluation of Sidimpuan Salak (Salacca sumatrana Becc) Based on Flesh Color

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Abstract: Salak is a native Indonesian plant with various cultivars, one of which is the Sidimpuan salak originating from North Sumatra. Sidimpuan salak fruit has a distinctive taste, namely a fairly sweet but slightly sour taste, sticky, astringent, quite highs water content in the fruit, and various colors of the fruit flesh, namely white, red, and red tinge. This study aims to characterize the morphology of three types of Sidimpuan salak based on the color of the fruit flesh (white, red, red tinge) and compare the glucose content and vitamin C levels of the three types of salak. The method used in this study is a descriptive method and sample determination is done by purposive sampling. Glucose levels are analyzed using a UV-Vis spectrophotometer and vitamin C levels by the idiometry titration method. The results of the study showed that there are differences in morphological appearance between white, red, and red tinge salak. The morphological characteristics of the stems and leaves of red salak rank first, but the size and taste of white salak fruit are superior to red salak. The highest glucose levels were found in white snake fruit samples and the lowest in red snake fruit, while the highest vitamin C levels were found in red snake fruit and the lowest in red snake fruit. Variations in morphology, glucose content, and vitamin C in snake fruit are caused by genetic and environmental factors. The morphological and nutritional differences found in the three types of Sidimpuan snake fruit are predominantly due to genetic factors because the samples were obtained from the same environmental conditions.

Keywords: Glucose; Morphology; Salak Sidimpuan; Vitamin C

Introduction

Salak (*Zalacca*) is a native Indonesian plant with a wide variety of cultivars. Salak in Indonesia is generally named based on the location where it is cultivated. The five main provinces with the highest production of salak in Indonesia are Yogyakarta Special Region, North Sumatra, West Java, East Java, and Central Java. According to Simatupang et al. (2024), there are approximately 23 salak cultivars, but the most well-known in Indonesia are Salak Pondoh from Yogyakarta Special Region, Salak Bali from Bali, and Salak Sidimpuan from North Sumatra. Salak Sidimpuan is a superior local commodity from Padangsidimpuan and South Tapanuli, and has been nationally recognized. There are numerous cultivars of Salak Sidimpuan, based on fruit characteristics (fruit color) or the location where the salak is planted or cultivated (Warnita et al., 2019). Sidempuan salak has developed into several local varieties officially recognized by the government

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through the decree of the Minister of Agriculture, salak sibakua (SK. No. 427/Kpts/TP.240/7/2002), white Sidimpuan salak (SK. No. 764/Kpts/TP.240/6/99), red Sidimpuan salak (SK. No. 763/Kpts/TP.240/6/99) (BPS, 2009) in (Adelina et al., 2022). West Angkola District is the center of salak plants in North Sumatra Province and is considered the origin of the Sidimpuan salak plant, and from this area it spread to other areas. Sidimpuan salak fruit has a unique characteristic compared to other types of salak. The taste is quite sweet but slightly sour, sticky, astringent and the water content in the fruit is quite high (Junge et al., 2020; He et al., 2015). The fruit flesh comes in various colors, including white, red, and reddish hues (Khoo et al., 2016; Tang et al., 2025).

Phenotypic characterization describes morphological diversity, including observations of plant physical traits such as stem structure, leaves, and thorns, as well as fruit shape, color, and size. Salak Sidimpuan exhibits significant morphological diversity, and morphological characterization is expected to provide an accurate database for future reference in the selection and development of superior varieties of Salak Sidimpuan. Research on the morphology of Salak Sidimpuan based on location has been extensively conducted, including in South Angkola, West Angkola, and East Angkola (R. A. Harahap et al., 2024), Sisundung Village, Sibio-bio Village, Siamporik Village, and Parsalakan Village, West Angkola, South Angkola, and Marancar. These studies indicate morphological differences in stem, leaf, and fruit characteristics. These studies have all examined the morphological characteristics of the Sidimpuan snake fruit based on the location where it is grown. There is no information yet on morphological characteristics based on fruit flesh color.

Therefore, research is still needed to characterize the morphology of Sidimpuan snake fruit based on differences in fruit flesh color, namely red, white, and red-tinged snake fruit. In addition to its unique morphological diversity, snake fruit contains important nutrients such as sugar and vitamin C. Snake fruit contains various types of natural sugars, such as glucose, fructose, and sucrose, which give snake fruit its distinctive sweet taste. Sugar in the fruit is a simple carbohydrate that is easily absorbed by the body and provides a quick source of energy (Saleh et al., 2018). The sugar content of Sidimpuan snake fruit varies by region. The sugar content of Sidimpuan snake fruit from West Angkola is higher (17.47 brix) compared to snake fruit from Hutaimbaru (16.69 brix) and South Angkola (17.12 brix) (Hadiati et al., 2023). Research results Khairiyah et al. (2019) indicate that the sugar content of salak Sidimpuan from Marancar is 16.2 brix, West Angkola is 17.2 brix, and South Angkola is 17.1 brix. Besides sugar content, one of the most prominent nutritional features of salak is its vitamin C content. Several studies have shown that each type of salak Sidimpuan contains different levels of vitamin C.

The vitamin C content of salak Sidimpuan from Hutaimbaru is higher (49.90 mg/100 g) than that of salak Sidimpuan from West Angkola (49.87 mg/100 g) and South Angkola (44.68 mg/100 g) (M. F. Harahap et al., 2020). Research results Shanker et al. (2024), indicate that the vitamin C content of salak Sidimpuan from Palopat Maria Village is 48.32 mg/100 g. To date, information on the sugar and vitamin C content of Sidimpuan snake fruit, particularly the red, white, and red-tinged varieties, is limited. This study aims to provide a quantitative overview of the vitamin C and sugar content of three varieties of Sidimpuan snake fruit, thus providing a basis for consideration in developing the potential of Sidimpuan snake fruit as a functional food.

Method

This research was conducted from March to June 2025 on the snake fruit plantations of the Sitratoit village community in South Tapanuli Regency and at the Vahana Scientific chemistry laboratory in Padang City, West Sumatra. The tools used in this study were a meter, Iwaki test tubes, a Fujitsu FS-AR210 (INT-CAL) analytical balance, a 50 mm Iwaki funnel, an Iwaki volumetric flask, a 250 mL Iwaki beaker, a Taffware Ultrasonic 40 KHz ultrasonic bath, a 25 mL Iwaki burette, a 100 mL Iwaki Erlenmeyer flask, a rotary evaporator, an Agilent Technologies Cary 8454 UV-Vis spectrophotometer. The materials used in this study were white, red, and reddish-tinged Sidimpuan snake fruit, distilled water, 70% ethanol, Merck glucose, Merck phenol, Merck sulfuric acid, 0.01 N iodine (I2), potassium iodide (KI), 1% starch, and filter paper. Research Procedures.

Morphological Characterization

This study consisted of three snake fruit samples: the white, red, and red-tinged snake fruit. The method used in this study was descriptive, and purposive sampling was used, taking five samples of each type, resulting in a total of 15 samples. Data collection was conducted through direct observation in the snake fruit plantations and interviews with the snake fruit plantation owners (Prihastanti & Haryanti, 2021; Indratna et al., 2023). The observed characteristics were the morphology of the stems, leaves, flowers, and fruit.

Glucose Analysis

Glucose analysis in this study was conducted using a spectrophotometer. 0.1 g of snake fruit flesh was weighed and dissolved in 10 ml of distilled water. The solution was then sonicated for 30 minutes and diluted according to the dilution factor. 1 ml of the solution was pipetted, 1 ml of 5% phenol was added, and 5 ml of concentrated sulfuric acid was added. Incubate for 10 minutes and vortex. Results can be read using a UV-Vis spectrophotometer.

Vitamin C Content Analysis

Salak Fruit Extraction

Salak (red, white, and reddish varieties) were peeled and cleaned, then washed thoroughly. Next, the salak was thinly sliced and blended. 500 grams of the sample was weighed, placed in a beaker, and mixed with 1 L of 70% ethanol. Extraction was then carried out using the maceration method for 3 x 24 hours. After extraction, the filtrate was separated using filter paper and evaporated using a rotary evaporator to obtain a thick extract. gram of salak extract was weighed and dissolved in distilled water to make 25 ml. To 10 ml of the salak fruit extract solution, 5 drops of starch indicator were added. Titration using 0.01 N iodine solution until it turns purple.

Result and Discussion

Morpological Characterization of Sidimpuan Salak

Morphological variation in salak refers to differences in shape, size, and color in the salak's organ structures, such as stems, leaves, flowers, and fruit. Morphological characteristics can be used to differentiate between salak species or cultivars, such as differences in fruit flesh color (Fendiyanto et al., 2020). Table 1 shows morphological differences between white, red, and red-tinged salak. The plant height and leaf sheath length of red and red-tinged salak are higher than those of white salak. This indicates that the vegetative growth of red and red-tinged salak is superior to that of white salak. Morphological differences reflect the genetic diversity among Sidimpuan salak species. Different genetic makeups result in different morphological appearances.

Table 1. Quantitative Morphological Data of Three Types of Sidimpuan Snake Fruit

Parameter	Typs of Salak	Sample					Amount	Average
		1	2	3	4	5		
Plant height (m)	SP	4.80	5.20	4.50	5.80	5.60	25.90	5.18 ± 0.54
	SM	5.50	5.70	6.20	5.50	6.30	29.20	5.84 ± 0.38
	SSM	5.70	6.30	7.20	6.80	5.50	31.50	6.30 ± 0.72
Leaf sheath length (m)	SP	4.34	4.55	4.60	4.10	5.10	22.69	4.53 ± 0.37
	SM	5.15	5.25	5.20	5.10	5.25	25.95	5.19 ± 0.07
	SSM	5.16	5.15	5.2	5.10	5.30	25.91	5.18 ± 0.07
Number of bunches per tree	SP	5	5	3	4	5	22	4.40 ± 0.89
	SM	6	6	5	5	4	26	5.20± 0.84
	SSM	6	6	5	5	4	26	5.20 ± 0.84
Number of fruits per bunch	SP	23	26	23	32	27	131	26.20 ± 3.31
	SM	20	22	18	22	21	103	20.60 ±1.50
	SSM	24	25	25	22	22	118	23.60 ±1.36
Fruit weight (g)	SP	97.12	66.92	98.13	72.83	99.06	434.06	86.81 ±13.97
	SM	52.14	48.79	58.17	60.37	48.83	268.30	53.66 ± 4.79
	SSM	89.12	59.23	70.84	78.97	86.92	385.08	77.02 ±12.27

Note: SP (white snake fruit), SM (red snake fruit), SSM (red-tinged snake fruit)

Research results Wang et al. (2015), showed that the peroxidase isoenzyme analysis of Sidimpuan snake fruit from the Sisundung region showed 42% genetic similarity and 58% genetic diversity. Genetic diversity leads to physiological differences in snake fruit plants because each variety has a genetic code that regulates growth, photosynthesis, and fruit formation. Each gene contains information for producing specific proteins, such as the growth hormone auxin. Auxin is a hormone that promotes stem elongation; if the gene regulating auxin production is more active, the plant will grow taller (Reed et al., 2018). This explains why the red Sidimpuan snake fruit is taller than the white Sidimpuan snake fruit, likely due to the more active gene regulating the growth hormone.

Table 1 shows that red snake fruit has a lower size and weight than other Sidimpuan snake fruit varieties. One factor contributing to lower fruit size is energy availability (Romero et al., 2020). Plants produce energy through photosynthesis, a process known as photosynthate. Photosynthate is allocated to vegetative and generative growth. Red snake fruit tends to allocate more nutrients to stem and leaf sheath growth, resulting in taller stems, but smaller fruit due to reduced nutrient availability (Garrido et al., 2023). White snake fruit focuses more on fruit formation, resulting in larger fruit size. According to Huang et al. (2023), besides nutrition, another factor influencing fruit enlargement is the gibberellin hormone. If the gene that regulates gibberellin production is more active, the resulting fruit tends to be larger.

Table 2. Qualitative Morphological Data of Three Types of Salak Sidimpuan

Parameter	Types of snake fruit		
	Salak Putih	Salak Merah	Salak Semburat Merah
Bar color	Dark Green	Light brown	Dark green
Leaf color	Dark Green	Dark green	Dark green
Thorn color	Black	Black	Black
Thorn shape	Short Pointed	Long pointed	Long pointed
The color of the flower sheath	Brown	Brown	Brown
Fruit shape	Round	Oval	Oval round
Fruit skin color	Yellowish Brown	Reddish brown	Yellowish brown, blackish brown
Fruit flesh color	White	Red	White with a red tinge
Fruit Flavor	Sweet	Sweet astringent	Sweet and sour
Seed color	Blackish Brown	Blackish brown	Blackish brown

Based on qualitative observations, the leaves of the three types of salak sidimpuan plants are dark green and contain a waxy coating on the leaf surface (Table 2). Striking differences are seen in the shape of the thorns: red and red-tinged salak have long, pointed thorns, while white salak has short, pointed thorns. In terms of fruit shape, red salak is oval, white salak is round, and red salak exhibits a combination of round-oval shapes. Red salak has several morphological similarities to both white and red salak. This confirms that red salak is a natural cross between red and white salak. The three types of salak sidimpuan have distinct flavors: white salak is sweet, red salak is sweet and sour, and red salak is sweet and astringent (Table 2). This is consistent with research by Hadiati et al. (2023), which states that salak sidimpuan has several flavors: sweet, sour, sweet and sour, and sweet and astringent. The taste of snake fruit is influenced by genetic and environmental factors, which cause sugar, organic acid, and tannin levels to vary among snake fruit varieties (Djaafar et al., 2024). Higher sugar levels result in a sweeter taste, while organic acid levels contribute to a sour taste. Higher tannin content in snake fruit results in an astringent taste. Research Halim et al. (2019) and Siregar (2023), indicates that Sidimpuan snake fruit contains tannins.

The skin of the white snake fruit is brown, while the red snake fruit is yellowish-brown and reddish-brown, while the red snake fruit is reddish-brown. The flesh color of the Sidimpuan snake fruit, as the name suggests, is white, red-tinged, and red. The differences in fruit color are due to differences in pigment content and quantity, with the most abundant pigments being carotenoids and anthocyanins (Arena et al., 2021; Wang et al., 2022). Gonzali et al. (2021), Espley et al. (2023) states that variations in fruit flesh color are closely related to genetic expression and the concentration of bioactive compounds such as anthocyanins. High anthocyanin content leads to a tendency toward red and purple fruit color and also higher antioxidant content (Pérez et al., 2023).

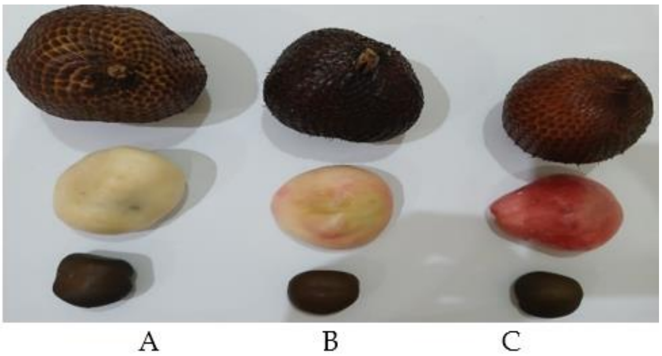

Figure 1. A) White Salak, B) Red salak, C) Red salak

Glucose Content of Sidimpuan Snake Fruit

Glucose is a reducing sugar that directly contributes to the perception of sweetness. Higher glucose levels result in a sweeter taste, making it an important indicator, especially for snake fruit consumed fresh. Based on Figure 2, white snake fruit has the highest glucose content at 20.01%, followed by red snake fruit (18.87%), and red-tinged snake fruit (18.30%). Variations in glucose content are caused by environmental and genetic factors (Nishio et al., 2021). The snake fruit samples in this study were taken from the same environmental conditions, so the differences in glucose content between white, red, and red-tinged snake fruit are predominantly due to genetic factors.

Genetic factors influence the size and density of carbohydrate storage tissue within the fruit flesh. Fruit flesh cell vacuoles function as the primary storage sites for sugars, organic acids, secondary metabolites, inorganic ions, and water in high quantities, which significantly determine fruit quality (Eisenach et al., 2015). Fruit cultivars with larger vacuoles or a greater number of vacuoles tend to store sugars in higher concentrations (Kuang et al., 2022). Research Lü et al.

(2020), indicates that differences in sugar content in pears are largely controlled by genetic factors through the regulation of gene expression encoding key enzymes in sucrose metabolism, such as sucrose phosphate synthase (SPS), sucrose synthase (SUS), fructokinase (FRK), and glucose-6-phosphate isomerase (PGI). These enzymes play a role in regulating the conversion of photosynthesis products (especially sucrose) into simple sugars, including glucose and fructose, and determine sugar accumulation in the vacuoles of the fruit's flesh.

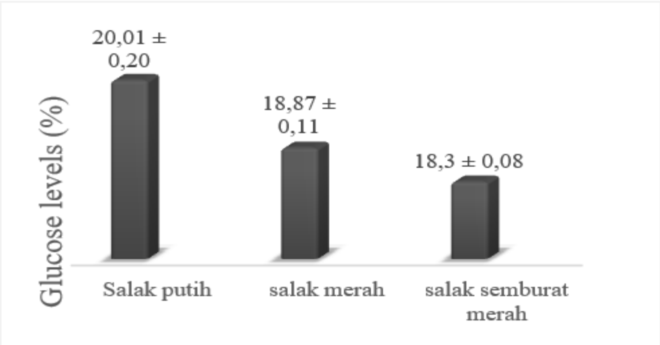

Figure 2. Comparison of glucose content in Salak Sidimpuan

Vitamin C in Salak Sidimpuan

Vitamin C is a natural antioxidant that helps ward off free radicals and boosts the immune (Martey & Osei, 2024; Carr & Maggini, 2017). In plants, vitamin C, or ascorbic acid, functions as an enzyme cofactor in various biosynthetic pathways, including the formation of hormones and secondary metabolites, and aids in the formation of chlorophyll and sugars. Vitamin C is an essential element in determining fruit quality, such as aroma and flavor. Research Ścibisz et al. (2019) indicates that vitamin C contributes to the fresh and slightly sour taste of Salak Sidimpuan. Each variety of salak fruit has a different vitamin C content, even salak fruit grown in the same area contains different levels of vitamin C (Hu et al., 2025). Figure 3 shows that the red Sidimpuan snake fruit contains the highest levels of vitamin C compared to the white and red-tinged snake fruit. Differences in vitamin C levels among snake fruit varieties are the result of a complex interaction between genetic, physiological, and environmental factors that influence the biosynthesis, distribution, and degradation of ascorbic acid in fruit tissue (Liao et al., 2023; Zheng et al., 2022).

Salak has a metabolic profile controlled by a distinct gene arrangement. Vitamin C production and accumulation are influenced by the expression of key genes such as GDP-mannose pyrophosphorylase (GMP) and L-galactose-1-phosphate phosphatase (GPP). Genetic variation in GMP or GPP among salak varieties will lead to differences in enzyme activity, which will affect the rate of vitamin C formation (Alahyane et al., 2024). Salak varieties with higher GMP or GPP gene expression patterns are likely to produce fruit with higher vitamin C content.

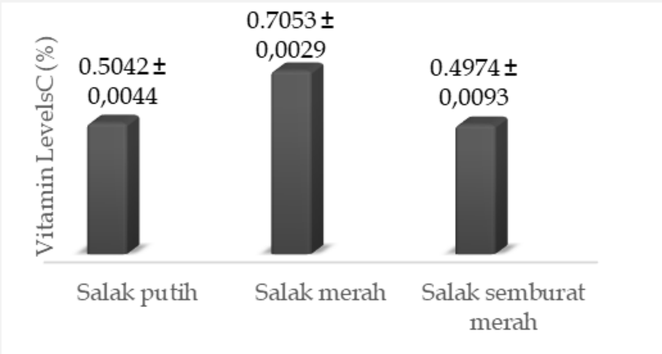

Figure 3. Comparison of vitamin C levels in Sidimpuan Salak

Conclusion

The evaluation results of this study indicate that Sidimpuan snake fruit has diverse characteristics in terms of morphology, glucose content, and vitamin C. The morphological characteristics of the stems and leaves of red snake fruit ranked first, but the size and flavor of white snake fruit were superior to those of red snake fruit. The highest glucose content was found in white snake fruit samples and the lowest in red snake fruit, while the highest vitamin C content was found in red snake fruit and the lowest in red snake fruit. Variations in morphology, glucose content, and vitamin C in snake fruit are due to genetic and environmental factors. The morphological and nutritional differences found in the three Sidimpuan snake fruit varieties are predominantly due to genetic factors because the samples were obtained from the same environmental conditions.

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Author Contributions

Conceptualization; Y. W. S.; methodology.; I. F. S; validation; N.; formal analysis; N. M.; investigation.; M. N. H. N.; resources; Y. W. S.; data curation: I. F. S.; writing—original draft preparation. N.; writing—review and editing: N. M.; visualization: M. N. H. N. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

References

Alahyane, A., Elateri, I., Ayour, J., Elqarnifa, S., Lasky, M., Ait-Oubahou, A., Benichou, M., & Abderrazik, M. (2024). Evolution of pigments and their relationship with skin color and sensory profile in date fruits (Phoenix dactylifera L.). *Brazilian Journal of Biology*, *84*, e252426. https://doi.org/10.1590/1519-6984.252426

Arena, M. E., Povilonis, I. S., Borroni, V., Constenla, D., & Radice, S. (2021). Changes in physicochemical properties at different development stages of Hexachlamys edulis fruit, an underutilized South American species. *Heliyon*, *7*(11), e08323. https://doi.org/10.1016/j.heliyon.2021.e08323

Carr, A., & Maggini, S. (2017). Vitamin C and Immune Function. *Nutrients*, *9*(11), 1211. https://doi.org/10.3390/nu9111211

Djaafar, T. F., Marwati, T., Budiyanti, T., Riska, & Hadiati, S. (2024). Chemical and Sensory Evaluation on Several Varieties of Salak (Salacca zalacca) Fruit from Indonesia. *International Journal on Advanced Science, Engineering and Information Technology*, *14*(2), 723–729. https://doi.org/10.18517/ijaseit.14.2.19175

Eisenach, C., Francisco, R., & Martinoia, E. (2015). Plant vacuoles. *Current Biology*, *25*(4), R136–R137. https://doi.org/10.1016/j.cub.2014.11.056

Espley, R. V., & Jaakola, L. (2023). The role of environmental stress in fruit pigmentation. *Plant, Cell & Environment*, *46*(12), 3663–3679. https://doi.org/10.1111/pce.14684

Fendiyanto, M. H., Satrio, R. D., & Darmadi, D. (2020). Metabolic profiling and pathway analysis in red arillus of Salacca sumatrana demonstrate significant pyruvate, sulfur, and fatty acid metabolisms. *Biodiversitas Journal of Biological Diversity*, *21*(9). https://doi.org/10.13057/biodiv/d210955

Garrido, A., Conde, A., Serôdio, J., De Vos, R. C. H., & Cunha, A. (2023). Fruit Photosynthesis: More to Know about Where, How and Why. *Plants*, *12*(13), 2393. https://doi.org/10.3390/plants12132393

Gonzali, S., & Perata, P. (2021). Fruit Colour and Novel Mechanisms of Genetic Regulation of Pigment Production in Tomato Fruits. *Horticulturae*, *7*(8), 259. https://doi.org/10.3390/horticulturae7080259

Hadiati, S., Indriyani, N. L. P., & Jumjunidang. (2023). Review: Population establishment and genetic study of Java, Bali and Sumatra Salak crossing. *IOP Conference Series: Earth and Environmental Science*, *1253*(1), 012031. https://doi.org/10.1088/1755-1315/1253/1/012031

Halim, H. R., Hapsari, D. P., Junaedi, A., Ritonga, A. W., Natawijaya, A., Poerwanto, R., Sobir, Widodo, W. D., & Matra, D. D. (2019). Metabolomics dataset of underutilized Indonesian fruits; rambai (Baccaurea motleyana), nangkadak (Artocarpus nangkadak), rambutan (Nephelium lappaceum) and Sidempuan salak (Salacca sumatrana) using GCMS and LCMS. *Data in Brief*, *23*, 103706. https://doi.org/10.1016/j.dib.2019.103706

Harahap, M. F., Lubis, R. A., Syawaluddin, Silitonga, Y. W., & Harahap, I. S. (2020). The Quality of Salacca Tree Midrib Latex Flour as a Thickening Agent. *Journal of Physics: Conference Series*, *1477*(7), 072008. https://doi.org/10.1088/1742-6596/1477/7/072008

Harahap, R. A., Syah, E., & Sipahutar, A. (2024). Chemical Content Study of Salak Sidimpuan (Salacca sumatrana Becc.) Fruit Based on Altitude. *JERAMI : Indonesian Journal of Crop Science*, *7*(1), 18–22. https://doi.org/10.25077/jijcs.7.1.20-24.2024

He, M., Tian, H., Luo, X., Qi, X., & Chen, X. (2015). Molecular Progress in Research on Fruit Astringency. *Molecules*, *20*(1), 1434–1451. https://doi.org/10.3390/molecules20011434

Hu, H., Pradhan, N., Xiao, J., Xia, R., & Liao, P. (2025). Chromatic symphony of fleshy fruits: Functions, biosynthesis and metabolic engineering of bioactive compounds. *Molecular Horticulture*, *5*(1), 19. https://doi.org/10.1186/s43897-024-00142-y

Huang, X., Wu, X., Sun, G., Jiang, Y., & Yan, H. (2023). Transcriptome Analysis Reveals Candidate Genes Involved in Gibberellin-Induced Fruit Development in Rosa roxburghii. *Plants*, *12*(19), 3425. https://doi.org/10.3390/plants12193425

Indratna, A. D., Putri, A. P. I. K. S., Azzahra, E. O., Oktavia, M. S., Widodo, T., Agustina, A., & Pertiwi, Y. A. B. (2023). Potential economic value of non-wood forest products in agroforestry system at Gempolan Village, Kerjo District, Karanganyar Regency: An economic perspective. *IOP Conference Series: Earth and Environmental Science*, *1220*(1), 012014. https://doi.org/10.1088/1755-1315/1220/1/012014

Junge, J. Y., Bertelsen, A. S., Mielby, L. A., Zeng, Y., Sun, Y.-X., Byrne, D. V., & Kidmose, U. (2020). Taste Interactions between Sweetness of Sucrose and Sourness of Citric and Tartaric Acid among Chinese and Danish Consumers. *Foods*, *9*(10), 1425. https://doi.org/10.3390/foods9101425

Khairiyah, M., & Harahap, P. (2019). Exploration and identification of aren plant (Arengapinnatamerr) in district of South Tapanuli. *IOP Conference Series: Earth and Environmental Science*, *260*(1), 012121. https://doi.org/10.1088/1755-1315/260/1/012121

Khoo, H. E., Azlan, A., Kong, K. W., & Ismail, A. (2016). Phytochemicals and Medicinal Properties of Indigenous Tropical Fruits with Potential for Commercial Development. *Evidence-Based Complementary and Alternative Medicine*, *2016*(1), 7591951. https://doi.org/10.1155/2016/7591951

Kuang, L., Chen, S., Guo, Y., Scheuring, D., Flaishman, M. A., & Ma, H. (2022). Proteome Analysis of Vacuoles Isolated from Fig (*Ficus carica* L.) Flesh during Fruit Development. *Plant and Cell Physiology*, *63*(6), 785–801. https://doi.org/10.1093/pcp/pcac039

Liao, G., Xu, Q., Allan, A. C., & Xu, X. (2023). L-Ascorbic acid metabolism and regulation in fruit crops. *Plant Physiology*, *192*(3), 1684–1695. https://doi.org/10.1093/plphys/kiad241

Lü, J., Tao, X., Yao, G., Zhang, S., & Zhang, H. (2020). Transcriptome Analysis of Low- and High-Sucrose Pear Cultivars Identifies Key Regulators of Sucrose Biosynthesis in Fruits. *Plant and Cell Physiology*, *61*(8), 1493–1506. https://doi.org/10.1093/pcp/pcaa068

Martey, A., & Osei, R. (2024). Biosynthesis of Ascorbic Acid and Its Metabolism across Plant Growth Stages, Fruit Maturation, and Postharvest Physiology: A Review. *Asian Research Journal of Agriculture*, *17*(3), 180–190. https://doi.org/10.9734/arja/2024/v17i3487

Nishio, S., Hayashi, T., Shirasawa, K., Saito, T., Terakami, S., Takada, N., Takeuchi, Y., Moriya, S., & Itai, A. (2021). Genome-wide association study of individual sugar content in fruit of Japanese pear (Pyrus spp.). *BMC Plant Biology*, *21*(1), 378. https://doi.org/10.1186/s12870-021-03130-2

Pérez, M. B., Carvajal, S., Beretta, V., Bannoud, F., Fangio, M. F., Berli, F., Fontana, A., Salomón, M. V., Gonzalez, R., Valerga, L., Altamirano, J. C., Yildiz, M., Iorizzo, M., Simon, P. W., & Cavagnaro, P. F. (2023). Characterization of Purple Carrot Germplasm for Antioxidant Capacity and Root Concentration of Anthocyanins, Phenolics, and Carotenoids. *Plants*, *12*(9), 1796. https://doi.org/10.3390/plants12091796

Prihastanti, E., & Haryanti, S. (2021). The development and the growth of salak pondoh fruit (Salacca edulis L.) planted using different planting methods. *Journal of Physics: Conference Series*, *1943*(1), 012062. https://doi.org/10.1088/1742-6596/1943/1/012062

Reed, J. W., Wu, M.-F., Reeves, P. H., Hodgens, C., Yadav, V., Hayes, S., & Pierik, R. (2018). Three Auxin Response Factors Promote Hypocotyl Elongation. *Plant Physiology*, *178*(2), 864–875. https://doi.org/10.1104/pp.18.00718

Romero, P., Alférez, F., Establés-Ortiz, B., & Lafuente, M. T. (2020). Insights into the regulation of molecular mechanisms involved in energy shortage in detached citrus fruit. *Scientific Reports*, *10*(1), 1109. https://doi.org/10.1038/s41598-019-57012-7

Saleh, MohammedS. M., Siddiqui, M., Mediani, A., Ismail, N., Ahmed, Q., So'ad, S. M., & Saidi-Besbes, S. (2018). *Salacca zalacca*: A short review of the palm botany, pharmacological uses and phytochemistry. *Asian Pacific Journal of Tropical Medicine*, *11*(12), 645. https://doi.org/10.4103/1995-7645.248321

Ścibisz, I., Ziarno, M., & Mitek, M. (2019). Color stability of fruit yogurt during storage. *Journal of Food Science and Technology*, *56*(4), 1997–2009. https://doi.org/10.1007/s13197-019-03668-y

Shanker, M. A., Krishnan, R., Kumar, G. S., Mohammed, T., Hymavathi, A. S., Rosamma, Ragesh, N., George, S., Rana, S. S., & Abdullah, S. (2024). Insights on the astringency of non-alcoholic beverages: Fruit, vegetable & plantation-based perspective. *Food Chemistry Advances*, *4*, 100630. https://doi.org/10.1016/j.focha.2024.100630

Simatupang, T. H., Hartini, S., Mustika, D. A., Purwoto, A., Junef, M., Sanusi, A., Firdaus, Nugroho, T. W. A., Mareta, J., Jazuli, A., & Firdaus, I. (2024). Salak from Indonesia: Legal protection, potential geographical indications and development practices toward international markets. *Cogent Social Sciences*, *10*(1), 2341963. https://doi.org/10.1080/23311886.2024.2341963

Siregar, E. S. (2023). Identifikasi Morfologi Tanaman Salak Sidimpuan (Salacca sumatrana Becc) Pada Elevasi Yang Berbeda. *Jurnal AGROHITA: Jurnal Agroteknologi Fakultas Pertanian Universitas Muhammadiyah Tapanuli Selatan*, *8*(4), 745. https://doi.org/10.31604/jap.v8i4.14470

Tang, Y., Wang, P., Chen, J., Li, L., Tang, L., Huang, W., Wei, X., & Xu, J. (2025). The accumulation pattern of sugars and organic acids in diverse fruit pulps coordinates sweet-sour taste of passion fruit. *LWT*, *225*, 117948. https://doi.org/10.1016/j.lwt.2025.117948

Wang, L., Li, J., Zhao, J., & He, C. (2015). Evolutionary developmental genetics of fruit morphological variation within the Solanaceae. *Frontiers in Plant Science*, *6*. https://doi.org/10.3389/fpls.2015.00248

Wang, X., Luo, S., Li, Q., Song, L., Zhang, W., Yu, P., Xuan, S., Wang, Y., Zhao, J., Chen, X., & Shen, S. (2022). Delphinidins and Naringenin Chalcone Underlying the Fruit Color Changes during Maturity Stages in Eggplant. *Agronomy*, *12*(5), 1036. https://doi.org/10.3390/agronomy12051036

Warnita, Suliansyah, I., Syarif, A., & Adelina, R. (2019). Flowering induction and formation of salak

(Salacca sumaterana Becc) fruit with potassium and boron fertilization. *IOP Conference Series: Earth and Environmental Science*, *347*(1), 012092. https://doi.org/10.1088/1755-1315/347/1/012092

Zheng, X., Gong, M., Zhang, Q., Tan, H., Li, L., Tang, Y., Li, Z., Peng, M., & Deng, W. (2022). Metabolism and Regulation of Ascorbic Acid in Fruits. *Plants*, *11*(12), 1602. https://doi.org/10.3390/plants11121602