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Physicochemical and Nutritional Characterization of Palmyrah (*Borassus flabellifer* L.) Pith Waste: A Study to Explore Potential Agricultural and Industrial Applications

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ABSTRACT

Purpose: *The palmyrah fibre industry generates a large number of wastages during the production process, and the wastages have not been utilized in a proper way. The combustion of those wastages may result in environmental issues. This study aims to analyze the physicochemical properties of palmyrah pith developed from palmyrah fibre production line waste to be utilized in the future for agricultural and industrial applications.*

Research Method: *The palmyrah wastages from the fibre production line from all the regional centres in the Jaffna peninsula were collected and washed. The dried waste was ground using a laboratory motor mill and sieved using a laboratory sieve shaker, and the palmyrah fibre pith was packed in a stainless steel container for further analysis.*

Findings: *Palmyra pith exhibited total ash of 15.6 g/100g, total carbon of 48.96 g/100g, and total organic matter of 84.4 g/100g. The nutritional content of the pith was nitrogen 1.90 mg/g, phosphorous 0.015 mg/g, sodium 0.621 mg/g, potasium 0.311 mg/g, calcium 3.196 mg/g, magnesium 1.918 mg/g and iron 0.014 mg/g. Physiochemical properties of the palmyrah pith were determined as pH 5.64, EC 0.586 dS/m, bulk density 0.241 g/cm3, particle density 0.60 g/cm3, total porosity 59.9%, water retention capacity 15%, C: N ratio of 259:1, and moisture content of 12%*

Originality/ Value: *This research paves the way for the utilization of palmyrah wastages in agricultural and industrial applications.*

Keywords: *Palmyrah fibre wastages, palmyrah pith, physiochemical properties and nutritional composition, waste utilization*

INTRODUCTION

Palmyrah (*Borassus flabellifer* L.) palm commonly grows in the north and east parts of Sri Lanka. The palm is known to be a tree of life, so all of its parts are used to produce valuable products. Palmyrah fibre is produced from the leaf sheath of the palmyrah tree, and the fibre is known to be hard and stiff. In addition to that, it is considered to be resistant to alkali and acidic treatment, so it is mostly used to prepare scrubbing brushes for sanitary purposes and road cleaning brushes at both the domestic and industrial levels (Palmyrah Development Board, 2018). Moreover, the palmyrah fibres proved to be used as a filler in natural rubber vulcanizate (Nwabanne *et al*., 2014).

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The basal sheath of palmyrah leaf is known as '*KankuMattai*' in Tamil and is used to produce palmyrah fibre. To harvest the basal sheath, the palmyrah tree leaves should be cut off from the 5 to 10-year-old palmyrah palms from the base to the upward direction in an orderly manner. Harvesting leaves once every two years is preferred to get a stiff palmyrah fibre. After the removal of the leaves, the dried leaf sheath left on the palm is known as "Riot' which is used to extract the fibre (Palmyrah Development Board, 2018).

The fibre extraction from the palmyrah leaf sheath is carried out by the regional fibre processing centres on the Jaffna peninsula. Dry leaf sheaths, or riots, were soaked into the water and beaten by wooden mallets, and they were bundled according to their length. The bundle was then subjected to the loosening process. Loosened fibres were combed on steel spikes and bundled again based on their size. The bundles were trimmed using a heavy knife to maintain uniformity. Fibres were then dried on a cemented floor, pressed using 50 kg bales, and packed (Palmyrah Development Board, 2018).

During the bundling, loosening, sizing, and trimming processes of palmyrah fibre, a considerable amount of waste is generated, which includes short-length fibres and sheaths remaining. Removal of these wastages is known to be difficult, and the combustion of these wastages may cause environmental issues; thus, there is a need for converting the wastages into a value-added final product without environmental issues. Therefore, this study aims to analyze the physicochemical properties of palmyrah fibre waste. It will be a base for further research on palmyrah fibre wastage and generating value-added products from the waste of the palmyrah fibre industry, and at the same time, this research will disseminate adequate knowledge about the properties of the fibre waste for innovative applications.

MATERIALS AND METHODS

Preparation of Palmyrah Fiber Pith

Wastes from fibre production lines (Figure 01) from all the fibre-producing regional centres in Jaffna were collected, washed to remove impurities, and dried. The dried wastes were ground using a laboratory motor mill. The grounded fibre pith (Figure 02) was sieved using a laboratory sieve shaker (Model OrtoAlresa, 0.71 mm mesh size), and the palmyrah fibre pith was collected and packed in a stainless-steel container for further analysis.

Determination of Total Ash Content

Ash content of the palmyrah fibre pith was measured according to the official method of analysis Association of Official Analytical Chemists (AOAC) International (2019), 21st edition.

Figure 01: Waste generated from the Palmyrah fibre industry

Figure 02: Palmyrah fibre pith (before sieving) produced from the fibre production line wastage.

Determination of Total Organic Matter and Organic Carbon

Total organic matter (%) and total organic carbon (%) were calculated based on the following equations (Anon, 2016).

Total organic matter % = 100.00 – total ash

Total organic carbon = Total organic matter/1.724

Determination of Nutrient Content

Nutrient analysis and their testing methods are given in Table 01.

Determination of Physicochemical Properties

pH: Palmyrah fibre pith (50 g) was mixed with distilled water (100 mL) and allowed to equilibrate for 30 minutes, and the pH of the filtrate was measured using a calibrated digital pH meter (Model:Trans benchtop digital pH meter, made in Germany).

Electrical conductivity: Twenty grams of palmyrah fibre pith were mixed with 100 mL of distilled water and kept for one hour with stirring at regular intervals. Electrical conductivity was measured using a conductivity meter (Thermo Scientific EUTECH PC 450) after the calibration.

Water-holding capacity: A hundred millilitres of water were added to a hundred milligrams of palmyrah fibre pith packed in a funnel and kept undisturbed until no more water drainage was observed. Water holding capacity was calculated by subtracting the volume of filtered water from the initial volume of water added (Wang *et al*., 2012).

Bulk density: Palmyrah fibre pith was oven-dried. Oven-dried fibre pith was filled into a pre-weighed 250 ml measuring cylinder. Sample weight and volume were measured, and the bulk density was determined by using the following formula (Kalaivani and Jawaharlal, 2019).

Bulk density = weight of the sample/ volume of the sample

Particle density: Palmyrah fibre pith was oven-dried and filled into a pre-weighed measuring cylinder up to a known volume, and the weight was again noted. Distilled water was slowly added along the inner wall of the measuring cylinder until the fibre pith got saturated and the increase in volume was measured. Particle density was calculated by using the following formula (Kalaivani and Jwaharlal, 2019).

Particle density = weight of the sample/ (Volume of fibre dust – pore space volume)

Table 01: Nutrient analysis and their testing methods.

Nutrients analyzed	Method of analysis
Total Nitrogen	Determined according to the official method of analysis AOAC international (2019), 21st edition using the Kjeldahl method.
Phosphorous	Determined according to the official method of analysis AOAC International (2019), 21st edition, using a photometric method with a UV-Vis spectrophotometer.
Sodium and potassium	Determined according to the official method of analysis of AOAC International (2019), 21st edition, using flame photo spectrometer.
Iron	Measured using the spectrometric method (Jankiewicz, et al. 2002)
Calcium and Magnesium	Determined using the EDTA titration method (Tucker and Kurtz, 1961)

Where pore space volume = (Volume of fibre dust + volume of water added)-Volume of fibre dust +water at the end of the experiment.

Porosity (%): Porosity was calculated according to the formula given by Murumkar *et al* 2013.

*Porosity (%) = [1- (bulk density/particle density)] *100*

Moisture content: Moisture content was measured using an oven-dried method (AOAC International, 2019)

Evaporation rate: Oven-dried palmyrah fibre pith was weighed, saturated fully with distilled water, and kept under monitoring. The weight of the fibre pith was measured every single day, and the evaporation rate was calculated for five days (Kalaivani and Jawaharlal, 2019).

C: N ratio: The ratio was calculated by using the following equation.

C: N = Total organic carbon: Total nitrogen

RESULTS AND DISCUSSION

Total Ash, Total Organic Carbon, and Total Organic Matter of Palmyrah Fiber Pith

Ash content, total organic carbon, and total organic matter content of palmyrah pith produced from the wastages of the palmyrah fibre production line are shown in Table 02. The utilization of fibre wastages as a soil amendment can be taken into consideration as it exhibits 48.9 g/100 g of total organic carbon, which is stated to be a vital part of the soil system and affects many physiochemical properties of the soil, including water infiltration ability, water-holding capacity, nutrient availability, and the biological properties of the soil, including the microorganisms and their activity (Yantai *et al*., 2013). The studies revealed that the total organic carbon content of raw coconut pith is nearly 29% (Ramamoorthy *et al.,* 1999) whereas the organic carbon and organic matter content of light peat were reported as 62.8%, 36.42%, respectively, and vermiculture was reported as 1.1%, 0.64%, respectively, by Sabahy *et al* (2015). These results support the fact that, comparatively, the organic carbon content and organic matter content were highest for raw palmyrah fibre pith, and it can be taken into consideration to be utilized as a soil amendment with further research.

However, these attributes can also be taken into consideration when using the palmyrah fibre waste as a raw material to produce biochar or activated carbon; thus, the raw material used for the production of activated carbon or biochar is preferred to be high in carbon content and low in inorganic content (Azbar *et al*., 2004; Rafatullah *et al*., 2013). Inorganic content indicates the mineral content of the sample (Doug, 2009).

Nutrient Profile of Palmyrah Fibre Pith

The nutrient profile of the palmyrah pith exhibited a higher amount of nitrogen, calcium, magnesium, and nitrogen compared to other elements. However, the pith consisted of potassium, phosphorous, sodium, and iron in relatively lower amounts (Table 03). According to Epstein (1965), the typical concentrations of nutrients that are sufficient for plant growth are reported as follows: nitrogen (15 mg/g), phosphorous (2 mg/g), potassium (10 mg/g), magnesium (2 mg/g), calcium (5 mg/g) and iron (0.1 mg/g) (Epstein, 1965).

Considering the above fact, the palmyrah pith nutrient content is lower than the suggested level in all the mentioned nutrients; therefore, it can be suggested that mixing palmyrah pith with soil or other growing media would be better than using palmyrah pith alone as a growing medium, and further research should be done in this particular regard. At the same time, the nutritive value of raw coconut pith was reported as follows by Joshi and others; nitrogen (0.26%), phosphorous (0.01 %), potassium (0.78 %), calcium (0.40 %), magnesium (0.36 %), and iron (0.07 %) (Joshi *et* *al*., 2013). These amounts are not at a sufficient level for plant growth, as mentioned by Epstein (1965). Comparing the nutritive value of raw coir pith (Joshi *et al*., 2013) with the results of raw palmyrah pith (Table 03), it is more or less similar except for potassium content, where raw coconut pith exhibited a higher potassium content than raw palmyrah pith. Conversely, the same research findings by Joshi et al (2013) revealed that composting raw coir pith increases the above nutritive values as follows; nitrogen (1.24%), phosphorous (0.06%), potassium (1.20 %), calcium (0.50%), magnesium (0.48%) and iron (0.09%) which are considered sufficient for plant growth. Hence, the feasibility of techniques like composting needs to be researched on palmyrah raw pith to increase the nutritive value for plant growth.

Physiochemical Properties of Palmyrah Fiber Pith

The pH of the palmyrah raw pith is 5.64 (Table 04), and the pH plays a vital role in nutrient availability when using it as a growing medium. Lower pH is not suitable as the mobility of micronutrients increases at low pH and the plants absorb them in excess, which causes toxicity in plants. In contrast, a higher pH decreases the mobility of micronutrients and thus prevents their absorption by plants resulting in micronutrient deficiencies (Pennisi and Thomas, 2005). It is reported that the ideal pH range of crops varies from 5.5 to 6.5 (Oshunsanya and Saurabu, 2018; Landis, 1990; Bunt, 1988). Coconut raw pith was reported to be in the pH range of 5.4 to 5.8 in un-retted form and 5.6 to 6 in retted form (Anon, 2016), and the pH of coco pith as a soilless medium was reported as 6.23 (Anbarasu and Gurusamy, 2021), which is in the ideal pH range (5.5 – 6.5) for plant growth. The pH of raw palmyrah pith also falls within the ideal pH range of growing media, though the pH is considered moderately acidic (Oshunsanya and Saurabu, 2018)). It is stated that phosphate ions tend to react with iron at low or acidic pH, resulting in insoluble compounds (Jensen and Thomas, 2010), which might be the reason behind the lower availability of phosphates and iron in raw palmyrah pith (Table 03). The moderately acidic nature of palmyrah coir pith may have the potential to be used as a soil amendment to reduce the pH of alkaline soils. However, depending on the plants to be grown, the suitability of palmyrah raw pith to be used as a soilless medium needs to be researched further.

Table 02: Total ash, total organic carbon, and total organic matter of palmyrah fiber pith. (n=12)

Parameters tested	Amount presents (g)in hundred grams
Total ash	15.60 g
Total organic carbon	48.96 g
Total organic matter	84.40 g

(values were expressed as mean of the replicates. (n= 12)

Table 03: Nutrient profile of palmyrah fibre pith.

Parameters	Amount in mg/g	Amount in % (Approximate)
Nitrogen	1.900	0.2
Phosphorous	0.015	0.0
Sodium	0.621	0.1
Potassium	0.311	0.0
Calcium	3.196	0.3
Magnesium	1.918	0.2
Iron	0.014	0.0

(values were expressed as mean of the replicates (n=12)

Table 04: Physiochemical properties of Palmyrah fibre pith.

Parameters	Amount
pH	5.64
Electrical conductivity	0.586 dS/m
Bulk density	0.241 g/cm^3
Particle density	0.60 g/cm^3
Total porosity	59.9 %
Water retention capacity	15 %
C: N ratio	259:1
Moisture content	12.3%

(values were expressed as mean of the replicates n=12)

Electrical conductivity is another important parameter for soil amendment and soilless media, as it reflects the salt concentration of the substrate (Robert, 2022). The most acceptable and satisfactory level of the EC content for the soilless medium is stated to be less than 3.5 dS/m (Jeyaseeli and Samuel, 2010). However, the studies stated that the EC content of soilless media lower than 0.29 dS/m is very low for plant growth (Jayaseeli and Samuel, 2010). The palmyrah pith showed 0.586dS/m (Table 04), which is above the lower limit stated by Jeyaseeli and Samuel (2010) for plant growth. The ideal EC content of the coconut pith is stated as 0.2 to 0.5 dS/m (Jeyaseeli and Samuel, 2010).

The bulk density of the palmyrah raw pith is considered the weight of a unit volume of dried pith including the pore space, whereas particle density is the mass of a unit volume of dried pith excluding the pore space (Bache et al, 2008). The bulk density of the palmyrah raw pith is 0.241 g/cm^3, the particle density is 0.6 g/cm^3 and the porosity of the pith is 59.9 % (Table 4). The ideal bulk density and porosity of the growing medium were stated as 0.19 to 0.7 g/cm^3 and 50 to 85%, respectively, by Pardossi et al (2011). Conversely, the ideal bulk density of the growing medium consists of vermiculture and perlite, reported as 0.1 g/cm^3 by Nelson (1985). The bulk density and porosity of coconut coir pith have been reported as 0.08 to 0.15 g/cm^3 and 95 %, respectively (Evans, 1996; Pardossi *et al*., 2011), and compared to this finding, palmyrah raw pith showed a higher bulk density (0.241 g/cm$^{3)}$ and low porosity (59.9%) (Table 04) than coir pith. The bulk density and porosity share a negative relationship (Jeyaseeli and Samuel, 2010), which might be the reason behind the higher bulk density and low porosity of palmyrah coir pith. At the same time, higher bulk density was reported to decrease the macropores and increase the mesopores and micropores of the medium (Ashokkumar *et al*., 2020), which may obstruct the root growth and penetration. However, the higher bulk density provides strong anchorage to the plant and mechanical support. The porosity of the palmyrah raw pith is 59.9 % (Table 04) and within the ideal range to be used as a growing medium (Pardossi *et al*., 2011) but comparatively lower than coconut pith (Evans, 1996). At the same time, the water retention capacity of the palmyrah raw pith is too low (15%) to be used as a growing medium compared to coir pith, which is reported as 40% by Paramanandham *et al*. (2014). It is reported that increasing the size of the pith particle will reduce the water retention capacity (Jayaseeli and Samuel, 2010). The mesh size of 0.71mm was used to prepare the palmyrah pith, which might be the reason behind the low water holding capacity. The evaporation rate of palmyrah raw pith was expressed as a graph (Figure 03), where the evaporation rate was increasing with days, which supports the fact that palmyrah pith has a low water retention capacity. The raw palmyrah pith exhibited low moisture content (12%) (Table 04), whereas the coir pith was reported as containing 20-40 % moisture content (Anon, 2016). However, to be used as a growing medium, mixing organic matters/ compost with palmyrah or producing palmyrah pith with a smaller particle size may improve the water holding capacity of raw palmyrah pith.

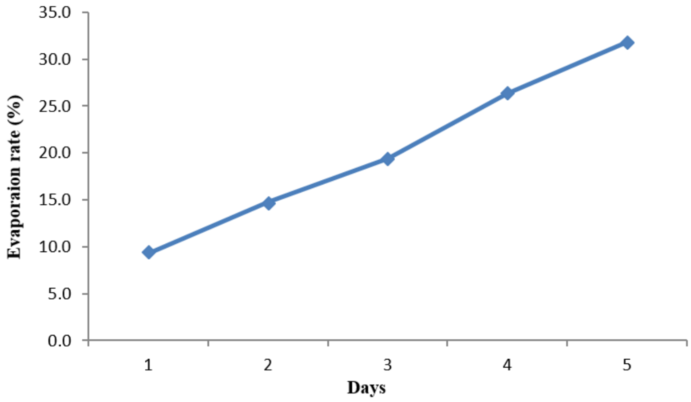

Figure 03: **Evaporation rate of moisture in palmyrah fibre pith.**

The C: N ratio is the parameter that expresses the number of carbon presented relative to the number of nitrogen. In the case of palmyrah raw pith, it is 259:1 (259 carbon is available for 1 unit of nitrogen) (Table 04), which is considered to be too high. The C: N ratio of raw coconut pith was reported as 112:1, and the biodegraded coir pith was reported as 24:1 after an effective composting (Anon, 2016). The ideal C: N ratio was reported as 24:1 (Howell, 2005). A lower C: N ratio will cause the quick release of nitrogen for plant use, and a higher C: N ratio will result in the utilization of nitrogen by the microbes and thereby the immobilization of plant nutrients. A higher C: N ratio will also result in a very slow degradation or a prolonged composting span (Anon, 2016) (Christos *et al.*, 2017). Therefore, it is suggested not to apply raw palmyrah pith directly (C: N = 259:1) as a growing medium that causes immobilization of plant nutrients; instead, effective and efficient composting or biodegradation should be done on palmyrah raw to be used as a growing medium.

CONCLUSION

The raw palmyrah pith is a fertile source with a high C: N ratio, organic carbon, bulk density, an acceptable level of porosity and electrical conductivity, and a low water retention capacity. Even though it has the potential to be used as a growing medium, biochar, and raw material for industrial applications, some parameters should be amended to an acceptable level. Further research should be needed to raise all the parameters to an acceptable level and to check the feasibility of using raw palmyrah coir pith as a raw material for industrial and agricultural applications.

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