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Exploring the nutritional profiling and health benefits of Palmyra palm haustorium

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ABSTRACT

The Palmyra tree has its own cultural, nutritional, and medicinal values from ancient times. Every part of the tree is useful either in its native form or a modified form, though the seeds is generally neglected by people as a waste and are not utilized. The current study is conducted with the germinated seed embryo of Asian Palmyra palm (*Borassus flabellifer*) termed as Palmyra haustorium (PH). The nutritional, phytochemical, and nutraceutical aspects were evaluated to explore the pharmacological significance of three different samples prepared from Palmyra haustorium (PH) i.e., Palmyra haustorium powder (PHP), Palmyra haustorium milk (PHM) and Palmyra haustorium milk extracted cake powder (PHMCP). The PHP is found to be superior in all nutritional aspects compared to other samples analyzed in the study. Proximate analysis of PH samples has shown that it is rich in carbohydrates, protein, and fiber but negligible in fat while PHMCP is a greater source of fiber content. Mineral analysis has shown that PHP is rich in Potassium and Phosphorus, moderate in Calcium and Sodium levels, whereas PHMCP is rich in Iron. High-performance liquid chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GCMS) analysis showed the presence of different phenolic compounds like Gallic acid and chlorogenic acid in all PH samples; similarly various phytochemicals such as Clindamycin, Sucrose, Hexadecanoic acid, Myristic acid were present in these samples. Functional groups present in samples were identified as aldehydes, primary amines, alkanes were carried out by Fourier transform infrared (FTIR) spectroscopy. The results depict that the germinated seed embryo of Palmyra palm is rich in macro and micronutrients that act as nutraceuticals in enhancing the human health and well-being. Also these products may help in mitigating the effects of malnutrition, prevalent among the vulnerable population and PHM can be an alternate nutrient for individuals susceptible to digest lactose.

1. Introduction

Plants and trees play an important role in improving human life and are predominantly the main diet for more than 5 billion people in the world today (Jez, 2020). From the ancient time, the Palmyra palm possess great commercial and therapeutic uses that has been exploited as a source of food and as a folklore medicine to mitigate micronutrient deficiency and the fruits are used as an aperient among the rural population (Ghosh et al., 2012). Apart from the edible purpose the tree is used in construction to act as a scaffold, the leaves are used for thatching to make a shelter and the petiole part of the leaves can be used for making ropes. Also, the tree has religious values like the leaves and fruits are hanged on doorways in ceremonial occasions and marriages (Jana and Jana, 2017). Due to its nutritional, commercial, and cultural aspects, the tree is called as “Karpaha” in the language “Tamil” which means, “a celestial tree” – the tree that can fulfil all the wishes of mankind (Banji and Rao, 2010; Sarma et al., 2022). The Palmyra palm (*Borassus flabellifer*) belongs to the family of Arecaceae, and is commonly called double palm, toddy palm, Asia toddy palm or Palmyra palm. It is estimated that there are 140 million palmyrah palm trees worldwide that are used as a source for food, medicine and help to sustain people's livelihood (Elumalai et al., 2021). Even though it is thought that tree is native to Africa, it is widely cultivated in tropic and sub tropic regions of the world. The tree is commonly found in India, Sri Lanka, Bangladesh, Burma, Malaysia, the Philippines, and in parts of east Africa regions. In India it is widely found in the states of Tamil Nadu, Kerala, Andhra Pradesh,

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Bihar, West Bengal, Odisha and also along the western coastal regions of India (Vengaiah and Murthy, 2017).

The Palmyra palm, *Borassus flabellifer* has derived its scientific name from the Greek word, "Borassus", meaning leathery fruit, and "flabellifer", meaning the fan-shaped leaves of a tree. It is a monocot, dioecious, and a perennial tree that starts fruiting after 15 years of planting. The young roots are a potential source of vitamin E, rich in phenolic compounds and diuretic in nature that provides a cooling effect to the body (Arunachalam et al., 2011). The secretion of the leaf has antimicrobial activity which aids in wound healing (Sahni et al., 2014). The male flower are rich in steroidal saponins like dioscin and borassosides that are known to interact with bile acids and cholesterol forming micelles, thus exhibiting a hypocholesterolaemic effect (Yoshikawa et al., 2007). The daily intake of leaf extract at 600 mg/kg body weight improves cardiovascular health by increasing HDL level in the blood (Goyal et al., 2015). The sugar prepared from the sap extracted from the spadix acts as body cleanser, which is recommended to treat liver disorders and pain (Keerthi et al., 2007). The Palmyra fruit is a good source of vitamin C, carotenoids, minerals, and sugars (Uluwaduge et al., 2006) and the fruit pulp is used to treat skin problems, nausea, vomiting and improves digestion by relieving constipation. The consumption of Palmyra fruit during summer keeps the body hydrated and replenishes the lost minerals and nutrients by fatigue. The crude flavonoids, saponins, and phenolic compounds present in Palmyra palm contributes to anti-inflammatory and antioxidant activity (Pramod et al., 2013). The fruit pulp and the sap extracted from spadix are used as a natural low calorie sweetener in the preparation of traditional dishes that is recommended for diabetic patients (Yoshikawa et al., 2007). Especially in Cambodia the Palmyrah jaggery and sweet sap used as a natural substitute for table sugar (Le et al., 2020). The consumption of spadix ash from the Palmyra tree is used to treat splenomegaly and hepatomegaly, as well as heartburn (Johnson, 2011). The extract prepared from the fruit husk has been reported to have 15 bioactive compounds like fatty acids, cyanides, and ketones that showed antimicrobial activity (Vijayakumari et al., 2014; Mummaleti et al., 2022; Le et al., 2021). Also, pectin an essential component of jam and jelly making is being recovered from post harvest waste of the Palmyrah palm fruit (Assoi et al., 2017). The antifouling coat prepared from fruit extract could potentially inhibit the formation of biofilm by preventing the settlement of marine microfoulers like bacteria and microalgae on artificial surfaces (Viju, 2020; Mummaleti et al., 2021). A triterpenoid extracted from the Palmyra palm seed coat has been demonstrated to suppress inflammatory enzymes in prostate cancer cells and speeding up the apoptotic process (Malayil et al., 2020). A traditional drink prepared from the sap of the tree called "Legen" is used to clear kidney stones when taken daily for 30 days (Ramya, 2018). Beside all the health prompting aspects of the Palmyra tree, during the time of germination the liquid endosperm present inside the seed nut matures to form a spongy tissue called as the spongy endosperm or Thavan, which is scientifically referred as the haustorium (Manivannan et al., 2018). The thavan is believed to have ample health promoting properties and is consumed as a food material in the rural areas of south India. As there were no information available elsewhere in the literature regarding the nutritional aspects of the Palmyra haustorium, the current study was designed to investigate and characterize various nutrients, phytochemicals, and other nutraceuticals found in the haustorium of *Borassus flabellifer* and also to document the nutritional profile and bioactive compound found in haustorium samples.

2. Materials and methods

2.1. Sample collection

The germinated Palmyra seeds were collected around the suburban regions of Thanjavur, Tamil Nadu. The seeds were washed thoroughly and dehusked to obtain the raw haustorium. The collected haustorium was packed in a polythene bag and stored in a deep freezer at a temperature below -18 °C until further analysis.

2.2. Extraction and preparation of sample

About 100 g of raw haustorium was taken for preparation of sample to be used in the experiments. First, the sample was dried in a tray dryer at a temperature of 60 °C for 24 hand ground into fine powder *i.e*. Palmyra haustorium powder (PHP). Second, the raw haustorium was ground with a blender and the milk was extracted by squeezing the sample using a muslin cloth without adding water and referred as Palmyra haustorium milk (PHM). Finally, the left-over cake material after the extraction of the milk was dried in a tray dryer (60 °C for 24 h) and powdered termed as Palmyra haustorium milk cake powder (PHMCP).

2.3. Yield of sample from raw haustorium

The yield of the palmyrah haustorium powder and milk is calculated using the following formula:

$$Yield(\%) = (W_1 \times 100)/W_2$$

Where, W_1 is the Weight of the haustorium powder or haustorium milk obtained and W_2 is the total weight of raw haustorium taken.

2.4. Determination of proximate composition

The samples were analyzed for moisture, protein, fat, ash, and crude fiber content using standard AOAC method 2019. Moisture and total ash content were determined by gravimetrical method at 103 °C for 3 h (Ref. 935.29, AOAC, 2019) and ash at 550 °C for 3–5 h, respectively (Ref. 900.02A, AOAC, 2019). The protein content of samples is determined by Kjeldahl method and obtained nitrogen content was multiplied with a conversion factor of 6.25 to obtain protein value (Ref. 976.05, AOAC, 2019). Soxhlet apparatus is used to estimate the fat content using hexane as a solvent. Crude fiber was estimated according to the method described in AOAC 978.10 (AOAC, 2019). The total amount of carbohydrate was estimated by the difference method using the formula: total carbohydrate (%) = moisture (%) − protein (%) − fat (%) - ash (%) and finally expressed in g/100g. The calorific value was calculated according to Atwater method: kcal/100g = (3.36 × % protein) + (3.60 × % total carbohydrate) + (8.37 × % fat) (Sahni et al., 2014). All samples are analyzed in triplicates and results are reported as mean ± SD.

2.5. Mineral analysis by ICP-OES (Inductively coupled plasma - optical emission spectrometry)

About 10 g of test sample was taken in a 100 ml standard measuring flask and slurry was prepared with water. Accurately, 0.5 g of the test portion from slurry was transferred to microwave digester system along with 5 ml of HNO_3 and 5 ml of H_2O_2 for 10 min at room temperature with lid loosely capped. The digestive mixture was heated to 200 ± 20 °C for 15 min and kept on hold at 200 °C for 25 min with lid tightened. The contents were cooled to room temperature and diluted with water followed by filtering with ashless filter paper. The filtrate was injected into ICP-OES system for mineral analysis. The nebulizer inside the ICP system creates an aerosol of the injected sample which gets ionized in the presence of plasma maintained at high temperature of 6000 °C. The corresponding wave length emitted by sample is recorded and compared with reference wavelength of respective elements. Minerals such as Calcium,

Potassium, Iron, Phosphorus, and Sodium are analyzed using appropriate procedures described in AOAC (2019).

2.6. Phenolic compound screening by HPLC (High-performance liquid chromatography)

Phenolic compounds screening was performed according to the method described by Tsao and Yang (2003). About 10 g of sample was homogenized in 70% methanol and vortexed for 5 min followed by centrifugation at 4500 rpm for 10 min. The supernatant was filtered using a 0.45 μm syringe filter and injected in to the HPLC system. The column used for analysis was shimpack C18 (4.6 × 250 mm), 5 μm with column oven temperature maintained at 30 °C. Mobile phase A was 6% acetic acid in 2 mM sodium acetate aqueous solution (v/v, final pH 2.55) and mobile phase B was acetonitrile. The injection volume was 20 μL and the flow rate was set to 1.0 ml/minute. The sample thermostat was set at 5 °C and the sample was run for 90 min. The obtained chromatogram is assessed for the presence of phenolic compounds with the help of the retention time of samples against respective standards.

2.7. Phytochemical screening by GCMS/MS (Gas chromatography-mass spectrometry)

The equipment TSQ 9000 Triple Quadrupole GCMS/MS is used to analyse the phytochemical screening of all three samples with column Trace GOLD™ TG-5MS, 30 m × 0.25 mm ID × 1.4 m df and detector TSQ quadrupole mass spectrometer. The carrier gas was maintained at 1ml per minute and split ratio was set at 10:1. The sample injected was 1 μl, with injector temperature was maintained at 280 °C. The oven temperature is programmed at 110 °C and kept on hold for 3.50 min. The temperature was slowly increased up to 200 °C at the rate of 10 °C/min and continued up to 280 °C at the rate of 5 °C / min for 12 min on before placing on hold. The mass scan (m/z) was set to 50–500 amu while the source temperature was maintained at 250 °C and inlet line temperature was maintained at 290 °C. The electron ionization energy was 70 eV. The solvent delay set 0–3.5 min with a total MS running time of 40.5 min. MS program library used NIST (National Institute Standard and Technology) version-2011.The interpretation of the results through mass spectrum was done based on the NIST database and the spectrum of unknown samples was compared with known ones which is stored in the Library database (Sahni et al., 2014).

2.8. Antioxidant activity

The antioxidant activity PH was determined by 2,2-diphenyl picryl-1-picryl-hydrazyl (DPPH) method (Yen and Chen, 1995). The DPPH solution was prepared by adding 4 mg of DPPH into 100 ml of methanol and stored in amber glass. 1 g of sample is dissolved in 10 ml of methanol and is kept in rotary shaker for overnight. The sample solution was filtered with Whatman filter paper. The filtered sample extract is further used for analysis. For 1 ml of sample extract, 3 ml of DPPH solution was added and incubated for 30 min in a dark condition. Methanol was taken as blank. The absorbance is measured at 517 nm using a spectrophotometer and is expressed in inhibition percentage.

$$Inhibition\ (\%) = (\text{Absorbance of Control} - \text{Absorbance of Sample})/\text{Absorbance of Control}$$

2.9. Functional group analysis by FTIR (Fourier transform infrared) spectroscopy

The different functional groups present in the sample were detected by FTIR (Fourier Transform Infrared Spectroscopy) system, Model Spectrum Two 99065 with 16 scans at a scan speed of 0.2 and resolution set at 4. Spectra of samples were recorded from 450 nm to 4000 nm using MIR as a source of radiation and MIR TGS as a detector. The results were analyzed by a spectrogram comparing the wave numbers with their corresponding functional group using a standard FTIR chart (Mariselvam et al., 2020).

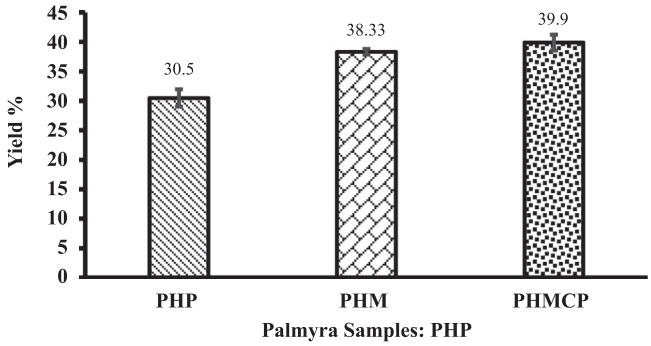

Fig. 1. Yield of PH samples from 100 g of haustorium.

2.9. Statistical analysis

The data obtained were statistically analyzed and the results were reported as mean ± SD. The data is subjected to one-way analysis of variance (ANOVA) and significant differences between means were determined by the Tukeys method ($p < 0.05$) using the software Minitab 18.

3. Result and discussion

3.1. Yield of samples

On the onset of germination, the basal part of the embryo that is embedded in the solid part of the germination pore enlarges to form a spongy absorbing tissue called the haustorium. The present study was conducted in palm seeds that were approximately 30days old after germination where the haustorium is completely filled inside the kernel without any space. The haustorium alone is excised carefully and used for the present study. The yield of the haustorium products *viz.,* PHP and PHMCP were 30.5 ± 1.4, 39.9 ± 1.3%, respectively are presented on dry basis whereas for PHM it is 38.3 ± 0.4% on wet basis and the values are shown in Fig. 1. Since the haustorium is succulent it is obvious that greater loss of moisture was noticed in the PHP and PHMCP samples thus the yield of these samples were approximately about 35%. Similarly no external water was added to extract milk form the PH sample, the innate moisture present in the sample was utilized to squeeze out the milk from the haustorium.

3.2. Proximate composition

The proximate composition of different Palmyra haustorium samples were examined and presented in Table 1. All the parameters tested in the samples are presented on fresh weight basis. The PHP and PHMCP samples were found to be rich in carbohydrates (83.47 and 87.43 g/100 g), protein (7.49 and 6.54 g/100 g) and low amount of fat content (1.08 and 0.48 g/100 g).These values were comparable for PHP as reported by Umara et al. (2015) whereas the obtained information is slightly higher for Palmyrah tube powders reported by Devi and Sharmila. (2019). Beside, the haustorium serves as a

Table 1
Proximate composition of PH samples.

Parameters	PHP	PHM	PHMCP
Energy(Kcal)	$334.69^{a}\pm 3.25$	$80.53^{b}\pm 4.24$	$340.73^{a}\pm 2.14$
Moisture (g/100g)	$3.92^{b}\pm 0.36$	$77.22^{a}\pm 1.21$	$2.6^{b}\pm 0.55$
Water activity	$0.25^{b}\pm 0.004$	$0.97^{a}\pm 0.00$	$0.18^{c}\pm 0.00$
Carbohydrates (g/100g)	$83.47^{b}\pm 0.22$	$17.66^{c}\pm 1.23$	$87.43^{a}\pm 0.31$
Proteins (g/100g)	$7.49^{a}\pm 0.19$	$3.44^{b}\pm 0.05$	$6.54^{a}\pm 0.26$
Fat (g/100g)	$1.08^{a}\pm 0.35$	$0.64^{a,b}\pm 0.07$	$0.48^{b}\pm 0.15$
Crude fiber (g/100g)	$3.71^{b}\pm 0.19$	$0.001^{c}\pm 0.0001$	$42.59^{a}\pm 0.6$
Ash (g/100g)	$4.04^{a}\pm 0.10$	$1.03^{c}\pm 0.02$	$2.96^{b}\pm 0.02$

Data are represented in terms of mean ± SD ($n = 3$). Means that do not share a letter are significantly different ($p < 0.05$).

warehouse of nutrients especially the sugars and proteins in the form of amino acids that are essential for sprout formation by the growing embryo to synthesize various structural components (Staples, 2001). These quality traits of the samples can be exploited to develop new products targeting the diabetic and hypertensive population who require a food item less in fat content. With respect to crude fiber content the PHMCP samples had 42.59 g/100 g, which would be an additional benefit to promote health for individuals suffering from lifestyle disease ailments. With respect to the sample PHM, carbohydrates, protein and fat are low as compared to the other two samples which may be due to the higher amount of moisture content and perhaps the nutrients are slightly compromised that is evident from the water activity values.

GC-Ms/Ms analysis of the PHP and PHMCP samples revealed that presence of medium chain fatty acids such as Hexadecanoic acid, Myristic acid, 9,12-Octadecadienoic acid (Z,Z)-, methyl ester, Oleic Acid, Linoleic acid ethyl ester. These medium chain fatty acids are oxidized in the liver and are considered as less obesogenic in comparison with long chain fatty acids (Xiang et al., 2018). Further the samples also contained 2-Bromotetradecanoic acid which is a straight chain derivative of hexadecanoic acid and acts as a fatty acid oxidation inhibitor. In recent decade this type of natural inhibitors are on high demand for treatment of chronic artherosclerosis (Samudio et al., 2010), chronic stable angina (Samudio et al., 2010), colorectal cancer (Mozolewska et al., 2020) and leukemia (Folmes et al., 2005).

The ash content is an indirect measure of the minerals composition of the PH samples. The ash content of PHP is 4.04 g/100 g which is similar to the values obtained in oven-dried African palm fruit flour of 4.14 ± 0.11 mg/100 g reported by Abe-Inge et al. (2018) and slightly less compared to study on palmyrah roots by Sahni et al. (2014) of 4.95 mg/100 g. Correspondingly, the ash content of PHM and PHMCP is 1.03 g and 2.96 g for 100 g. The ash of the palymarh parts are consumed as an immune booster in parts of Africa (Atchley, 1984) and it is presumed that the ash of PH samples may also exhibit such an effect.

It is estimated that 68% of the worldwide population have low lactase levels, which may lead to lactose intolerance and difficulty in digesting dairy products (Storhaug et al., 2017). Therefore, it is imperative to identify an alternative milk source less or nil lactose content for lactose intolerant children or adults. The PHM contained available carbohydrates of about 17.66 g/100 g fresh weight of which most is simple soluble sugar. The PHM could be used as a source of hydrolyzed sugars along with other nutrients for developing food supplements for lactose intolerance children and adult individuals.

3.3. Mineral analysis by ICP-OES

All three PH samples *i.e* PHP, PHM, PHMCP were analyzed for the presence of various essential elements by Inductively coupled plasma – optical emission spectroscopy (ICP-OES). The elements such as Calcium, Iron, Phosphorus, Potassium and Sodium play significant role in various biological function and normal development of body. The results of the analysis are shown in Table 2. It was found that all three samples were found to contain all five elements except for iron content in PHM sample. This may be due to the PHM extraction process in which the iron content might have retained in PHMCP. PHMCP exhibits higher iron content which is near to values reported by Devi and Sharmila (2019), in a study of raw Palmyrah tube powder (18.4 mg/100 g) and is higher than the values reported by Umara et al. (2015) tested in Palmyrah palm shoots (11.51 ± 0.4 mg/100 g). Iron is an essential element for human health as it participates in a wide variety of metabolic processes, including oxygen transport, deoxyribonucleic acid (DNA) synthesis, and electron transport (Abbaspour et al., 2014).

PHP was comparatively higher in calcium content (20.88 mg/100 g) as compared to the rest of the samples. The calcium level of PHM and PHMCP were 8.21 mg/100 ml and 191.90 mg/100 g which is in line with the values obtained by Vijayakumari et al. (2014) from palmyrah fruit pulp. Calcium is important for strengthening bones and teeth, regulating muscle functioning, regulating heart functioning and blood clotting (Pu et al., 2016). The PHP and PHMCP had higher values of phosphorus (14,210 mg/Kg and 10,040 mg/Kg) and potassium (14,210 mg/Kg and 10,040 mg/Kg) which is higher than reported in the study of Palmyrah fruit by Ali et al. (2010) and Palmyrah seed embryo. The phosphorous is designated as the fifth most important mineral found in living cells and essential for an important mineral for the function of skeletal, smooth muscle cells and also vital for energy production (Bruna et al., 2021). It also plays a major role in muscle contraction, repairing of damaged cells, kidney function and for normal rhythm of heart (Kovacs, 2015). Similarly, potassium acts as an intracellular cation in the body and is involved in maintaining the membrane potential and electrical excitation of both nerve and muscle cells and also requires for the regulation of acid-base balance through the kidneys (Lanham-New and Lambert, 2012; Olofinnade et al., 2021). The level of sodium is higher in PHP and in PHMCP i.e., 274.8 and 198.10 mg/Kg, respectively, which is in accordance with the values obtained by Arthur, 2018 in freeze dried palmyrah palm fruit flour. Sodium helps to maintain the fluid or electrolyte balance in the body and regulates blood pressure (Cook et al., 2020). The sample PHM was found to be comparatively

Table 2
Mineral analysis of PH samples by ICP-OES

Sl. No	Minerals	Palmyra Haustorium Powder (PHP)	Palmyra Haustorium Milk (PHM)	Palmyra Haustorium Milk Extracted Cake Powder (PHMCP)	RDA*	
					Men	Women
1	Calcium (mg/Kg)	208.80	82.15	191.90	600.00	600.00
2	Phosphorous (mg/Kg)	14210.00	5054.00	10040.00	600.00	600.00
3	Iron (mg/Kg)	5.88	ND	247.50	17.00	21.00
4	Potassium(mg/Kg)	16220.00	5622.00	12980.00	3750.00	3225.00
5	Sodium(mg/Kg)	274.80	102.30	198.10	2100.00	1900.00

ND- Not Detected
*RDA: Indian Council of Medical Research (ICMR), Nutrient Requirements and Recommended Dietary Allowances for Indians. A Report of the Expert Group of the Indian Council of Medical Research 2010, National Institute of Nutrition, Hyderabad, India, 2010.

Table 3
Phenolic compound screening of PH samples by HPLC.

Sl. No	Phenolic compound	Palmyra Haustorium Powder (PHP)	Palmyra Haustorium Milk (PHM)	Palmyra Haustorium Milk Extracted Cake Powder (PHMCP)
1	Gallic acid	+	+	+
2	Chlorogenic acid	+	+	+
3	Caffeic acid	-	+	-
4	Rutin	+	-	-
5	Quercetin	-	-	-

+ represents the presence and - represents the absence of the phenolic compound

low in all minerals is due to the moisture content which acted as the only extraction medium and most of the constituents present are hydrophobic in nature may have been retained in the milk extracted cake portion of the sample.

The present study has identified that Palmyrah haustorium is rich in many essential minerals, which are required for normal function of the human body. The intake of 100 g of PHP or PHMCP could contribute about 1.5 to 4 folds higher than the RDA of the potassium, about 33% of calcium according to RDA, 16 to 23 folds higher than the RDA of phosphorus, 0.35 to 14 folds of iron and 9.4 to 13% of sodium as per RDA. Hence, Palmyrah haustorium is a rich source of potassium, calcium, phosphorous, iron and sodium which can be utilized as a potential diet or can be used one of the constituents in preparing a balanced diet to mitigate hidden hunger in many developing countries, where the average diet is deficient in vital minerals.

3.4. Screening of phenolic compounds by HPLC and antioxidant activity

The screening of phenolic compounds present in the PH samples was performed by HPLC analysis. The results are presented in the Table 3 and the chromatogram of the samples run are presented in Fig. 2. In this study we used five different phenolic standards *viz.*, Gallic acid (GA), chlorogenic acid (CH), caffeic acid (CA), rutin (RH) and quercetin (QU) to compare with the chromatograms produced from the PH samples, and the separation was allowed to run for 80 min in a C18 reverse phase column. Symmetrical, sharp and well-resolved peaks were observed for the five phenolic standards and the elution order with the retention times for GA, CH, CA, RH and QU were 5.5, 21.1, 23.7, 49.7 and 64.2 min, respectively. The sample PHP is found to contain phenolic compounds like GA, CH, and RH, whereas PHM sample contained GA, CH and CA, similarly PHMCP contained only GA and CH. It was observed that Gallic acid and chlorogenic acid were present commonly in all samples, but quercetin was found to be absent in all three samples.

Gallic acid (GA) when administered orally the absorption and elimination process is faster when compared with other polyphenols in human system. It mitigates the inflammatory response by reducing the release of inflammatory cytokines, chemokines, adhesion molecules, and slows down the infiltration of inflammatory cells and hence can be used to treat inflammation (Bai et al., 2021). It also

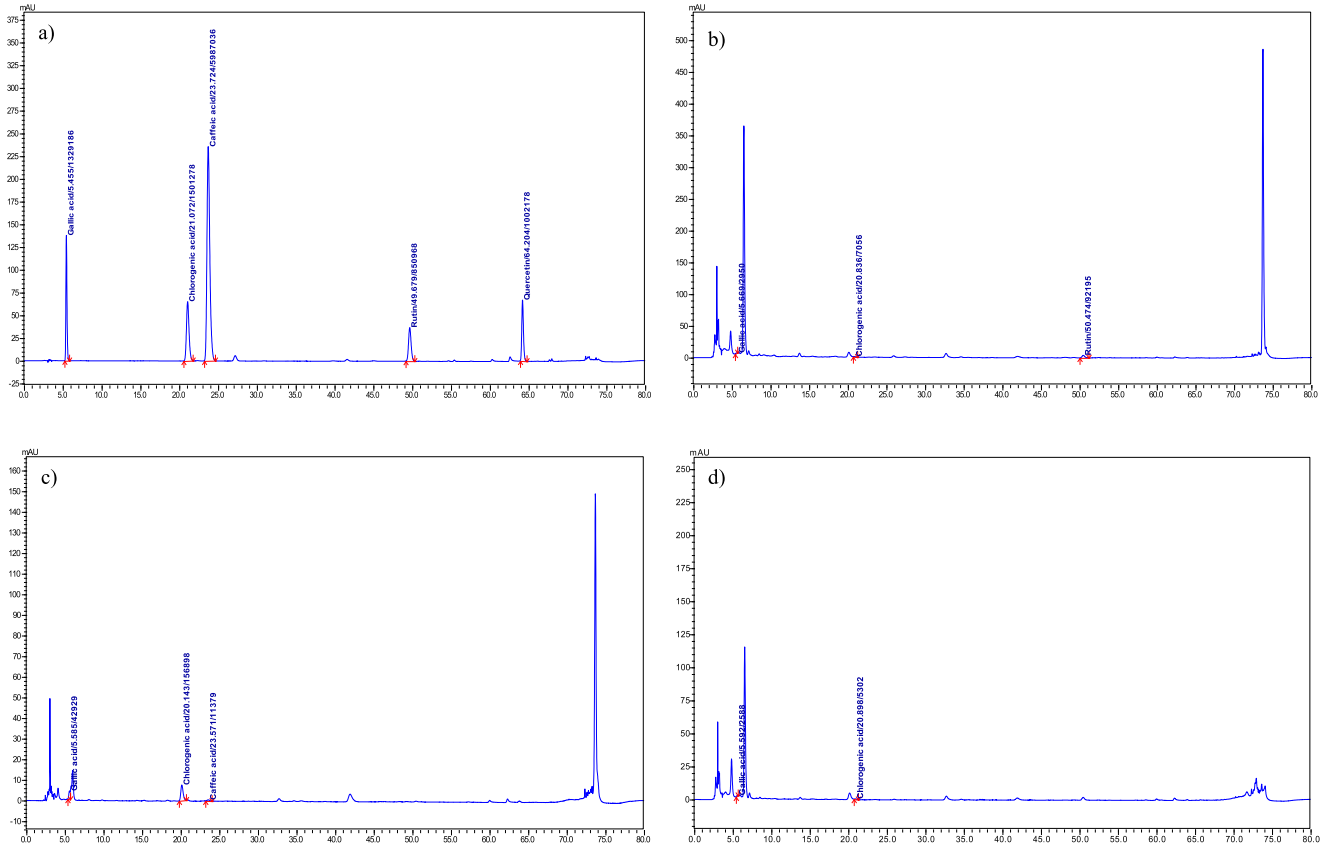

Fig. 2. The Phenolic compound screening of Palmyra samples using HPLC. (a) Standards, (b) PHP, (c) PHM and (d) PHMCP.

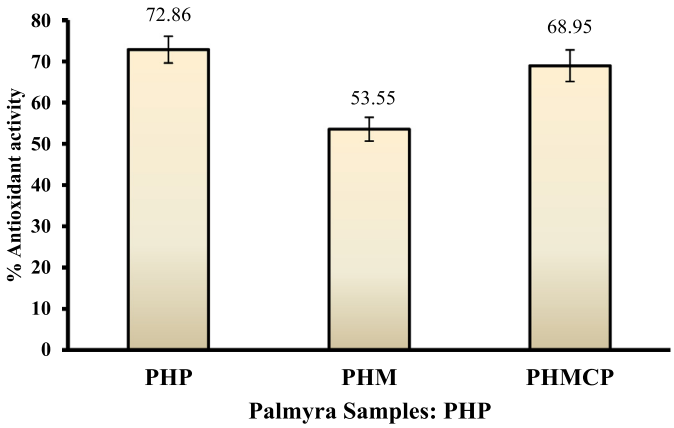

Fig. 3. The antioxidant activity of PH samples (a) PHP, (b) PHM and (c) PHMCP.

imparts health beneficial properties like antioxidant, gastrointestinal, cognitive, metabolic, and cardiovascular problems (Kahkeshani et al., 2019). Especially, it exerts anti-cancerous activity against ovarian, lung and cervical cancer cells, inhibits cellular proliferation and induces apoptosis (Aborehab and Osama, 2019). Chlorogenic acid (CH) is reported to exhibit anti-inflammatory property, enhance cardio vascular health, scavenges free radical, acts as a neuroprotective agent and CNS stimulator (Naveed et al., 2018; Stefanucci et al., 2018). Although Rutin (RU) and Caffeic acid (CA) Hence presence of Phenolic compounds helps to perform different health enhancing properties through various biological process. A spectrum of compounds present in the haustorium exhibits antioxidant activity that is quantified by DPPH method is represented in Fig. 3. The antioxidant capacity of the PH samples was tested against ascorbic acid standard. It is observed that the PHP sample has more antioxidant scavenging activity of 72.86% as compared with either PHM or PHMCP which is 53.55 and 68.95%, respectively. It is presumed that the compounds responsible for antioxidant activity may have been shared with PHM and PHMCP while it may be conserved in PHP.

3.5. Phytochemical screening by GCMS

The detailed information of all the identified phytochemicals from the methanol extract of PH samples are presented in Table 4. Correspondingly, the mass spectrum of the compounds with the respective retention time (RT) of the bioactive compounds identified is shown in Fig. 4. PHP showed the presence of 16 different phytochemicals like Clindamycin, Sucrose, Hexadecanoic acid, Myristic acid, Oleic Acid,3-Deoxy-d-mannonic acid, Linoleic acid ethyl ester and PHMCP has all the aforementioned types of phytochemicals except for two phytochemicals in PHMCP *i.e,* "d-Mannose" and "9,12-Octadecadienoic acid (Z,Z)-, methyl ester". The presence of saturated fatty acids such as Hexadecanoic acid (used in cosmetic and soaps), Myristic acid, and Oleic acids has been shown to regulate a wide variety of biological processes such as blood pressure, blood lipid levels, blood coagulation, the immunological response, and the inflammatory response to

Table 4
Phytochemical screening of PH samples by GCMS/MS.

Sample 1 - Palmyra Haustorium Powder (PHP)					
No	RT (min)	Name of the compound	Molecular	Molecular Weight	Peak Area %
1	3.36	Clindamycin	$C_{18}H_{33}ClN_2O_5S$	424	5.86
2	4.46	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	$C_6H_8O_4$	144	6.93
3	5.75	5-Hydroxymethylfurfural	$C_6H_6O_3$	126	1.74
4	8.02	Methyl 4-nitrohexanoate	$C_7H_{13}NO_4$	175	11.98
5	10.14	Sucrose	$C_{12}H_{22}O_{11}$	342	32.61
6	11.64	Octadecanoic acid, ethyl ester	$C_{20}H_{40}O_2$	312	1.25
7	12.00	3-Deoxy-d-mannonic acid	$C_6H_{12}O_6$	180	5.33
8	12.24	á-D-Glucopyranose, 4-O-á-D-galactopyranosyl-	$C_{12}H_{22}O_{11}$	342	4.48
9	12.78	3-O-Methyl-d-glucose	$C_7H_{14}O_6$	194	21.40
10	15.21	Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	270	0.61
11	15.65	Hexadecanoic acid	$C_{16}H_{32}O_2$	256	2.77
12	15.78	Myristic acid	$C_{14}H_{28}O_2$	228	1.39
13	17.45	9,12-Octadecadienoic acid(Z,Z)-, methyl ester	$C_{19}H_{34}O_2$	294	0.43
14	17.52	Oleic Acid	$C_{18}H_{34}O_2$	282	0.27
15	18.01	9-Octadecenoic acid (Z)-	$C_{18}H_{34}O_2$	282	1.74
16	18.22	2-Bromotetradecanoic acid	$C_{14}H_{27}BrO_2$	306	0.75
17	20.67	Linoleic acid ethyl ester	$C_{20}H_{36}O_2$	308	0.44
Sample 2 – Palmyra Haustorium Milk (PHM)					
1	7.97	E-9-Methyl-8-tridecen-2-ol,acetate	$C_{16}H_{30}O_2$	254	27.54
2	8.98	Lactose	$C_{12}H_{22}O_{11}$	342	67.04
3	15.26	7,9-Di-tert-butyl-1-oxaspiro(4,5) deca-6,9-diene-2,8-dione	$C_{17}H_{24}O_3$	276	5.41
Sample 3 – Palmyra Haustorium Milk Extracted Cake Powder (PHMCP)					
1	3.36	Clindamycin	$C_{18}H_{33}ClN_2O_5S$	424	6.61
2	4.46	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	$C_6H_8O_4$	144	2.10
3	5.75	5-Hydroxymethylfurfural	$C_6H_6O_3$	126	1.48
4	8.02	Methyl 4-nitrohexanoate	$C_7H_{13}NO_4$	175	16.68
5	10.33	Sucrose	$C_{12}H_{22}O_{11}$	342	43.15
6	11.68	Octadecanoic acid, ethyl ester	$C_{20}H_{40}O_2$	312	0.67
7	12.02	3-Deoxy-d-mannonic acid	$C_6H_{12}O_6$	180	6.14
8	12.30	d-Mannose	$C_6H_{12}O_6$	180	4.27
9	12.74	3-O-Methyl-d-glucose	$C_7H_{14}O_6$	194	17.22
10	15.21	Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	270	0.82
11	17.45	9,12-Octadecadienoic acid(Z,Z)-, methyl ester	$C_{19}H_{34}O_2$	294	0.50
12	17.52	Oleic Acid	$C_{18}H_{34}O_2$	282	0.36

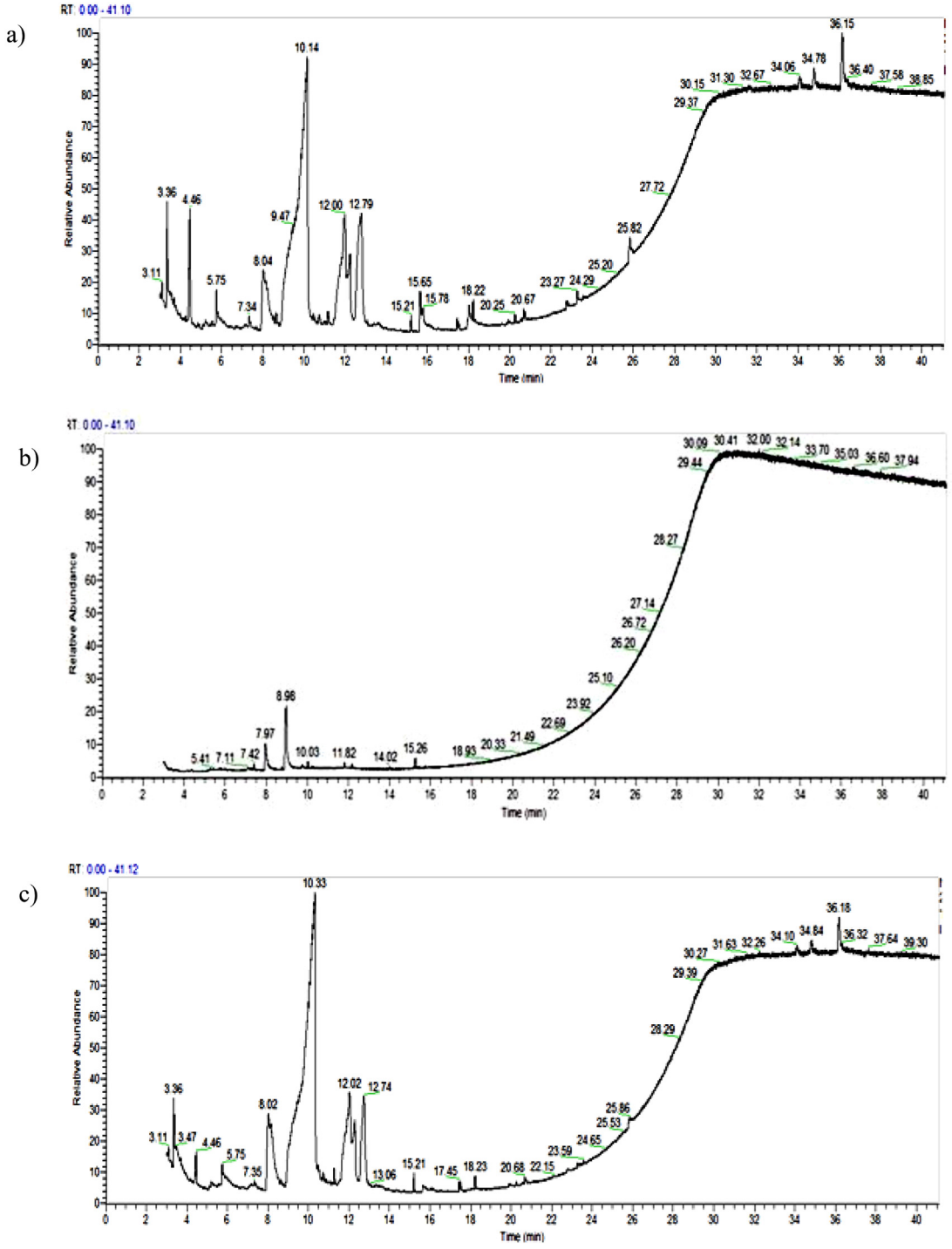

Fig. 4. The Phytochemical screening of Palmyra samples using GC-Ms/Ms. (a) PHP, (b) PHM and (c) PHMCP.

injury and infection (Rungnapa et al. 2007). Compared to other saturated fatty acids present in the PH samples, stearic acid is has been shown to be heart healthy and does not involve in raising the risk of heart disease. It is presumed that the body partially converts stearic to oleic acid and the heart utilizes such fatty acids during stress condition to mitigate the toxic effects (Enig and Fallon, 2000). The presence of fatty acids like "Hexadecanoic acid", "9,12-Octadecadienoic acid", "methyl ester, 9-Octadecenoic acid" were reported by Sahni et al. (2014) the monounsaturated fatty acid such as oleic acid and Hexadecanoic acid were recorded by Chuku et al. (2018) and (Meechaona et al., 2007). These fatty acid may have originated from the haustorium which is fully covered with an oily colloidal inner endosperm termed here as 'mucilage' which contained free oil (Manivannan et al., 2018).

PHM showed the presence of phytochemicals like "E-9-Methyl-8-tridecen-2-ol, acetate", "Lactose" and "7,9-Di-tert-butyl-1-oxaspiro (4,5) deca-6,9-diene-2,8-dione"which was entirely a different composition as compared to PHP and PHMCP. The E-9-Methyl-8-tridecen-2-ol, acetate exhibits pharmacological activity: anti-malarial, anti-allergy (Ubaid et al., 2016). In the glucose histamine products, 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one acts as a potent strong antioxidant (Yu et al., 2013). From the current analysis,

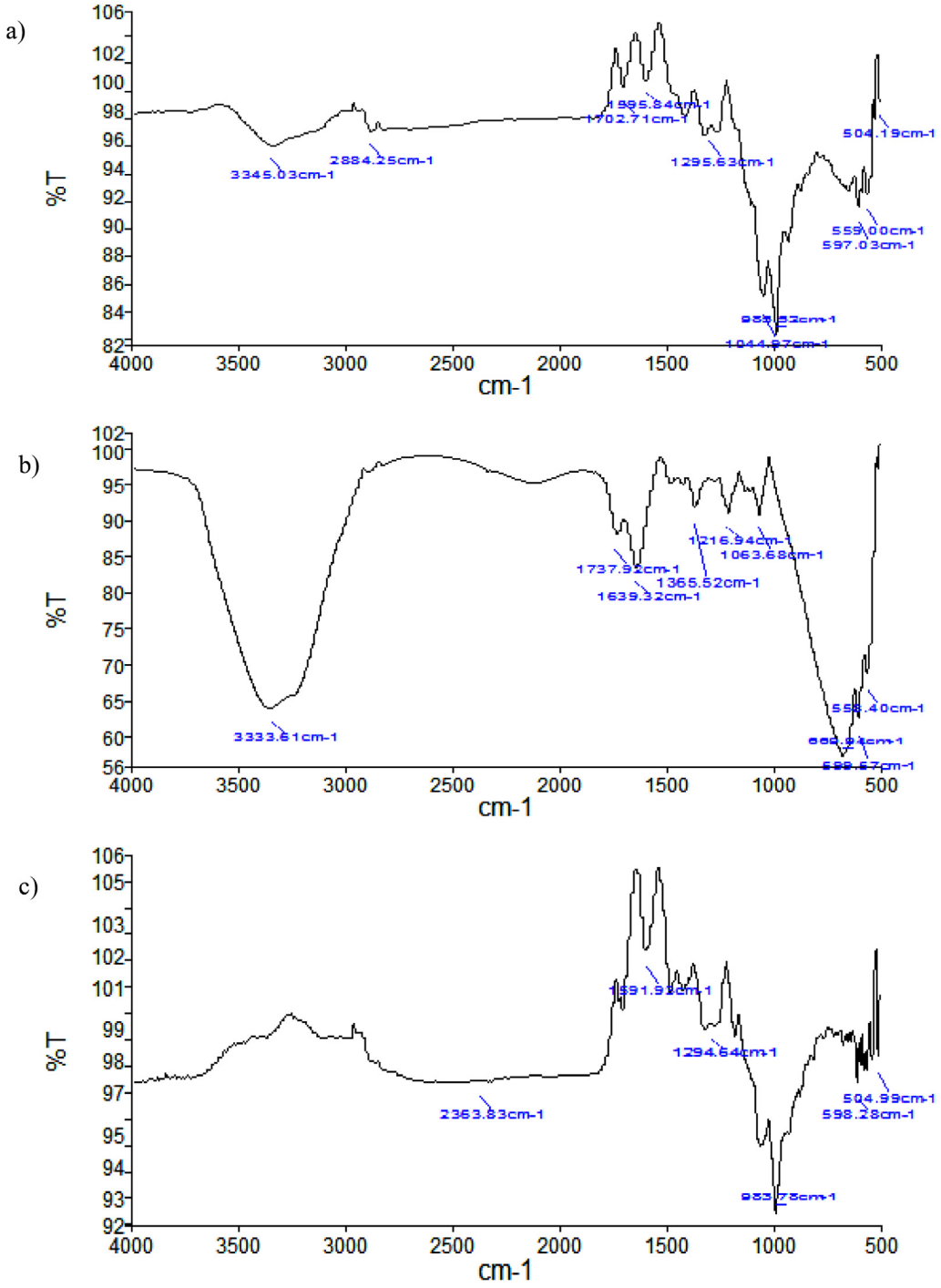

Fig. 5. Functional group analysis of Palmyra samples using FTIR. (a) PHP, (b) PHM and (c) PHMCP.

it is confirmed that PHP consists of potential phytochemicals, minerals, and nutraceuticals that can be included in a diet for the betterment of health.

3.6. Functional group analysis by FTIR

Functional groups are essential to investigate since as they are part of a molecule that undergo certain reactions which can define the chemical properties of a sample. When the sample is introduced into the system, functional groups are identified based on peak ratio. The prominent functional groups observed in PH samples showed in the range of 3345–504 cm^{-1} Fig. 5. The peak observed at 3345.03 cm^{-1} in sample PHP was due to presence of N-H stretching vibrations of secondary amines. The peaks centered at 2884.25 cm^{-1}, 1702.71 cm^{-1}, 1595.84 cm^{-1} and 1295.63 cm^{-1} corresponds to C-H stretching alkane, C=O conjugated aldehyde, C=C cyclic alkene and C-O stretching aromatic ester functional groups. Spectral peaks at 504.19 cm^{-1} - 597.03 cm^{-1} indicated the presence of halo compounds. Similar functional group of C- H alkyl groups were observed at 2920 cm^{-1} and 2850 cm^{-1} by Reddy et al. (2016).

In PHM sample a strong broad peak at 3333.61 cm^{-1} was observed indicating the O-H stretching of water molecules. The peaks at 1737.92 cm^{-1} and 1216.94 cm^{-1} is due to C=O stretching and ester of 6-membered lactone and C-O stretching of vinyl ether. The weak

bands observed in the regions of 1639.32 cm^{-1}, 1365.52 cm^{-1}, 1063.68 cm^{-1} and 669.94 cm^{-1} were vibrations of C=C stretching conjugated alkene, O-H bending of water molecules, C-O stretching primary alcohol, C=C bending alkene. Similar spectrum was observed by Saravanya et al. (2020) at 1732.52 and 1242.19 corresponds to C=O and C-O vibrations in palmyrah sprout samples. The broad OH group observed at 3333.61 was similar to peak reported by Astuti et al. (2020) in palmyrah sugar indicating the stretch of OH group. The PHMCP showed major peaks in the regions of 2363.83 cm^{-1}, 1591.93 cm^{-1}, 1294.64 cm^{-1}, 983.78 cm^{-1} that corresponds to C-N nitrile, C=C stretching cyclic alkene, C-O stretching aromatic ester, C=C bending alkene. The similar peaks obtained by Astuti et al. (2020) at 1582 cm−1 and 1157 corresponds to C-C and C-O stretching vibrations. As OH group has the potential to form hydrogen bonding and can inhibit the activity of microbes (Abulyazid et al., 2013).

Collectively, Stretching of the hydroxyl group (OH) bond was seen as a broad peak in PH samples were around a wavelength of 3325 cm^{-1} due to the hydrogen bonding in the cellulose present in the cell wall of the haustorial cells. Absorption at 1735 cm^{-1} was due to stretching of the carboxyl bond C=O of the acetyl group in hemicellulose that is present in the haustorial encasement and binds with the cellulose to provide structural integrity of the cells. The peak at 1512 cm^{-1} contributed to the conjugated C-O group for the aromatic skeletal in lignin, and peak at 1449 cm^{-1} referred to C-H group of lignin. The prominent peak at 1610 cm^{-1} in the spectrum is due to stretching-vibration of the C=C bond in the benzene ring. The peak at 1244 cm^{-1} is probably due to stretching-vibration of the C-O bond in the COH phenolic group.

4. Conclusion

The palmyrah haustorium is a potential source of nutraceuticals that have high therapeutic values. Especially the macro and micronutrients present in the PH samples may help in mitigating the effects of malnutrition, particularly in women and children who are categorized as the vulnerable population. The PHM can be alternate source for the nutrients for those individuals who are susceptible to digest lactose. The study has identified that palmyrah haustorium is a good source of carbohydrate, fiber, and protein and has limited fat content. Hence, food products made out of PH can be used to combat lifestyle disease like obesity, diabetes, hypertension and heart problems. Further, the phenolic compounds in the PH samples can scavenge free radicals and show greater antioxidant activity there by offer health benefits upon consumption. The mineral analysis showed higher amount of potassium, phosphorus, and calcium are present in PH samples which are essential element for normal growth and development of the body. GCMS analysis revealed the presence of pharmacologically important secondary metabolites that are responsible for a variety of health promoting properties like antioxidant activity, cardio protective effect and anti-inflammatory properties. Collectively, the current study revealed that the germinated seed embryo called as palmyrah haustorium is known to harbour various nutraceuticals and minerals that can alleviate the problem of hidden hunger in developing nations.

Declaration of Competing Interest

The authors confirm no conflict of interest.

Compliance of Ethical standards

The current article does not contain studies on animal or human subjects.

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