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Phytochemical constituents in Kithul (*Caryota urens*) and its medical significance: A Mini Review

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Abstract

Kithul (fishtail/toddy palm) tree is scientifically known as *Caryota urens*. It is an economically and medicinally significant plant native to tropical Asia. This plant consists of major phytochemical constituents including polyphenols (*e.g.,* caffeoylquinic acids, caffeoylshikimic acids, *etc.*), flavonoids (*e.g.,* quercetin, kaempferol, eriocitrin, *etc.*), amino acids, fatty acids, phytosterols and sugars. The phloem sap of Kithul tree, collected from the tapped inflorescence is called sweet toddy and it is mainly used to prepare an alcoholic beverage, commonly known as Kithul toddy. Phloem sap is also used to produce treacle and jaggary. Kithul toddy is obtained by fermenting the sap while treacle is made by heating the fresh sap. In the pith of the tree, the sap is stored as starch, and this is later transformed into flour. Phytochemicals present in Kithul roots, leaves, bark, seeds, flowers, and sap exhibit medicinal properties such as anti-diabetic, anticancer, antioxidant, antimicrobial, anti-inflammatory, libido-enhancing ability, *etc.* Hence, the parts of Kithul tree are used as traditional and Ayurvedic medicine to treat many different conditions

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such as rheumatic swelling, snake bite poisoning, tooth ailments, anemia, jaundice, *etc*. The main scope of this article is to review major phytochemical constituents in Kithul plant and how its medicinal properties benefit the world.

Keywords: Kithul*, Caryota urens, phytochemicals, treacle, jaggary, toddy*

Introduction

Kithul (*i.e.,* also known as fishtail palm, Indian sago plant, wine palm, jaggary palm and toddy palm) is a flowering plant in palm family which is mainly seen in tropical Asian countries (Everett, 1995). The nuts (or fruits) of this plant (*Caryota urens*) can cause skin irritation (Das et al, 2023; Wijesinghe et al, 2015a). "Kithul tapping" in Sri Lanka has a unique cultural value as it combines with indigenous knowledge, which generally passes from one generation to another. Kithul toddy and treacle are the foremost liquid products obtained from the phloem sap of the plant (which runs out from the tapped inflorescence) (Wijesinghe et al, 2020). Kithul jaggary ("Hakuru" in Sinhalese) is a solid product prepared from Kithul treacle. Kithul flour is an alternative to commonly used wheat or rice flour (Wijesinghe et al, 2015a; Wijesinghe et al, 2015b; Wijesinghe et al, 2016). Leaves, seeds, sap, and bark of the Kithul tree consist of numerous phytochemicals (*e.g.*, polyphenols, flavonoids, amino acids, sugars, *etc*.); some of these exhibit antioxidant, anti-inflammatory, anticancer, antimicrobial and also anti-diabetes properties (Mariyan & Ajay, 2012; Vanaja et al, 2017; Ferreres et al, 2020). Almost all the parts of the Kithul tree are used in Ayurvedic and folk medicine in Asian countries (De Silva et al, 2022; Jayshree et al, 2023). However, adulterations of Kithul products can hinder the desired medicinal value of the phytochemicals present in this plant (Wijesinghe et al, 2020). The scope of this mini review is to present phytochemicals of Kithul plant and their medicinal properties.

Distribution of Kithul in Sri Lanka and its Morphology

The natural habitats of the Kithul plant have distributed in wet and intermediate wet zones (*i.e.,* mid, and low country, interior up to 1500 meters, and predominantly in the natural lowland forests) in Sri Lanka (Wijesinghe et al, 2015a; Deepakkumar, 2016). Thus, Kithul

trees are widely spread in Rathnapura, Badulla, Monaragala, Matara, Kandy, Kegalle, Nuwara Eliya, Kalutara, Galle, Kurunegala, and Matale districts in the country (Statistics on Kithul palms in Sri Lanka, 2009).

The survey (Statistics on Kithul palms in Sri Lanka, 2009), held by the Department of Census and Statistics in 2009, revealed that the total count of Kithul trees grown in Sri Lanka was approximately 3,000,000. It was also stated that 19% out of the total Kithul trees were matured whilst 31% of them were middle-aged, and the rest of the trees were young. According to this survey, only 15% of the total Kithul trees were tapped.

The height of a Kithul tree normally varies from 15 to 20 meters and the diameter of a grey-colored, smooth cylindrical trunk ranges between 30-60 cm (Everett, 1995). The trunk is composed of widely spaced leaf-scar rings (Everett, 1995). The name “fishtail palm” was given to it as it consists of triangular bipinnate long (*i.e.*, about 2-3 m) leaves (Everett, 1995).

A Kithul inflorescence (*i.e.*, a cluster of flowers held on a stalk) contains unisexual flowers and it lasts for 3-4 months (Everett, 1995; Vanaja et al, 2017). A completely developed and fully grown tree is called a mature tree, and it bears about 8-10 tappable inflorescences within its lifetime (Statistics on Kithul palms in Sri Lanka, 2009). The immature inflorescence is white in color as shown in (Figure 1), while a matured inflorescence appears in brown color. They consist of small female flowers, (Figure 2) which change into red color drupes when matured (Everett, 1995).

Figure 1. Kithul inflorescences (white - young inflorescence, brown - mature inflorescence)
https://natgeotraveller.in/local-flavour-kithul-is-sri-lankas-smoky-dessert-secret/

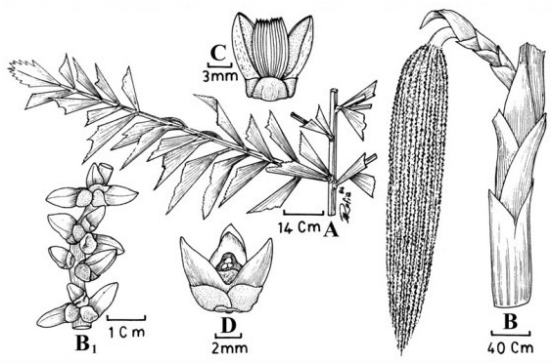


Figure 2. Some parts of the Kithul tree: **A** - leaf, **B** & **B1** - inflorescence, **C** - petal removed male flower, **D** - female flower
http://www.efloras.org/object_page.aspx?object_id=86616&flora_id=5

Phytochemical constituents

Phytochemicals are special chemical compounds that are produced by plants through primary and secondary metabolic pathways (Patay et al, 2016). They are useful in building up a self-defense system against microorganisms and as they are known to act against several plant diseases (Patay et al, 2016).

Polyphenols and acids

Some acids and phenolic compounds found in extracts of Kithul leaves, fruits, seeds, and inflorescences are given in Table 1 and the structures of the compounds are given in Figure 3 (Ananth et al, 2013; Balaji & Ganesan, 2021; Ma et al, 2019; Ferreres et al, 2020; Radha et al, 2019; El-Akad et al, 2021).

Some of these phenolic compounds have shown antioxidant, anti-inflammatory and antimicrobial properties (Ananth et al, 2013; Das et al, 2023; Radha et al, 2019). Without affecting the viability of the cells, umbelliferone or 7-hydroxycoumarin **4** has shown the ability to inhibit nitric oxide, which causes inflammation according to studies published in 2019 and 2021 (Balaji & Ganesan, 2021; Radha et al, 2019).

Table 1. *Some polyphenolics and acids present in the Kithul tree*

Parts of Kithul plant	Compound
Leaves	Coumaric acid **1a** Caffeic acid **1b** Ferulic acid **1c** Sinapic acid **1d** and their derivatives Citric acid **2** Quinic acid **3** Acetyl quinic acid **3a** Umbelliferone **4**
Seed and inflorescence	3-O-caffeoylquinic acid **5a** 4-O-caffeoylquinic acid **5b** 5-O-caffeoylquinic acid **5c** 3-O-caffeoylshikimic acid **6a** 4-O-caffeoylshikimic acid **6b** 5-O-caffeoylshikimic acid **6c**
Fruits	2-Methoxy-4-vinylphenol **7** Pyrogallol **8** Thymol **9**

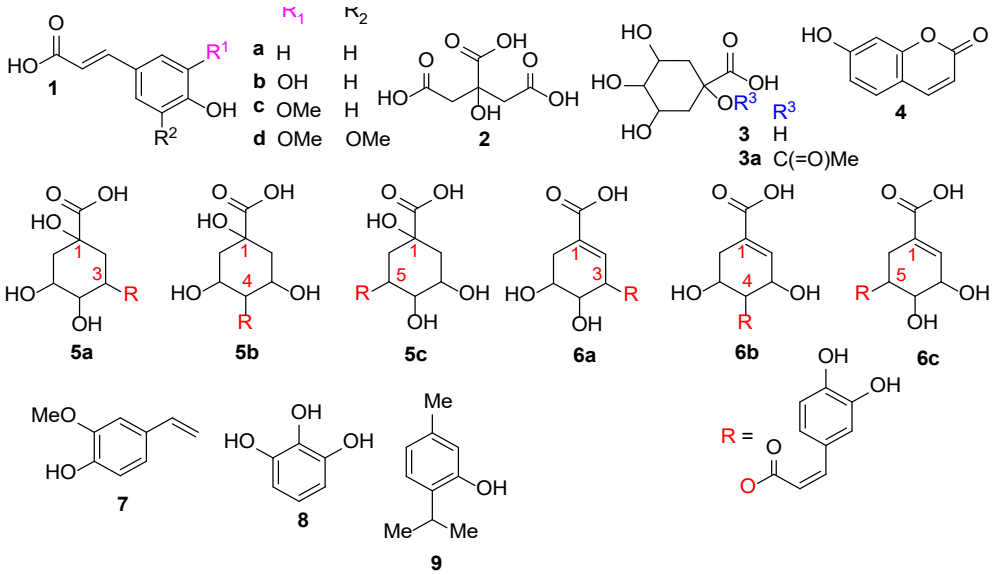


Figure 3. Structures of some polyphenolics and acids

Flavonoids

Different types of flavonoid conjugates, including (i) flavonols (Figure 4) (*e.g.*, quercetin **10** and kaempferol **11** and their derivatives), (ii) flavones (Figure 5) (*e.g.*, apigenin and luteolin-C-glycosides), and (iii) flavanols (Figure 6) (*e.g.*, proanthocyanidins) were found in Kithul leaves (El-Akad et al, 2021). Apigenin derivatives **19** are also present in the bark and fruits of this plant (Ma et al, 2019; Sujitha & Kripa, 2018). Types of flavonoids present in Kithul seed extracts are given in Table 2 and Figures 4-7 (Ma et al, 2019).

Table 2. *Flavonoids present in Kithul seed extracts*

Flavonols	**Flavones**
Quercetin **10**	Apigenin-6,8-di-C-glucoside or Vicenin-2 **19a**
Kaempferol **11**	Apigenin-6-C-glucoside or Isovitexin **19b**
3-Methoxysinensetin **12**	Chrysoeriol-7-O-glucoside **20a**
3-Methoxynobiletin **13**	Chrysoeriol-7-O-(6"-malonyl-glucoside) **20b**
Quercetin-3-O-rutinoside or Rutin **14**	
Quercetin-3-O-glucoside or Isoquercitrin **15a**	**Flavanones**
Kaempferol-3-O-glucoside or Astragalin **15b**	Eriocitrin **21a**
Quercetin-3-O-(6"-malonyl-glucoside) **16**	Hesperetin-3′-O-glucuronide **21b**
5,4′-Dihydroxy-3,3′-dimethoxy-6:7 methylenedioxyflavone **17**	**Flavanols**
Isorhamnetin **18**	Procyanidin dimer B1 **22**
	3′-O-methyl-(-)-epicatechin-7-O-glucuronide **23**

Anthocyanins	**Isoflavonoids**
Peonidin 3-O-sophoroside **24**	Daidzein-4′-O-glucuronide **26**
Petunidin 3-O-(6"-acetyl-glucoside) **25**	

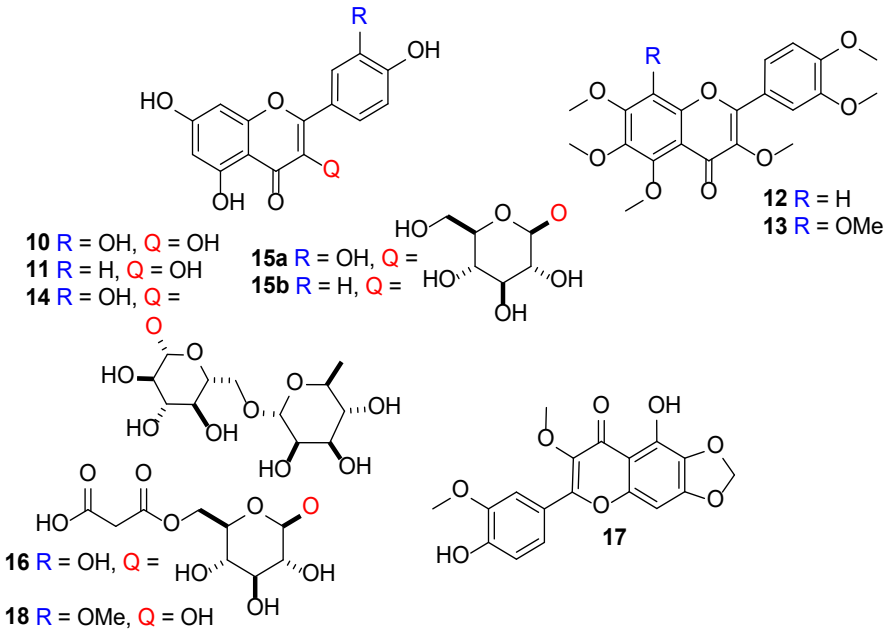


Figure 4. Structures of some flavonols

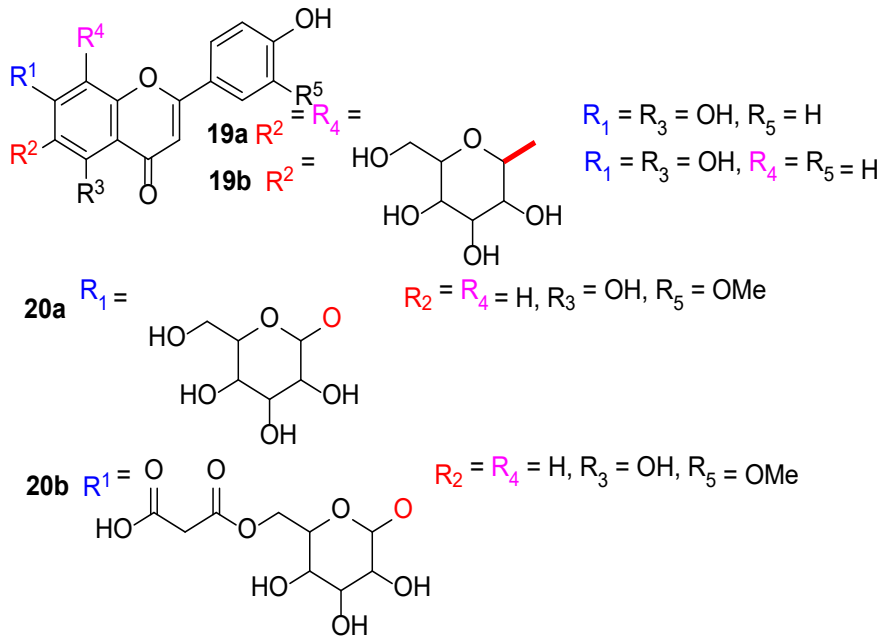


Figure 5. Structures of some flavones

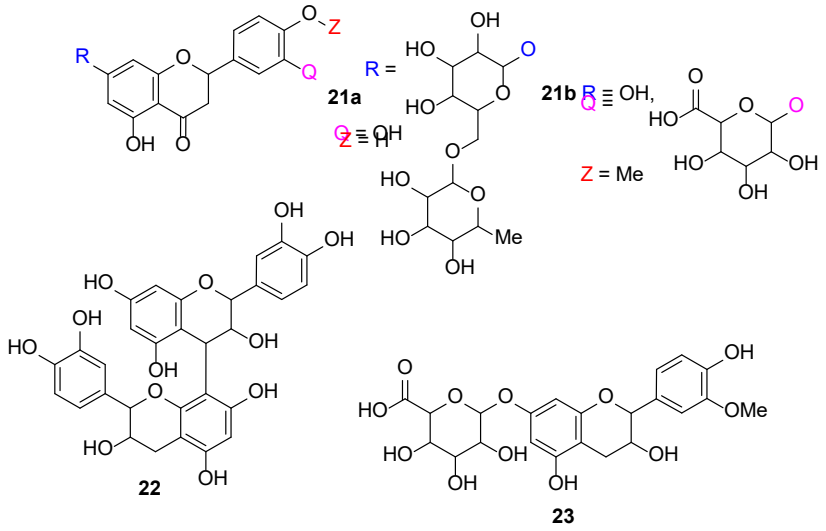


Figure 6. Structures of some flavanones and flavanols

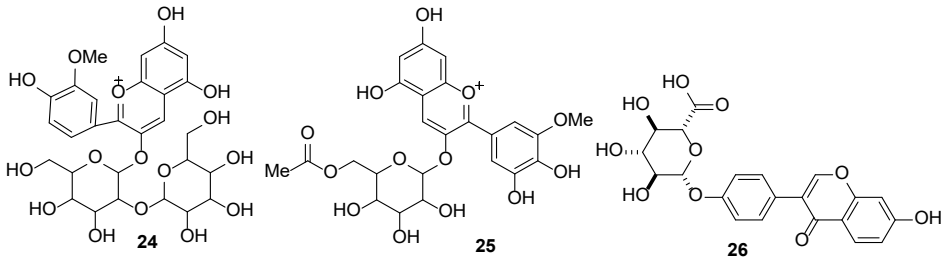
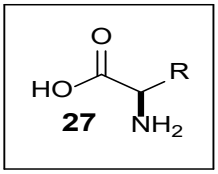


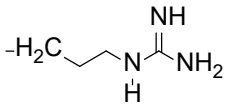
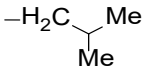
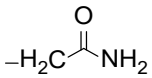
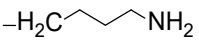
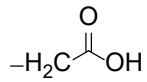
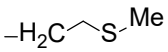
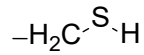
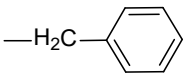
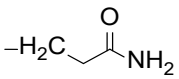
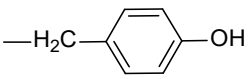
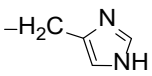
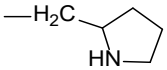
Figure 7. Structures of some anthocyanins and an isoflavonoid

Amino Acids

Kithul sap is rich in amino acids and their derivatives which are shown in Table 3 (Ranasinghe et al, 2012; Somasiri et al, 2012). The compound glutamine **27f** gives the characteristic flavor to the sap, as it is present in considerable amounts in Kithul sap (Somasiri et al, 2012). DL-arginine **27b** is another compound present in barks, fruits, and leaves of the tree (Sujitha & Kripa, 2018).

Table 3. *Names and structures of amino acids present in Kithul tree parts*

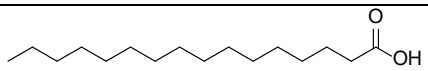
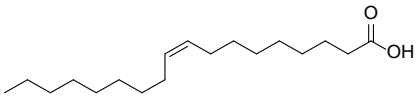
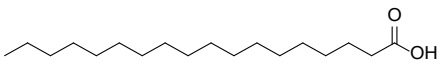
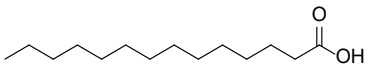
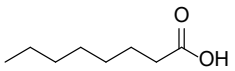
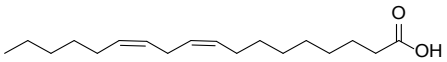
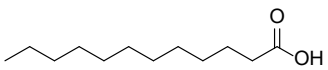


Amino acid	R	Amino acid	R
Alanine **27a**	—Me	Isoleucine **27h**	
Arginine **27b**		Leucine **27i**	
Asparagine **27c**		Lysine **27j**	
Aspartic acid **27d**		Methionine **27k**	
Cysteine **27e**		Phenylalanine **27l**	
Glutamine **27f**		Tyrosine **27m**	
Histidine **27g**		Proline **27n**	

Other phytochemicals

Piceatannol **28** (Figure 8) was obtained from the fruit extracts of the Kithul tree (Wijesinghe et al, 2015a). Saponins, fatty acids, amides and lignins were also detected from leave and fruit extracts of Kithul (Ma et al, 2019; El-Akad et al, 2021). Fatty acids found in Kithul seeds are given in Table 4 (Srinivasan et al, 2018).

Table 4. *Fatty acids found in Kithul seeds*

Fatty acid	Composition %	Structure
Palmitic Acid **29**	41.24	
Oleic Acid **30**	28.48	
Stearic Acid **31**	15.7	
Myristic Acid **32**	8.01	
Caprylic acid **33**	4.31	
Linoleic acid **34**	0.63	
Lauric Acid **35**	0.24	

Phytosterols such as daucosterol **36** and stigmasterol **37** are extracted from both bark and fruits, and leaves, respectively (Sujitha & Kripa, 2018). Structures of the compounds mentioned above are given below in Figure 8.

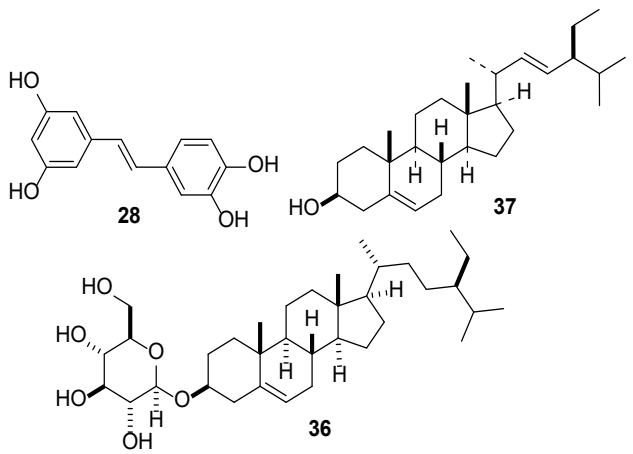


Figure 8. Structures of compounds **28**, **36** and **37**

Carotenoids in leaves are degraded to produce megastigmanes, which exhibit anti-proliferative, insulinotropic, and anti-allergic properties (El-Akad et al, 2021). Several di/tri-hydroxylated megastigmane hexoside conjugates are also obtained from Kithul leaves (El-Akad et al, 2021).

Kithul Sap and Flour

Glucose is produced by photosynthesis and the excess glucose is stored as starch in the pith, which is a special tissue composed of soft, spongy parenchyma cells (Wijesinghe et al, 2020). During the process of tapping, the stored starch is converted into phloem sap and passed through the phloem tubes (Wijesinghe et al, 2020). The phloem sap mainly consists of sucrose, glucose, and fructose (Wijesinghe et al, 2020). The sweet taste to the sap is given by these sugars, thus, Kithul phloem sap is called sweet toddy (in Sinhalese, "thelijja, theli diya or mee-raa") (Everett, 1995). Sweet toddy is rich in vitamin C and mineral salts containing iron, calcium, and phosphorous (Wijesinghe et al, 2020). When the tapping is over, the phloem sap restores in the pith again (Sudheesha et al, 2020; Wijesinghe et al, 2020; Wijesinghe et al, 2015a; Wijesinghe et al, 2015b).

The main products obtained from Kithul sap are treacle, toddy and jaggary (Wijesinghe et al, 2020; Wijesinghe et al, 2015a). Treacle is prepared by heating the extracted fresh sap. During this process, the organic compounds in the sap undergo Millard and caramelization reaction to form volatile aldehydes, ketones and heterocyclic compounds (Wijesinghe et al, 2020). This is a non-enzymatic heat-induced browning reaction, and it gives the characteristic aroma, color and flavor to the treacle (Wijesinghe et al, 2020).

When the sap is heated, invertase enzyme (*i.e.*, the enzyme that catalyzes the conversion of sucrose into fructose and glucose) becomes denatured. Thus, the sucrose content present in a sample of Kithul treacle remains high, and the fructose amount becomes low (Wijesinghe et al, 2020). Dissolved sugar content can be measured by the Brix value (*i.e.*, Brix value indicates the dissolved sugar content in a liquid sample) and Brix values of pure Kithul treacle sample, and pure table sugar syrup are about 69 and 89, respectively (Wijesinghe et al, 2020). Adulterated treacle has a high sucrose level (*i.e.*, higher brix value than 69) than the original Kithul treacle as it contains table

sugar syrup (Wijesinghe et al, 2020). For this reason, consumption of adulterated treacle may lead to diabetes (Wijesinghe et al, 2020).

During heating, reducing sugars such as glucose and fructose undergo caramelization reaction. Prolonged heating in higher temperatures accelerates the hydrolysis reactions of sucrose present in the Kithul sap. The reducing sugars formed by the hydrolysis reactions interact with amino acids. The unique brown color of treacle is given by Millard's reaction. The amount of the reducing sugars present in treacle can be determined by titration methods and this value for a pure Kithul treacle sample is around 69% (W/W).

Unadulterated Kithul jaggary is known as medicinal jaggary as it is used in indigenous medicine to cure diseases (Wijesingha et al, 2019). In order to maintain the quality of the Kithul treacle, the Sri Lankan Standard, (SLS 1701; part 1: Kithul treacle), was introduced.

Approximately about 100-150 kg of pith is produced by the Kithul tree when the trunk is fully matured (Wijesinghe et al, 2015a; Wijesinghe et al, 2015b). Furthermore, Kithul trees generate about 24 tons of flour per hectare per year, while rice, corn and potato produce 6, 5.5 and 2.5 tons of flour per hectare per year, respectively (Wijesinghe et al, 2015b). However, tapping trees have less content of flour (Wijesinghe et al, 2015b). Kithul flour is a quick swelling starch as it consists of high amylose content (about 28%) and about 71% of amylopectin on a dry basis (Wijesinghe et al, 2015b). Due to the high amylose content, Kithul flour has a slightly lower gelatinization temperature (76.74 ^{o}C - peak temperature) than that of corn (80 ^{o}C) (Wijesinghe et al, 2015b).

This odorless and water insoluble pinkish flour contains proteins and other mineral salts of calcium, sodium, potassium, zinc and magnesium (Sudheesha et al, 2020; Wijesinghe et al, 2015b). The pink color of Kithul flour is mainly given by polyphenolic compounds (about 52% of crude flour), ascorbic acid and carotenes (Wijesinghe et al, 2015b).

Wijesinghe et al. (2015) categorized Kithul plants into different clusters, based on the characteristics (*e.g.*, ash content, mineral content, *etc.*) of the Kithul flour. The chemical composition and mineral content of the Kithul flour in different districts are given in Table 5 (Wijesinghe et al, 2015a).

Table 5. *District wise contents in Kithul flour (db = dry base)*

Contents (g/100g db)	**District**				
	Kandy	**Kurunegala**	**Matale**	**Kegalle**	**Rathnapura**
Ash	0.24± 0.15	0.92± 0.34	0.67± 0.16	1.12± 0.67	0.91± 0.37
Total fat	0.29± 0.01	0.36± 0.06	0.37± 0.08	0.34± 0.03	0.43± 0.15
Crude fibre	0.85± 0.49	1.34± 0.37	1.11± 0.68	1.15± 0.39	0.87± 0.58
Crude protein	1.00± 0.22	1.09± 0.16	0.92± 0.17	1.04± 0.12	0.93± 0.13
Calcium	38.95± 12.07	75.13± 28.57	80.95± 27.38	76.44± 23.29	71.85± 21.75
Potassium	28.22± 3.57	55.66± 21.19	54.27± 18.11	68.73± 18.38	55.68± 14.31
Sodium	42.57± 20.29	57.17± 36.90	52.20± 23.74	35.56± 16.95	62.78± 41.78
Iron	12.92± 4.25	13.51± 3.33	11.65± 3.14	11.96± 3.61	14.13± 3.83
Zinc	3.34± 2.49	3.43± 2.40	4.24± 2.75	3.90± 3.02	2.47± 1.84
Magnesium	41.81± 13.92	58.10± 25.62	59.23± 9.66	82.12± 31.94	78.38± 27.17

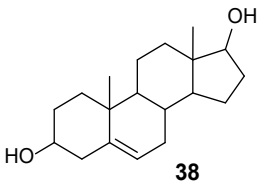
Generally, Kithul flour in the market is found to be adulterated with the addition of wheat flour and the adulterated flour can be easily recognized by its appearance and the gelatinization temperature.

Health benefits of phytochemicals present in the Kithul plant

According to Ayurveda, Kithul tree contains many medicinal values. Kithul sap is traditionally used for seminal weakness, since it consists

of arginine **27b**, which is known as the natural Viagra (Ananth et al, 2013; Somasiri et al, 2012). Histidine **27g** and tyrosine **27m** are other amino acids which are helpful to maintain a healthy reproductive system. Proline **27n** helps to improve the texture of the skin (Somasiri et al, 2012).

Kithul belongs to the family Aceraceae and the members of this family can produce human sex hormones. Androstenediol **38** (Figure 9) is a steroid which is isolated from leaves and fruits of Kithul that can act as a libido enhancer. Kithul sap is used to treat urinary disorders (El-Akad et al, 2021).



38

Figure 9. Structure of Androstenediol **38**

Kithul treacle has a slightly lower glycemic index (GI) (GI < 55) than the GI values which are shown by medium-level carbohydrates (Weeraratne & Ekanayake, 2022; Wijesinghe et al, 2020). Anti-diabetic activity (*via* alpha-glucosidase inhibition action) of Kithul sap decreases glucose absorption into the blood stream (Ferreres et al, 2020; Somasiri et al, 2012). Thus, moderate consumption of food products, prepared from Kithul sap and flour, is recommended for diabetic patients (Vanaja et al, 2017; Wijesinghe et al, 2020). Anti-aging and antioxidant properties are also shown by phytochemicals such as flavonoids and polyphenols present in Kithul sap (Ranasinghe et al, 2012; Somasiri et al, 2012).

In traditional medicine, flower porridge is used for treating gastric ulcers and migraine (Charles & Ramani, 2011). Hair growth can be promoted by using the tender flowers of Kithul (Charles & Ramani, 2011). Root barks and terminal buds of the Kithul palm are applied as the treatment of rheumatic swellings and snake bite poisoning (Ananth et al, 2013; Perumpuli et al, 2022; Srivastav et al, 2015). The roots of Kithul tree are used for treating tooth ailments (Ananth et al, 2013; Patel & Nema, 2021). Methanolic extracts of the Kithul leaves give analgesic and anti-inflammatory effects, due to the presence of flavonoids and polyphenolic compounds such as rutin **14** and

umbelliferone **4** (Mariyan & Ajay, 2012). Cystine **27e** plays a major role in healing rheumatic arthritis and the hardening of arteries. Stilbenes have a potency to act as antiviral and anticancer agents (El-Akad et al, 2021). Kithul leaf and starch are used to cure hemicranias (De Silva et al, 2022; Patel & Nema, 2021). In folk medicine, the pulp of Kithul fruits is used for hyperpiesia and fatigue (Balaji & Ganesan, 2021; Sujitha & Kripa, 2018; Vanaja et al, 2017). Summary of Kithul based traditional medicines is given in Table 6 (De Silva et al, 2022; Patel & Nema, 2021, Vanaja et al, 2017; Jayshree et al, 2023).

Table 6. *Kithul-based traditional medications*

Part of the plant	**Medication**
Leaves	To cure hemicranias
Bark	As a treatment for earache
Root bark	As treatments for rheumatic swelling, snake bite poisoning and tooth ailments
Flowers (tender)	To promote hair growth
Seeds	To treat hyperpiesia and fatigue
Treacle	To treat jaundice
Jaggery	To treat anemia, jaundice and bleeding from various parts of the body
Toddy	As a treatment for constipation and to increase digestive power
Starch	To treat hemorrhoids

Ethanoic extract of the Kithul flower inhibits 20 bacterial species (*e.g., Bacteroides fragilis, Bacteroides melaninogenicus, Bacteroides oralis, Lactobacillus, Shigella* sp*., Clostridium septicum, Clostridium tetani, Bifidobacterium bifidum, Staphylococcus aureus, Enterococcus faecalis, Escherichia coli, Salmonella enteritidis, Klebsiella pneumonia, Enterobacter* sp*., Proteus mirabilis, Pseudomonas mutant, streptococcus* sp*., Proteus vulgaris, Bacillus subtilis* mutant and *Yersinia*) and 7 fungal species (*e.g., Aspergillus niger, A. flavus, A. nidulans, A. oryzae, Penicillium* sp*., Mucor*) which are present in various organs including gut, oral, kidney, urinary track, liver, *etc.*

This anti-microbial property is given by the phenolic and flavonoid compounds that present in the Kithul flower (Charles & Ramani, 2011). Similarly, methanol leaf extract of Kithul act against bacteria (*e.g.*, *Pseudomonas* sp., *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus*) and fungi including *Rhizopus* sp., *Aspergillus niger*, *Penicillium* sp. and *Fusarium* sp. (Vanaja & Kavitha, 2017). Terpenoids may disrupt the lipophilic compounds present in microbes while, polyphenolics acids inhibit the enzymes by oxidizing (Vanaja & Kavitha, 2017).

Recently, Al Aboody (2020) reported the biosynthesis of silver nanoparticles using methanolic extracts of fresh inflorescence. These silver nanoparticles were harmless to non-toxic organisms and showed the highest mortality against dengue causing vector, *Aedes aegypti* (*i.e.,* the dengue mosquito). The nanoparticles penetrate the exoskeleton of the vector and interact with nucleic acids in the living cells. Thus, mutated DNA causes lethal damage to the insect (Al Aboody; 2020).

Conclusions

Kithul is a traditionally and commercially valuable plant in Sri Lanka. Its parts are used in indigenous medicine as well as in Ayurveda. Kithul plant contains many phytochemicals including, polyphenols, flavonoids, amino acids, fatty acids, phytosterols, *etc.*, exhibiting anti-diabetes, antioxidant, anticancer, antiviral and libido-enhancing properties. Kithul sap is the main component of dietary products (*e.g.*, treacle, jaggary, flour, toddy). Sri Lankan researchers are encouraged to promote Kithul treacle as an alternative to Maple syrup, consumed mainly by Europeans and Aussies with pancakes, waffles, French toast, porridge, *etc*.

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