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MINI REVIEW

Caryota urens: value addition, nutritional and medicinal values

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Abstract

Caryota urens which is commonly known as *Kithul*, is a multipurpose and underutilized palm mainly distributed in Asia. Due to its numerous applications, it has been considered an important plant that ensures the livelihood of the village people in Sri Lanka. Thus, this article reviews the nutritional and medicinal values of *kithul* palm and its value-added products. *Kithul* sap is widely used in the production of *kithul* treacle and jaggery due to its high amount of sugar content. *Kithul* seed oil is high in palmitic and oleic acid and is a good source of biofuels. *Kithul* fruit has skin-irritating nature due to the presence of oxalic acid, and also it contains anti-nutritional substances such as phytate, tannin and saponin. Different parts of *Kithul* palm such as leaves, flowers, fruit, sap is rich in antioxidants, anti -inflammatory, antimicrobial, and anti-diabetic properties due to the existence of flavonoids, glycosides like phytochemicals. Low gelatinization temperature has identified *Kithul* flour as a good gelling agent, stabilizer and thickener. Owning to its low Glycemic Index, *kithul* flour has become beneficial for people suffering from diabetics. Thus, value-added products like biscuits, noodles, bread, muffin, rotti, porridge, dessert, yoghurt are identified as potential products that must be commercialized with more investigations.

1. Introduction

Caryota urens is a widely distributed palm in Asia that belongs to the *Aceraceae* family. It is a well-known plant as a food source and income generator among other 27 species in the genus *Caryota* (Saranandha, 2015). In Sri Lanka, *Caryota urens* known as *Kithul* is primarily distributed in areas with even rainfall patterns with an altitude of 2000-2800 feet of primary areas as Kandy, Matale, Ratnapura, Rakwana, North Matara, Lower Uva and Moneragala and in secondary areas such as Colombo, Kalutara, Galle, Kegalle, Kurunegala and Badulla Districts (Abeysinghe, 1991). It's also one of the major prevalent trees in the perennial highland forest gardens of Sri Lanka (Everett, 1995). This plant is underutilized and mostly found in South Asian countries like Malaysia, Indonesia, India and the Philippines (Ranasinghe *et al*., 2012). *Kithul* is used as a garden plant during its younger stage. Mostly, this plant is distributed in evergreen, semi-evergreen and moist deciduous forests.

Kithul is a multipurpose palm tree that is commonly grown in areas such as homesteads in deserts, pastoral and agroforestry systems (Renuka, 1999). Because of its numerous applications, it has a long history as an income for poor farmers (Loftus, 2014), and thus it is considered an important plant that ensures the livelihood of the village people. Products dependent on *Kithul* sap provides a major revenue stream for a vast population living in agronomic areas of developing countries (Somasiri *et al*., 2011; Ranasinghe *et al*., 2012). Every year from November to April, a farmer who has one to two *kithul* trees in their field will receive an average income of about Rs. 40,000 to 50,000 since it is the time with the highest sap production (Kumar *et al*., 2012).

Generally, *Kithul* palm is grown up to a height of 15 to 20 meters under suitable growing conditions, and bipinnate leaves of *kithul* normally grow as much as 7-8 meters in length (McCurrach, 1960; Trimen, 1998). Due to their natural origin and the methods of organic food processing, the sap products of *kithul* have a very strong demand. However, the shortage in supply and the greater demand due to the unique taste, fragrance and its possible therapeutic benefits, make these products very expensive (Ranasinghe *et al*., 2012).

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The trunk of the *Kithul* palm produces around 100 - 150 kg of pith per palm from which flour is made. It is reported that the flour from *Kithul* is of better quality than the best industrial sago which is received from *Caryota urens*, while it is valued for cooling properties (Council of scientific, 1992). Flour is the stored product of carbohydrates in the food reserves which is mainly located in the pith of the trunk. Consequently, tapping trees are found to be deficient in flour. Once the production of sap is complete, sugar can be converted to starch and re-stored in the pith. The pith of starch-rich trees is soft and tasty. According to Seneviratne (2011), the most suitable months for the extraction of *Kithul* starch are January, February and March.

As it was reported by Kumar (2012), *kithul* is a rich source of antioxidant, anti-diabetic, anti-ageing, and anti-rheumatic properties which have benefited the medical industry. Nutritional values of sap, seeds, flowers, fruits, leaves of *Kithul* had been investigated by many researchers. It is proven that the *Kithul* plant has the potential to address some issues related to the food crisis, especially in developing countries (Somasiri *et al*., 2008; Kumar *et al*., 2012; Srivastav *et al*., 2015; Wijesinghe *et al*., 2016; Grace and Henry, 2020; Sharmin and Sakekin, 2020). Also, *Kithul* can be considered as an income generator through value addition. Therefore, this article reviews nutritional values and medicinal properties of different parts of *Kithul* palm, and different types of values added products of *Kithul*.

2. Nutritional values of different parts of *Caryota urens* palms

According to reported data, palms are related to one of the earliest families of plants in the world (Ishizuka *et al*., 1995), and it is a good source of starchy food. Hence, it is necessary to focus on the potential of *Kithul* palm as a food source. Previous studies reported that each part of the *Kithul* palm has a considerable nutritive value.

2.1 Sap

According to the literature, *Kithul* sap contains a combination of basic sugars along with glucose, fructose and sucrose (Somasiri *et al*., 2008). Moreover, the unfermented *Kithul* sap with 12-14% sucrose is extensively used in making jaggery or treacle due to its high amount of sugar. Similarly, high sugar content in *Kithul* palm sap tends to rapid fermentation (Dissanayake, 1986; Kumar *et al.,* 2012) that results in the production of toddy (Jayathilake and Wijeyatatne 1999). According to Theivendirajah *et al.* (1977), *Kithul* sap consists of 6.5 pH, 0.34% reducing sugars, 15-16% total sugars. However, as reported by Kapilan (2015), fermentation of *Kithul* sap can be effectively prevented by adding 3 g of commercial lime to 1 L of *Kithul* sap.

Owing to the availability of large amounts of minerals and vitamins, the unfermented palm sap is very sweet and has excellent nutritional value (Sharmala *et al*., 1988; Theivendirarajah, 2008). Jaggery made from *Kithul* sap is a rich source of sucrose (76.6-83.5%). Other than that, it contains reducing sugars (0.76-0.90%), ash (1.65-1.98%), protein (1.79-2.27%), and pectin (6.6-8.34%) (Dissanayake, 1986). Therefore, *Kithul* jaggary can be considered a rich source of sweetener in the food industry (Wijesingha *et al.,* 2019).

2.2 Seeds

It is reported that *Kithul* seeds are rich in starch and basic sugars including glucose, fructose and sucrose (Somasiri *et al*., 2008). As mentioned by Srinivasan *et al*. (2018), seeds of *Kithul* were found to be poor in fat, mineral, and protein. In addition to that, *Kithul* seeds contain 80–82% carbohydrates, 64% starch, 10-15% moisture, 1.5-2.5% ash, and 0.2-3.5% fibre. Furthermore, the oil extracted from *Kithul* seeds was found to be a potential source of biofuel (Preedy, 2010; Deepakkumar, 2016). Moreover, the results of a fatty acid profile of the extracted oil show that the *Kithul* seeds have a considerably higher level of palmitic acid (41.24%) and oleic acid (28.48%). Palmitic acid is mostly used to produce soaps and cosmetics at the industrial level and oleic acid is considered a healthy substitute for saturated animal fat due to having a low risk for coronary heart disease (Preedy, 2010). However, as per the World Health Organization high palmitic acid consumption can result in cardiovascular diseases due to increasing Low-density lipid (LDL) in the blood. In medicinal values, it is reported that *Kithul* seeds are a good source to treat boils (Fleming, 2007). In addition, Srinivasan *et al*. (2018) reported that using the KOH stimulant, the extracted oil from the seeds can be converted into bioethanol with a yield of more than 80%.

2.3 Fruit

The name *Caryota* is derived from the Greek word *Karyot* which means "like a nut." This refers to the small, harp palms of the trees. *Urens* translates as "burning" and is associated with, the outer shell of the fruit (McCurrach, 1960) which irritates the skin due to the presence of oxalic acid (Tekula, 2016).

Shivprasad *et al*. (2016), investigated the nutritional values of fruits of six wild edible plants including *Kithul* using bromatological analysis. The study found that *Kithul* fruits have higher dry matter (37.9±0.50% FW) and less moisture (62.1±0.50% FW, and total sugar (0.29±0.00% DW) content when compared to other tested species *(Bauhinia recemosa Lam, Gmelina*

Table 1. Comparison of nutritional values of wild edible plants

Parameter	*Caryota urens*	*Gmelina arborea*	*Bauhinia recemosa*	*Zanthoxylum rhetsa*	*Oroxylum indicum*
Non reducing sugar (g/100 g of DW)	0.1072	0.053	0.0161	0.0558	0.0556
Reducing sugar (g/100 g of DW)	0.1872	0.2041	0.203	0.1836	0.1558
Total sugar (g/100 g of DW)	0.2944	0.2572	0.2193	0.2375	0.2102
Starch (g/100 g of DW)	0.8772	0.969	1.1045	1	0.9576
Total carbohydrate (g/100 g of DW)	1.1716	1.2335	1.3238	1.258	1.1766
Energy (kcal/100 g of DW)	19.5657	20.59	22.1074	20.674	19.6492
Crude protein (g/100 g of DW)	3.125	2.4375	1.375	4.518	4.1612
Moisture (% in fresh weight)	62.1	94.2	76.3	89.4	77.9
Dry matter (% in fresh weight)	37.9	5.8	23.7	10.6	22.1
Crude fat (% in DW)	1.5	1	0.9	3.8	2.3
Crude fiber (% in DW)	7.93	7.68	7.69	6.23	8.84
Total ash (% in DW)	10.39	18.16	6.24	6.34	9.4

DW: Dry Weight Basis
Source: Shivprasad *et al*. (2016)

arborea Roxb, Zanthoxylum rhetsa (Roxb.) DC, Commelina benghalensis L., Smilax zeylanica L., Oroxylum indicum (Table 1).

Antinutritional factors of *kithul* fruit have been identified by Mahadkar *et al.* (2012) which is important when producing food products and livestock feed. Anti-nutritional factors are compounds that decrease the supply of at least one nutrient either by themselves or through their metabolic products when present in food, animal feed or water (Yacout, 2016). According to Fekadu and Ratta (2014), oxalate, phytate, tannin and saponin are in charge of reducing the rate of growth, feed efficiency, intake feed amount and digestibility of protein in experimental animals. Mahadakar *et al.* (2012) revealed *Kithul* fruit also contains oxalate, phytate, tannin and saponin as the major antinutritional compounds. However, they further reported that levels of identified antinutritional compounds are below the toxic level for human consumption.

2.4 Leaves

Muhaisen (2014) found flavonoids named 5,7-dihydroxy, 4-O-methylflavone and Sorbifolin 6-O-glucoside contained in *kithul* leaves which can reduce the occurrence of many diseases, inhibit cell damage, repair the DNA mechanism and reduce oxidative stress. The only palms with bipinnate leaves are *Caryota species.* Fishtail palm derives its name from the shape of its leaflets, which resembles the tail of a fish (Ahmad *et al*., 2020). *Kithul* leaves are used as a roofing material in huts, and the leaves are turned into a fibrous rope (Kumar *et al*., 2012; Tekula, 2016). Strong fibre made from the leaves is used to produce brushes and baskets (Tekula, 2016). Since they are recognized as strong and high-quality brush fibre, this fibre has higher demand in the export market. In Kerala, *Kithul* leaves are commonly used to feed domesticated elephants (Kumai and Rajyalakshmi, 2000).

In addition to the above-mentioned plant parts, since ancient time, *Kithul* bark and the stem apex has been used in treating boils (Srinivasan *et al*., 2018). Furthermore, the apex of the stem can be consumed when cooked and the root of the *Kithul* palm is useful to cure tooth ailments. Other than its nutritive values, Krishnan *et al*. *(*2019) found that *Kithul* fibre taken from the outer sheath of bark is having favourable biological, chemical and physical properties on brake pads of vehicles.

2.4 Flour

Palm trees are found to be a perfect source for starch production (Ishizuka *et al*., 1995). Flour extracted from rice, wheat and maize, offers suitable raw material for the processing of starch and sweeteners which can be used in the food and beverage industry (Zehr *et al*., 1995; Radosavljević, 2002). Recently, there are many pieces of research carried out to uncover the potential underutilized sources of flour, and *Kithul* was found to be a welcoming candidate in the food industry. Therefore, the chemical, physical and nutritional properties of *Kithul* flour have been investigated (Wijesinghe *et al*., 2015a). *Kithul* flour has immense potential to be used in the food industry due to its improved gelling property with other practical uses. According to Wijesinghe *et al*. (2015a), *kithul* flour is a rich source of carbohydrates (87.5 g/100 g dry basis) and minerals such as calcium (70.1 mg/100 g dry basis), magnesium (66.6 mg/100 g dry basis), potassium (59.5 mg/100 g dry basis) and Sodium (56.7 mg/100 g dry basis).

Wijesinghe *et al*. (2015b) investigated bulk density,

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gelatinization temperature and gelatinization enthalpy of *Kithul* flour. According to them, the bulk density of *Kithul* flour was investigated as 0.69 g/cm^3, and further, they found that *Kithul* flour has a higher bulk density than cornflour (0.51 g/cm^3). Flours with relatively high densities are being used as thickeners in the food processing industry. It is an important factor to determine the packaging, material handling and utilization in wet processes. Thus, by considering bulk density, *Kithul* flour can be used as a thickening agent in the food processing industry. Moreover, the high bulk density of *Kithul* flour has also made it an ideal stabilizing agent for baking powder and an emulsifying agent in the food processing industry.

Starch gelatinization is the process of permanent degradation of the molecular order of starch granules where the crystallinity of starch structure will be destroyed (BeMiller, 2018). Compared to corn starch, *kithul* flour is having a slightly lower gelatinization temperature where the gelatinization temperature of corn starch was found to be 80°C (Varavinit *et al*., 2003) and that of *kithul* flour was reported as 76.74°C (Wijesinghe *et al*., 2015a). Therefore, it showed that gelatinization temperature and good gelling properties of *Kithul* could be achieved during cooking (Wijesinghe *et al*., (2015a). According to Wijesinghe *et al*. (2015a), a lower level of gelatinization temperature in *kithul* flour is mainly due to its higher amount of amylopectin (71.32%) where a low amount of energy is required to break up less amount of amylose content (28.42%) in *kithul* flour. However, as it was reported by Grace and Henry (2020), flour of Kithul, sago and starch of sweet potato are showing a higher gelatinization temperature compared to flour of red rice and starch of water chestnut. Nevertheless, according to them, maize starch-containing a higher proportion of amylose showed the highest gelatinization completion temperature. Moreover, Grace and Henry (2020), reported that the granule size (>25 µm) of *kithul* flour found to be a positive straight association with gelatinization entropy (6.1±0.9 J/g) which is expressed in the elevated entropy for *kithul* flour.

Furthermore, Grace and Henry (2020) have reported the structural properties of the gels from *kithul* flour, red rice flour, starch of sweet potato, starch of tapioca, sago starch and starch of water chestnut. According to them, *kithul* flour was found to be having the hardest and the significantly chewiest gel out of all the tested flour. Further, they have reported that all the gels are similar in terms of springiness. However, the gel formed from red rice flour was found to be noticeably brittle and was not chewy as other flour since it cracked when pressure was applied. This indicated week elastic qualities of red rice flour that makes it less suitable in bakery industry.

High demand for starchy foods with a low glycemic index (GI) can be seen as a result of increasing health issues, as these foods digest and metabolize glucose more slowly. This will increase blood glucose level slower and is beneficial for people suffering from diabetics. A study carried out by Grace and Henry (2020) revealed that *kithul* flour had a significantly low digestion rate ($p<0.05$) than red rice, sago, sweet potato, water chestnut, tapioca (excluding maize starch-containing high amylose), and consequently having a comparatively low GI. They further explain that the comparatively low glycemic index in *kithul* flour is mainly due to the presence of higher content of protein, amylose and dietary fibre. Moreover, the larger granule size of *kithu*l flour also affects the lower glycemic index of *kithul* flour.

Both industrially and traditionally, the *kithul* plant has been mainly used in getting both sap and flour, and accordingly, there are two types of *kithul* palm trees as tapped and non-tapped trees. Thus, a study was done by Wijesinghe *et al. (*2015b) to compare the nutritional values of the flour from tapped *kithul* trees and non-tapping *kithul* trees and the obtained results are summarized in Table 2.

Table 2. Nutritional values of flour of *Kithul* from tapped and non-tapping kithul trees

Type Parameter	Tapped	Non-tapped
Moisture content (%)	13.64±0.91	13.75± 0.35
Crude protein (g/100 g db)	1.10±0.17	1.21±0.08
Total fat (g/100 g db)	0.36±0.03	0.37±0.03
Crude fiber (g/100 g db)	1.22± 0.02	1.35± 0.32
Ash (g/100 g db)	0.43±0.08	0.377±0.11
Carbohydrate (by difference)	83.25± 0.28	82.94± 0.31
Amylose (g/100 g db)	28.45±0.18	28.40±0.30
Amylopectin (g/100 g db)	71.04± 0.18	71.60±0.30
Total starch (g/100 g db)	66.64± 6.58	67.00± 11.07

DW: Dry Weight Basis
Source: Wijesinghe *et al*. (2015b)

Findings from the above study proved that there was no significant difference in major nutritional properties between the flour extracted from tapped and non-tapped *Kithul* trees. Furthermore, this study revealed that tapped trees of *kithul* are also suitable for flour production to empower the *kithul* industry.

Kithul flour production is known as a process industry because it turns raw material (*kithul palm*) into a consumer-valued commodity (*kithul flour*) using a basic process. In rural areas of Sri Lanka, *kithul* flour is usually made by grinding the pieces of pith in a mortar with a pestle, washing with water through a screen and ultimately, the remaining flour is drying under the sun.

Nevertheless, the current supply is inadequate to satisfy the demand of the food industry either quantitatively or qualitatively due to the presence of a bundle of hygienic problems associates with the traditional process (Wijesinghe *et al*., 2018a).

Traditionally, flour manufacturing process, the flour gets clumpy and mouldy in a brief period of time, which resulted in a shortening of the storage time of the refined flour, while the flour that processed through a hygienic method tends to have a much longer shelf-life (Eastman, 1980).

3. Medicinal values of kithul palm

3.1 Antioxidant properties

Traditionally, *Kithul* palm sap is known to exhibit many health advantages such as anti-rheumatic, anti-inflammatory, and anti-hyperglycemic effects, and it is believed that these health benefits are mainly incorporated largely via its antioxidant effects (Ranasinghe *et al*., 2012). Antioxidants have the ability to delay or avoid the oxidation of other molecules, shielding cells from the harmful effects of reactive oxygen species released through natural oxidation reactions. Previous experiments have discovered that these antioxidant properties can help cure human disorders including Alzheimer's disease, Parkinson's disease, cancer, Down's syndrome, atherosclerosis, and ageing (Wimalasiri *et al*., 2016). Table 3 lists the antioxidant properties of extracts from different parts of the *Kithul* palm.

3.2 Antidiabetic property

It is known that *kithul* products are used in *ayurwedhic* medical treatments due to their anti-diabetic properties (Senavirathna *et al*., 2016). Alpha-amylase and α-glucosidase, the two major carbohydrate hydrolysis enzymes are the primarily responsible enzymes for developing diabetes since they are responsible for the hydrolysis of starchy food that increases the post-plasma glucose level. Thus, inhibitors of both α-amylase and α-glucosidase are beneficial as they delay post-plasma glucose levels by delaying carbohydrate digestion in diabetic patients. Ranasinghe *et al*. (2012) found that the sap and treacle of *Kithul* possess glucosidase inhibition activity and it proved the presence of anti-diabetic properties. Wimalasiri *et al. (*2016) investigated the anti-diabetic properties of dried methanolic extracts of *Kithul* using assays of α-amylase and α-glucosidase enzyme inhibition. They found that the percentage α- amylase inhibitory activity of raw and boiled flour of *Kithul* was 8.42±0.97% and 10.77±2.64% respectively. The results revealed that *kithul* flour both fresh and boiled, hold really weak inhibition activity for α-glycosidase enzyme up to 5 mg/mL concentration. And this concludes that *Kithul* flour did not possess any considerable anti-diabetic values.

3.3 Antimicrobial property

Azam *et al. (*2016) found minimum inhibitory concentration (MIC) of *Kithul* leaves against different pathogenic microorganisms using the disc diffusion method. He found that *Kithul* can be used as an antimicrobial agent for several bacteria and fungi (Table 4). In addition to that Charles and Ramani (2011) investigated the antimicrobial effect of extracts of *Kithul* flower using the agar well diffusion method, and found its efficacy against 20 different bacterial species (*Bacteroides fragilis, Bacteroides melaninogenicus, Bacteroides oralis, Bifidobacterium bifidum, Clostridium septicum, Clostridium tetani, Enterobacter sp., Enterococcus faecalis, Escherichia coli, Klebsiella pneumonia, Proteus mirabilis, Proteus vulgaris, Pseudomonas mutant streptococcus sp., Salmonella enterica, Shigella sp, Staphylococcus aureus, Yersinia*) and 6 different fungal species (*Aspergillus flavus, Aspergillus nidulans, Aspergillus niger, Aspergillus oryzae, Mucor, Penicillium sp,*). Moreover, they revealed that the *Kithul* flower extracts are showing high susceptibility to several microorganisms as shown in Table 4. Sharmin and Salekin (2020) revealed that highest inhibition zone (13.0 mm) was demonstrated by the soluble fractions of carbon tetrachloride against *Shigella dysenteriae* by, fruit extracts of *Kithul*. Similarly, Ananth *et al. (*2013) found that *Kithul* fruit extract is also showing some antibacterial effects. The effect of different parts of *Kithul* palm on the growth and activity of microorganisms is summarized in Table 4.

3.4 Anti-inflammatory property

It has been reported that flavonoids are important for human health because of their anti-inflammatory activities due to the free radical scavenging ability that protect cells from oxidative damage (Muhaisen, 2014).

For decades, the *Kithul* palm has been used in herbal medicine to combat inflammatory diseases. Umbelliferone and rutin 2 which containing in hydroalcoholic leaf extracts of *kithul* leaf possessed inhibition properties of rheumatoid arthritis by blocking TNF- alpha which is responsible for (Sujitha and Kripa, 2020) development and progression of cancers (Idriss and Naismith, 2000).

Furthermore, Vanaja and Kavitha (2017) used the protein denaturation approach against egg albumin to explore the anti-inflammatory function of the *Kithul* leaf extract. As a standard anti-inflammatory medicine,

Table 3. Antioxidant properties of different parts of *kithul* tree

Part	Extraction solvent	Assay method	Inhibition (%)	Value of antioxidant property	References
Flower	Ethanol	DPPH assay described by Gyamfi *et al*. (2002)	17.0		Charles *et al*. (2011)
		Hydrogen Peroxide method described by Umamaheswari and Chatterjee (2008)	53.0		
		Reducing power scavenging activity described by Yildirim *et al.* (2001)	44.0		
Leaves	n-Hexane	DPPH assay described by Ranasinghe *et al*. (2012)	74.12		Azam *et al*. (2016)
Flour		ABTS+ described by Re *et al.* (1999)		raw 0.02±0.01 mg TE/g flour) boiled 0.04±0.01 mg TE/g flour)	Wimalasiri *et al*. (2016)
		Ferric reducing antioxidant power described by Knuck *et al*. (2007)		raw 0.10±0.03 mg TE/g flour boiled 0.36±0.11 mg TE/g flour),	
		Oxygen radical absorbance capacity described by Ou *et al*. (2001)		raw 2.29±0.71 mg TE/1g flour boiled 192.3 ± 57.71 mg TE/1 g flour)	
		Ferrous ion chelating assays described by Carter (1971)		raw 0.03±0.01 mg EDTA equivalents /g flour boiled 0.14±0.04 mg EDTA equivalents /g flour)	
Fruits	Chloroform	DPPH described by Molynux (2004)	61.58		Md. Sahab Uddin *et al*. (2000)
	Carbon tetrachloride	Radical scavenging assay Molynux (2004)	42.30		
	n-hexane	Molynux (2004)	32.62		
Sap		DPPH by Blois (1958)		0.74 mmol TE/100 g	Ranasinghe *et al*. (2012)
		ABTS+ by Re *et al.* (1999)		1.4474 mmol TE/100 g	
		Ferric reducing antioxidant power by Knuck *et al*., (2007)		2.5474 mmol TE/100 g	
		Metal chelating assay (50% concentration) by Carter (1971)		6.02 mg/ml	

DPPH: 1,1-diphenyl-2-picrylhydrazyl, ABTS+: 2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt

Table 4. Antimicrobial effect on different plant parts on microbes

Plant part	Affected microorganism		References
	Bacteria	Fungi	
Leaves	*Bacillus cereus, Bacillus megaterium, Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa, Sarina lutea, Shigella boydii, Vibrio mimicus*	*Aspergillus niger*, *Saccharomyces cerevisiae*	Azam *et al*. (2016)
Flower	*Clostridium septicum*, *Proteus mirabilis*, *Proteus vulgaris*	*Mucor*	Charles and Ramani (2011)
Fruit	*Escherichia coli*, *Vibrio cholerae*, *Shigella dysenteriae*		Ananth *et al*. (2013)

Diclofenac sodium was used, and findings revealed that the anti-inflammatory medicine of standard possesses the higher inhibition of 82.78 per cent at the concentration of 400 µg/mL. Moreover, the higher inhibition percentage from *Kithul* leaf extract was observed as 62.6% at the concentration of 400 µg/mL. It has been reported that the presence of phenols, terpenoids, and saponins in *kithul* is related to its anti-inflammatory activity. Therefore, a study revealed that the anti-inflammatory function of *kithul* has been attributed to the existence of phenols, terpenoids, and saponins.

4. Value-added food products from kithul

Owing to its nutritional value, bioactive components and other specific physico-chemical properties, *Kithul* palm is having a huge potential in developing products in the food industry.

The starch stored in the trunk of the *Kithul* tree is the main edible food product of this palm. According to figures, the *Kithul* palm produces 24 tons of starch per hectare per year, while rice-producing was only 6 tons of hectare per year. On the other hand, 5.5 tons/hectare of corn is produced while the starch production of potato is about 2.5 tons/hectare (Shoon, 2000). Generally, the trunk of *kithul* palm produces around 100-150 kg of pith per palm from which the flour is made. The flour from Kithul is claimed to be of a similar consistency to the best commercial sago obtained from Metroxylonmsagu Rottb, and it is coveted for its body-cooling properties (Council of scientific, 1992). Further sago is reported as resistant starch which passes the digestive tract undigested and feeds the gut bacteria and produces short-chain fatty acids which benefit health in lowering blood sugar level, reducing appetite and improving digestion (Nugent, 2005; Patel *et al*., 2010; Tan *et al*., 2014; Gill *et al*., 2018).

Kithul can be used to replace more costly imported starches in a variety of foods, including pasta, sauces, dry mixes, flakes, chips, and baby foods (Suwanliwong, 1998).

4.1 Biscuits

As reported by Kumai and Rajyalakshmi (2000), *Kithul* flour can be incorporated up to 60% in the preparation of biscuits. Furthermore, they reported that the incorporation of *kithul* flour in biscuit preparation will reduce the fat requirement in biscuit. However, they found that the reduction of fat requirement will not badly affect the sensory properties of the developed biscuit. Moreover, a study conducted by Tanuja and Rajyalakshmi (2004) revealed that *in vitro* starch digestibility of biscuits prepared by incorporating 60% *kithul* flour is 9.4%.

4.2 Noodles

A study by Sowbhagya and Zakiuddin (2001) investigated that incorporation of *kithul* flour has enhanced the quality through uniform appearance, translucency, mechanical strength, non-sticky nature, attractive surface colour, and the texture of noodles. According to Kumai and Rajyalakshmi (2000), proper quality noodles which having more elasticity, more firmness with less swelling power with less brittleness can be made when potato flour is mixed with 35% *Kithul sago*. Furthermore, Tanuja and Rajyalakshmi (2004) discovered that *kithul* sago noodles (62.9%) had substantially higher ($p<0.05$) *in vitro* starch digestibility than *kithul* sago gel (32.2%) and *kithul* sago biscuits (9.4%).

4.3 Bread

As it is reported by Dissanayaka (2015), bread has been developed successfully by incorporating 25% *Kithul* flour with wheat flour, and the nutritional composition revealed that the final product is consist of 55.3% carbohydrate, 34.08% moisture, 7.61% crude protein, 1.34% ash, 0.48% total fat, and 0.4% crude fibre content. Moreover, the authors have revealed that when compared to the normal wheat flour bread, the *Kithul* flour incorporated bread is rich in essential minerals such as Mg (503.39 ppm), Ca (426.45 ppm), Na (281.30 ppm), K (106.80 ppm), Fe (42.40 ppm), and Zn (36.80 ppm). Thus, it can be concluded that bread incorporated with *Kithul* flour is a better energy source of minerals and protein. Furthermore, they stated that there is no threat of cholesterol in the developed *Kithul* flour incorporated into bread due to its low-fat content. However, in contrast, the developed product is low in fibre. In addition, the developed bread can be kept for a period of 36 hrs and 48 hrs without any added preservative either without wrapping or wrapping with low-density polyethylene respectively.

4.4 Kithul in production of muffin, rotti, and porridge

Senavirathna *et al*. (2016) investigated the Glycemic Index (GI), proximate content, factors influencing GI for food products made using *kithul* flour, sago palm (*Cycas circinalis*), and *Hal* (*Vateria copallifera*). Accordingly, *pittu* and *rotti* were made using all 3 flour types. Additionally, porridge and muffin were also made using all three flour types. It is proved that muffin made from *kithul* flour has higher fat (27.5±1.1 g/100 g edible food's fresh weight) content when compared to other products. Digestible carbohydrate content was also found to be higher in *kithul rotti* (44±1.8/100 g edible food's fresh weight) compared to sago palm *rotti* (37.2±1.0 g/100 g edible food's fresh weight). Compared to white bread, *rotti* made with *kithul* and sago palm, and pittu prepared by *hal* were identified foods as low GI values. Furthermore, sensory analysis proved that all the above flour varieties including *kithul* have a high potential to be used as an alternative for wheat or rice flour.

4.5 Dessert

Wijesinghe *et al.* (2014) found that *kithul* flour can be used as a gelatinizing agent for fruit-based desserts. Currently, most of the jelly type deserts available in the market are made out of animal-based gelatin, (Shyni *et al*., 2014), and this has become a major constrain for most consumers to consume such deserts. Separated Wood apple fruit pulp was mixed with sugar, salt and *kithul* flour, and then the mixture was heated while mixing at 80 – 90°C until gelling properties appears. After heating, 30 mg of Potassium sorbate was added and filled the clean cups after mixing toughly. Among several samples, 1:1.5 flour: pulp of the fruit ratio showed the best performance for sensory evaluation, microbial analysis (2 months shelf life) pH (4.0) and 30° brix and the proximate analysis (262.28 kcal from 100 g of product). *Kithul* flour has better gelling property-owning least gelation concentration of 6% which is the lowest protein concentration at which gel remained in the inverted tube (Wijesinghe *et al*., 2015a). Thus, *kithul* flour can be used as an alternative for a gelatinizing agent.

4.6 Drinking yoghurt

Wijesinghe *et al.* (2016, 2018b) investigated the influence of modified *Kithul* flour as a stabilizer on the nutritional and physical properties of drinking yoghurt. Milk heated up to 45°C was inoculated with a starter culture (50 U in 400 L of milk), and the samples were allowed to incubate for 6 hrs and 30 mins at 43°C. The fermentation process was stopped when the pH of the mixture has reached 4.6, then the yoghurt samples were cooled and stored at 4°C. According to the obtained results modified *Kithul* flour gave better results for syneresis, viscosity and for all sensory attributes apart from colour. Additionally, drinking yoghurt made by *Kithul* has higher fat (3.55±0.26%), crude fibre (0.18±0.03%) and solid non-fat (9.83±1.15%) compared to the control drinking yoghurt prepared without adding *Kithul* flour (fat 3.01±0.18%, crude fibre 0.06±0.01%, solid non-fat 7.33±0.58%). Thus, *Kithul* can be successfully used as a stabilizer in the preparation of drinking yoghurt where *Kithul* will enhance the texture of drinking yoghurt due to its gelling properties.

4.7 Kithul flour porridge

Kithul flour can be successfully used in making porridge as an alternative to breakfast as well as to cure some illnesses that occurred due to "*Sem*" and "*Pith*" imbalance. In addition to that, traditional medicine uses *kithul* flour in treating stomach ulcers, headaches, high blood pressure, snake bites, and rheumatic inflammation (Kuhanneya *et al*., 2016). As it is reported by Kuhanneya *et al*. (2016), cinnamon flavoured porridge powder having a low temperature of gelatinization and enhanced biological properties was developed utilizing *Kithul* flour, where cinnamon is used as a flavouring agent and also an anti-diabetic agent.

4.8 Jelly and jams

Kithul flour has the potential to produce a gel that can be used in the production of jams and jelly. In addition, In the food industry, *kithul* flour is being used as a thickening agent, a stabilizer in baking powders, and an emulsifier. (Wijesinghe *et al*., 2015a).

4.9 Other uses of kithul

Kithul seeds have an oil content that can be extracted by bullock ghani like techniques, thus it could be used effectively in the production of biodiesel (Karthika *et al*., 2012; Girisha *et al*., 2014). As a potential fuel, biodiesel made from non-edible plants can compete commercially with petroleum diesel fuels. Bio-oil was derived from non-edible Kithul seeds by the extraction of Soxhlet using hexane as a solvent. The results indicated that the extracted bio-oil was 21.57% and the bio-oil extracted was classified by GC-MS, which showed palmitic and oleic acids to be the dominant fatty acids. In addition, the harvested bio-oil from plant seeds was processed into biodiesel using a KOH stimulant and the biodiesel yield was estimated to be 82%.

5. Conclusion

Kithul is a multipurpose plant owning a wide range of medicinal, nutritive and commercial values. The antioxidant, antidiabetic, anti-microbial and anti-inflammatory properties of different parts of the *kithul* palm remark its medicinal values. Despite its medicinal values each part of the *kithul* palm (sap, seeds, fruits, leaves and flour) has its nutritive values, and it makes *kithul* a functional ingredient in preparing many types of functional foods. Nevertheless, the *kithul* fruit is a potential source of anti-nutrients such as oxalate, tannin, saponin and phytate. However, the amount of antinutritional substances present in the *kithul* fruit has been found to be not harmful for livestock consumption. *Kithul* treacle, toddy, jiggery made from *kithul* flower sap and porridge powder and *kithul* flour obtained from the *kithul* pith are some of the most commercially valued products taken from *kithul* palm. *Kithul* flour has good gelling properties and is rich in carbohydrates, calcium, magnesium, potassium and sodium. Hence, products such as drinking yoghurt, cinnamon-flavoured porridge powder, muffin, roti, dessert, biscuits, bread noodles, jelly and jams made from *kithul* flour can be considered as nutritious value-added food products for developing countries like Sri Lanka.

Conflict of interest

The authors declare no conflict of interest.

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