Research Article

The Physicochemical Properties and Consumer Preferences of Three Popular Durian Varieties Cultivated in Pahang

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ABSTRACT

Durian (*Durio zibethinus*) is a tropical fruit widely cultivated in Malaysia, primarily in the states of Perak, Pahang, and Johor. Pahang is known for producing high-quality durian. This study aims to investigate the physicochemical properties and consumer preferences of three popular durian varieties in Malaysia. In the present work, three different varieties of durian: "D197", "D24" and "D200" were purchased from durian orchards in Pahang. Their physicochemical properties (L^*, a^*, b^*, firmness) and non-volatiles (sugar and organic acid content) were measured. To investigate consumer preference, Hedonic tests were performed. Results indicated a significant difference ($p < 0.05$) among all studied physicochemical properties. In terms of colour, "D24" had the highest L^*, "D200" had the highest a^*, and "D197" had the highest b^* values, which corresponded to the colour intensity of each durian pulp. For firmness, "D200" obtained the highest value. Sucrose was the major sugar in durian, followed by fructose and glucose. "D200" had the significantly highest sucrose, whereas "D197" had the significantly highest glucose and fructose content. Six organic acids (succinic, malic, lactic, citric, acetic, tartaric acid) were identified in durian. Results from the Hedonic tests showed that all varieties were preferred by consumers, with "D200" obtaining the highest liking scores, on average. In conclusion, "D200" was the most preferred variety by consumers, likely due to its attractive appearance, sweeter taste accompanied with bitterness, and firmer texture among all varieties studied.

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1. Introduction

Durian, often referred to as the "king of fruits," is a widely cultivated tropical fruit known for its distinct aroma and complex flavour profile. In Malaysia, durian is not only an iconic fruit but also a significant agricultural commodity. The rising demand for Malaysian durian in domestic and international markets has led to an expansion of durian plantations in recent years. According to the Malaysian Agricultural Department, durian plantations expanded from 17,050 acres in 2016 to 190,011 acres in 2022 (Sinar Daily, 2023; Statista, 2020).

Most durian plantations are located in Peninsular Malaysia, with states like Perak, Johor, and Pahang being prominent producers. Pahang is well-known for producing some of the highest-quality durians in the country (Rahman, 2022), making it an ideal region to study the physicochemical characteristics of various durian varieties. The three most popular durian varieties produced in Pahang are Sultan "D24", Musang King "D197" and Black Thorn "D200". Each of these varieties is distinguished by unique characteristics—"D24" is prized for its balanced sweetness and slight bitterness, "D197" is known for its creamy texture and bittersweet taste, while "D200" is prized for its rich and custard-like flesh. These varieties are among the most popular in both local and international markets due to their distinct flavour and texture, making them ideal for analyzing consumer preferences.

Despite the popularity of durian in Southeast Asia, there remains a gap in understanding the detailed physicochemical attributes and how these characteristics align with consumer preferences across different durian varieties. Understanding consumer preferences is important for producers and exporters to cater to varying taste profiles and optimize market potential. Insights from such studies can aid in strategic marketing and product positioning, ensuring the sustainability of the durian industry in a competitive global market. Therefore, the present study aims to investigate the physicochemical properties and consumer preferences of three popular durian varieties cultivated in Pahang: "D197", "D24" and "D200". This study is essential to bridge the gap between scientific analysis and market demand, offering insights into what drives consumer choice in durian consumption.

2. Materials and Methods

2.1 Sample collection

The samples of three durian varieties, namely "Sultan (D24)", "Musang King (D197)" and "Black Thorn (D200)" used in this study were purchased from local durian orchards located in Raub, Pahang in Malaysia during the fruiting season. These varieties were selected as they are varieties that are popular in local as well as international markets (Suntharalingam *et al.*, 2018). To minimize natural variation between individual fruits of the same variety, durians were sourced from the same batch within a single orchard, ensuring consistent growing conditions. Ripe durian fruits were collected and transported to Universiti Putra Malaysia (UPM) and kept in a cool and dry place (23-25°C). All were harvested and collected on the same day to ensure uniform maturity. Additionally, we collaborated with the supplier, who assisted in selecting fruits of uniform ripeness based on their expertise. Ripeness was identified based on the soft, yellow, and creamy aril, as well as its sweetness, strong aroma, and rich flavour (Sharma *et al.*, 2023). The de-husking process was carried out manually. The pulp was kept in a freezer at -18°C and thawed prior to analysis.

2.2 Colour

The L^* a^* b^* colour of durian pulp of each variety was measured using a CR-300 chromameter (Konica Minolta, Osaka, Japan) following the method of Mat Isa *et al.* (2019). The surface of durian pulp was aimed by the chromameter receptor during measurement. Six readings were obtained for each sample. The mean reading of each sample was recorded and expressed in L^*, a^* and b^*, which represent lightness, redness, and yellowness, respectively.

2.3 Firmness

The firmness of durian pulp of each variety was determined using a TA-XT2 Texture Analyser (Stable Micro Systems, Surrey, United Kingdom) equipped with a P10 cylindrical probe according to the method of Boonthanakorn *et al.* (2020). The seed of durian pulp was removed before being subjected to firmness measurement. During measurement, the probe was pressed to a depth of 5 mm at a test speed of 15 mm/min. Each pulp was pressed six times at different areas and the average results were recorded in Newton (N).

2.4 Sugars

The sugar content analysis of durian was performed following the method of Tan *et al.* (2020) with slight modification. Durian was homogenized with deionized water in a ratio of 1:3 and centrifuged at 4 °C for 20 min at 5000 *g*. The supernatant was then collected and filtered through a 0.22 µm syringe filter. The analysis was performed using a Waters 2695 Alliance high-performance liquid chromatography (HPLC) (Thermo Fisher Scientific, Loughborough, UK) system equipped with a refractive index (RI) detector. The sugars were separated using Purospher Star NH_2 analytical column (5 µm packing size, 250 mm length, 4.6 mm ID, Merck, Darmstadt, Germany) at 35 °C at a flow rate of 1.2 mL/min. The mobile phase used was 86:14 (v/v) acetonitrile and deionized water. The injection volume was 20 µL. External standards (glucose, sucrose, and fructose) (Carbohydrates Kit, Supelco, Inc., Pennsylvania, USA) were used to quantify sugar content in each durian sample. Triplicate analysis was run for each sample.

2.5 Organic acids

The organic acids content analysis of the durian sample was carried out using the method of Sturm *et al.* (2003) with slight modifications. Sample preparation was carried out using the method of Tan *et al.* (2020). Three grams of durian pulp was homogenized with 9 mL of deionized water followed by centrifugation at 4 °C for 20 min at 5000 *g*. The collected supernatant was filtered through a syringe filter of 0.45 µm before being injected into a Waters 2695 Alliance HPLC (Thermo Fisher Scientific, Loughborough, UK) system with a UV detector at 210 nm. A Purospher STAR RP18 analytical column (5 µm packing size, 250 mm length, 4.6 mm ID, Merck, Darmstadt, Germany) using 0.004 N aqueous sulfuric acid as mobile phase at a flow rate of 0.6 mL/min was used to separate organic acids. Organic acid standards used for quantification were acetic acid, lactic acid, tartaric acid, succinic acid, malic acid, and citric acid (Organic Acids Kit, Supelco, Inc., Pennsylvania, USA). Triplicate analysis was run for each sample.

2.6 Sensory evaluation

Fifty-six panelists aged 20-47 years (mean age = 24) were recruited from Universiti Putra Malaysia to evaluate fresh durian samples using the Hedonic Test. The panel consisted of individuals of both genders with the inclusion criteria of only individuals who had previously consumed durian and enjoyed the fruit were included, providing a diverse representation of consumer preferences. No formal training was provided to the panelists, as the focus was on capturing general consumer responses. We focused on individuals with real-world experience rather than trained evaluators since the Hedonic test can be used to measure the degree of pleasure experienced with each sample evaluated by consumers who have no special sensory training. A nine-point scale (1-dislike extremely to 9-like extremely) was used to evaluate the likeness of consumers of each attribute based on surface colour (yellowness, orangeness), aroma (fermented, green, floral, fruity, sulfury), texture (moistness, smoothness, stickiness), taste (bitterness, creaminess, gassiness, sweetness), and overall aftertaste. The sensory attributes were chosen based on a preliminary testing session conducted with durian experts before the sensory evaluation test. The selected sensory attributes were chosen based on their significance in determining durian quality and consumer acceptance. During evaluation, a whole pulp of each sample was served in a tightly closed transparent plastic container. Between samples, mineral water and unsalted crackers were provided to panelists to clean their palates. Panelists were also instructed to take some fresh air before moving on to the next sample. Tokens of appreciation were given to each panelist after sensory evaluation. The sensory evaluation was conducted in a controlled environment, with standardized factors such as lighting, temperature, and noise to ensure consistency and validity of the results. Sensory evaluation was carried out in duplicates and the mean scores of each attribute were recorded.

Table 1 Definition of the sensory descriptors used in sensory evaluation

Sensory attributes	Definition
Yellowness	The yellow colour of the durian pulp.
Orangeness	The orange colour of the durian pulp.
Fermented	Aroma associated with fermented odour.
Green	Aromatic characteristics of certain green fruits and underripe fruits in general.
Floral	Aroma associated with flowers.
Fruity	Aromatic associated with a mixture of non-specific fruits: berries, apples/pears, tropical, melons; usually not citrus fruits.
Sulfury	Aromatic associated with hydrogen sulfide and onions.
Moistness	The amount of moisture perceived as the sample is chewed
Smoothness	Textural property is manifested by an absence of detectable solid particles.
Stickiness	Degree of durian flesh adherence to hands.
Bitterness	Basic taste on the tongue stimulated by solutions of caffeine, quinine, and certain other alkaloids.
Creaminess	Smooth top note characteristic of fresh, sweet cream or butter.
Gassiness	Gas-like feeling in the mouth associated with fermented fruits, vegetables (can be yeasty) or grains.
Sweetness	Basic taste on the tongue stimulated by sugars and high-potency sweeteners.
Overall aftertaste	The chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as puckering/dry and associated with tannins or alum.

2.7 Statistical analysis

All data obtained were compared by one-way analysis of variance (ANOVA). Differences among mean values were tested for significance ($p < 0.05$) using Tukey's multiple t-tests. Minitab 19 software (Minitab Inc., Pennsylvania, USA) was used to perform ANOVA and Tukey's multiple t-tests.

3. Results and Discussion

3.1 Colour and firmness of durian

The colour profile of three durian samples is presented in Table 2. The L^* (lightness), a^* (redness) and b^* (yellowness) of the durians were significantly different ($p < 0.05$) among varieties. Results showed that "D24" had the highest L^*, indicating that it had the brightest colour among the three varieties, followed by

"D197" and "D200". Even though "D24" had the highest *L**, however, it had the lowest *a** and *b** values compared to "D197" and "D200". Meanwhile, "D200" with the lowest *L** had the significantly highest *a** value than others. This indicated that "D200" was less bright in colour, but it was more reddish. "D197" had the highest *b** values, due to its golden yellow pulp. The *L**, *a** and *b** values measured were consistent with the colour of each durian pulp, where "D24" had a light-yellow pulp, "D197" had a golden-yellow pulp and "D200" had an orangey-yellow pulp. The intensity of colour of the samples is likely affected by the concentration of carotenoids (Wisutiamonkul *et al.*, 2015). According to the study by Tan *et al.* (2020), the carotenoid content of "D200" was the highest, followed by "D197" and "D24".

Table 2 Physicochemical properties of three popular durian varieties cultivated in Pahang

Properties	"D24"	"D197"	"D200"
L^*	81.23 ± 2.94^{a}	77.44 ± 5.18^{ab}	75.22 ± 3.00^{b}
a^*	2.02 ± 0.68^{b}	4.35 ± 1.16^{b}	16.28 ± 3.96^{a}
b^*	37.72 ± 3.95^{b}	56.79 ± 4.68^{a}	53.79 ± 6.42^{a}
Firmness (N)	0.34 ± 0.04^{ab}	0.33 ± 0.08^{b}	0.39 ± 0.08^{a}

All values show mean ± standard deviation (n=6)
The different small letters indicate significant differences between different varieties ($p < 0.05$)

Meanwhile, firmness was chosen as a key parameter because it is a critical determinant of fruit quality and plays a significant role in consumer preference. Firmness is often associated with ripeness in durian, which affects both the eating experience and overall acceptability. Previous studies have also identified firmness as a key quality attribute influencing the sensory perception and marketability of durians (Tan *et al.*, 2020). The results found that the values were in the range of 0.33 N to 0.39 N. Among the three varieties, "D200" reported the highest value and "D24" had the lowest value. The variation in firmness of durian pulp could be linked to the strength of the flesh inside, the activity of polygalacturonase enzyme in the pulp during fruit ripening, and fibre content (Imsabai *et al.*, 2002; Onsawai *et al.*, 2021). According to SchleiBinger *et al.* (2013), increased fibre significantly increases the firmness of food. Water content is also an important factor affecting the firmness of fruit. Moisture loss has been positively correlated with firmness in previous studies (Cantín *et al.*, 2012; Paniagua *et al.*, 2013).

3.2 Sugars of durian

Sugars are an important factor in affecting fruit flavour and quality. Sucrose, glucose and fructose are the three major sugars found in durian. According to Table 3, the sucrose concentration (33.44 to 52.64 g/kg) was the highest among the three durian varieties, followed by fructose (7.74 to 11.45 g/kg) and glucose (4.60 to 8.93 g/kg). A similar trend was reported by Wasnin *et al.* (2012) that the sugar composition of "durian kampung" was highest in sucrose, followed by glucose and fructose. However, the study of Voon *et al.* (2007) reported a different trend, where the main sugar found in durian was sucrose, followed by glucose and fructose. Based on the study of Selvaraj & Pal (1984), the ratio of sugars in different fruit varieties could be different caused of enzyme activities. The sugar content varied significantly ($p < 0.05$) among the three durian varieties. The total sugar content of "D200" was the highest, hence it can be deduced that it was the sweetest compared to "D197" and "D24".

Table 3 Sugar content of three popular durian varieties cultivated in Pahang

Sugars	"D24"	"D197"	"D200"
Fructose (g/kg)	7.74 ± 0.11^{c}	11.45 ± 0.16^{a}	8.43 ± 0.09^{b}

Glucose (g/kg)	4.60 ± 0.09^{c}	8.93 ± 0.21^{a}	8.11 ± 0.08^{b}
Sucrose (g/kg)	36.00 ± 0.23^{b}	33.44 ± 0.15^{c}	52.64 ± 0.30^{a}

All values show mean ± standard deviation (n=3)
The different small letters indicate significant differences between different varieties ($p < 0.05$)

3.3 Organic acids of durian

Organic acids play a crucial role in the flavour and consumer acceptability of fruits. The proportion of sugars and organic acids is often used as a quality indicator in many fruits. In this study, six organic acid contents (tartaric, malic, lactic, acetic, succinic, and citric acid) were analyzed. The findings align with those of Tan *et al.* (2020) and Voon *et al.* (2007), who identified similar organic acids in various Malaysian durian varieties. Organic acids are likely to contribute to the sourness of durian flavour. However, the sourness is masked by the sweetness from their high sugar content (Lawless & Heymann, 2010; Sangpong *et al.*, 2021). Based on Table 4, a significant difference ($p < 0.05$) was detected in lactic, succinic and tartaric acid content in all samples. The variation in organic acid concentrations among different varieties could be attributed to genetic variations. Genetic makeup could influence the organic acid composition by regulating enzyme activity involved in organic acid production (Etienne *et al.*, 2013). In addition, the study of Jiang *et al.* (2020) showed that the rate of respiration and metabolism during ripening affect the acid levels.

These organic acids influence the fruit's acidity, tartness, and balance of sweetness, which are key factors affecting consumer perception and preference. Succinic acid was the major organic acid found in "D24" with a value of 5.53 g/kg, whereas citric acid was predominant in "D197" (7.72 g/kg) and "D200" (4.84 g/kg). Succinic acid can impart a slightly bitter or umami taste (Ma *et al.*, 2020), while citric acid provides a mild tartness that enhances flavour complexity in durian. Although tartaric acid is present in relatively low concentrations (0.54-1.84 g/kg), it plays a more significant role in enhancing overall taste perception and balancing the sweetness and sourness (Xiao *et al.*, 2022). Malic acid, on the other hand, can impart a smooth, apple-like acidity, contributing to the fruit's refreshing taste (Li *et al.*, 2021).

Table 4 Organic acid content of three popular durian varieties cultivated in Pahang

Organic acids	"D24"	"D197"	"D200"
Acetic acid (g/kg)	1.34 ± 0.41^{a}	1.31 ± 0.15^{a}	1.51 ± 0.15^{a}
Citric acid (g/kg)	5.17 ± 2.12^{a}	5.72 ± 0.53^{a}	4.84 ± 1.80^{a}
Lactic acid (g/kg)	1.66 ± 0.69^{a}	0.37 ± 0.10^{b}	ND
Malic acid (g/kg)	0.61 ± 0.16^{b}	1.24 ± 0.39^{a}	1.27 ± 0.13^{a}
Succinic acid (g/kg)	5.53 ± 1.26^{a}	3.46 ± 0.79^{b}	1.14 ± 0.24^{c}
Tartaric acid (g/kg)	1.18 ± 0.14^{b}	1.84 ± 0.46^{a}	0.54 ± 0.02^{c}

All values show mean ± standard deviation (n=3)
The different small letters indicate significant differences between different varieties ($p < 0.05$)

3.4 Sensory evaluation

The Hedonic test is used to assess consumer preference for the intensity of each sensory characteristic. Table 5 shows the likeness scores obtained for each characteristic of durian from 56 untrained panelists using the Hedonic test. The sensory preferences of durians were accessed in surface colour (yellowness, orangeness), aroma (fermented, green, floral, fruity, sulphury), texture (moistness, smoothness, stickiness), taste (bitterness, creaminess, gassiness, sweetness), and overall aftertaste. For surface colour, "D197" with golden yellow pulp and "D200" with orangey-yellow pulp obtained the significantly highest ($p < 0.05$) likeness score in yellowness and orangeness, respectively. "D24" had the lowest scores in both yellowness and orangeness, probably due to its light-yellow flesh, which was less attractive compared to "D197" and "D200". Therefore, it can be concluded that durians with a rich, golden orange colour tend to be more appealing to consumers.

Table 5 Sensory evaluation of three popular durian varieties cultivated in Pahang

Attributes		"D24"	"D197"	"D200"
Surface colour	Yellowness	6.2 ± 1.4^{b}	7.9 ± 1.3^{a}	7.0 ± 1.6^{ab}
	Orangeness	4.1 ± 2.1^{b}	6.1 ± 2.1^{ab}	7.3 ± 1.6^{a}
Aroma	Fermented	5.4 ± 2.0^{a}	6.3 ± 1.9^{a}	6.7 ± 1.7^{a}
	Green	4.0 ± 2.3^{a}	3.8 ± 2.3^{a}	5.1 ± 2.5^{a}
	Floral	5.1 ± 2.5^{a}	5.3 ± 2.3^{a}	5.9 ± 2.3^{a}
	Fruity	6.6 ± 1.9^{a}	7.2 ± 1.8^{a}	6.8 ± 1.7^{a}
	Sulfury	4.6 ± 2.3^{a}	4.9 ± 2.4^{a}	5.7 ± 2.3^{a}
Texture	Moistness	6.4 ± 2.0^{a}	7.1 ± 1.7^{a}	7.3 ± 1.5^{a}
	Smoothness	6.3 ± 2.2^{a}	7.1 ± 1.7^{a}	7.2 ± 1.4^{a}
	Stickiness	5.5 ± 2.1^{a}	6.1 ± 2.0^{a}	6.9 ± 1.6^{a}
Taste	Bitterness	4.9 ± 2.5^{a}	5.4 ± 2.3^{a}	6.5 ± 2.0^{a}
	Creaminess	6.6 ± 2.2^{a}	7.0 ± 1.6^{a}	7.4 ± 1.4^{a}
	Gassiness	4.9 ± 2.1^{a}	5.3 ± 2.3^{a}	6.0 ± 2.3^{a}
	Sweetness	6.4 ± 2.0^{a}	6.9 ± 1.9^{a}	6.9 ± 1.7^{a}
Overall aftertaste		6.7 ± 1.8^{a}	7.2 ± 1.6^{a}	7.4 ± 1.1^{a}

All values show mean ± standard deviation (n=2)
The different small letters indicate significant differences between different varieties ($p < 0.05$)

The aroma, texture and taste of durian pulp did not show any significant difference ($p > 0.05$) for all varieties. This lack of significant differences may be attributed to the relatively similar chemical composition and sensory profiles of these durian cultivars, which could have resulted in comparable perceptions among panelists. Additionally, the panelists involved were untrained, which may have limited their ability to discern subtle differences in these attributes, hence the likeness score difference was not significant (Diako *et al.*, 2013). However, the texture of "D200" obtained the highest likeness score rated by panelists in moistness, smoothness, and stickiness, which could be due to its flesh which was not fibrous and contributed to its melt-in-mouth texture as compared to others. On the other hand, as shown in Table 2, "D200" exhibited the firmest texture, which is likely more preferred by panelists compared to the softer pulp of "D24". The softer texture of "D24" may be attributed to its higher moisture content, resulting in a "mushier" consistency, which may be perceived as less pleasant.

In terms of taste, the bitterness of "D200" durians obtained the highest likeness scores from panelists. This could be due to the bitterness of "D200" being milder compared to "D197" but stronger than "D24", which suited the preference of panelists more. Previous studies have suggested that milder bitterness tends to be more appealing, as it allows sweetness to remain prominent, a key factor in consumer preference for durian (Safari *et al.*, 2023). Furthermore, the sweetness of the durian varieties preferred by panelists from lowest to highest was "D24", "D200", and "D197". Correspondingly, sugar content analysis revealed that

"D200" and "D197" had significantly higher sugar content than "D24", indicating their sweeter taste. In addition, the sugar content along with the balance of organic acids directly affects the sweetness and acidity of the durian pulp. Overall, it can be deduced that panelists preferred durian pulp with a sweeter flavour.

In our study, specific attributes like sweetness and bitterness appeared to be influential in shaping the overall liking scores. Sweetness was a major driver of preference, with "D200" and "D197" being preferred for their balance of sweetness and bitterness, which is consistent with findings that sweetness is a primary factor in tropical fruit preferences (Fan *et al.*, 2021; Dos Santos Moreira *et al.*, 2024). Although there were no significant differences in aroma and texture, their roles in overall liking scores may still be important in terms of contributing to the overall sensory experience.

Overall, "D200" obtained more highest scores in the sensory characteristics of durian. This could be possibly due to its attractive appearance, and possessing the best texture, with a stronger aroma compared to the others. The lower likeness scores obtained for "D197" durians could be due to the intense bitter taste which may have overshadowed the sweet taste in durians, as suggested by recent studies linking high bitterness to lower consumer acceptance in certain fruits (Cavallo *et al.*, 2019). In overall, consumers preferred durian with an attractive yellow colour, smooth and moist texture, as well as sweet, creamy and moderate bitterness.

4. Conclusion

This study provides insights into the physicochemical and sensory attributes distinguishing the durian varieties "D24," "D197," and "D200." In conclusion, the results of this study revealed significant differences in the physicochemical properties as well as the consumer preference of the three durian varieties. "D24" exhibited the highest L^* value corresponding to its light-yellow pulp. In contrast, "D197" displayed a golden-yellow pulp with the highest b^* value, while "D200" had an orange-yellow pulp with the highest a^* value, attributed to its carotenoid content. Among sugars, sucrose dominated, followed by fructose and glucose, with "D200" having the highest total sugar content. The sensory evaluation demonstrated that "D200" scored highest in overall sensory characteristics, with its attractive orange-yellow appearance, smooth and moist texture, mild bitterness, and balanced sweetness appealing most to panelists.

Limitations of this study include potential panelist biases in sensory evaluations due to the use of duplicates instead of odd-number repetitions. Additionally, the small sample size for colour and firmness measurements may affect the result's reliability. Although based on prior research and practical constraints, a larger sample in future studies would help validate the findings. The findings highlight the importance of both sensory attributes and chemical composition in consumer preference, offering insights into durian quality. These insights provide valuable information for the durian industry, particularly in aiding breeding programs where the goal could be to develop varieties with desirable sensory and chemical traits. Furthermore, the results inform marketing strategies to target specific consumer preferences and guide quality control practices aimed at enhancing product consistency. Understanding consumer preferences will help the durian industry meet growing demand and strengthen global competitiveness.

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