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VARIATION IN SUGAR CONTENT AND DISTRIBUTION IN *SYZYGIUM SAMARANGENSE* FRUITS

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ABSTRAK

Pudji Widodo, Elly Proklamasiningsih, Murni Dwiati, & Agus Hery Susanto 2023. *Variasi Kadar Gula dan Sebaran Gula pada Buah Syzygium samarangense*. *Floribunda* 7(3): 107–115 — Jambu semarang (*Syzygium samarangense*) terdiri dari banyak kultivar dengan kadar gula yang berbeda-beda. Pada setiap buah, kandungan gulanya tidak merata. Tingkat kemanisan buah seringkali menjadi penentu nilai ekonomi dari jambu semarang. Tujuan penelitian ini adalah 1) untuk mengetahui sebaran gula pada berbagai kultivar jambu semarang, 2) mengetahui sebaran kadar gula di dalam buahnya, 3) mengetahui pengaruh rerata hari hujan per bulan terhadap kandungan gula buah. Metode yang digunakan dalam penelitian ini adalah survei dengan purposive sampling, observasi laboratorium dengan mengukur kadar gula dengan refraktometer, mengkorelasikan faktor lingkungan dengan kandungan gula buah. Hasil penelitian ini menunjukkan bahwa buah dengan kadar gula tertinggi terdapat pada kultivar *Syzygium samarangense* 'Sukaluyu' (maks 16,5 ◦Brix), *S. samarangense* 'Madu' (maks 14 ◦Brix), *S. samarangense* 'Kesuma Merah' (max 10.5 ◦*Brix), S. samarangense* 'Citra' (maks 8.5◦Brix) yang cocok untuk buah-buahan segar. Sedangkan yang kadar gulanya rendah seperti *S. samarangense* 'Bajang Leang' (4.5 ◦Brix), *S. samarangense* 'Kuning' (4 ◦Brix) lebih cocok untuk lutis. Pada buah *S. samarangense*, gula tertinggi biasanya terakumulasi di bagian ujung buah, dan gula terendah berada di pangkal buah. Kadar gula berkorelasi negatif dengan rerata hari hujan per bulan. Makin sedikit hari hujan, buah semakin manis.

Kata kunci : kultivar, gula, rasa manis, Syzygium, jambu semarang

Pudji Widodo, Elly Proklamasiningsih, Murni Dwiati, & Agus Hery Susanto 2023. *Variation in Sugar Content and Distribution in Syzygium samarangense* Fruits. *Floribunda* 7(3): 107–115 — Semarang apple (*Syzygium samarangense*) consists of many cultivars with different sugar contents. In each fruit, the sugar content is not evenly distributed. Fruit sweetness often determines the economic value of the semarang apple. The objectives of this study were 1) to find out the distribution of sugar amongst several semarang apple cultivars, 2) to know the distribution of sugar content in the fruits, 3) to find out the correlation between average rainy days per month versus sugar contents. The method used in this study was survey with purposive sampling, laboratory observation by measuring sugar content with a refractometer, and correlating sugar content versus rainy days per month. The results of this study showed that the fruit with the highest sugar content are the cultivar of *Syzygium samarangense* 'Sukaluyu' (max 16.5 ◦Brix), *S. samarangense* 'Madu' (max 14 ◦Brix), *S. samarangense* 'Kesuma Merah' (max 10.5 ◦Brix), *S. samarangense* 'Citra' (max 8.5◦Brix) which are suitable for fresh fruits. While those with low sugar content such as *S. samarangense* 'Bajang Leang' (4.5 ◦Brix), *S. samarangense* 'Kuning' (4 ◦Brix) are more suitable for salad. In the fruits, highest sugar is normally accumulated at the fruit apex, and the lowest sugar is at the fruit base. Sugar levels are negatively correlated with the average rainy days per month. The fewer rainy days, the sweeter the fruit.

Keywords: cultivars, sugar, sweetness, Syzygium, *semarang apple*

Semarang apple or java apple (*Syzygium samarangense* (Blume) Merr. & L.M. Perry) is a tropical plant that is commonly cultivated in Indonesia and its vicinity. It has been cultivated in many countries including the Indonesia, Philippines, Malaysia, Thailand, Cambodia, Laos, Vietnam, and Taiwan. It is also frequently cultivated in India, Africa, Suriname, and northern Australia (Lim and Lim, 2012). This plant is used as fruit producer, shelter tree due to its dense canopy, and

ornamental plants.

There are at least 100 cultivars of semarang apple with various level of sweetness (Widodo, 2015). Of the many semarang apples, some of them have become favourable and tasty, cultivated, and for fresh fruits such as *S. samarangense* 'Citra', *S. samarangense* 'Sukaluyu', *S. samarangense* 'Demak', *S. samarangense* 'Madura Putih', *S. samarangense* 'Ijo' etc. The popular fruits are those with high sugar content which is greatly depending on the cultivars. Some contain high sugar, high water, some are with low sugar content.

Sweetness is very important because this characteristic often determine the economic value of the semarang apple. The quality of fruits is mainly dependant on the sweetness determined by the level of soluble sugars such as glucose, fructose and sucrose (Nookaraju *et al.*, 2010). The total soluble sugar could be correlated with fruit quality characteristics (Arena *et al*. 2013). The higher the sugar contents in fruits the more number of people will choose them, except for those with diabetes.

Semarang apples can grow well in tropical environments from lowlands to highlands reaching 1,000 m a.s.l. The temperature desired for these plants ranges from 18-28ºC with low or dry rainfall, around 500-3,000 mm / year. Most tropical fruits including semarang apples are sensitive to low-temperature (Rosen & Kader, 1989). Air humidity that ranges from 50-80% is also a requirement for good growth. This plant requires full sunlight for ideal growth ranges from is 40-80%. At this intensity, good quality fruit can be produced (Ika, 2014).

The suitable soil for semrarang apples is fertile, loose soil, containing lots of organic matter. The suitable soil acidity (pH) which is between 5.5-7.5 (Jonkers and Hoestra, 1978). The ideal water content depth for this plant cultivation is 0–50 cm; 50-150 cm and 150-200cm. These plants are very suitable to grow on plane land. Many efforts have been conducted to increase fruit products of semarang apple such as pest and disease control, because both can damage all the fruits.

The quality of fruits is mainly dependant on the sweetness determined by the level of soluble sugars such as glucose, fructose and sucrose. While Brix content, acidity, aroma, color, size and shape are the other quality parameters (Nookaraju *et al.*, 2010) . Total sugar content in semarang apple fruits is a function of genetic, nutritional, environmental and developmental factors.

The amount of total soluble sugars increases with semarang apple fruit maturity (Arena et al., 2013) reaching the maximum level at ripening. The sugar accumulation was also found to differ between mesocarp and locular tissues of the fruit (Mounet et al., 2009). Furthermore, sugar content varies with environmental factors such as climate, soil and storage conditions and plant nutrition. For example, the same cultivar like *S. samarangense* 'Citra' which is planted in Demak with low altitude and close to the sea is sweeter than those cultivated in Purwokerto. In fact, almost all of semarang apples cultivated in Demak contains a lot of sugar.

Semarang apple fruit contains natural sugars, which are a mix of sucrose, fructose and glucose with different composition depending on the plant. Although sugar is considered to be bad for health, however natural sugar is not when it comes from fruit. In fact, fructose is only harmful in excess amounts. Sugar content in semarang apples is not more than 20%, thus it is still good for health. In fact, *S. samarangense* contains some more useful nutrients The juicy content of the fruits' flesh consists of protein (92.9%), carbohydrate (6%), crude fiber (0.46%), and ash minerals (0.21%) (Tarigan, 2022).

The semarang apple can be used as an antipyretic and a diuretic (Tarigan, 2022). It also has the potential for anti-inflammatory activities from the dichloromethane extract of the air-dried leaves. Furthermore, the chemical content of *S. samarangense* varies greatly depending on the cultivar. Some cultivars are sweet, sweet – sour, sweet – astringent.

By observing the outer morphology of the fruit, we can predict the benefits of the plant parts based on the chemical content present. Research results up to September 2020 showed that relatively large *Syzygium* with relatively high fructose content is generally suitable for fresh fruit, while small *Syzygium* with high eugenol content is more suitable as a medicinal or spice ingredient.

The aims of this study were 1) to find out the sugar distribution amongst some cultivars of *S. samarangense* fruits, 2) to find out the sugar distribution of sugar in individual fruit of *S. samarangense*, 3) to find out the correlation between average rainy days versus sugar contents in *S. samarangense* fruits.

MATERIALS AND METHODS

Materials

The materials used in this study were fresh fruits of *Syzygium samarangense* 'Sukaluyu', *S. Samarangense* 'Madu', *S. Samarangense* 'Kesuma Merah'; *S. Samarangense* 'Citra', *S. Samarangense* 'Demak', *S. Samarangense* 'Madura Putih', *S. Samarangense* 'Ijo', *S. Samarangense* 'Bajang Leang', *S. Samarangense* 'Thailand', and *S. Samarangense* 'Kuning'. Those semarang apples were collected from several areas

including Banyumas, Karang Cengis, Karangbanjar Purbalingga, Banjarnegara, Wonosobo, and Magelang and several other locations that are planted in a sustainable manner.

The method used in this study was survey with purposive sampling technique. Then it was followed with laboratory observation by measuring sugar content with a refractometer (Magwaza & Opara, 2015). The environmental factors affecting sugar contents namely rain day per month were accessed from BPS Provinsi Jawa Tengah (2022) from 2019-2021. In this study, we used a handheld refractometer which is an analog instrument for measuring a liquid's refractive index. It works on the critical angle principle by which lenses and prisms project a shadow line onto a small glass reticle inside the instrument, which is then viewed by the user through a magnifying eyepiece. The sugar content has been measured with Refractometer Brix 0-32◦Brix (Serpen, 2012, Cirilli et al 2016) all year round from January to December 2020. The method used to determine the popularity of the fruits was web scraping which is an automatic method to obtain large amounts of data from websites (Khder, 2021).

RESULTS AND DISCUSSION

Sugar distribution among the cultivars are variable. Some are very sweet, some are medium, and the rests are less sweet. The most favourable semarang apple are *S. samarangense* 'Citra, *S. samarangense* 'Madu', *S. samarangense* 'Demak'etc. In fact, the most popular semarang apple does not have the highest sugar content. On the other hand, the sweetest one is not the popular one such as *S. samarangense* 'Sukaluyu'. This apple is known to be the mixture between malay apple and semarang apple.

Phylogenetic analysis amongst 10 cultivars showed that they can be classified into three groups namely: 1) sweet, 2) medium, and 3) less sweet (Figure 1). The evolutionary history was inferred using the UPGMA method (Sneath & Sokal, 1973). The optimal tree is shown. The tree is drawn to scale, with branch lengths (next to the branches) in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The evolutionary distances were computed using the Maximum Composite Likelihood method (Tamura et al. 2004) and are in the units of the number of base substitutions per site. This analysis involved 10 nucleotide sequences. Codon positions included were $1^{st}+2^{nd}+3^{rd}$+Noncoding. All ambiguous positions were removed for each sequence pair (pairwise deletion option). There were a total of 13 positions in the final dataset. Evolutionary analyses were conducted in MEGA11 (Tamura *et al*. 2021).

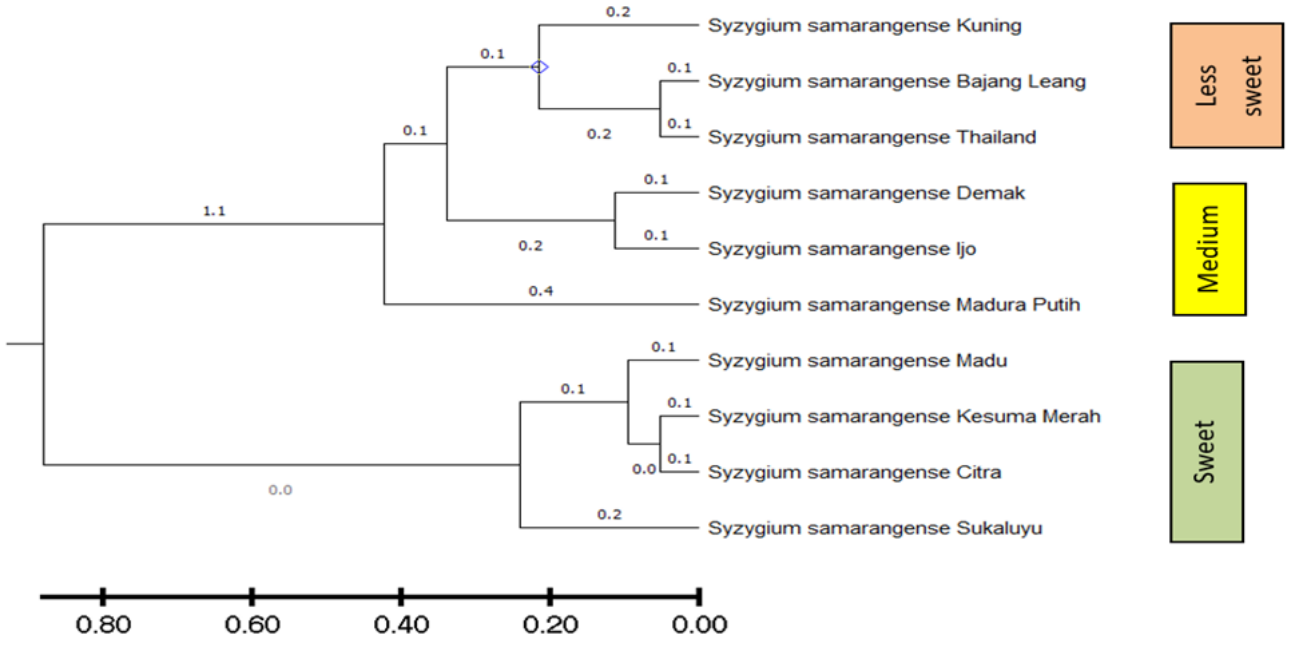

Figure 1. A phenogram of *Syzygium samarangense* cultivars based on sugar content

The results of this study showed that the highest sugar content was present in *S. Samarangense* 'Sukaluyu' (16.5◦Brix) followed by *S. Samarangense* 'Madu' (14◦Brix), *S. Samarangense* 'Kesuma Merah' (10.5 Brix), *S. Samarangense* 'Citra' (8.5◦Brix), *S. samarangense* 'Demak' (8◦Brix). The others are mediumly sweet and not very sweet ranging (4-6.5◦Brix) (Figure 2). Each part of mature fruit has also various fructose content namely the fruit apex tend to has higher fructose content than the fruit base. Each cultivar has certain sugar content which is affected mainly by the genetic factors (Ma et al., 2017) because this plant were cultivated at the relatively same habitat. Sugar content is also affected by environmental factors especially temperature. In this case, an increase in temperature leads to a decrease in total sugar in fruits (do Nascimento, 2008).

S. samarangense 'Sukaluyu' has the highest sugar content, because of the genetic factors which affect the metabolic processes to accumulate more sugar (Halford et al 2011) This can be reached especially in dry season from June – August, while in wet season the sweetness is commonly at the lowest stage. This sweetness is also affected by an orchad's climate, tree fruit set, ripeness when picked, seasonal sunlight and temperatures, harvest date (Larsen *et al.*, 2019), and the overall terroir of the growing region.

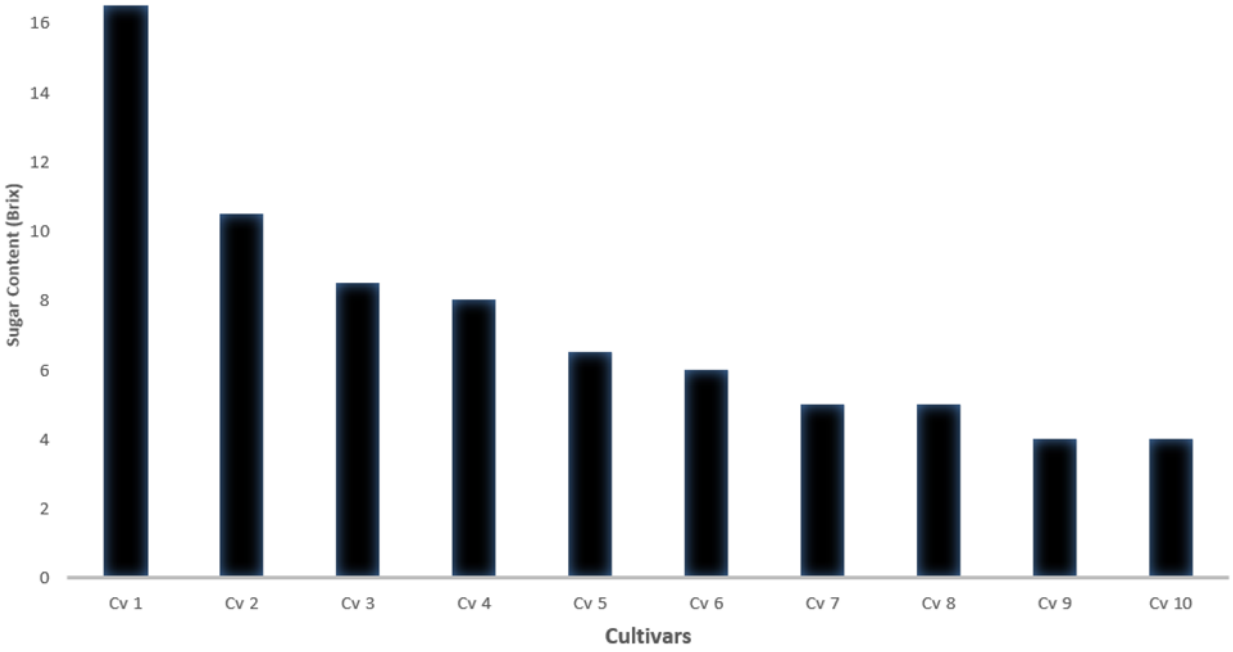

Figure 2. Average sugar contents (◦Brix) of 10 *Syzygium samarangense* cultivars

Notes:
Cv 1 = *Syzygium samarangense* 'Sukaluyu', Cv 2 = *S. Samarangense* 'Madu', Cv 3 = *S. samarangense* 'Kesuma Merah', Cv 4 = *S. samarangense* 'Citra', Cv 5 = *S. samarangense* 'Demak', Cv 6 = *S. samarangense* 'Madura Putih', Cv 7 = *S. samarangense* 'Ijo', Cv 8 = *S. samarangense* 'Bajang Leang', Cv 9 = *S. samarangense* 'Thailand', Cv 10 = *S. samarangense* 'Kuning'

Sugar contents in semarang apples varies depending on the cultivars. Some cultivar may have low sugar like *S. Samarangense* 'Bajang Leang' and *S. Samarangense* 'Kuning'. Several other semarang apples may have high sugar such as *S. Samarangense* 'Madu' and *S. Samarangense* 'Sukaluyu' (Table 1). Different months may also influence the sugar content, for example in rainy seasons the sugar may be low, due to high water but low light intensity. Whereas in dry seasons the sugar tend to be high because the drought has led to intensified flavors namely sweeter semarang apples. Part of the reason is the lack of rain will cause higher sugar content. Drought stress has caused the accumulation of dissolved sugars (Khan et al. 2023) in the fruits (Figure 3). The sugar production may be affected by environmental factors such as humidity. Sugar concentration could be associated with variations in the balance between water and assimilate influx to the fruit i.e. between the fluxes of the phloem and xylem saps and of fruit transpiration (Guichard *et al.*, 2001).

The results of correlation analysis showed that there is a negative correlation between the average

number of rainy days per month and sugar contents in *S. samarangense* cultivars. Pearson's correlation of rainy days and sugar-contents = -0,887, P-Value = 0,045. Correlation of -0.89 indicated that there was significantly negative correlation between both factors. The regression equation is Sugar-contents = 15,7 – 0,358 rainy days. Partial test beta0 and beta1 significant, meaning that this model is valid, r-square 78% good enough, although it did not reach 90, the R is good enough (Figure 3).

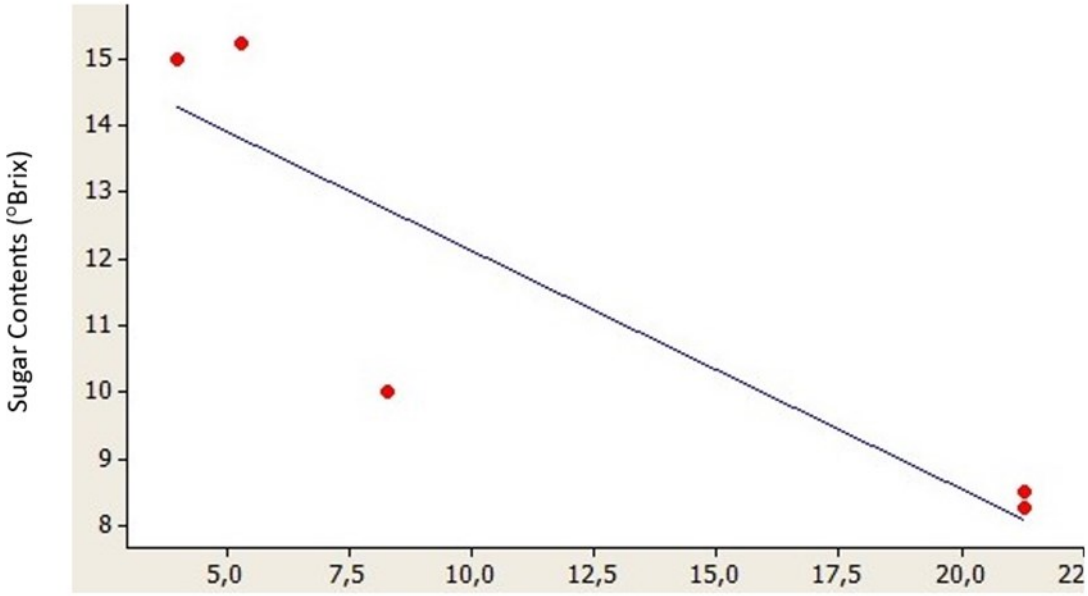

Figure 3. A negative correlation between average number of rainy days per month and sugar contents in *S. samarangense* cultivars

Semarang apple is considered as a nonseasonal plant (Khandaker *et al.*, 2012), in fact, this species consists of many cultivars with different time of flowering (Rafferty 2017). For example *S. Samarangense* 'Citra' which is the most popular semarang apple fruits three times a year in August, November, May with different sugar contents. Cultivar of *S. Samarangense* 'Sukaluyu' produces fruits in June-August which were sweeter than those fruiting in December-February. Our data on the *S. Samarangense* 'Sukaluyu' cultivar showed that the fruits in June-August contains 14 – 16.5◦Brix sugar, while those in December – February contains 8 – 12◦Brix. We don't have the data for other cultivars because mostly they still produce flowers not fruits in December – January. As many other fruits, to obtain the best sweet semarang apples, a long, warm growing season is required. During late fruit maturation and ripening, there should be nearly rainfree, as soil wetness and low insolation adversely affect fruit sweetness (Paris, et al, 2012).

Table 1. Sugar content amongst the 10 cultivars of *Syzygium samarangense*

No	Cultivar	Figure	Sugar Content	pH	Notes
1	*Syzygium samarangense* "Sukaluyu"		High sugar (max 16,5◦Brix)	4.24	This cultivar is not popular, rarely sold in the market

Table 1. Sugar content amongst the 10 cultivars of *Syzygium samarangense* (continued)

No	Cultivar	Figure	Sugar Content	pH	Notes
2	*Syzygium samarangense* 'Madu'		High sugar (max 14◦Brix)	4.11	Medium, found in some places and in the market
3	*Syzygium samarangense* 'Kesuma Merah'		High sugar (max 10.5◦Brix)	3.95	Medium, Sold in some places and markets.
4	*Syzygium samarangense* 'Citra'		Relatively high sugar (max 8.5◦Brix)	3.91	Although sugar content is not high, this cultivar is the most popular one. Widely sold in the markets
5	*Syzygium samarangense* 'Demak'		Medium sugar (max 8◦Brix)	3.96	Medium, very popular, sold a lot in many places and in markets
6	*Syzygium samarangense* 'Madura Putih'		Medium sugar (max 6.5◦Brix)	4.14	Popular but not very sweet. Sometimes for sale
7	*Syzygium samarangense* 'Ijo'		Medium sugar (max 6◦Brix)	3.8	Not popular, not for sale
8	*Syzygium samarangense* 'Bajang Leang'		Low sugar (max 5◦Brix)	5.33	Medium, there are more than three trees, sometimes for sale
9	*Syzygium samarangense* 'Thailand'		Low sugar (max 4◦Brix)	4.11	Rare, only one found, not for sale
10	*Syzygium samarangense* 'Kuning'		Low sugar (max 4◦Brix)	3.52	Rare, only one was found, the tree had been cut down, not for sale

Sugar distribution within the fruits

In a fruit itself, the distribution of sugar is not equal, for example the sugar in the fruit base is lower than those at the fruit apex. This due to the accumulation of the sugar at the end of the fruit part (Figure 4). While those at the fruit base, the fruit part is not mature enough, and there are still many hormones or other substances like salicilic acid which inhibit the production of the sugar (Yuan et al 2023).

Sugar accumulation in fruit is regulated by sugar transporter gene (ClTST2). The accumulation of soluble sugars in fruit, is a major factor for fruit quality. Molecular and biochemical analyses indicated that ClTST2 encodes a vacuolar membrane protein, whose expression is associated with tonoplast uptake and accumulation of sugars in fruit flesh cells. The functional characterization of ClTST2 and its expression regulation by SUSIWM1 provide novel tools to increase sugar sink potency in fruits such as watermelon and in other vegetable and fruit crops (Ren *et al.*, 2018).

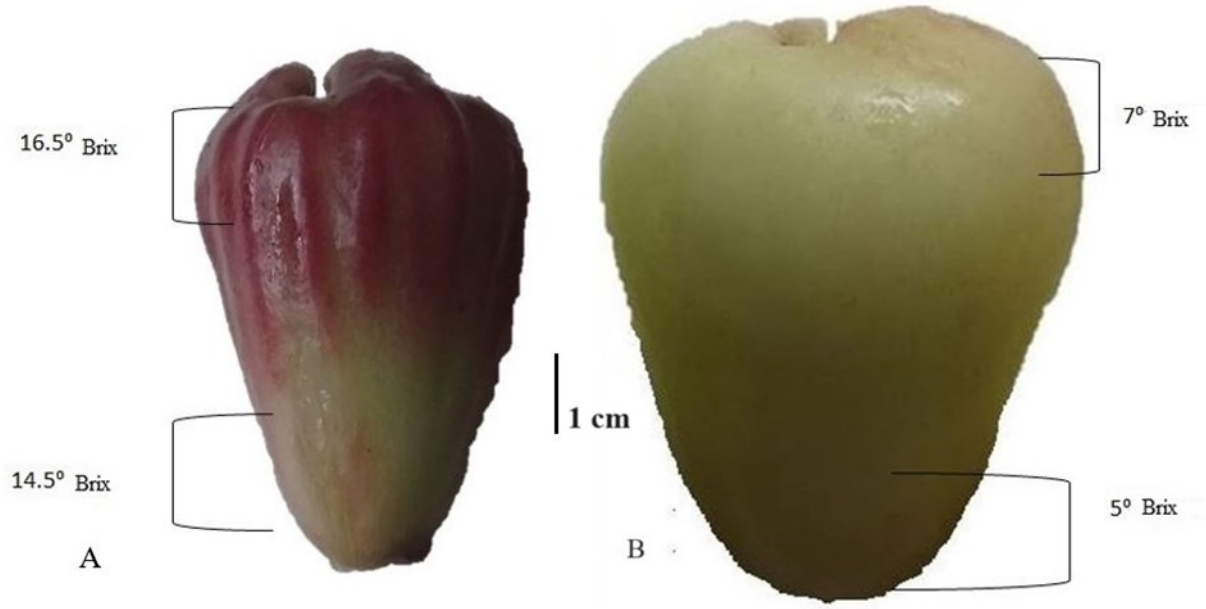

Figure 4. Sugar distribution within the sweetest and the less sweet fruit. A. *S. Samarangense* 'Sukaluyu' . B. *S. Samarangense* 'Madura Putih'

Soluble sugars accumulated mainly when the fruit was still attached to the plant. After harvest, however, there was still sucrose synthesis, and the sucrose-phosphate synthase activity was highly correlated to the sucrose content, indicating the importance of this enzyme in the process (Botha & Black, 2000). Thus, the sweetness of the fruit still increase at post harvest.

Our research contribution to science is a better understanding on the sugar content on some cultivars of semarang apples leading to improve breeding program and commercial applications. In fact, there are many semarang apple cultivars with various levels of sugar contents. Not all of the cultivars are liked by many people. They normally choose the sweet ones. Studies of fruit sweetness have been done by using various methods in many fruits (Setiadi and Umar, 2019). Furthermore, the relationship between sugar content and degree Brix has been done (Pistón *et al.*, 2017).

CONCLUSION

Based on sugar content, there are three categories namely: 1) high sugar content (>12◦Brix) which includes *Syzygium samarangense* 'Sukaluyu', *S. samarangense* 'Madu', *S. samarangense* 'Kesuma Merah'; 2) medium sugar content (6-11.99◦Brix) consists of *S. samarangense* 'Citra', *S. samarangense* 'Demak', *S. samarangense* 'Madura Putih', and *S. samarangense* 'Ijo'; 3) low sugar content (<6◦Brix) includes *S. samarangense* 'Bajang Leang', *S. samarangense* 'Thailand', and *S. samarangense* 'Kuning'. The sugar content in the fruits showed a difference between fruit base and fruit apex. The fruit base contains less sugar than the fruit apex. The fewer rainy days, the sweeter the fruit. This research is important for better understanding on how to choose and develop semarang apples for breeding program.

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REFERENCES

Arena, M. E., Zuleta, A., Dyner, L., Constenla, D., Ceci, L., & Curvetto, N. 2013. Berberis buxifolia fruit growth and ripening: evolution in carbohydrate and organic acid contents. *Scientia Horticulturae*, *158*, 52-58.

Botha, F. C., & Black, K. G. 2000. Sucrose phosphate synthase and sucrose synthase activity during maturation of internodal tissue in sugarcane. Functional Plant Biology, 27(1), 81-85.

BPS Provinsi Jawa Tengah. 2022. Banyak Curah Hujan dan Hari Hujan Menurut Bulan di Provinsi Jawa Tengah, 2019 – 2021. https://jateng.bps.go.id/statictable/2020/07/28/2049/. Accessed 18 October 2023.

Cirilli, M., Bassi, D., & Ciacciulli, A. 2016. Sugars in peach fruit: a breeding perspective. Horticulture Research, 3.

Guichard, S. *et al.* 2001. 'Tomato fruit quality in relation to water and carbon fluxes', *Agronomie*, 21(4), pp. 385–392. doi: 10.1051/agro:2001131.

Halford, N. G., Curtis, T. Y., Muttucumaru, N., Postles, J., & Mottram, D. S. 2011. Sugars in crop plants. Annals of Applied Biology, 158 (1), 1-25.

Jonkers, H. and Hoestra, H. 1978. 'Soil pH in fruit trees in relation to specific replant disorder of apple. I. Introduction and review of literature', *Scientia Horticulturae*, 8(2), pp. 113–118. doi: https://doi.org/10.1016/0304-4238(78)90015-8.

Khan, M. A., Liu, D. H., Alam, S. M., Zaman, F., Luo, Y., Han, H., ... & Liu, Y. Z. 2023. Molecular physiology for the increase of soluble sugar accumulation in citrus fruits under drought stress. *Plant Physiology and Biochemistry*, 108056.

Khandaker, M.M. *et al.* 2012. 'Physiochemical and phytochemical properties of wax apple (syzygium samarangense [Blume] Merrill & L. M. Perry var. Jambu Madu) as affected by growth regulator application', *The Scientific World Journal*, 2012. doi: 10.1100/2012/728613.

Khder, M. A. 2021. Web Scraping or Web Crawling: State of Art, Techniques, Approaches and Application. *International Journal of Advances in Soft Computing & Its Applications*, *13* (3).

Larsen, B. Migicovsky, Z, Jeppesen, A.A, Gardner, K.M., Toldam-Andersen, T.B. et al. 2019. 'Genome-Wide Association Studies in Apple Reveal Loci for Aroma Volatiles, Sugar Composition, and Harvest Date', *The Plant Genome*, 12(2), p. 180104. doi: 10.3835/plantgenome2018.12.0104.

Lim, T. K. and Lim, T. K. 2012. 'Syzygium samarangense', in *Edible Medicinal And Non Medicinal Plants*. doi: 10.1007/978-94-007-2534-8_105.

Ma, Q. J., Sun, M. H., Lu, J., Liu, Y. J., Hu, D. G., & Hao, Y. J. 2017. Transcription factor AREB2 is involved in soluble sugar accumulation by activating sugar transporter and amylase genes. Plant Physiology, 174(4), 2348-2362.

Magwaza, L. S., & Opara, U. L. 2015. Analytical methods for determination of sugars and sweetness of horticultural products—A review. Scientia Horticulturae, 184, 179-192.

Mounet, F., Moing, A., Garcia, V., Petit, J., Maucourt, M., Deborde, C., ... & Lemaire-Chamley, M. 2009. Gene and metabolite regulatory network analysis of early developing fruit tissues highlights new candidate genes for the control of tomato fruit composition and development. *Plant Physiology*, *149*(3), 1505-1528.

Nookaraju, A. *et al.* 2010. 'Molecular approaches for enhancing sweetness in fruits and vegetables', *Scientia Horticulturae*. Elsevier B.V., 127(1), pp. 1–15. doi: 10.1016/j.scienta.2010.09.014.

Paris, H. S., Amar, Z. and Lev, E. 2012. 'Medieval emergence of sweet melons, Cucumis melo (Cucurbitaceae)', *Annals of Botany*, 110(1), pp. 23–33. doi: 10.1093/aob/mcs098.

Pistón, F. *et al.* 2017. 'Relationship between sugar content and brix as influenced by cultivar and ripening stages of strawberry', *Acta Horticulturae*, 1156, pp. 491–495. doi: 10.17660/ActaHortic.2017.1156.72.

Rafferty, N. E., & Nabity, P. D. 2017. A global test for phylogenetic signal in shifts in flowering time under climate change. Journal of Ecology, 105(3), 627-633.

Ren, Y., Guo, S, Zhang, J, He, H, Sun, H. *et al.*

2018. 'A tonoplast sugar transporter underlies a sugar accumulation QTL in watermelon', *Plant Physiology*. doi: 10.1104/pp.17.01290.

Rosen, J. C. and Kader, A. A. 1989. 'Postharvest Physiology and Quality Maintenance of Sliced Pear and Strawberry Fruits', *Journal of Food Science*, 54(3), pp. 656–659. doi: 10.1111/j.1365-2621.1989.tb04675.x.

Serpen, J. Y. 2012. Comparison of sugar content in bottled 100% fruit juice versus extracted juice of fresh fruit.

Setiadi, R. N. and Umar, L. 2019. 'Fruit Sweetness Characterization Using Impedance Spectroscopy Method', *Spektra: Jurnal Fisika dan Aplikasinya*, 4(2), pp. 81–88. doi: 10.21009/spektra.042.04.

Sneath P.H.A. and Sokal R.R. 1973. *Numerical Taxonomy*. Freeman, San Francisco.

Tamura K., Nei M., and Kumar S. 2004. Prospects for inferring very large phylogenies by using the neighbor-joining method. *Proceedings of the National Academy of Sciences* (*USA*) 101:11030-11035.

Tamura K., Stecher G., and Kumar S. 2021. MEGA 11: Molecular Evolutionary Genetics Analysis Version 11. *Molecular Biology and Evolution* https://doi.org/10.1093/molbev/msab120.

Tarigan, C. 2022. 'Syzygium Samarangense : Review of Phytochemical Compounds and Pharmacological Activities', 12(2), pp. 2084–2107.

Widodo, P. 2015. *Jambu Semarang & Jambu Air*. 1st edn. Purwokerto: Unsoed Press.

Yuan, R., Mao, L., Min, T., Zhao, Y., Duan, Y., Wang, H., & Lin, Q. 2023. Salicylic acid treatment inhibits ethylene synthesis and starch-sugar conversion to maintain apple fruit quality during shelf life. Scientia Horticulturae, 308, 111586.