

Chemical Composition of Durian (*Durio zibethinus*) cv. Long Lab Lae Grown in Thailand

องค์ประกอบทางเคมีของผลทุเรียนพันธุ์หลงลับแลที่ปลูกในประเทศไทย

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Abstract

This study investigated the chemical composition and nutritional characteristics of Long Lab Lae durian (*Durio zibethinus* Murr.), an economically important Thai fruit cultivar that is officially recognized as a Geographical Indication (GI) product. Fruits were collected from three growing regions, namely Uttaradit Province (UT), Lower Northern Thailand (LN), and Eastern Thailand (ES), and analyzed for proximate composition, mineral content, fatty acid profile, carotenoids, total phenolic content, and antioxidant activity. The growing location significantly influenced the chemical composition and nutritional characteristics of Long Lab Lae durian. Fruits from UT and LN contained higher carbohydrate and fat but lower moisture levels than those from ES. Sucrose was the predominant sugar in all samples, with the highest concentration observed in LN fruit 22.07 g/100 g fresh weight (FW). Potassium was the most abundant mineral, followed by phosphorus, magnesium, and calcium. Monounsaturated fatty acids constituted the major lipid fraction, with elevated oleic acid levels detected in fruits from UT and LN (2.37 and 2.33 g/100 g FW, respectively). In addition, UT fruit exhibited the highest β -carotene content (86.29 μ g/100 g FW). In contrast, total phenolic content and antioxidant activity did not differ significantly among growing regions. These findings demonstrate that geographical origin plays an important role in determining the chemical and nutritional attributes of Long Lab Lae durian. The distinctive GI

characteristics of Uttaradit Long Lab Lae durian, including its dry texture, fine flesh, and rich sweet-creamy flavor, are closely linked to variations in the physicochemical properties of the fruit associated with the growing environment. This study provides scientific evidence supporting the unique quality attributes and geographical identity of Long Lab Lae durian and thereby reinforcing its recognition as a geographical indication product.

Keywords: durian, geographical indication, Long Lab Lae, nutritional profile, proximate composition, Uttaradit province,

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อประเมินองค์ประกอบทางเคมีและลักษณะทางโภชนาการของทุเรียนพันธุ์หลงลับแล (*Durio zibethinus* Murr.) ซึ่งเป็นทุเรียนที่มีความสำคัญทางเศรษฐกิจของประเทศไทยและได้รับการขึ้นทะเบียนสิ่งบ่งชี้ทางภูมิศาสตร์ (Geographical Indication: GI) โดยเก็บตัวอย่างผลทุเรียนจาก 3 แหล่งปลูก ได้แก่ จังหวัดอุดรดิตถ์ (UT) ภาคเหนือตอนล่าง (LN) และภาคตะวันออก (ES) นำไปวิเคราะห์องค์ประกอบทางเคมีโดยประมาณ แร่ธาตุ กรดไขมัน แคโรทีนอยด์ สารประกอบฟีนอลิกรวม และฤทธิ์ต้านอนุมูลอิสระ ผลการศึกษาพบว่าแหล่งปลูกมีอิทธิพลอย่างมีนัยสำคัญต่อองค์ประกอบทางเคมีและลักษณะทางโภชนาการของทุเรียนพันธุ์หลงลับแล โดยทุเรียนจากจังหวัดอุดรดิตถ์และภาคเหนือตอนล่างมีปริมาณคาร์โบไฮเดรตและไขมันสูงกว่า แต่มีความชื้นต่ำกว่าทุเรียนจากภาคตะวันออก ซูโครสเป็นน้ำตาลหลักที่พบในทุกตัวอย่าง โดยทุเรียนจากภาคเหนือตอนล่างมีปริมาณสูงที่สุด (22.07 g/100 g FW) โพแทสเซียมเป็นแร่ธาตุหลัก รองลงมาคือ ฟอสฟอรัส แมกนีเซียม และแคลเซียม กรดไขมันไม่อิ่มตัวเชิงเดี่ยวเป็นองค์ประกอบหลักของไขมันทั้งหมด โดยพบกรดโอเลอิกในระดับสูงในตัวอย่างจากจังหวัดอุดรดิตถ์และภาคเหนือตอนล่าง (2.37 และ 2.33 g/100 g FW ตามลำดับ) นอกจากนี้ ทุเรียนจากจังหวัดอุดรดิตถ์มีปริมาณเบตาแคโรทีนสูงที่สุด (86.29 µg/100 g FW) ขณะที่ ปริมาณสารประกอบฟีนอลิกรวมและฤทธิ์ต้านอนุมูลอิสระไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติระหว่างแหล่งปลูก ผลการศึกษาชี้ให้เห็นว่าแหล่งปลูกมีบทบาทสำคัญต่อการกำหนดคุณลักษณะทางเคมีและโภชนาการของทุเรียนพันธุ์หลงลับแล ลักษณะเด่นตามสิ่งบ่งชี้ทางภูมิศาสตร์ของทุเรียนหลงลับแลจังหวัดอุดรดิตถ์ ได้แก่ เนื้อสัมผัสแห้งละเอียดและรสชาติหวานมันเข้มข้นอันเป็นเอกลักษณ์ โดยลักษณะเด่นดังกล่าวมีความเชื่อมโยงกับความแตกต่างขององค์ประกอบทางกายภาพและเคมีของผลที่เกิดจากอิทธิพลของพื้นที่ปลูก ผลการศึกษานี้เป็นหลักฐานทางวิทยาศาสตร์ที่สนับสนุนคุณลักษณะด้านคุณภาพอันโดดเด่นและอัตลักษณ์ทางภูมิศาสตร์ของทุเรียนพันธุ์หลงลับแลที่ได้รับการรับรองสิ่งบ่งชี้ทางภูมิศาสตร์

คำสำคัญ: ทุเรียนหลงลับแล สิ่งบ่งชี้ทางภูมิศาสตร์ คุณค่าทางโภชนาการ การวิเคราะห์ส่วนประกอบโดยประมาณ จังหวัดอุดรดิตถ์

Introduction

Durian (*Durio zibethinus* L.), commonly known as the “King of Fruits,” is one of the most popular fruits in Thailand due to its distinctive aroma and unique flavor. Thailand is the world’s leading producer and exporter of high-quality durian, surpassing other major producing countries such as Malaysia and Indonesia. Nearly 200 durian cultivars have been identified in Thailand; however, only approximately 60–80 cultivars are commercially cultivated. Among these, Mon Thong, Chanee, Kan Yao, and Kradum Thong are the most widely grown cultivars. Major production areas are located in the eastern and southern regions of the country, particularly in Chanthaburi, Rayong, Chumphon, Trat, and Nakhon Si Thammarat Provinces (Somsri, 2018). Owing to the economic importance and widespread cultivation of durian, extensive studies have been conducted on the physical characteristics, physiology, chemical composition, and bioactive compounds of major Thai commercial cultivars, particularly Mon Thong, Chanee, Kan Yao, and Kradum Thong (Kongkachuichai *et al.*, 2010; Gorinstein *et al.*, 2011; Charoenkiatkul *et al.*, 2016; Arsa *et al.*, 2021; Ascharyaphotha *et al.*, 2021).

While most durian cultivars in Thailand are predominantly cultivated in the Eastern and Southern regions, Long Lab Lae durian, originating from Uttaradit Province in Northern Thailand, has gained increasing popularity due to its distinctive fruit quality. The cultivar is characterized by its small round-to-oval fruits, thin rind, thick dark-yellow flesh, mild aroma, creamy texture,

and sweet taste, although some fruits may contain aborted seeds. Owing to these unique characteristics, Long Lab Lae durian has been registered as a Geographical Indication (GI) product of Uttaradit Province (Department of Intellectual Property, Ministry of Commerce, 2019). Geographical indications identify products whose quality, reputation, or other distinguishing characteristics are linked to their geographical origin. Environmental conditions and local production practices are considered key factors underlying the distinctive quality of GI products (Cassago *et al.*, 2021). Previous studies have shown that geographical origin can influence the composition and quality characteristics of fruit crops. For example, significant differences in the elemental composition of fruits have been observed among production regions, reflecting the influence of environmental and locational factors on fruit characteristics (Debbarma *et al.*, 2021). In the case of Long Lab Lae durian, the GI-designated production area comprises Lab Lae, Mueang Uttaradit, and Tha Pla districts, where sandy loam soils, mountainous landscapes, and favorable rainfall distribution are believed to contribute to the characteristic flavor and texture of the fruit (Department of Intellectual Property, Ministry of Commerce, 2019). In recent years, increasing market demand has promoted the cultivation of Long Lab Lae durian beyond the registered GI area to several provinces in Northern and Eastern Thailand, including Sukhothai, Phitsanulok, Chanthaburi, and Rayong. Fruit quality may vary according to differences in growing environments and cultivation practices,

including soil and climatic conditions, irrigation, fertilization, pest management, and tree management (Dichi, 2018).

However, scientific information regarding the chemical composition and nutritional characteristics of Long Lab Lae durian cultivated in different production regions remains limited. Therefore, this study aimed to investigate the chemical composition and nutrient content of Long Lab Lae durian cultivated in different regions of Thailand. The findings are expected to improve our understanding of regional variation in fruit quality and provide scientific evidence supporting the geographical identity and distinctive characteristics of Long Lab Lae durian.

Materials and methods/Methodology

Plant material

Durian fruits, specifically *Durio zibethinus* Murr. cultivar 'Long Lab Lae' (Figure 1), were collected from orchards located in different regions of Thailand during May–June 2018. The experiment was conducted using a completely randomized design (CRD), in which planting regions were assigned as treatments. Three planting regions were included: Uttaradit Province (UT), the original cultivation area of the cultivar; the Lower Northern region (LN); and the Eastern region (ES). For UT, fruits were collected from four orchards located in Lab Lae and Mueang Districts, Uttaradit Province (soil series no. 62; annual rainfall 842.8 mm; mean temperature 28.0 °C). In LN, fruits were

obtained from four orchards, including three orchards in Si Satchanalai District, Sukhothai Province (soil series no. 62; annual rainfall 736.2 mm; mean temperature 28.8°C) and one orchard in Noen Maprang District, Phitsanulok Province (soil series no. 62; annual rainfall 867.6 mm; mean temperature 28.6°C). In ES, fruits were sourced from four orchards, including three orchards in Khao Khitchakut and Khlung Districts, Chanthaburi Province (soil series no. 26; annual rainfall 2,538 mm; mean temperature 28.5°C) and one orchard in Mueang District, Rayong Province (soil series no. 35; annual rainfall 946 mm; mean temperature 28.8°C). All fruits were harvested at 105 days after flowering (DAF). Twelve durian fruits were collected from each orchard, with each orchard considered one replicate. The fruits from each orchard were divided into three subgroups of four fruits each, resulting in a total of 48 fruits per planting area. After harvest, the fruits were transported to the Food Science and Technology Laboratory, Faculty of Agriculture, Uttaradit Rajabhat University, and allowed to ripen at room temperature for 3–5 days prior to chemical and nutritional analyses. The edible pulp was separated and homogenized into a uniform paste. Moisture content was measured immediately after homogenization, while the remaining pulp was vacuum-sealed in aluminium foil and stored at -18°C. For bioactive compound and antioxidant assays, separate aliquots were freeze-dried, vacuum-sealed, and maintained under identical cold storage conditions until analysis.

Nutrient determination

1. Proximate composition

The proximate composition of Long Lab Lae durian pulp including moisture, ash, crude protein, crude fat, total dietary fiber, available carbohydrates, and energy was determined using standardized analytical protocols. Major macronutrients were quantified according to official methods of the Association of Official Analytical Chemists (AOAC, 2005). Moisture content was measured by oven drying at $100\pm 2^{\circ}\text{C}$ to constant weight (Method 952.45), while ash content was determined by incineration in a muffle furnace at $550\pm 5^{\circ}\text{C}$ (Method 945.46). Total nitrogen content was determined using the Kjeldahl method (AOAC Method 981.10), and crude protein was calculated by applying a standard conversion factor of 6.25 to the measured nitrogen value. Crude fat was extracted following acid digestion and continuous Soxhlet extraction with petroleum ether (Method 945.16). Total dietary fiber was quantified using an enzymatic-gravimetric method (Method 985.29; AOAC, 2016).

Available carbohydrates (percentage) were calculated by difference: Available carbohydrate (%) = $100 - [\text{Moisture} + \text{Protein} + \text{Fat} + \text{Ash} + \text{Total dietary fiber} (\%)]$. Total energy (kcal/100 g fresh weight) was then estimated using at water conversion factors: 4 kcal/g for protein and carbohydrates, and 9 kcal/g for fat (FAO, 2003).

Comprehensive sugar profiling including total sugar, glucose, fructose, and sucrose was performed by the Institute of Nutrition,

Mahidol University (Nakhon Pathom, Thailand) in accordance with AOAC Method 982.14 (AOAC, 2016).

2. Mineral, fatty acid, and carotenoid

The quantitative profiling of mineral, fatty acid, and carotenoid content was performed at the Institute of Nutrition, Mahidol University, Nakhon Pathom, Thailand. Mineral concentrations were quantified using Atomic Absorption Spectrophotometry (AAS) and Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), following AOAC Official Methods 985.35 and 984.27 (AOAC, 2016). Meanwhile, the fatty acid profiles were determined and characterised in accordance with standardised AOAC protocols (Methods 963.22 and 969.33; AOAC, 2016). Carotenoid content was measured based on the method of Speek *et al.* (1986) using high-performance liquid chromatography (HPLC). All procedures adhered to the respective validated standard protocols.

Total phenolic content and antioxidant activity

All chemicals and reagents used in this study were of analytical grade and obtained from Sigma-Aldrich (St. Louis, MO, USA), including Folin-Ciocalteu reagent, gallic acid, DPPH, Trolox, and TPTZ.

1. Total phenolics

The Folin-Ciocalteu method was used to determine the total phenolic (TP) content (Lu *et al.*, 2007). For extraction, a freeze-dried sample was added to 70% ethanol and shaken for two

hours at room temperature. A ten-fold diluted Folin-Ciocalteu reagent (2.5 mL) was reacted with the extract (0.5 mL) for 5 min, followed by the addition of a 7.5% sodium carbonate solution (2 mL). The mixture was measured using a spectrophotometer at 760 nm after being incubated for two hours at room temperature in the dark. Standards of gallic acid at concentrations of 0, 10, 20, 40, 60, and 80 µg/mL were prepared and measured for comparison with the unknown sample.

2. Antioxidant activity assay

2.1 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay. The DPPH assay was performed following established techniques as described by Moreno *et al.* (2002). The ethanolic extract of the sample was combined with 2 mL of DPPH solution in ethanol to obtain a final concentration of 0.05 mM. After being stored at ambient temperature in the

absence of light for 30 minutes, the absorbance was measured at a wavelength of 517 nm. The Trolox standards were prepared at concentrations of 0, 0.01, 0.02, 0.04, 0.06, 0.08, and 0.1 mM.

2.2 Ferric reducing antioxidant power (FRAP) assay. The FRAP assay was assessed using a minor adaptation of the methodology developed by Benzie and Strain (1996). An acetate buffer (300 mM, pH 3.6), TPTZ (10 mM) in 40 mM HCl, and ferric chloride in deionized water (20 mM) were combined in a ratio of 10:1:1 to generate the FRAP reagent. Subsequently, the reagent had a reaction with the ethanolic extract of the sample in a 3:1 ratio for four minutes at a temperature of 37°C under dark conditions. The absorbance was thereafter obtained at a wavelength of 595 nm and subsequently compared to the Trolox standard at concentrations of 0, 6.25, 12.5, 25, 50, and 100 µM.

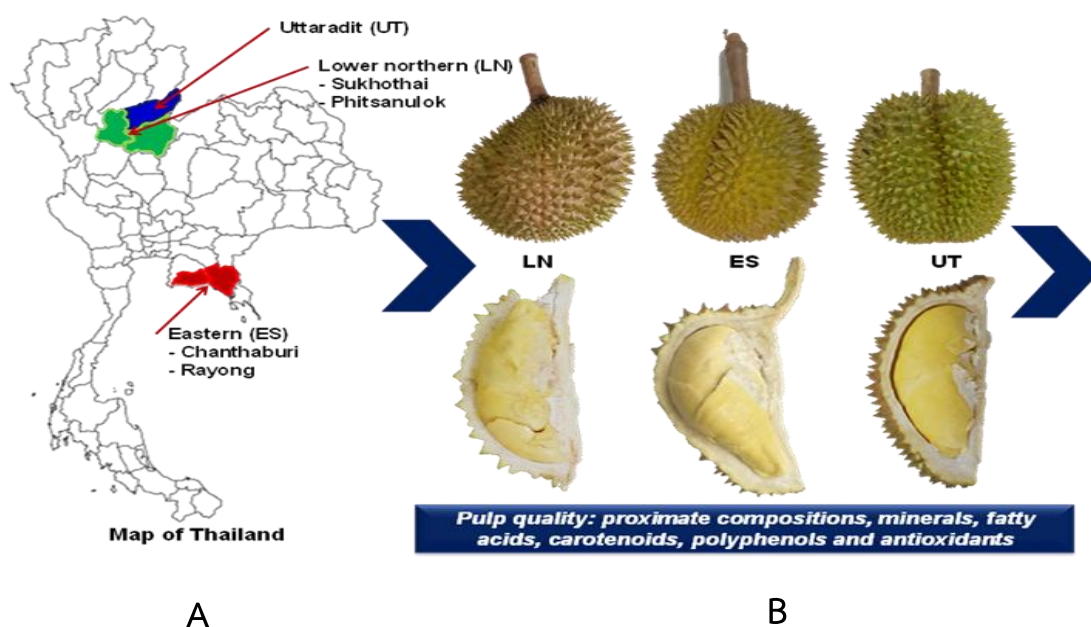


Figure 1 (A) geographic locations of the studied orchards across three regions in Thailand and (B) the physical characteristics of 'Long Lab Lae' durian (*Durio zibethinus* Murr.) harvested from different planting sites

Results and Discussions

Proximate composition

The pulp of Long Lab Lae durian cultivated in UT and the LN had the same energy content but was greater than that of those cultivated in the ES, with values of 175.83 ± 5.23 , 178.57 ± 5.56 , and 152.24 ± 2.19 kcal/100 g FW, respectively (Table 1). It was reported that the energy content of durian pulp from four Indonesian and four Thai cultivars ranged between 84 and 185 kcal/100 g FW. The energy content of the four Thai durian varieties Monthong, Chanee, Kradum, and Kobtakam were 134–162, 145, 185, and 145 kcal/100 g FW, respectively (Aziz and Jalil, 2019), which corresponded to those of Long Lab Lae durian grown in all three areas in this experiment.

Long Lab Lae durians produced in UT and LN had similar fat content (5.38 ± 0.16 and 5.51 ± 0.01 g/100 g FW, respectively), whereas the fruits produced in the ES had a lower fat content (4.82 ± 0.04 g/100 g FW) (Table 1). The fat content of the pulp of Long Lab Lae durian was higher than the amount found in four Indonesian durian varieties: Ajimah, Hejo, Matahari, and Sukarno, but the values were similar to the fat content of the pulp of four Thai durian varieties: Monthong, Chanee, Kradum, and Kobtakam (Aziz and Jalil, 2019).

The carbohydrate content of durian pulp produced in the LN area was higher than that of durian produced in the ES (26.24 ± 1.60 and 20.89 ± 0.81 g/100 g FW, respectively); however, the value obtained from ES did not differ from

that of durian pulp produced in the UT location (25.25 ± 1.75 g/100 g FW). Charoenkiatkul *et al.* (2016) also reported that Monthong, Chanee, Kradum, and Kobtakam cultivars contained 21–29 g/100 g FW of carbohydrates in their pulp. The LN's durian pulp had the highest total sugar concentration, which corresponded to the sucrose content. Durian pulp produced in UT and ES showed similar total sugar and sucrose content. Furthermore, the findings revealed that the fructose content of durian pulp produced in the three areas was not different. Glucose was not detected in all durian pulp (Table 1). A study on sugar composition in four Indonesian durian varieties, six Malaysian varieties, and four Thai varieties discovered that the total sugar content generally ranged between 3.10–14.05, 7.52–16.90, and 14.83–19.97 g/100 g FW, respectively (Aziz and Jalil, 2019). In addition, Thai durian cultivars such as Monthong, Chanee, Kradum, and Kobtakam contain sucrose, fructose, and glucose, with sucrose being the predominant sugar (Charoenkiatkul *et al.*, 2016; Aziz and Jalil, 2019). These results indicate that Long Lab Lae durian variety exhibits a higher total sugar content than most other Thai durian cultivars, with sucrose being the main contributor to its distinctive sweetness. The higher sugar accumulation observed in durians from northern Thailand (UT and LN) may be associated with pre-harvest environmental conditions, particularly low rainfall and well-drained hillside orchard systems. Such conditions may induce mild water deficit stress, which can influence carbohydrate allocation

and dry matter accumulation in fruit. In durian, increased dry matter and total soluble solids (TSS) during ripening are strongly associated with perceived sweetness and eating quality (Jerapat and Siriphanich, 2008).

As for protein content in Table 1, fruit from UT contained the highest amount. Meanwhile, the protein level of durian pulp produced in other locations was comparable. The protein content in the pulp of the Long Lab Lae durian variety grown in all three regions ranged from 6.08 ± 0.23 to 6.62 ± 0.11 g/100 g FW, which was higher than that reported for Thai durian cultivars 2.2–3.4 g/100 g FW (Thiyajai *et al.*, 2020). The nutritional content, particularly protein, and postharvest quality of horticultural crops are significantly influenced by pre-harvest factors, including genetic, environmental, cultural, and physiological factors (Thokar *et al.*, 2022).

The dietary fiber content of durian produced in UT was 3.34 ± 0.19 g/100 g FW, comparable to that of durian produced in the ES (3.67 ± 0.27 g/100 g FW). Table 1 shows that durian pulp from the LN area had the lowest amount of dietary fiber: 2.54 ± 0.02 g/100 g FW. The experiment results showed that the amount of dietary fiber in Long Lab Lae durian was similar to values reported for Monthong, Chanee, Kradum, Kan Yao, Puang Manee, and Kobtakam, which contained dietary fiber between 1.20 and 3.58 g/100 g FW (Aziz and Jalil, 2019). Devalaraja *et al.* (2011) previously found that durian is a high-fiber source, accounting for 3.1% of its total fiber content. This finding aligns with the research conducted by Gorinstein *et al.* (2011), which also indicated that fresh durian pulp is abundant in

dietary fiber, including soluble fiber, insoluble dietary fiber, and total dietary fiber. The ash content was highest in durian pulp from the ES region (1.29 ± 0.01 g/100 g FW) followed by fruit from the LN area (1.14 ± 0.04 g/100 g FW). Durian pulp from UT had the lowest ash content (1.05 ± 0.02 g/100 g FW) as illustrated in Table 1. The ash content of the Long Lab Lae durian pulp in this study was lower than that reported for Thai durian cultivars (Charoenkiatkul *et al.*, 2016). According to Table 1, durian cultivated in the eastern region contained the highest water content in its pulp, measuring 62.69 ± 1.69 g/100 g FW. Conversely, the moisture content of durian pulp from UT and LN did not differ significantly, with values of 58.38 ± 2.56 and 59.06 ± 1.11 g/100 g FW, respectively. These values were slightly lower than those previously reported for Thai durian pulp, which typically ranges from approximately 60 to 65 g/100 g FW (Aziz and Jalil, 2019; Thiyajai *et al.*, 2020). Generally, the moisture content of fully ripe durian pulp varies depending on cultivation practices and growing location (Ketsa *et al.*, 2020). The higher moisture content observed in durian from the eastern region may be associated with its growing environment, which is characterized by higher rainfall and lower elevation, thereby promoting greater water availability and retention within orchard systems. In contrast, durian orchards in UT and LN are often located in more sloped areas with relatively lower rainfall, which may reduce soil water retention. Pre-harvest environmental conditions, particularly rainfall patterns and orchard-specific microclimate,

have been reported to influence durian pulp dry matter, which is inversely related to moisture content (Jerapat and Siriphanich, 2008). Furthermore, when considered together with the environmental factors that contribute to the elevated sugar content observed in durians from the LN area, this specific agroecological environment appears to play a significant role in producing Long Lab Lae durians cultivated in northern Thailand. These characteristics are consistent with the geographical indication attributes of Long Lab Lae durian, which are characterized by a dry flesh texture and sweet taste.

Mineral contents

The Eastern region provided durian pulp with the highest calcium (7.36 ± 1.62 mg/100 g FW) while the mineral content in durian pulp from UT and LN was similar (3.09 ± 0.1 and 4.01 ± 0.66 mg/100 g FW, respectively) (Table 2). On the contrary, phosphorus in the pulp of durians cultivated in the UT and LN areas was found to be much greater than that of durians grown in the Eastern part of Thailand. The pulp of durian cultivated in the Eastern region contained the highest amount of potassium, followed by that of durian cultivated in LN. Meanwhile, the UT area provided the lowest potassium content in Long Lab Lae pulp. In the case of magnesium, cultivating durians in ES and LN provided a similar amount of the magnesium contents; however, the value was much greater than that from the UT location. Although the pulp of durian grown in the eastern region

contained the highest copper level, it contained the lowest amount of zinc. Furthermore, durian grown in the LN area contained the most zinc in its pulp, followed by durian farmed in UT and ES. Nonetheless, durians from the three locations had similar amounts of sodium and iron. Charoenkiatkul *et al.* (2016) determined the mineral content of four types of Thai durians (2 indigenous and 2 commercial cultivars) and discovered that potassium concentration was the greatest in all four types, followed by phosphorus. In addition, all four durian varieties contained significantly high levels of magnesium, sodium, and calcium. The results aligned with our study, which found that Long Lab Lae contained the highest amount of potassium, followed by phosphorus, sodium, magnesium and calcium. The eastern region consisted of several soil series, including soil series 35 in Rayong Province and soil series 26 and 27 in Chanthaburi Province (Land Development Department, n.d.), which are generally characterized as acidic soils with adequate to moderate drainage. Although these soils are commonly classified as having relatively low natural fertility, favorable environmental conditions together with well-drained soil profiles may promote root growth and nutrient uptake in durian trees. Well-drained soils are generally considered favorable for durian cultivation because they support root development and nutrient absorption. Furthermore, potassium plays a critical role in fruit development and quality, and nutrient accumulation in durian fruit has been reported to be influenced by fertilization

practices (Poovarodom and Phanchindawan, 2006). Therefore, the higher concentrations of K, Ca, Mg, and Cu observed in fruits from the eastern region may be associated not only with soil characteristics but also with intensive nutrient management practices commonly employed in commercial durian orchards. In addition, interactions among K, Ca, and Mg can affect nutrient availability, uptake, and translocation within plants, thereby contributing

to the mineral composition observed in the fruit (Kitprasong *et al.*, 2021). Although soil nutrient concentrations were not directly measured in this study, the characteristics of the soil series present in the eastern region suggest environmental conditions that may support nutrient acquisition by durian trees. Nevertheless, the observed mineral composition is likely influenced by a combination of soil properties, fertilization practices, and orchard management factors.

Table 1 The nutritional value of fully ripe durian cv. Long Lab Lae grown in different areas of Thailand (Uttaradit Province; UT, lower Northern region; LN, and Eastern region; ES)

Nutritional parameter	Planting area			F-test	CV
	Uttaradit Province (UT)	Lower Northern region (LN)	Eastern region (ES)		
Energy (kcal/100 g FW)	175.83±5.23 ^a	178.57±5.56 ^a	152.24±2.19 ^b	*	2.72
Fat (g/100 g FW)	5.38±0.16 ^a	5.51±0.01 ^a	4.82±0.04 ^b	*	1.81
Carbohydrate (g/100 g FW)	25.25±1.75 ^{ab}	26.24±1.60 ^a	20.89±0.81 ^b	*	6.00
Total sugar (g/100 g FW)	20.49±0.13 ^b	23.27±0.45 ^a	20.07±0.42 ^b	*	1.71
- Sucrose (g/100 g FW)	19.19±0.36 ^b	22.07±0.14 ^a	18.82±0.18 ^b	*	1.24
- Fructose (g/100 g FW)	1.31±0.23	1.21±0.30	1.26±0.23	NS	20.62
- Glucose (g/100 g FW)	ND	ND	ND	-	-
Protein (g/100 g FW)	6.62±0.11 ^a	6.08±0.23 ^b	6.27±0.22 ^b	*	2.55
Fiber (g/100 g FW)	3.34±0.19 ^a	2.54±0.02 ^b	3.67±0.27 ^a	*	5.96
Ash (g/100 g FW)	1.05±0.02 ^c	1.14±0.04 ^b	1.29±0.01 ^a	*	2.73
Moisture content (%)	58.38±2.56 ^b	59.06±1.11 ^b	62.69±1.69 ^a	*	2.02

Different letters within rows indicate significant difference based on Least Significant Difference Test, $p \leq 0.05$.

NS and * mean non-significant or significant at $p \leq 0.05$, respectively

ND, not detected

Fatty acid composition

Table 3 shows the fatty acid compositions of ripe Long Lab Lae durian. Palmitic and oleic acids were the main saturated (16:0) and monounsaturated (18:1) fatty acids, respectively, in the cultivar. Durian cultivated in the LN region contained the highest concentration of palmitic acid in its pulp, with durian from UT coming in second. The ES region exhibited the lowest palmitic acid content in durian pulp (1.34 ± 0.01 g/100 g FW; 34.78 ± 0.26 % of total fatty acids). In the case of oleic acid, the fruit from UT and LN contained comparable amounts; however, the two regions had higher levels than the pulp from ES. Furthermore, the findings indicated that durian pulp from the LN region exhibited the highest concentration of saturated fatty acids. Meanwhile, there was no significant difference in the pulp of durian grown in UT and ES.

Nevertheless, the pulp of durian cultivated in all three regions contained a similar composition of various fatty acids, including lauric acid, myristic acid, palmitoleic acid, stearic acid, linoleic acid (omega 6), linolenic acid (omega 3), and polyunsaturated fatty acids, as shown in Table 3. The relatively high oleic acid and total monounsaturated fatty acid contents in durian pulp from Uttaradit may contribute to its fatty mouthfeel. Lipids and unsaturated fatty acids play an important role in oral perception, smoothness arising from oral processing and texture interactions (Stokes *et al.*, 2013). In addition, fatty acids have been associated with fat-related taste perception (oleogustus), particularly in relation to creaminess and supporting their role in oral fat sensation (Mattes, 2009). Therefore, the elevated oleic acid content may partially explain the rich and fatty sensory characteristics of this cultivar.

Table 2 Mineral content of fully ripe durian cv. Long Lab Lae grown in different areas of Thailand (Uttaradit Province; UT, lower Northern region; LN, and Eastern region; ES)

Mineral parameter (mg/100 g FW)	Planting area			F-test	CV (%)
	Uttaradit Province (UT)	Lower Northern region (LN)	Eastern region (ES)		
Calcium	3.09 ± 0.10^b	4.01 ± 0.66^b	7.36 ± 1.62^a	*	20.99
Phosphorus	86.62 ± 7.90^a	70.17 ± 2.91^{ab}	63.22 ± 3.71^b	*	7.25
Sodium	38.51 ± 1.69	35.16 ± 0.45	36.02 ± 1.41	NS	3.55
Potassium	308.30 ± 1.77^c	353.92 ± 4.24^b	382.84 ± 0.13^a	*	0.76
Magnesium	18.98 ± 0.93^b	21.75 ± 0.72^{ab}	23.23 ± 1.36^a	*	4.87
Iron	0.30 ± 0.01	0.33 ± 0.01	0.29 ± 0.01	NS	0.00
Copper	0.10 ± 0.01^b	0.11 ± 0.01^b	0.16 ± 0.01^a	*	4.68
Zinc	0.31 ± 0.01^b	0.39 ± 0.01^a	0.19 ± 0.01^c	*	0.00

Different letters within rows indicate significant difference based on Least Significant Difference Test, $p \leq 0.05$.

NS and * mean non-significant or significant at $p \leq 0.05$, respectively

Table 3 Fatty acid composition of fully ripe durian cv. Long Lab Lae grown in different areas of Thailand (Uttaradit Province; UT, lower Northern region; LN, and Eastern region; ES)

Fatty acid composition (g/100 g FW)	Planting area			F-test	CV (%)
	Uttaradit Province (UT)	Lower Northern region (LN)	Eastern region (ES)		
Lauric acid	0.01±0.00	0.01±0.00	0.02±0.01	NS	0.00
Myristic acid	0.03±0.01	0.04±0.01	0.04±0.01	NS	3.96
Palmitic acid	1.44±0.03 ^b	1.56±0.04 ^a	1.34±0.01 ^c	*	1.83
Palmitoleic acid	0.22±0.00	0.24±0.01	0.22±0.01	NS	2.27
Stearic acid	0.04±0.01	0.04±0.01	0.04±0.01	NS	4.59
Oleic acid	2.37±0.00 ^a	2.33±0.06 ^a	2.03±0.01 ^b	*	1.58
Linoleic acid (omega 6)	0.09±0.01	0.08±0.01	0.07±0.01	NS	13.14
Linolenic acid (omega 3)	0.12±0.00	0.12±0.01	0.11±0.01	NS	2.63
Saturated fatty acids (SFA)	1.52±0.03 ^b	1.65±0.05 ^a	1.43±0.01 ^b	*	1.84
Monounsaturated fatty acids (MUFA)	2.59±0.01 ^a	2.57±0.05 ^a	2.25±0.01 ^b	*	1.30
Polyunsaturated fatty acids (PUFA)	0.21±0.01	0.19±0.01	0.18±0.02	NS	6.86

Different letters within rows indicate significant difference based on Least Significant Difference Test, $p \leq 0.05$.

NS and * mean non-significant or significant at $p \leq 0.05$, respectively

Carotenoid content

The findings indicated that the durian pulp cultivated in UT had the greatest concentration of β -carotene, specifically $86.29 \pm 3.77 \mu\text{g}/100 \text{ g FW}$, while the composition in pulp grown in the LN and ES regions showed no significant difference, with values of 74.16 ± 0.22 and $78.13 \pm 0.18 \mu\text{g}/100 \text{ g FW}$, respectively. Similarly, α -carotene and lutein contents did not differ significantly among the regions, ranging from 14.64 ± 0.19 to $17.40 \pm 1.90 \mu\text{g}/100 \text{ g FW}$ and from 24.32 ± 4.67 to $28.70 \pm 8.03 \mu\text{g}/100 \text{ g FW}$, respectively (Table 4). Typically, the flesh of the durian fruit has a yellow color. Varying concentrations of carotenoid molecules lead to distinct hue values in the durian pulp (Wisutiamonkul *et al.*, 2015). The pulp of durian

fruit (cv. Long Lab Lae) is characterized by its dark yellow color derived from its carotenoid component (Namitha and Negi, 2010). The findings of this investigation demonstrated that the pulp of Long Lab Lae durian cultivated in all three regions contained three distinct carotenoid compounds: β -carotene, α -carotene, and lutein. The durian pulp had the greatest quantity of β -carotene, followed by lutein, and a trace amount of α -carotene. The experimental findings aligned with previous reports on the presence of carotenoids in the pulp of durian varieties Chanee and Monthong. The primary carotenoid molecule discovered in the ripe fruit's pulp is β -carotene, with α -carotene following closely behind. Lutein and zeaxanthin are present as minor carotenoid compounds. The

mature Chanee durian pulp exhibited a greater concentration of total carotenoids, including β -carotene and α -carotene, compared to the pulp of Monthong durian. In addition to carotenoid composition, instrumental color analysis further confirmed differences in pulp coloration among growing regions. A previous study by Somniyam *et al.* (2024) reported that durian pulp from Uttaradit exhibited lower L^* values compared with those from the eastern and lower northern regions,

indicating a darker yellow appearance. In contrast, higher chroma values in pulp from Uttaradit suggested a more vivid and saturated yellow color, while hue angle values indicated subtle differences in color tone among regions. When considered together, L^* , chroma, and hue angle values suggest that durian pulp from Uttaradit exhibits a more intense golden-yellow coloration, which is consistent with its higher β -carotene content observed in the present study.

Table 4 Carotenoid content of fully ripe durian cv. Long Lab Lae grown in different areas of Thailand (Uttaradit Province; UT, lower Northern region; LN, and Eastern region; ES)

Carotenoid content ($\mu\text{g}/100 \text{ g FW}$)	Planting area			F-test	CV (%)
	Uttaradit Province (UT)	Lower Northern region (LN)	Eastern region (ES)		
β -carotene	86.29 $\pm$ 3.77 ^a	74.16 $\pm$ 0.22 ^b	78.13 $\pm$ 0.18 ^b	*	2.74
α -carotene	17.40 $\pm$ 1.90	16.40 $\pm$ 1.44	14.64 $\pm$ 0.19	NS	8.54
Lutein	24.32 $\pm$ 4.67	28.70 $\pm$ 8.03	27.75 $\pm$ 1.14	NS	20.08
Zeaxanthin	ND	ND	ND	-	-
β -cryptoxanthin	ND	ND	ND	-	-
Lycopene	ND	ND	ND	-	-

Different letters within rows indicate significant difference based on Least Significant Difference Test, $p \leq 0.05$.

NS and * mean non-significant or significant at $p \leq 0.05$, respectively

ND, not detected

Total phenolic content and antioxidant activity

The study found no significant difference in total phenolic content among durians cultivated in three locations, with values ranging from 37.72 $\pm$ 3.62 to 38.92 $\pm$ 6.06 mg GAE/g FW. Furthermore, the results revealed that the pulp of durian grown in various places showed similar trends in antioxidant activity, as measured by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay and

the ferric reducing antioxidant power (FRAP) assay (Table 5). The antioxidant activities ranged from 22.94 $\pm$ 1.67 to 24.00 $\pm$ 4.49 $\mu\text{mol TE/g FW}$ for the DPPH assay and from 13.43 $\pm$ 0.66 to 14.37 $\pm$ 1.59 $\mu\text{mol TE/g FW}$ for the FRAP assay. Phenolic compounds are considered secondary metabolites in plants that include a wide range of chemical compounds. The metabolites with several structures and activities can be classified into two

groups according to water solubility: a water-soluble type (phenolic acids, phenylpropanoids, flavonoids, and quinones) and a water-insoluble type (condensed tannins, lignin, and cell-wall-bound hydroxycinnamic acids) (Rispa *et al.*, 2005). Durian is a fruit that is known to be high in phenolics, flavonoids, and carotenoids. The

amount and proportion of each type of compound in durian vary depending on its origin, agro-climatic conditions, and genetic diversity, making durian an important fruit in terms of composition and antioxidant properties (Arancibia-Avila *et al.*, 2008; Leontowicz *et al.*, 2008; Toledo *et al.*, 2008).

Table 5 Phenolic content and antioxidant activity of fully ripe durian cv. Long Lab Lae grown in different areas of Thailand (Uttaradit Province; UT, lower Northern region; LN, and Eastern region; ES)

Phenolic content and Antioxidant activity	Planting area			F-test	CV (%)
	Uttaradit Province(UT)	Lower Northern region (LN)	Eastern region (ES)		
Total phenolic content (mg GAE/g FW)	38.92±6.06	37.72±3.62	38.33±1.68	NS	10.93
Antioxidant activity					
- DPPH ^{ns} (μmol TE/g FW)	24.00±4.49	23.77±2.01	22.94±1.67	NS	12.73
- FRAP ^{ns} (μmolTE/g FW)	13.43±0.66	14.37±1.59	14.08±0.44	NS	7.35

Different letters within rows indicate significant difference based on Least Significant Difference Test, $p \leq 0.05$.

NS and * mean non-significant or significant at $p \leq 0.05$, respectively

Conclusion

This study investigated the nutritional value, mineral content, fatty acid composition, carotenoid content, phenolic content, and antioxidant activity of fully ripe durian cv. Long Lab Lae cultivated in Uttaradit Province (UT), the lower northern region (LN), and the eastern region (ES). The results showed that the growing region influenced the nutritional composition and mineral levels of the fruit. Slight variations were observed in fatty acid composition and carotenoid content, whereas no significant differences were found in phenolic content and antioxidant activity among regions. These compositional characteristics may be

associated with the distinctive quality attributes described in the geographical indication specification of Long Lab Lae durian from Uttaradit, particularly its dry and fine-textured pulp with a rich sweet and creamy flavor. The lower moisture content may be associated with a drier pulp texture, while higher sugar levels may enhance sweetness perception. In addition, the higher oleic acid and monounsaturated fatty acid contents may contribute to a fatty mouthfeel. Collectively, the results highlight the potential influence of regional growing conditions on the physicochemical properties and eating quality of Long Lab Lae durian and may explain the distinctive quality attributes of fruits cultivated in Uttaradit.

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References

- AOAC. 2005. **Official Methods of Analysis**. 18th ed. Washington DC: Association of Official Analytical Chemists. 1200 p.
- AOAC. 2016. **Official Methods of Analysis**, 20th ed. Gaithersburg, MD: Association of Official Analytical Chemists. 1400 p.
- Arancibia-Avila, P., F. Toledo, Y. Park, S. Jung, S. Kang, B.G. Heo, S. Lee, M. Sajewicz, T. Kowalska and S. Gorinstein. 2008. Antioxidant properties of durian fruit as influenced by ripening. **LWT-Food Science and Technology** 41: 2118–2125. <https://doi.org/10.1016/j.lwt.2007.12.001>.
- Arsa, S., A. Wipatanawin, R. Suwapanich, O. Makkerdchoo, N. Chatsuwan, P. Kaewthong, P. Pinsirodom, R. Taprap, R. Haruenkit, S. Poovarodom, M. Lubinska-Szczygeł, E. Katrich and S. Gorinstein. 2021. Properties of different varieties of durian. **Applied Sciences** 11: 5653. <https://doi.org/10.3390/app11125653>
- Ascharyaphotha, W., C. Wongs-Aree, K. Bodhipadma and S. Noichinda. 2021. Fruit volatile fingerprints characterized among four commercial cultivars of Thai durian (*Durio zibethinus*). **Journal of Food Quality** 2021: 1–10. <https://doi.org/10.1155/2021/1383927>
- Aziz, N.A.A. and A.M.M. Jalil. 2019. Bioactive compounds, nutritional value, and potential health benefits of indigenous durian (*Durio zibethinus* Murr.): a review. **Foods** 8(3): 1–18.
- Benzie, I.F.F. and J.J. Strain. 1996. The ferric reducing ability of plasma (FRAP) as a measure of “antioxidant power”: the FRAP assay. **Analytical Biochemistry** 239(1): 70–76. <https://doi.org/10.1006/abio.1996.0292>
- Cassago, A.L.L., M.M. Artêncio, J.M.E. Giralddi and F.B. Costa. 2021. Metabolomics as a marketing tool for geographical indication products: a literature review. **European Food Research and Technology** 247: 2143–2159. <https://doi.org/10.1007/s00217-021-03782-2>
- Charoenkiatkul, S., P. Thiyajai and K. Judprasong. 2016. Nutrients and bioactive compounds in popular and indigenous durian (*Durio zibethinus* Murr.). **Food Chemistry** 193: 181–186. <https://doi.org/10.1016/j.foodchem.2015.02.107>

- Debbarma, N., S. Manivannan, V.R. Muddarsu, P. Umadevi and S. Upadhyay. 2021. Ionome signatures discriminates the geographical origin of jackfruits (*Artocarpus heterophyllus* Lam.). **Food Chemistry** 339: 127896. <https://doi.org/10.1016/j.foodchem.2020.127896>
- Department of Intellectual Property, Ministry of Commerce. 2019. **Thai Geographical Indication (GI)**. Bangkok: ONPA Co., Ltd. 100 p. [in Thai].
- Devalaraja, S., S. Jain and H. Yadav. 2011. Exotic fruits as therapeutic complements for diabetes, obesity and metabolic syndrome. **Food Research International** 44(7): 1856–1865. <https://doi.org/10.1016/j.foodres.2011.04.008>.
- Dichi, D.B. 2018. Review on factors affecting postharvest quality of fruits. **Journal of Plant Science Research** 5(2): 180.
- FAO. 2003. Food Energy: Methods of Analysis and Conversion Factors. pp. 1–84. *In* **FAO Food and Nutrition Paper 77**. Rome: Food and Agriculture Organization of the United Nations.
- Gorinstein, S., S. Poovarodom, H. Leontowicz, M. Leontowicz, J. Namiesnik, S. Vearasilp, R. Haruenkit, P. Ruamsuke, E. Katrich and Z. Tashma. 2011. Antioxidant properties and bioactive constituents of some rare exotic Thai fruits and comparison with conventional fruits: *In Vitro* and *In Vivo* studies. **Food Research International** 44(7): 2222–2232. <https://doi.org/10.1016/j.foodres.2010.10.009>
- Jerapat, S. and J. Siriphanich. 2008. Effect of irrigation on dry matter of durian pulp cv. Monthong. **Acta Horticulturae** 768: 251–255. <https://doi.org/10.17660/ActaHortic.2008.768.31>
- Ketsa, S., A. Wisutiamonkul, Y. Palapol and R.E. Paull. 2020. The Durian: Botany, Horticulture, and Utilization. pp. 125–211. *In* Warrington, I. (ed.). **Horticultural Reviews**. Hoboken, NJ: John Wiley and Sons, Inc.
- Kitprasong, P., K. Khaowmee, J. Poonpakdee and J. Onthong. 2021. Soil magnesium: status and ratios on potassium and calcium in economic crop planted soils of southern Thailand. **Thai Science and Technology Journal** 29(3): 437–450.

- Kongkachuichai, R., R. Charoensiri and P. Sungpuag. 2010. Carotenoid, flavonoid profiles and dietary fiber contents of fruits commonly consumed in Thailand. **International Journal of Food Sciences and Nutrition** 61: 536–548. <https://doi.org/10.3109/09637481003677308>
- Land Development Department. n.d. **Din online: soil and land use information service**. Bangkok: Ministry of Agriculture and Cooperatives, Thailand. Retrieved from <https://dinonline.ldd.go.th> [in Thai]
- Leontowicz, H., M. Leontowicz, R. Haruenkit, S. Poovarodom, Z. Jastrzebski, J. Drzewiecki, A.L.M. Ayala, I. Jesion, S. Trakhtenberg and S. Gorinstein. 2008. Durian (*Durio zibethinus* Murr.) cultivars as nutritional supplementation to rat's diets. **Food and Chemical Toxicology** 46: 581–589. <https://doi.org/10.1016/j.fct.2007.08.042>
- Lu, J., H. Zhao, J. Chen, W. Fan, J. Dong, W. Kong, J. Sun, Y. Cao and G. Cai. 2007. Evaluation of phenolic compounds and antioxidant activity during malting. **Journal of Agricultural and Food Chemistry** 55: 10994–11001. <https://doi.org/10.1021/jf0722710>
- Mattes, R.D. 2009. Is there a fatty acid taste? **Annual Review of Nutrition** 29: 305–327.
- Moreno, M.I.N., M.I. Isla, A.R. Sampietro and M.A. Vattuone. 2002. Comparison of free radical scavenging activity of propolis from several regions of Argentina. **Journal of Ethnopharmacology** 71(1–2): 109–114. [https://doi.org/10.1016/S0378-8741\(99\)00189-0](https://doi.org/10.1016/S0378-8741(99)00189-0)
- Namitha, K.K. and P.S. Negi. 2010. Chemistry and biotechnology of carotenoids. **Critical Reviews in Food Science and Nutrition** 50(8): 728–760. <https://doi.org/10.1080/10408398.2010.499811>
- Poovarodom, S. and N. Phanchindawan. 2006. Effects of chloride and sulfate in various N and K fertilizers on soil chemical properties and nutrient concentrations in durian leaf and fruit. **Acta Horticulturae** 721: 191–197. <https://doi.org/10.17660/ActaHortic.2006.721.25>
- Rispail, N., P. Morris and K. Webb. 2005. Phenolic Compounds: Extraction and Analysis. pp. 349–354. In Márquez, A.J. (ed.). **Lotus japonicus Handbook**. Berlin: Springer.
- Somniyam, V., P. Seehanam and D. Naksavi. 2024. Physical characteristics of durian fruit cv. Long Lab-Lae produced in different regions. **Kaen Kaset Journal** 52(5): 964–976. [in Thai]

- Somsri, S. 2018. **Durian in Thailand**. Bangkok: Asia-Pacific Association of Agricultural Research Institutions (APAARI). 86 p.
- Speek, A.J., J. Schrijver and W.H.P. Schreurs. 1986. Vitamin A composition of Indonesian foods: determination of carotene and retinol by high-performance liquid chromatography. **Food Chemistry** 19(1): 65–74.
- Stokes, J.R., M.W. Boehm and S.K. Baier. 2013. Oral processing, texture and mouthfeel: from food structure to sensory perception. **Current Opinion in Food Science** 3: 43–49.
- Thiyajai, P., S. Charoenkiatkul, K. Kulpradit, S. Swangpol, P. Sridonpai and K. Judprasong. 2020. Nutritional composition of indigenous durian varieties. **Malaysian Journal of Nutrition** 26(1): 93–99.
<https://doi.org/10.31246/MJN-2019-0083>
- Thokar, N., D. Kattel and S. Subedi. 2022. Effect of pre-harvest factors on postharvest quality of horticultural products. **Food and Agriculture Economics Review** 2(2): 92–95.
<http://doi.org/10.26480/faer.02.2022.92.95>
- Toledo, F., P. Arancibia-Avila, Y.S. Park, S.T. Jung, S.G. Kang, B.G. Heo, J. Drzewiecki, Z. Zachwieja, P. Zagrodzki, P. Pasko and S. Gorinstein. 2008. Screening of the antioxidant and nutritional properties, phenolic contents and proteins of five durian cultivars. **International Journal of Food Sciences and Nutrition** 59(5): 415–427.
<https://doi.org/10.1080/09637480701603082>
- Wisutiamonkul, A., S. Promdang, S. Ketsa and W.G. van Doorn. 2015. Carotenoids in durian fruit pulp during growth and postharvest ripening. **Food Chemistry** 180: 301–305.
<https://doi.org/10.1016/j.foodchem.2015.01.129>