Sains Malaysiana 53(5)(2024): 1105-1118
http://doi.org/10.17576/jsm-2024-5305-11

Investigating Potential Sources of Sore Throat: Physico-Chemical Attributes and Microbial Contamination in Rambutan from Fresh Harvests and Retail Stores

(Mengkaji Punca Potensi Sakit Tekak: Sifat Fiziko-Kimia dan Pencemaran Mikrob dalam Rambutan daripada Penuaian Segar dan Kedai Runcit)

Iliya Zakirah Izhar[1], Saiful Irwan Zubairi[1,*], Zainun Nurzahim[1], Harisun Yaakob[2] & Zalifah Mohd Kasim[1]

[1]*Department of Food Sciences, Faculty of Science & Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia*
[2]*Institute of Bioproduct Development (IBD), Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia*

Received: 9 December 2023/Accepted: 25 March 2024

ABSTRACT

Rambutan (*Nephelium lappaceum*), a tropical fruit cherished for its succulent flesh and vibrant appearance, is cultivated extensively across various regions worldwide. However, despite its popularity, the fruit faces challenges related to particulate contamination during the harvesting process. Particulate matter contamination refers to the presence of solid or liquid particles suspended in the air or adhered to the fruit's surface, posing potential risks to both consumer health and fruit quality. Hence, this study aims to identify the factors in rambutan that could cause sore throats by analysing its physicochemical properties and conducting a microbiological study. For this study, two samples of rambutan fruit which are rambutan sold in stores (RS) and rambutan freshly harvested from the tree (RT) were collected and analysed for their external peel, internal peel, and pulp parts (n = 3). The assessment included the weight of visible fine dirt, pH value, oil content, surface morphology and total coliform (TPC). The results showed that the weight of visible fine dirt on RT external peel (93.50 ± 5.00 mg) and the pH value of its external peel and pulp (4.17 ± 0.00 - 5.17 ± 0.00) were significantly higher and more acidic (p<0.05) than those of RS. However, there were insignificant differences (p>0.05) in oil content (0.36 ± 0.7 - 0.38 ± 0.8%) between the external peels of the rambutan samples. Additionally, the surface morphology and image analysis of RS showed more foreign particles, represented as black or white dots on its internal peel and pulp, compared to RT, which was suspected to be yeast. Moreover, the total coliform count for both samples was significantly different (p<0.05) in their external peel and pulp, but it was still within the safe eating limit. The study concluded that environmental pollution and contamination during rambutan handling could cause sore throat.

Keywords: Contamination; microbes; physicochemical properties; Rambutan particulates: sore throat

ABSTRAK

Rambutan (*Nephelium lappaceum*) adalah buah tropika yang digemari kerana isinya yang lembut dan tampaknya yang menarik, ditanam secara meluas di pelbagai kawasan di seluruh dunia. Walau bagaimanapun, buah ini menghadapi cabaran berkaitan dengan pencemaran partikulat semasa proses penuaian. Pencemaran bahan partikulat merujuk kepada kehadiran zarah pepejal atau cecair yang terampai di udara atau melekat pada permukaan buah yang membawa risiko kepada kesihatan pengguna dan kualiti buah. Oleh yang demikian, kajian ini bertujuan untuk mengenal pasti faktor pada buah rambutan yang dapat menyebabkan sakit tekak melalui analisis sifat fizikokimia dan mikrobiologi. Dalam kajian ini, dua sampel buah, iaitu rambutan yang dijual di kedai (RS) dan rambutan yang baru dituai daripada pokok (RT) dikumpul dan dianalisis untuk bahagian kulit luar, kulit dalam dan isi buah (n = 3). Analisis yang dijalankan merangkumi berat kotoran halus terlihat, nilai pH, kandungan minyak, morfologi permukaan dan jumlah koliform (TPC). Hasil kajian menunjukkan bahawa berat kotoran halus terlihat pada kulit luar (93.50 ± 5.00 mg); dan nilai pH pada kulit luar dan isi sampel RT (4.17 ± 0.00 - 5.17 ± 0.00) lebih signifikan tinggi dan berasid (p<0.05) berbanding

RS. Namun, perbezaan dari segi kandungan minyak pada kulit luarnya (0.36 ± 0.7 - 0.38 ± 0.8%) tidak signifikan (p>0.05). Seterusnya, imej dan analisis morfologi pada kulit dalam dan isi RS menunjukkan lebih banyak zarah asing berbanding RT yang merujuk kepada imej titik hitam dan putih yang disebabkan oleh pertumbuhan yis. Kemudian, jumlah koliform pada kulit luar dan isi kedua-dua sampel juga signifikan berbeza (p<0.05), namun masih dalam had yang selamat dimakan. Kajian ini menyimpulkan bahawa pencemaran persekitaran dan kontaminasi semasa pengendalian rambutan boleh menyebabkan sakit tekak.
Kata kunci: Ciri fizikokimia; kontaminasi; mikrob; partikulat Rambutan; sakit tekak

Introduction

Rambutan (*Nephelium lappaceum*) is a tropical fruit that belongs to Sapindaceae botanical family, along with other tropical fruits like lychee, cat's eye, *pulasan*, Spanish lime, and akee. However, it is in a different genus (Jahurul et al. 2020). It originally comes from the Malaysia-Indonesia region and has been introduced to various countries in Asia, Australia, Africa, and tropical America (Mahmood et al. 2018). The word 'rambutan' refers to the fruit's hairs and is derived from a Malay word meaning 'hair'. Most rambutan fruits are red, although some are yellow. Peeling the rambutan's peel will reveal the sweet, gelatinous white pulp that clings to the seeds (Li, Zeng & Shao 2018; Prakash 2021). The pulp is delicious, soft, juicy, firm, and rich in vitamin C (Chai et al. 2018a) (Figure 1). *Rambutan Anak Sekolah* or known as Clone R191 is one of the most well-known and delicious rambutan clones, which was first cultivated in Thailand. It has a red external peel and an oval shape with a medium size of 40 g per fruit. The rambutan is composed of 26.4% total weight, 14.2% peel, 12.1% pulp, 2.59% seed and 1.56% embryo on a dry basis (Afzaal et al. 2022).

Based on Chai et al. (2018a), rambutan has a balanced sweet and sour taste due to its high sugar content and acidity from organic acids. However, overeating rambutan can lead to sore throats. A sore throat is a discomfort in the throat that can cause pain, irritation, or inflammation. The most common cause of a sore throat is a viral infection, such as the flu (pharyngitis) or a virus-induced sore throat from Streptococcal infections (Coutinho et al. 2020). Sore throats caused by bacteria require treatment with antibiotics to prevent complications. On the other hand, less common types of sore throats may require more complex treatments (Krüger et al. 2021).

Fresh fruits like rambutans, which are typically consumed raw, have the potential to be contaminated with bacteria that can compromise food safety. Improper handling of fresh food products can lead to degradation, making them vulnerable to the growth of microorganisms and other spoilage agents (Karanth et al. 2023; Tavares et al. 2021; Zubairi et al. 2022). Fruits could be contaminated with microbes through contact with dirt, dust, and water. Additionally, rambutan seeds contain alkaloid elements and are believed to be bitter and toxic. It is also suspected that the fruit's peel contains toxic substances such as tannins and saponins (Chai et al. 2018b).

Studies have shown that individuals with pollen allergies or oral allergy syndrome may experience allergic reactions to specific fruits, such as rambutan and its relative, the lychee (Lee, Ford & Randall 2019). These fruits contain cross-reacting antigens that can lead to allergic reactions including swollen eyes, itchy eyelids and a swollen throat. However, the prevalence of rambutan allergies remains unknown as most research has focused on other allergens like latex, medications and contrast agents (Banoub et al. 2023; Blumenthal et al. 2019). So far, the potential cause of throat inflammation after consuming rambutan from either a tree or a store has not been investigated. Therefore, this study aims to investigate the physico-chemical attributes and microbial contamination of fresh harvests and retail stores rambutan in order to determine possible causes of throat irritation. Additionally, educating individuals on how to consume rambutan properly may help reduce and even eliminate the risk of developing a sore throat.

Materials and Methods

Chemicals

Analytical-grade materials were used for all the chemicals and solvents used in this experiment. For the extraction of oil from rambutan's peel, a solvent 95% pure n-Hexane (Merck, Germany) was used.

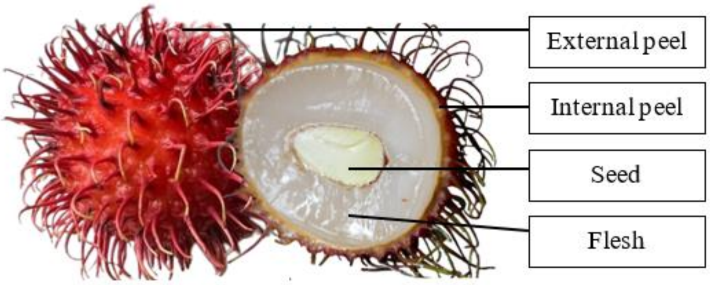


FIGURE 1. Morphological structure of rambutan (*Nephelium lappaceum*)

MATERIALS

A fully ripe fruit (100% maturity, 120 ± 2 days after flowering) of the red colour Rambutan *Nephelium lappaceum* (*Anak Sekolah*/Clone R191) was divided into two categories: (a) rambutan sold in stores (RS) and (b) rambutan freshly harvested from the tree (RT). RS samples were obtained from a market in Ipoh, Perak while RT samples were obtained from Kampung Parit, Perak. The fruits used in this study were uniform in size and colour; and free of defects. For both categories of rambutan, ripe fruits weighing 40 ± 5 g with a diameter of 40 ± 5 mm and length of 50 ± 5 mm, were selected and collected in a clean and dry container. The samples were then stored in a chiller at 4 °C until use. The external peel, internal peel and pulp were subsequently peeled and evaluated separately.

PHYSICOCHEMICAL ANALYSIS

WEIGHT OF VISIBLE FINE DIRT

A total of 100 g of rambutan samples were collected for analysis. These samples were obtained from both the store and freshly harvested from the tree. To remove any impurities, the samples were shaken for 1 min using a plastic sieve. The weight of the fine dirt (mg) was determined by collecting all the impurities and then weighed using an analytical balance brand SECURA 224-1S Sartorius, Germany. However, the dry end of the rambutan's hair is not considered dirt because it is a part of the fruit itself. The dirt was then dried in a Mammert oven UFB-500, Germany at 100 °C for 12 h and weighed. The analysis was performed in triplicate (n = 3).

pH ANALYSIS

The pH value was measured using AOAC (1990), Method no. 981.12 with a Professional Benchtop pH Meter (BP3001) at a room temperature of 27 ± 0.3 °C. Calibration was completed by measuring buffer solutions at pH 7 (neutral), pH 4 (acidic) and pH 9 (alkaline) prior to testing the sample. A weight of 1 g of either rambutan external peel or pulp was weighed using SECURA 224-1S Sartorius, Germany. The sample was then ground using a dry warring blender into a paste consistency with the assistance of 10 mL distilled water. The resulting mixture was then pressed using a muslin cloth to extract the rambutan juice. Approximately, 10 mL of rambutan juice was poured into a 25 mL beaker. The pH probe was placed into the beaker and gently swirled. The pH value was recorded once it stabilized. Three readings were taken for each sample (n = 3).

OIL EXTRACTION

Prior to oil extraction, 50 g of rambutan external peel was weighed and cut into small pieces. It was then dried using a Mammert oven UFB-500, Germany for 6 h ± 10 min at a temperature of 100 ± 2 °C. The rambutan was extracted using a Soxhlet Extractor following the method used by Hegazy and Ibrahium (2012) with some modifications. A total of 10 g of dried rambutan sample was weighed using a SECURA 224-1S Sartorius, Germany analytical balance. The sample was wrapped in filter paper and placed into a Soxhlet thimble. The n-Hexane solution was placed into a Buchi flask and connected to the extractor for 4 h at 65 °C to ensure oil production. The solvent mixture was then evaporated at 70 °C using a rotary evaporator to recover the crude oil and determined its weight (Kasmin et al. 2020). The readings were taken in triplicate (n = 3). The oil production was calculated using the formula:

$$\text{Oil yield (weight \%)} = \frac{\text{Weight of oil}}{\text{Weight of dried sample}} \times 100\%$$

SCANNING ELECTRON MICROSCOPY (SEM) ANALYSIS

Samples were examined using a Hitachi TM-1000 Scanning Electron Microscope, United States, following the method outlined by Abdul Karim, Hanafi and Zulkifli (2018). The microscope was turned on allowed to warm up for 3 min until the LED light indicator turned green. The rambutan's external peel, internal peel and pulp were then cut into small pieces using a clean knife into 1 µm thickness and placed on a glass slide. Next, the sample was placed on an aluminium stub and coated with a thin layer of gold to ensure clear image resolution and prevent electrostatic charging during microscope examination. The cover chamber was then slowly closed, and the sample was analysed at an accelerating voltage of 15 kV. Analysis was conducted at three different magnifications: 40x, 100x and 250x (Aizad et al. 2021).

MICROBIOLOGICAL ANALYSIS

The microbial analysis was based on study conducted by Ismael et al. (2013). The rambutan external peel, internal peel and pulp were cut into 2 cm × 2 cm pieces for sample preparation. To prepare the nutrient agar, 28 g of Oxoid CM0003 nutrient agar powder was weighed and dissolved in 250 mL of distilled water. The mixture was then boiled with a stirrer for one minute to ensure complete dissolution before being autoclaved at 121 °C for 15 min. The agar solution was then cooled to 50 °C and poured into sterile petri dishes. During microbial analysis, sterile cotton swabs were used to collect samples from rambutan and streaked into the nutrient agar. The petri dish was then incubated at 37 °C for 24 h before observation. Each sample was read twice ($n = 2$).

STATISTICAL ANALYSIS

Minitab version 17 (Minitab Inc., Sydney, Australia) was used to analyse the statistics of a one-way ANOVA. The Fisher test ($p<0.05$) at a 95% confidence level was then used to determine the significant difference in physicochemical and microbial aspects between rambutan from the store (RS) and rambutan freshly harvested from the tree (RT). This approach is used to assess the potential consequences of consuming rambutan on a sore throat.

RESULTS AND DISCUSSION

PHYSICOCHEMICAL PROPERTIES

Table 1 shows the physicochemical properties of rambutans sold in stores (RS) and rambutans freshly harvested from the tree (RT). The rambutan's physicochemical properties observed include the weight of visible fine dirt (mg), pH value, oil content (%) and surface morphology.

WEIGHT OF VISIBLE FINE DIRT (mg)

The weight of visible fine dirt on the external peel of RS and RT samples is shown in Table 1. It was observed that the weight of visible fine dirt on the RT external peel was significantly higher ($p<0.05$) than on the RS external peel. Figure 2 shows the visible fine dirt present on both rambutan's external peel, includes soil, small rocks, dry leaves, dust, and other tiny particles. Some dirt was found in clumps, while others were in individual pieces. The dirt varied in size, shape (such as round, oval and stick), texture (such as hard and soft) and colour (such as black, brownish and grey). The lower weight of dirt observed on RS sample in this study may be due some filtering activity by retailer or the removal of dirt during the fruit's handling process before being displayed in stores. Currently, there is limited review addressing the weight of visible fine dirt on fruit's external peels, making comparison difficult. However, previous research by Elhassaneen et al. (2022) and Vella et al. (2023) claims that fine dirt is commonly found on fruit external peel. Therefore, it is recommended to thoroughly wash the fruits with water to remove any dust, sand, wax or pesticide residue that may be present. Additionally, Torgbo et al. (2022) also conducted a study on pesticide residue on rambutan peels. Most recent studies have focused on the nutritional and bioactive compounds of rambutan peels, thus more research on the presence of dirt on the rambutan external peel is needed (Jantapaso & Mittraparp-arthorn 2022; Venturini et al. 2018).

The dirt found on the rambutan external peel is caused by the fruit being exposed to the dust and soil in the environment. This dirt can get trapped in the hairy structure of the rambutan external peel. In addition, oil contains various particles and microscopic organisms such as bacteria, fungi, mites, nematodes, yeasts, beetles, worms, ants, minerals, and industrial dust. Thus, soil is often associated with dirt or contamination (Chaurasia, Bharati & Mani 2019; Rahmadi et al. 2020; Saparbekova, Latif & Altekey 2021). Even a tiny speck of dust from soil can significantly affect air quality as it is the second largest source of particulate matter after sea salt (Tian et al. 2021). Dust on the ground can be carried through the air by natural means or through organisms like insects intentionally or unintentionally. Furthermore, dust from soil can contain hazardous substances that are harmful to human health if inhaled, ingested or touched, in addition to the hazards associated with the dust itself (Aguilera et al. 2021; Mama et al. 2020). There is also a possibility that rambutan could be cross contaminated by pollen and food allergens such as nuts or gluten that come into contact with the air, which can be a become a health concern (Luo et al. 2021).

In addition, pollution can also occur due to soil and poor agronomic practices, such as the use of unprocessed or improperly treated animal waste as fertiliser, or the usage of contaminated water drainage systems. Furthermore, fruits may become contaminated during the selection and packing process, as food handlers could potentially carry microbial pathogen carriers (Feroz & Noor 2019). Rambutan that is exposed to the elements, such as airborne dust, insects and other animals may become dirty. Both the air and soil can contribute to the dirt present on the fruit. Therefore, the external peel of the RS contains amount of higher visible fine dirt resulting from contamination from the environment, soil, differences in the handling process and contamination from the store itself. In contrast, the RT has a lower amount of visible fine dirt and is less polluted as the fruit did not come into direct contact with soil and did not undergo handling processes like RS sample.

TABLE 1. Physicochemical properties for rambutan sold in stores (RS) and rambutan freshly harvested from the tree (RT)

Parts	Sample	Physicochemical properties		
		Weight of visible fine dirt (mg)	pH value	Oil content % (w/w)
External peel	RS	80.00 ± 2.80*	4.25 ± 0.00	0.36 ± 0.7
	RT	93.50 ± 5.00	4.17 ± 0.00*	0.38 ± 0.8
Internal peel	RS	NM	NM	NM
	RT	NM	NM	NM
Pulp	RS	NM	5.37 ± 0.00	NM
	RT	NM	5.17 ± 0.00*	NM

*Mean is significantly different ($p<0.05$) between sample ($n = 3$), NM: Not measured

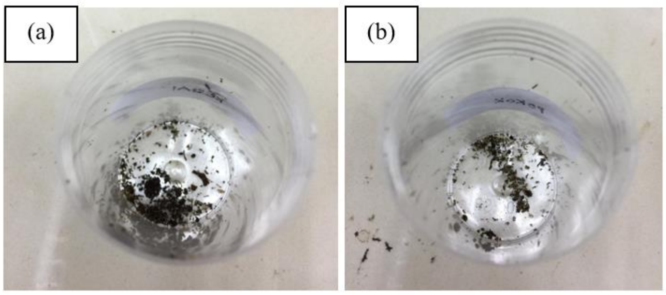


FIGURE 2. Visible dirt on the external peel of a) RS and b) RT

pH VALUE

Table 1 shows the pH values for the external peel and pulp of RS and RT. The result indicate that the pH of the RS external peel was significantly more acidic ($p<0.05$) than RT, ranging from 4.17 to 4.25. These findings were aligned with previous research conducted by Chai et al. (2018a), who reported a pH range of 4.18 to 4.25 for rambutan peel. Lufu, Ambaw and Opara (2020) stated that pH values can be influenced by factors such as rain and ambient humidity. In environments with high dust content, the pH may become more alkaline, reaching a reading of 11. However, this situation is uncommonly and only occurred in heavily polluted areas. Therefore, it is likely that minor fluctuations in the external peel pH of rambutan will occur due to the air and contact in the storage and transportation environment. Additionally, the pH may also be affected by substances present in rambutan peel, such as ellagic acid, corilagin and geranin. The presence of acidic substances tends to shift the pH toward acidity (Hernández et al. 2017; Rosa-Esteban et al. 2023).

In addition, the results also show that RS pulp was significantly more acidic ($p<0.05$) than RT, with a pH value of around 5. The pH value obtained in this study was slightly higher than the values reported by Suriati et al. (2020) and Deng et al. (2023) for Rambutan from Leleng Regency, Bali, Indonesia and rambutan cultivar BY2 respectively, with pH values of around 4.2 and 4.6, respectively. These differences are suspected to be due to deterioration caused by enzymes, microbes or non-enzymatic activities. Meanwhile, Zainol et al. (2020) claims that variations in pH levels are directly associated with the fruits' maturity level. The pulp is the freshest part of the rambutan and can be consumed raw, as juice or in other food products. The pH value of the rambutan pulp was measured for both types of samples to determine whether different locations of rambutans could affect the pH value for each sample and its potential to cause a sore throat. The acidic properties of rambutan pulp are demonstrated by the presence of organic acids such as citric acid, tartaric acid, malic acid, lactic acid, and ascorbic acid in the rambutan's constituent parts (Rakariyatham et al. 2020), which can cause a sore throat when consumed in large amounts. Indeed, the slightly acidic properties of the rambutan's external peel and pulp are important for preventing the growth of microbes and preserving their freshness. Furthermore, the results of this research are in accordance with Subedi (2022), who claims that tropical fruits across various regions consistently have a slightly acidic pH, with values ranging from 3.17 to 5.40.

OIL CONTENT

Prior studies have shown that rambutan seeds have high crude fat content and are capable of producing oil similar to other vegetable oils. The bioactive components and nutritional qualities of rambutan seed oil make it a promising functional food product, with a high production rate of 38.9% (Hernández et al. 2019). To determine whether rambutan peel can also produce oil, the oil was extracted from rambutan peel for this trial. This is because there is a lack of research on rambutan peel oil extraction. The amount of oil generated by the external peel of both RS and RT samples is calculated to see if the production of oil is impacted by contact with soil and other surfaces. It has been shown that the aqueous extract of rambutan peel contains bioactive substances with antioxidant (Mohd Aris et al. 2023) and antibacterial qualities, but it also shows cytotoxicity (Jantapaso & Mittraparp-arthorn 2022). It is significant to note that rambutan essential oil is safe for topical application; however, repeated usage may cause sensitization (Abu Bakar et al. 2019). In this study, oil extraction is only conducted on the external peel due to time constraints and budget limitations. Further studies on the rambutan internal peel and pulp need to be carried out in the future for a better understanding.

Table 1 demonstrate that the rambutan external peel had a low oil content ranging from 0.36% to 0.38% (w/w), which did not contribute to the development of sore throats. There were insignificant differences ($p>0.05$) in oil content between the RS and RT external peel, indicating that the process from the farm to the store had no impact on the oil yield of the rambutan's external peel. Mele and Giuffré (2018) suggested that environmental, agronomic, and genetic factors such as climate, tree age, and species could affect the oil content of fruits. This finding was supported by Edyson et al. (2022) and Zaouay et al. (2020) who found that fruit maturity, variety, handling, and pest infestations significantly influenced the fruit's oil content. Therefore, it was initially expected that the results would be insignificant since both RT and RS belong to the same genetic type, which is red colour Rambutan *Nephelium lappaceum* (*Anak Sekolah*/ Clone R191). Additionally, the rambutan used in the study were similar in size, maturity and environmental factors, with only slight differences between the RS obtained from a market in Ipoh, Perak and the RT obtained from Kampung Parit, Perak. It was also assumed that the farmers and retailers in the Perak area followed good fruit handling practices. However, the oil yield obtained from the rambutan's external peel in this study was slightly higher than the 0.23% reported by Mahmood et al. (2018). This suggest that the rambutan's external peel used in this study may have better quality than the rambutan sample used in previous research, which requires further exploration.

SURFACE MORPHOLOGY MICROENVIRONMENT

The scanning Electron Microscope (SEM) was used in the research to identify the type of foreign particles and sample morphology that are invisible to the human eye. The surface morphology of rambutan sold in stores and rambutan freshly harvested from the tree is shown in Table 2(a) and Table 2(b), respectively.

Table 2(a) shows the presence of white foreign objects on the RS external peel of the rambutan fruit in the store. It was observed that there are higher white foreign objects on the rambutan's internal peel and pulp. Additionally, higher concentrations of these white foreign particle were observed on the internal peel and pulp of the rambutan. This foreign particle has an irregular shape and non-uniform size and are dispersed across the entire surface area. Some of the particles are clustered together, while others are found individually. According to Alegbeleye et al. (2022) fruits can become contaminated with spoilage germs due to handling, processing, and farming practices. The white foreign objects on the RS external peel, internal peel and pulp can be more clearly seen at magnifications of 100x and 250x. Based on the research conducted by Olakunle, Joy and Irene (2019), these white foreign objects could be fungi, dirt or unknown particles from the environment. The RS may have been displayed in the stores for several days under a moist environment, which could facilitate the growth of bacteria and fungi. Furthermore, a black foreign particle was also detected on the RS pulp surface, which was suspected to be a small stone or rambutan seed husk. The hard texture of stones and rambutan seed husks can irritate the throat during consumption and cause a sore throat (Surboyo, Ernawati & Parmadiati 2019). Most of the foreign particles appear in various irregular forms and sizes and scattered unevenly on the surface of rambutan.

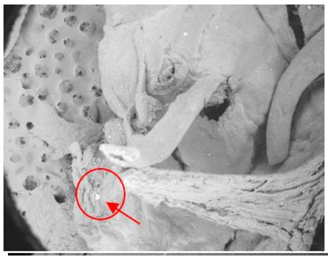
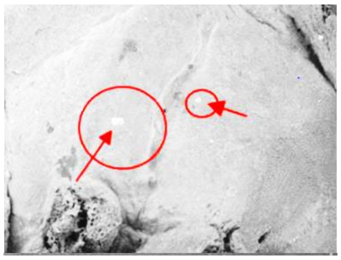
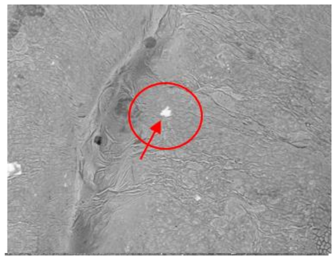
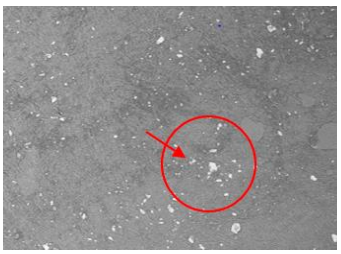
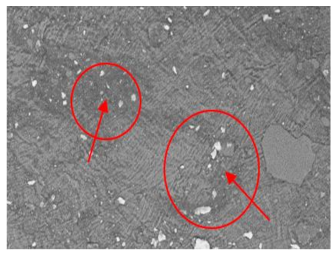
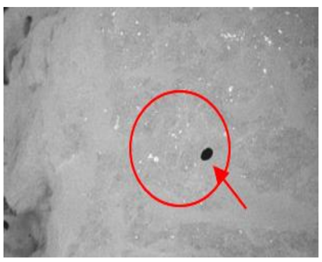
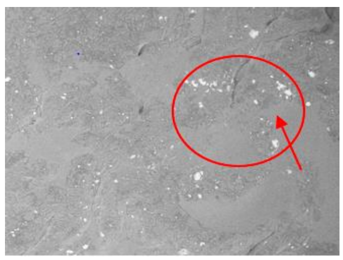
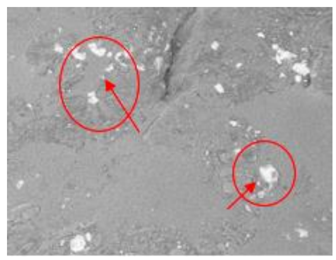
Meanwhile, Table 2(b) indicates that the external peel of the rambutan freshly harvested from the tree has a few white foreign items on it, which are suspected to be yeast or dirt. The dirt present on RT's external peel, internal peel and pulp is also aptly demonstrated at magnitudes of 100x and 250x. RT was exposed to the open environment with different weather conditions, which affected the impurities present on it. Meanwhile, the image for its internal peel verifies that there are very fine visible foreign particles present (red circle). It was observed that the foreign particle scattered unevenly on RT's external and internal peel. However, no impurities were observed on the RT pulp. Azrina, Mohamad Firdaus and Mohd Azmier (2022) claim that the firm texture of rambutan peel indicates that it is not porous in its original state. These results were as expected since the internal peel and pulp were protected by its external peel from impurities. Despite that, the dirt found in the rambutan's external peel in this study was visually higher than reported by Azrina, Mohamad Firdaus and Mohd Azmier (2022), possibly due to the rambutan being observed directly without undergoing any cleaning process.

The particle area represents the distribution of particles on the fruit surface. Referring to Table 3, the particles present on most parts of the RS and RT areas showed maximum readings, as indicating that the particle area exceeded the machine's detection limit. These particles were too large to be detected, which represents large impurities from the environment such as soil, clay, and dust (Ural 2021). Meanwhile, only the particles on the RT pulp within the device detection limit at a small area are suspected to be fungus. According to Serrato et al. (2019), tropical fruit trees like rambutan and longan, are prone to dieback, fruit rots, and stem cankers caused by fungi from the *Botryosphaeriaceae* family.

In terms of particle composition, it has been observed that the particle composition of RS pulp is higher than at of its external peel and internal peel. These particles likely represent contamination from the environment or contact with RS external peel, such as soil and dust from the ground or ventilation systems (Ural 2021). This is likely to occur because some materials accidentally or intentionally originate from external sources. There are instances when RS is accidentally contaminated by materials used during the packing process, such as metal, glass, iron, paint, or processing tools (Simonetti et al. 2021). This contamination can occur at any stage of the supply chain, including raw material harvesting, transportation, and storage (Parajuli, Thoma & Matlock 2019). The contaminated RS external peel, environment and hygiene level during the handling process can cross-contaminate with its internal peel and pulp, thus increasing the particle composition value (Julien et al. 2019).

Meanwhile, for RT, there are more particles found on the external peel than on the internal pulp. This indicates that only a few particles are present on both the RT external peel and internal peel. This is likely because the RT external peel is neither purposely nor accidentally contaminated with compounds from airborne dust, which could also come into contact with the RT internal peel and pulp. However, there is not much contamination on the RT internal peel. Based on Phuong et al. (2020) findings, rambutan peel extract has shown strong antimicrobial activity against various bacteria, thus, only least foreign particles were detected on its pulp. Overall, the RT fruit is cleaner than the RS fruit, as the rambutan is picked from the tree and not in contact with the ground.

TABLE 2. a) The surface morphology of external peel, internal peel, and pulp for rambutan sold in store at magnificent power of 40x, 100x and 250x

Rambutan Parts	Surface morphology of rambutan sold in stores (RS)		
	40x	100x	250x
External peel			
Internal peel			
Pulp			

MICROBIAL CONTAMINATION

TOTAL COLIFORM (CFU) PROFILE

Total coliforms mainly come from human and animal waste. This analysis is an important measure of hygiene indicators because they are naturally found in fresh fruits and vegetables (Nnenna & Gift 2020). As a result of using organic fertilisers and contaminated soil, fresh fruits can become contaminated with bacteria that can cause foodborne outbreaks. These bacteria include *Escherichia coli, Listeria monocytogenes* and *Salmonella* spp. (Dubreuil 2020; He et al. 2021; Zhang et al. 2020). Microbial contamination can occur at any stage of food chain, from the farm to the fork and can have potentially fatal consequences. As a result, people are now concerned about the fruit's quality and safety. Table 4 shows the total coliform count for both rambutan sold in stores and rambutan freshly harvested from the tree, including the external peel, internal peel and pulp. The number of coliforms increases the possibility of pathogenic microorganisms.

TABLE 2. b) The surface morphology of external peel, internal peel, and pulp for rambutan freshly harvested from the tree at magnificent power of 40x, 100x and 250x

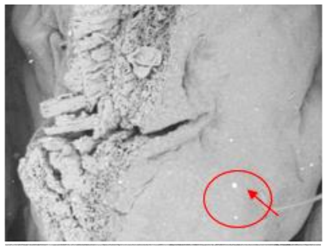
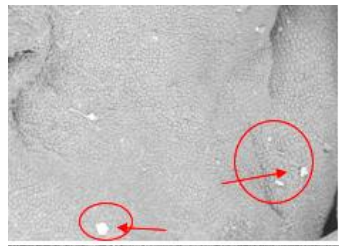
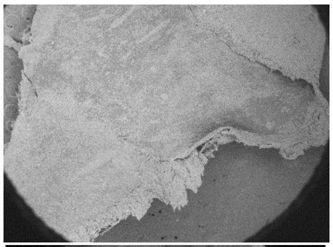
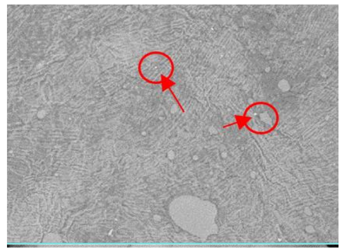
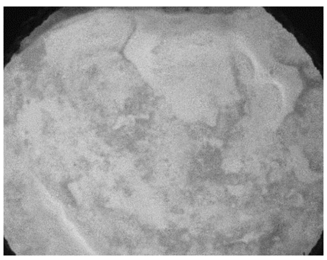
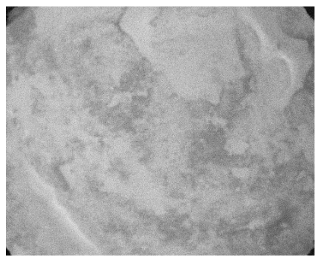
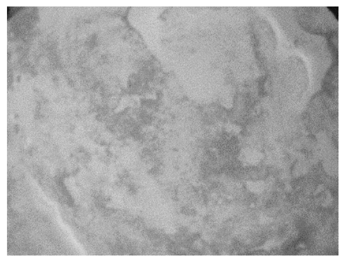
Rambutan Parts	Surface morphology of rambutan freshly harvested from the tree (RT)		
	40x	100x	250x
External peel			
Internal peel			
Pulp			

TABLE 3. Particle area and particle composition (%) of rambutan sold in store and rambutan freshly harvested from the tree on its external peel, internal peel and pulp parts

Parts	Sample	Particle area (%)	Particle composition (%)
External peel	RS	55.694*	12.240
	RT	55.694*	12.190
Internal peel	RS	55.694*	13.540
	RT	55.694*	11.950
Pulp	RS	55.694*	14.00
	RT	14.47	0.006

*Machine detection limit (MeeSoft™ Image Analyzer 1.43: https://meesoft.com/Analyzer/)

Based on Table 4, a significant difference ($p<0.05$) in total coliform was observed between the external peel and pulp of RS and RT. The total coliform count on the RS external peel was significantly higher ($p<0.05$) than RT. These results were expected considering that RS was exposed to dirt from its surroundings including orchards, roadside, personnel handling, and customers, while in the store. Fruits and vegetables surfaces are often contaminated with dirt during handling, which is known to harbour various germs (Julien et al. 2019). Besides, the study by González et al. (2023), Machado et al. (2019), and Yu et al. (2021) have shown that the surface of fruits and vegetables frequently come into contact with soil, trace elements, heavy metals, insects and microbes, leading to natural contamination. Typically, when fresh food reaches the packaging station, it can harbour a population of 10^4 to 10^6 microorganisms/g, including *Enterobacter, Klebsiella* spp., *Escherichia coli* and coliform bacteria such as faecal coliform (Fairuz, Nor Azlin & Farah Ayuni 2021; Zubairi et al. 2021). However, there was no significant difference ($p>0.05$) in the total coliform count in the internal peel between RS and RT. This shows that both the RS and RT internal peel were less contaminated by dirt as they were protected by the external peel.

In addition, the contamination of rambutan pulp in this study may have occurred due to the contamination of the external peel of the rambutan during microbiological analysis. It is possible that the cotton swab used was contaminated or not properly sanitised. Furthermore, the result shows that both RS and RT have high standard deviation values. This is because the analysis was only performed twice and the quantity of colonies on the two agar plates varied. Therefore, it is recommended to minimise contamination during microbial analysis and perform higher sample dilution before plating the sample onto the selected agar media. Further extensive studies are needed to revalidate the microbial profile data in the future.

Based on European Commission Regulation 2073/2005 on microbiological criteria in foodstuff, the maximum tolerance for coliform in fresh-cut fruit is 10^2 CFU/g. Meanwhile, the International Commission on Microbiological Specifications for Foods, ICMSF (1986) claims that total coliform count below 10^3 CFU/g are considered acceptable and safe. When following European regulation, all total coliform count, except for RS external peel were below the guidelines. However, all sample total coliform reading was acceptable when following ICMSF (1986) guidelines. Therefore, the hygiene quality of RS and RT used in this research is good and safe to consume. To reduce the risk of sore throats, it is important to highlight the hygiene requirements such as properly washing fruit and hands before eating; and using clean tools like a cutting board and knife. It is advised to eat an adequate amount of rambutan because it contains high levels of glucose, which can adhere to the throat. Bacteria easily breed in high glucose levels area if there is no proper oral and dental care after eating the fruit (Du et al. 2020).

TABLE 4. Total Coliforms (CFU) of Rambutan sold in stores (RS) and Rambutan freshly harvested from the tree (RT)

Parts	Sample	Total Coliform (CFU/g)
External peel	RS	195.0 ± 7.1
	RT	36.0 ± 12.7*
Internal peel	RS	47.0 ± 59.4
	RT	1.5 ± 2.1
Pulp	RS	81.5 ± 12.0
	RT	11.5 ± 10.6*

*The total coliform showed a significant difference ($p<0.05$) between sample ($n = 3$)

Conclusions

In this study, a potential source of sore throat in fresh rambutan harvests and retail stores by examined the physicochemical attributes and microbial contamination aspect to determine the possible causes of throat irritation. Overall, the analysis findings indicate that contamination during rambutan handling could be responsible for sore throat. It was observed that the rambutan freshly harvested from the tree (RT) had a higher weight of visible fine dirt than the rambutan sold in stores (RS). The dirt present on RT parts likely comes from the environment such as dirt, leaves and soil but it did not undergo as many handling procedures as RS. Meanwhile, RS might accumulate small foreign particles in the air (particulates matter (PM): <2.5 µm) during handling, transportation and storing. The surface morphology diagram from the SEM analysis confirms that RS fruit parts contain many foreign particles, particularly on the internal peel and pulp. Besides, both samples have an acidic pH value and a very low oil content in their external peel which suggests a low tendency of causing sore throat. Next, the total coliform unit for both samples pulp is also safe to consume as the reading was within the acceptable limit ($<10^3$). However extra precaution needs to be taken before touching RS extracellular to prevent cross contamination. For that reason, it is recommended to wash the rambutan with clean water and peel it properly before consuming to reduce sore throat risk.

Acknowledgements

We acknowledge the financial assistance from Universiti Kebangsaan Malaysia (UKM) (ST-2023-043) and the access to the laboratory at UKM Bangi's Department of Food Sciences, Faculty of Science and Technology.

References

Abdul Karim, A.F., Hanafi, I. & Zulkifli, M.A. 2018. Effects of kenaf loading and alkaline treatment on properties of kenaf filled natural rubber latex foam. *Sains Malaysiana* 47(9): 2163-2169.

Abu Bakar, N.H., Othman, H.F., Rajab, N.F., Budin, S.B., Shamsuddin, A.F. & Mohamed Nor, N.A. 2019. Primary skin irritation and dermal sensitization assay: *In vivo* evaluation of the essential oil from *Piper sarmentosum* roxb. *Pharmacognosy Magazine* 15: 352-358.

Aizad, S., Zubairi, S.I., Lazim, A. & Yahaya, B.H. 2021. *Centella asiatica* extract potentiates anticancer activity in an improved 3-D PHBV-composite-CMC A549 lung cancer micro-environment scaffold. *Arabian Journal for Science & Engineering* 46: 5313-5325.

Afzaal, M., Saeed, F., Bibi, M., Ejaz, A., Shah, Y.A., Faisal, Z., Ateeq, H., Akram, N., Asghar, A. & Shah, M.A. 2022. Nutritional, pharmaceutical, and functional aspects of rambutan in industrial perspective: An updated review. *Food Science & Nutrition* 11(7): 3675-3685.

Aguilera, A., Bautista, F., Goguitchaichvili, A. & García-Oliva, F. 2021. Health risk of heavy metals in street dust. *Frontiers in Bioscience* 26: 327-345.

Alegbeleye, O., Olumide, A.O., Mariyana, S. & Deyan, S. 2022. Microbial spoilage of vegetables, fruits and cereals. *Applied Food Research* 2(1): 100122.

AOAC Official Methods of Analysis. 1990. AOAC International. *Official Method* 981.12. 15th ed. Arlington. p. 988.

Azrina, A., Mohamad Firdaus, M.Y. & Mohd Azmier, A. 2022. Removal of Bisphenol S from aqueous solution using activated carbon derived from rambutan peel via microwave irradiation technique. *Sains Malaysiana* 51(12): 3967-3980.

Banoub, R., Alalade, E., Bryant, J., Winch, P. & Tobias, A.J. 2023. Allergic reactions to Sugammadex: A case series and review of the literature. *The Journal of Pediatric Pharmacology and Therapeutics* 28(4): 374-379.

Blumenthal, K.G., Wolfson, A.R., Li, Y.Z., Seguin, C.M., Phadke, N.A., Banerji, A. & Mort, E.A. 2019. Allergic reactions captured by voluntary reporting. *Journal of Patient Safety* 17: e1595-e1604.

Chai, K.F., Mohd Adzahan, N., Karim, R., Rukayadi, Y. & Ghazali, H.M. 2018a. Effects of fermentation time and turning intervals on the physicochemical properties of rambutan (*Nephelium lappaceum* L.) fruit sweatings. *Sains Malaysiana* 47(10): 2311-2318.

Chai, K.F., Mohd Adzahan, N., Karim, R., Rukayadi, Y. & Ghazali, H.M. 2018b. Characteristics of fat, and saponin and tannin contents of 11 varieties of rambutan (*Nephelium lappaceum* L.) seed. *International Journal of Food Properties* 21: 1091-1106.

Chaurasia, P.K., Bharati, S.L. & Mani, A. 2019. Significances of fungi in bioremediation of contaminated soil. *New and Future Developments in Microbial Biotechnology and Bioengineering*, edited by Singh, J.S. & Singh, D.P. Elsevier. pp. 281-294.

Coutinho, G., Duerden, M.G., Sessa, A., Caretta, B.S. & Altiner, A. 2020. Worldwide comparison of treatment guidelines for sore throat. *International Journal of Clinical Practice* 75(5): e13879.

Deng, H., Wu, G., Zhang, R., Yin, Q., Xu, B., Zhou, L. & Chen, Z. 2023. Comparative nutritional and metabolic analysis reveal the taste variations during yellow rambutan fruit maturation. *Food Chemistry X* 19(17): 100580.

Du, Q., Fu, M., Zhou, Y., Cao, Y., Guo, T., Zhou, Z., Li, M., Peng, X., Zheng, X., Li, Y., Xu, X., He, J. & Zhou, X. 2020. Sucrose promotes caries progression by disrupting the microecological balance in oral biofilms: an *in vitro* study. *Scientific Reports* 10: 2961.

Dubreuil, J. 2020. Fruit extracts to control pathogenic *Escherichia coli*: A sweet solution. *Heliyon* 6: e03410.

Edyson, E., Murgianto, F., Ardiyanto, A., Astuti, E.J. & Ahmad, M.P. 2022. Preprocessing factors affected free fatty acid content in crude palm oil quality. *Jurnal Ilmu Pertanian Indonesia* 27(2): 177-181.

Elhassaneen, Y.A., Hassab El-Nabi, S.E., Bayomi, A.I. & ElKabary, A.R. 2022. Potential of watermelon (*Citrullis lanatus*) peel extract in attenuating benzo[a]Pyrene exposure-induced molecular damage in liver cells *in vitro*. *Journal of Biotechnology Research* 8(3): 32-45.

European Commission. 2005. Microbiological criteria for food stuffs. No. 2073/2005. https://publications.europa.eu/en/publication-detail/-/publication/d62db802-56e9-4052-888fff5def2 fa0f2/ language-e Accessed 20 February 2023.

Fairuz, H.I., Nor Azlin, M.N. & Farah Ayuni, S. 2021. The heavy metals and microbial profile of organic fruits sold at retail in Malaysia. *Malaysian Journal of Medicine and Health Sciences* 17(Suppl. 8): 1-6.

Feroz, F. & Noor, R. 2019. Transmission of pathogens within the commonly consumed vegetables: Bangladesh perspective. *Stamford Journal of Microbiology* 8(1): 46-49.

González, R.L., Djabayan, D.P., Prato, J., Ríos, C., Carrero, J., Trelis, M. & Fuentes, M. 2023. Field study of parasitic contamination of fruits, vegetables and leafy greens in the Ecuadorian Andes. *F1000Research* 12: 532.

He, Y., Chen, R., Qi, Y., Salazar, J., Zhang, S., Tortorello, M., Deng, X. & Zhang, W. 2021. Survival and transcriptomic response of *Salmonella enterica* on fresh-cut fruits. *International Journal of Food Microbiology* 348: 109201.

Hegazy, A.E. & Ibrahium, M.I. 2012. Antioxidant activities of orange peel extracts. *World Applied Sciences Journal* 18(5): 684-688.

Hernández, H.C., Aguilar, C.N., Rodríguez, H.R., Flores, G.A.C., Morlett, C.J.A., Govea, S.M. & Ascacio, V.J.A. 2019. Rambutan (*Nephelium lappaceum* L.): Nutritional and functional properties. *Trends in Food Science & Technology* 103: 201-210.

Hernández, C., Juan, A.A.V., Heliodoro, D.L.G., Jorge, E.W.P., Cristobal, N.A., Guillermo, C.M., Cecilia, C.L. & Antonio, A.C. 2017. Polyphenolic content, *in vitro* antioxidant activity and chemical composition of extract from *Nephelium lappaceum* L. (Mexican rambutan) husk. *Asian Pacific Journal of Tropical Medicine* 10(12): 1201-1205.

International Commission on Microbiological Specifications for Foods (ICMSF). 1986. *Microorganisms in Foods 2, Sampling for Microbiological Analysis: Principles and Specific Applications*. Canada: University of Toronto Press.

Ismael, R., Aviat, F., Michel, V., Le Bayon, I., Gay-Perret, P., Kutnik, M. & Fédérighi, M. 2013. Methods for recovering microorganisms from solid surfaces used in the food industry: A review of the literature. *International Journal of Environmental Research and Public Health* 10(11): 6169-6183.

Jahurul, M.H.A., Azzatul, F.S., Sharifudin, M.S., Norliza, M.J., Hasmadi, M., Lee, J.S., Patricia, M., Jinap, S., George, M.R., Khan, M.F. & Zaidul, I.S.M. 2020. Functional and nutritional properties of rambutan (*Nephelium lappaceum* L.) seed and its industrial application: A review. *Trends in Food Science & Technology* 99: 367-374.

Jantapaso, H. & Mittraparp-arthorn, P. 2022. Phytochemical composition and bioactivities of aqueous extract of Rambutan (*Nephelium lappaceum* L. cv. Rong Rian) peel. *Antioxidants* 11(5): 956.

Julien, J.F., Gérard, C., Campagnoli, M. & Zuber, S. 2019. Strategies for the safety management of fresh produce from farm to fork. *Current Opinion in Food Science* 27: 145-152.

Karanth, S., Feng, S., Patra, D. & Pradhan, A.K. 2023. Linking microbial contamination to food spoilage and food waste: The role of smart packaging, spoilage risk assessments, and date labelling. *Frontiers in Microbiology* 14: 1198124.

Krüger, K., Töpfner, N., Berner, R., Windfuhr, J.P. & Oltrogge, J.H. 2021. Sore throat. *Deutsches Arzteblatt International* 118(11): 188-194.

Kasmin, N.H., Zubairi, S.I., Lazim, A. & Awang, R. 2020. Thermal treatments on the oil palm fruits: Response surface optimization and microstructure study. *Sains Malaysiana* 49(9): 2301-2309.

Lee, W., Ford, M. & Randall, K.L. 2019. IgE-mediated allergy to remifentanil? *Anaesthesia and Intensive Care* 47: 98-99.

Li, W., Zeng, J. & Shao, Y. 2018. Rambutan – *Nephelium lappaceum.* In *Exotic Fruits,* edited by Rodriguez, S., de Oliveira Silva, E. & de Brito, E.S. Massachusetts: Academic Press. pp. 369-375.

Lufu, R., Ambaw, A. & Opara, U.L. 2020. Water loss of fresh fruit: Influencing pre-harvest, harvest and postharvest factors. *Scientia Horticulturae* 272: 109519.

Luo, W., Yang, S., Huang, H., Wu, L., Cheng, Z.J., Zheng, P., Zheng, J. & Sun, B. 2021. Analysis of peanut allergen components sensitization and cross reaction with pollen allergen in Chinese southerners with allergic rhinitis and/or asthma. *Journal of Asthma and Allergy* 14: 1285-1293.

Machado, M.B., Richards, K., Brennan, F., Abram, F. & Burgess, C. 2019. Microbial contamination of fresh produce: What, where, and how? *Comprehensive Reviews in Food Science and Food Safety* 18(6): 1727-1750.

Mahmood, K., Kamilah, H., Alias, K. & Fazilah, A. 2018. Nutritional and therapeutic potentials of rambutan fruit (*Nephelium lappaceum* L.) and the by-products: A review. *Journal of Food Measurement and Characterization* 12(3): 1556-1571.

Mohd Aris, H., Mohd Kasim, Z., Zubairi, S.I. & Babji, A.S. 2023. Antioxidant capacity and sensory quality of soy-based powder drink mix enriched with functional hydrolysate of swiftlet (*Aerodramus fuciphagus*). *Arabian Journal of Chemistry* 16(3): 104553.

Mama, C.N., Nnaji, C.C., Emenike, P.C. & Chibueze, C.V. 2020. Potential environmental and human health risk of soil and roadside dust in a rapidly growing urban settlement. *International Journal of Environmental Science and Technology* 17: 2385-2400.

Mele, M.Z. & Giuffré, A.M. 2018. Pre-and post-harvest factors and their impact on oil composition and quality of olive fruit. *Emirates Journal of Food and Agriculture* 30(7): 592-603.

Nnenna, O. & Gift, O. 2020. Effect of antibacterial agents on the microbial flora of some fruits and vegetables. *International Research Journal of Science and Technology* 1(4): 299-304.

Olakunle, O.O., Joy, B.D. & Irene, O.J. 2019. Antifungal activity and phytochemical analysis of selected fruit peels. *Journal of Biology and Medicine* 3(1): 40-43.

Parajuli, R., Thoma, G. & Matlock, M. 2019. Environmental sustainability of fruit and vegetable production supply chains in the face of climate change: A review. *The Science of the Total Environment* 650(2): 2863-2879.

Phuong, N., Le, T., Camp, J. & Raes, K. 2020. Evaluation of antimicrobial activity of Rambutan (*Nephelium lappaceum* L.) peel extracts. *International Journal of Food Microbiology* 321: 108539.

Rahmadi, A., Yusriandi, Hanafi, M., Junaifid, Supriadi, Setianingrum, D., Dina, W.A. & Susilawati, R. 2020. Physical, microbial and pesticide contaminations on fresh vegetables and fruit marketed in Samarinda-Indonesia. *IOP Conference Series: Earth and Environmental Science*. p. 443.

Rakariyatham, K., Zhou, D., Rakariyatham, N. & Shahidi, F. 2020. Sapindaceae (*Dimocarpus longan* and *Nephelium lappaceum*) seed and peel by-products: Potential sources for phenolic compounds and use as functional ingredients in food and health applications. *Journal of Functional Foods* 67: 103846.

Rosa-Esteban, D.L.K., Sepúlveda, L., Chávez, G.M.L., Torres, L.C., Estrada-Gil, L.E., Aguilar C.N. & Ascacio, V.J.A. 2023. Valorization of Mexican Rambutan peel through the recovery of ellagic acid via solid-state fermentation using a yeast. *Fermentation* 9(8): 723.

Saparbekova, A.A., Latif, A.S. & Altekey, A. 2021. Risks of microbiological contamination of fruits and vegetables used for food. *Bulletin of the Innovative University of Eurasia*. pp. 97-102.

Serrato, D.L., Aviles, N.A., Soto, B.A., Rivera, V.L., Goenaga, R. & Bayman, P. 2019. Botryosphaeriaceae fungi as causal agents of dieback and corky bark in rambutan and longan. *Plant Disease* 104(1): 105-115.

Simonetti, T., Peter, K., Chen, Y., Jin, Q., Zhang, G., LaBorde, L. & Macarisin, D. 2021. Prevalence and distribution of *Listeria monocytogenes* in three commercial tree fruit packinghouses. *Frontiers in Microbiology* 12: 652708.

Subedi, T. 2022. Determination of chemical parameters of fruits available in the markets of Pokhara, Nepal. *Prithvi Journal of Research and Innovation* 4: 11-23.

Surboyo, M.D., Ernawati, D.S. & Parmadiati, A.E. 2019. Glossitis mimicking median rhomboid glossitis induced by throat lozenges and refreshment candies. *Journal of International Oral Health* 11: 323-328.

Suriati, L., Supartha, U., Bambang, A.H. & Ida, B.W.G. 2020. Physicochemical characteristics of fresh-cut tropical fruit during storage. *International Journal on Advanced Science Engineering and Information Technology* 10(5): 1731-1736.

Tavares, J., Martins, A.P., Fidalgo, L.G., Lima, V., Amaral, R.A., Pinto, C.A., Silva, A.M. & Saraiva, J.A. 2021. Fresh fish degradation and advances in preservation using physical emerging technologies. *Foods* 10: 780.

Tian, M., Jixi, G., Zhang, L., Zhang, H., Feng, C. & Jia, X. 2021. Effects of dust emissions from wind erosion of soil on ambient air quality. *Atmospheric Pollution Research* 12(1): 101108.

Torgbo, S., Prapassorn, R., Udomlak, S. & Prakit, S. 2022. Biological characterization and quantification of Rambutan (*Nephelium lappaceum* L.) peel extract as a potential source of valuable minerals and ellagitannins for industrial applications. *ACS Omega* 7(38): 34647-34656.

Tripathi, P.C. 2021. Rambutan (*Nephelium lappaceum* var. *lappaceum*). In *Tropical Fruit Crops: Theory to Practical,* edited by Ghosh, S.N. & Sharma, R.R. New Delhi: Jaya Publishing House. pp. 542-575.

Ural, N. 2021. The significance of scanning electron microscopy (SEM) analysis on the microstructure of improved clay: An overview. Open Geosciences 13(1): 197-218.

Vella, F.M., Calandrelli, R., Cautela, D. & Laratta, B. 2023. Natural antioxidant potential of melon peels for fortified foods. *Foods* 12: 2523.

Venturini, M.E., Gimeno, D., Franco, K., Redondo, D. & Oria, R. 2018. Rambutan peel as a source of food antioxidant extracts. *Acta Hortic.* 1194: 971-978.

Yu, Z., Li, X., Wang, S., Liu, L. & Zeng, E. 2021. The human and ecological risks of neonicotinoid insecticides in soils of an agricultural zone within the Pearl River Delta, South China. *Environmental Pollution* 284: 117358.

Zainol, N., Subramanian, S., Adnan, A.S., Zulkifli, N.H., Zain, A.A.M., Kassim, N.R.W. & Kamarudin, A.A. 2020. The potential source for composite flours as food ingredient from local grown crops. *Food Research* 4(2): 24-30.

Zaouay, F., Brahem, M., Boussaa, F., Mahjoub, H.F., Tounsi, M.S. & Mars, M. 2020. Effects of fruit cracking and maturity stage on quality attributes and fatty acid composition of pomegranate seed oils. *International Journal of Fruit Science* 20: S1959-S1968.

Zhang, H., Yamamoto, E., Murphy, J. & Locas, A. 2020. Microbiological safety of ready-to-eat fresh-cut fruits and vegetables sold on the Canadian retail market. *International Journal of Food Microbiology* 335: 108855.

Zubairi, S.I., Md Zabidi, N.A.S., Azman, Z.Z., Mohd Kamaruddin, S.N.D., Mohd Kasim, Z., Jamil, S. & Lazim, A. 2022. *Pleurotus ostreatus* cultivation: Development of a robust pre-blocks oyster mushroom substrate from wood ash and palm fronds. *Sains Malaysiana* 51(2): 329-343.

Zubairi, S.I., Ishak, N., Sani, N.A., Mohd Kassim, Z. & Nurzahim, Z. 2021. Yogurt drink spoilage profiles: Characterization of physico-chemical properties and coliform potability analysis. *Arabian Journal of Chemistry* 14(9): 103340.

*Corresponding author; email: saiful-z@ukm.edu.my