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# Chromatographic profiling and phytomedicinal properties on heartwood extractives of farm grown teakwood (*Tectona grandis* L.f.)

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**Abstract**

Teak (*Tectona grandis* L.f.) is a highly sought-after tree species due to its exceptional quality and strong resistance to fungal and termite attacks. Tectoquinone, a major bioactive compound found in teak (*T. grandis*) heartwood, is of interest in phytomedicine due to its diverse therapeutic properties. The purpose of the current study is to analyse and compare the chemical constituents especially tectoquinone content of teak heartwood from north eastern zone of Tamil Nadu. The biochemical analysis of two heartwood samples; namely, 11 and 17 years age were analyzed using gas chromatography mass spectrometry technique. Nine secondary metabolites were detected; namely, alkaloids, phenols, aldehydes, ketones, heterocycle, acids, benzene series, alkanes, esters and study result found that presence of higher proportion of alkaloids in both the samples. Among the alkaloids, tectoquinone principle compound exhibited relatively higher proportion of 5.156 % with the retention time of 25.572 RT in 17 years sample which acts as a resistant phytomedicinal compound against termite attack in order to increase the durability of wood. It helps to identify that secondary metabolites concentration especially tectoquinone content increased with increasing age and hence wood durability is achieved only in the matured trees.

## 1. Introduction

Teak (*Tectona grandis* L.f.) heartwood is renowned for its high durability and is also gaining recognition in phytomedicine due to its diverse bioactive compounds. Traditionally, teak has been valued in folk medicine across Asia for its antimicrobial, anti-inflammatory, and wound-healing properties (Vongkhamho *et al*., 2022). Teak heartwood is eminent for its exceptional durability, beauty, and resistance to decay. It is highly sought after in the furniture and construction industries due to its remarkable properties (Balakrishnan *et al*., 2021). Teak heartwood is derived from the *T. grandis* tree, which is native to Southeast Asia, particularly countries like India, Myanmar, and Indonesia. Chemically, teak heartwood is composed of a variety of compounds that contribute to its unique characteristics (Suryanti *et al*., 2020). Its heartwood contains compounds like tectoquinone, lapachol, and anthraquinones, which exhibit significant antimicrobial and antifungal activity. Teak extracts have shown promising antioxidant effects, potentially benefiting cardiovascular health and protecting cells from oxidative stress (Rosamah *et al*., 2020). Additionally, teak heartwood demonstrates anticancer activity by inducing apoptosis in certain cancer cells. Its potential in treating gastrointestinal disorders, skin infections, and parasitic diseases is under research, making it a valuable natural resource in developing herbal medicines (Lourenco *et al*., 2015). The main components of teak heartwood are natural oils and resins, which account for its resistance to water, insects, and rot. These oils and resins also give teak heartwood its distinctive aroma (Budianto *et al*., 2023).

The chemical constituent of teak heartwood plays a crucial role in its outstanding performance and longevity (Palanisamy *et al*., 2009). These inherent properties make it a preferred choice for various applications, including outdoor furniture, decking, boat building, and high-end woodworking (Pandey and Brown, 2000). The most prominent chemical compound found in teak heartwood is called teak oil or teakwood oil, scientifically known as tectoquinone (Colbu *et al*., 2021). This compound is responsible for the natural waterproofing and insect-repellent properties of teak heartwood. It helps prevent water penetration and discourages the growth of fungi and bacteria (Haupt *et al*., 2003). In addition to teak oil, teak heartwood also contains other chemical compounds such as terpenes, quinones, and tannins (Lukmandaru *et al*., 2021; Bhat *et al*., 2010). These compounds contribute to the wood's natural resistance to termites, fungi, and other pests. They also provide a characteristic reddish-brown color to teak heartwood and protection against weathering and ultra violet damage (Kumar *et al*., 2022; Alabi and Oyeku 2017). Furthermore, teak heartwood possesses a high silica content, which enhances its strength and durability. The silica in teak heartwood acts as a natural reinforcement, making it highly resistant to warping, splitting, and cracking (Wen and Hu, 2019).

It is important to note that while teak heartwood possesses remarkable attributes, its chemical composition can vary slightly depending on various factors such as the tree's age, growing conditions, and the specific region in which it is cultivated (Yang *et*

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*al*., 2020; Niamke *et al*., 2014). In this study, the chemical composition of teak, with a focus on its extractives, was examined to provide a theoretical foundation for understanding color variation and developing color-matching techniques for teak wood. Such insights have significant research value for practical applications (Rathor *et al.,* 2022). Specifically, the study quantitatively analyzed the chemical constituents of teak samples from the northeastern region of Tamil Nadu. Ethanol extraction was applied to the heartwood of two teak samples, aged 11 and 17 years, respectively. Gas chromatography mass spectrometry was used to compare the extractive compositions between the two age groups.

## 2. Materials and Methods

In the presence of metabolites in the heartwood were profiled using standard procedures to know the quality standards of farm grown teak as influenced by climatic and edaphic factors. The details of the procedure are given below.

### 2.1 Identification of plant material

Dr. S. S. Hameed, Scientist 'F' and Head of Office, Ministry of Environment, Forest and Climate Change, Botanical Survey of India, Southern Regional Centre, TNAU Campus, Lawley Road, Coimbatore, Tamil Nadu, India, identified and verified, *Tectona grandis* L.f. - Lamiaceae. The specimen is accessed to TNAU herbarium (TNAU Herbarium Accession Number 534).

### 2.2 Preparation of the sample

Eleven and seventeen years old teak wood samples were taken from the farmer's field of north eastern agroclimatic zone and heartwood was separated for metabolite analysis. Heartwood samples were chipped to a 20 mm size using a chipper and then finely pulverized with a Wiley mill. A precise 10 g of the resulting heartwood powder, after defatting with petroleum ether, was subjected to ethanol extraction in a Soxhlet apparatus for 6 h (Karthick and Parthiban, 2019; Mohammad *et al.,* 2016).

### 2.3 Gas chromatography and mass spectrometry (GC-MS) analysis

The bioactive compounds in the heartwood extract of farm-grown teak were analyzed using a GC-MS (gas chromatography mass spectrometry) system (Perkin Elmer Clarus SQ8C), equipped with a nonpolar DB-5 capillary column, which is low-bleed and capable of operating at high temperatures (30 m length, 0.25 mm internal diameter, and 0.25 µm film thickness). For the analysis, a 1 µl sample of the ethanolic extract was injected, with helium serving as the carrier gas at a flow rate of 1 ml/min. The oven temperature was programmed to increase from 80ºC (held for 5 min) to 285ºC (held for 10 min). The mass spectrometer's scan range was set from 45 to 650 da and included an internal pre-filter to reduce neutral particle interference. The relative percentages of extract constituents were calculated using peak area normalization (Figure 1).

### 2.4 Identification of the compounds

The mass spectra obtained from GC-MS analysis were interpreted using the National Institute of Standards and Technology (NIST14) database. The spectra of known compounds were matched against those of unknown components available in the instrument's integrated library for identification (Priyanka *et al.,* 2016). Finally, the bioactive extraction compounds of teak heartwood samples were arrived.

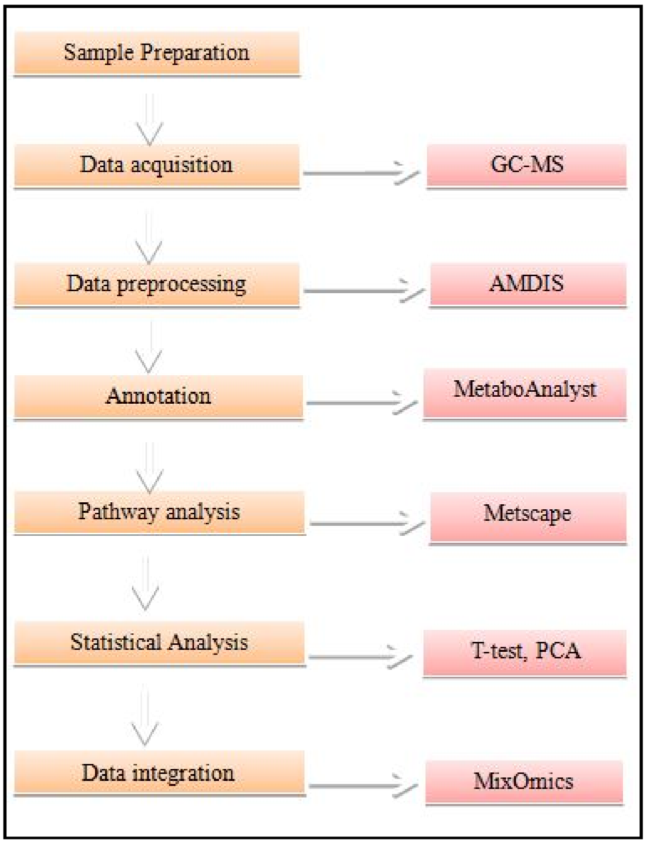


**Figure 1: Flowchart of biochemical analysis of teak heartwood using GC-MS.**

## 3. Results

A variety of biochemical compounds have been isolated from the heartwood portion of two teak samples collected from north eastern zone with the age of 11 and 17 years by using GC-MS technique. Chemical compounds with varied degree of structure, belonging to different classes such as alkaloids, phenols, aldehydes, ketones, heterocycle, acids, benzene series, alkanes and esters were detected. Among the nine secondary metabolites detected, high proportion of alkaloid compound were identified in heartwood of teak in both age class samples. Among the alkaloid group, tectoquinone was the specific analyte compound detected with the maximum peak area of 5.156% with the retention time of 25.572 RT in 17 years teak heartwood sample. Whereas, 11 years sample observed with the maximum peak area of 0.206 % with the retention time of 25.593 RT (Table 1). The tectoquinone is the major chemical component in teak heartwood which shows resistance against the termite attack and increases the durability of wood. While the other metabolites such as ketones with the chemical compound of 9,10-anthracenedione, 2-methyl attained the maximum peak area of 4.329% with the retention time of 24.677 RT and the phenols were also detected with the chemical compound of 2-methyl-6-(1-methyl-1-phenylethyl) phenol attains the maximum peak area of 5.070% with the retention time of 21.336 RT under 17 years teak sample (Table 1). Presence of these biochemical components determines the chemical traits related to its natural durability of teak against insects.

The Table 1 shows diverse phytomedicinal activities for compounds in heartwood at 11 and 17 years of age, highlighting antimicrobial and protective roles. Alkaloids like anthraquinone-1-carboxylic acid and tectoquinone exhibit antimicrobial and antitermitic effects, respectively, while menadione and lapachol offer antibacterial and antibiotic properties. Phenolic compounds include antioxidants and antibiotics, with (E)-4-(3-hydroxyprop-1-en-1-yl)-2-methoxyphenol serving as an antioxidant. Piperonal and 2-propenal act as insecticidal and cytotoxic agents. Ketones such as 9,10-anthracenedione provide antiviral effects, and cyclohexanone derivatives contribute anti-inflammatory properties. Heterocycles and acids show pesticidal and antiparasitic effects, while benzene series compounds bring antibacterial and fungicidal benefits. Finally, alkanes and esters add further anti-inflammatory, antiparasitic, and pesticidal activities, demonstrating a wide range of potential therapeutic applications.

The alkaloid compound 2-(hydroxymethyl) anthraquinone, a characteristic substance in teak, is thought to contribute to its unique color and surface properties (Table 2). Upon comparing the two samples, the heartwood sample from 17-year-old teak showed a higher peak area percentage for the standard solution (0.223%) compared to the 11-year-old sample (0.177%). The present study identified that among the various ethanol extractives alkaloids, phenols, aldehydes and ketones had relatively high contents in both the samples where as acids, esters, alkanes, heterocycle and benzene series were much less in teak heartwood (Table 2). Among the extractives, aldehydes and ketones exhibit relatively high heartwood content.

**Table 1: Metabolic profiling of teak as influenced by climatic and edaphic factors**

| S. No. | Secondary metabolite | Compound name | Molecular formula | Phytomedicinal activity | Age (11 years) | | Age (17 years) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | RT | Area % | RT | Area % |
| 1 | | Anthraquinone-1- carboxylic acid | $C_{15}H_8O_4$ | Antimicrobial | 26.67 | 0.158 | 22.16 | 0.294 |
| 2 | | Tectoquinone | $C_{15}H_{10}O_2$ | Antitermitic | 25.59 | 0.206 | 25.57 | 5.156 |
| 3 | Alkaloids | Menadione lapachol2- (Hydrox | $C_{11}H_8O_2$ | Antibacterial | 28.54 | 0.174 | 12.96 | 0.233 |
| 4 | | ymethyl) anthraquinone | $C_{15}H_{14}O_3$ | Antibiotic | 27.27 | 0.899 | 23.13 | 0.973 |
| 5 | | | $C_{15}H_{10}O_3$ | Antifungal | 9.97 | 0.177 | 26.65 | 0.223 |
| 6 | Phenol | (E)-4-(3-Hydroxyprop -1-en-1-yl) -2-methoxyphenol | $C_{10}H_{12}O_3$ | Antioxidant | 17.54 | 0.302 | 17.49 | 0.219 |
| 7 | | 2-Methyl-6-(1-methyl-1-pheny-lethyl) phenol | $C_{16}H_{18}O$ | Antibiotic | 21.33 | 0.140 | 23.40 | 5.070 |
| 8 | Aldehyde | Piperonal 2-Propenal, | $C_8H_6O_3$ | Insecticidal | 9.68 | 1.281 | 9.64 | 2.936 |
| 9 | | 3-(1,3-benzodioxol-5-yl) | $C_{10}H_8O_3$ | Cytotoxic | 15.98 | 1.274 | 15.94 | 3.602 |
| 10 | Ketones | 9,10-Anthracenedione, 2-methyl | $C_{15}H_{10}O_6$ | Antiviral | 24.70 | 1.982 | 24.67 | 4.329 |
| 11 | | Cyclohexanone, 2-me-thyl-5-[1-(t-butyldime-thylsilyloxymethyl) ethenyl | $C_{10}H_{18}O$ | Anti-inflammatory | 20.70 | 0.196 | 21.83 | 0.546 |
| 12 | Heterocycle | 4a-Methyl-1-methylene-1,2,3,4, 4a,9,10,10a- octahydrophenan-threne | $C_{14}H_{18}$ | Pesticidal | 23.25 | 0.292 | 23.22 | 0.398 |
| 13 | | 1-Ethoxy-7-phenylvi-nylidene -bicyclo [4.1.0] heptane | $C_{10}H_{16}$ | Antioxidant | 28.38 | 0.156 | 21.30 | 0.220 |
| 14 | Acid | Benzoic acid, 4-methyl-,[4-(meth-oxycarbonyl) phenyl]methyl ester | $C_{17}H_{16}O_4$ | Antiparasitic | 9.76 | 0.240 | 20.14 | 0.329 |
| 15 | | Benzoicacid,3,4-met-hylenedioxy -,3-for- mylphenyl ester | $C_{15}H_{12}O_4$ | Antibiotic | 13.54 | 0.172 | 13.47 | 0.283 |
| 16 | Benzene series | Benzene, (3-octy- lundecyl) | $C_{25}H_{44}$ | Antibacterial | 4.48 | 0.185 | 13.09 | 0.297 |
| 17 | | 1,3,5-Trimethyl-2-(2-nitrovinyl) benzene | $C_{11}H_{13}NO_2$ | Fungicidal | 25.87 | 0.431 | 23.40 | 5.070 |
| 18 | Alkane | Tetracyclo[5.4.3.0 (7,11)] tetra-decane-2á-5á diol-10-one, 1,4à, 6,14-tetramethyl-4-vinyl | $C_{20}H_{32}O_2$ | Anti-inflammatory | 20.70 | 0.196 | 20.14 | 0.329 |
| 19 | | 5,6,7,8,9,10-hexahydro -9-phenyl -spiro[2H-1,3-benzoxazine-4,1'-cyclohexane]-2-thione | $C_{14}H_{23}NOS$ | Antiparasitic | 28.67 | 0.380 | 28.32 | 1.037 |
| 20 | Ester | Tetradecanoic acid, 2-phenyl -1,3 -dioxan- 5-yl ester | $C_{24}H_{38}O_4$ | Pesticidal | 25.52 | 0.166 | 19.97 | 0.246 |

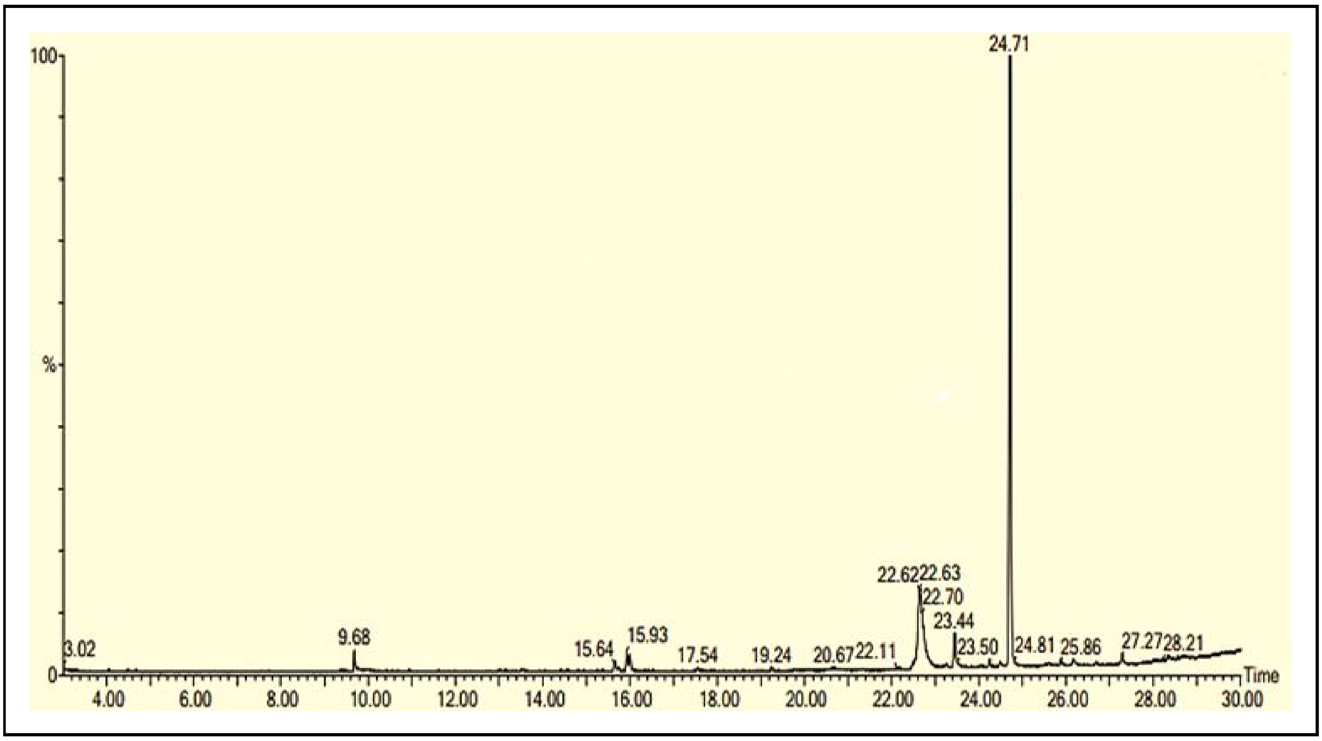


**Figure 2: Metabolic profile of teak heartwood (11 years).**

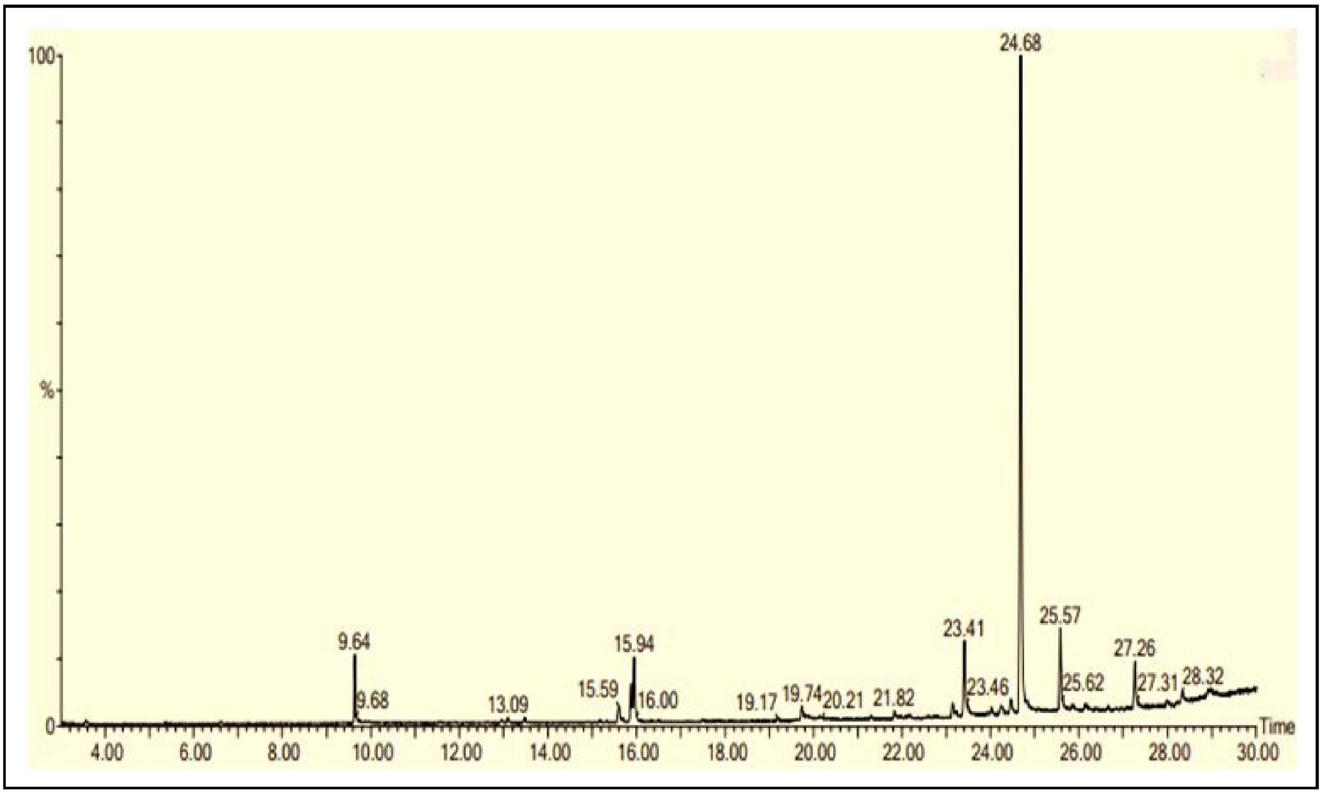


**Figure 3: Metabolic profile of teak heartwood (17 years).**

The Table 2 compares the concentration of various extractives in heartwood samples at 11 and 17 years, showing notable trends in chemical changes over time. Alkaloids and phenols increase moderately from 41.2 to 49.4 µg/g and 35.2 to 39.0 µg/g, respectively, suggesting a gradual accumulation with age. Aldehydes, however, show a slight decrease, from 89.9 to 84.8 µg/g, possibly indicating some degradation over time. Keytones display a mild increase, rising from 67.1 to 73.6 µg/g, while heterocycles increase from 10.0 µg/g to 11.0 µg/g, reflecting steady growth. Acids present the most significant change, tripling from 4.5 to 13.0 µg/g, hinting at an age-dependent accumulation. The benzene series, alkanes, and esters all show smaller increases, from 6.4 to 7.7 µg/g, 4.7 to 5.0 µg/g, and 5.6 to 6.1 µg/g, respectively, indicating subtle yet consistent growth with age. Overall, most extractives increase in concentration over time, suggesting that aging heartwood undergoes complex biochemical changes, possibly enhancing certain properties.

**Table 2: Comparison on heartwood content of ethanolic extractives in teak**

| S.No. | Extractives | 11 years heartwood (µg/g) | 17 years heartwood (µg/g) |
|---|---|---|---|
| 1 | Alkaloids | 41.2 | 49.4 |
| 2 | Phenol | 35.2 | 39.0 |
| 3 | Aldehyde | 89.9 | 84.8 |
| 4 | Keytones | 67.1 | 73.6 |
| 5 | Heterocycle | 10.0 | 11.0 |
| 6 | Acid | 4.5 | 13.0 |
| 7 | Benzene series | 6.4 | 7.7 |
| 8 | Alkane | 4.7 | 5.0 |
| 9 | Ester | 5.6 | 6.1 |

On comparing both age group samples heartwood extraction of 17 years showed highest content of tectoquinone (2-Methylanthraquinone) with the peak area of 5.156% (Figure 3), followed by 11 years sample with the peak area of 0.206% (Figure 2).

## 4. Discussion

The color variation in the heartwood may be attributed to the presence of quinone compounds in the sample. The study results are in line with the verdicts of Qiu *et al.* (2019) and they observed the similar alkaloid compound 2-methyl-anthraquinone using gas chromatography-mass spectrometry technique which is responsible for the color morphology of teak heartwood. Hence, it can be presumed that the higher concentration of alkaloids and phenols in the studied sample heartwood might be acting as resistant metabolites against pests and diseases (Sharma *et al*., 2021). Identical results were reported by Windeisen *et al.* (2003) and Qiu *et al.* (2019) that their GC-MS analysis using acetone extractives detects similar kind of metabolites with varying proportions which acts as an antifungal and antitermitic compound in the heartwood of teak. The present study results are in concomitant with the findings of Alabi and Oyeku (2017) reported that similar compounds were detected by using GC-MS technique with the use of different extractives.

A similar study was conducted by Xie *et al.* (2011), the extractive chemical components of teak heartwood from three different provenances were analyzed and compared (Nigeria, India and Thailand), and found that tectoquinone proportion was higher in Indian teak heartwood when compared to other two provenance. However, it is interesting to note that tectoquinone compound functions as an antitermitic and decay resistant which increases the durability of teakwood. The study findings are corroborates with the detections of Lukmandaru (2020) who reported that tectoquinone exhibited both strong toxicity and antifeedancy as well as it was far superior to other extractive compounds. The present study result agrees with those reported by earlier researcher (Haupt *et al.,* 2003; Bhat and Thulasidas, 2007; Lukmandaru and Takahashi, 2009; Hassan *et al.,* 2018; Rizanti *et al.,* 2018; Rosamah *et al.,* 2020 and Yang *et al.,* 2020). Among the alkaloid group extracted in the study, tectoquinone was the major compound which acts as a resistant against termite attack and increases the durability of the teak wood (Sumthong *et al.,* 2006; Li *et al.,* 2017; Vyas *et al.,* 2018; Lukmandaru *et al.,* 2020). Hence, the study findings indicated that tectoquinone is a key secondary metabolite in teak heartwood, known for its strong antitermitic properties that help protect the wood against termite attacks. As teak heartwood ages, the concentration of tectoquinone generally increases, enhancing the wood's natural resistance to decay and pests (Budianto *et al*., 2023). This increase is evident from the rising area percentage in older samples, reflecting a buildup of protective compounds over time (Lote *et al*., 2023). The compound shows enhanced antitermitic activity with age, increasing the wood's resistance to pests and decay. This natural accumulation reinforces teak's durability, supporting its medicinal value as a protective agent in long-lasting wood applications.

## 5. Conclusion

The biochemical compounds present in teak heartwood samples collected from north eastern zone with two different age class (11 and 17 years) were detected by using gas chromatography-mass spectrometry technique. Among the nine detected secondary metabolites, alkaloid group of compounds had higher proportion than other groups. Among the alkaloids, tectoquinone is the major biochemical compound exhibited higher peak area of 5.156% in 17 years sample which acts as a resistant mechanism against termites and increases the durability of wood. Its potent antimicrobial action makes it effective against various bacterial and fungal pathogens, which has applications in treating skin infections, respiratory diseases, and gastrointestinal disorders. Tectoquinone also demonstrates strong antioxidant activity, helping to reduce oxidative stress, which is implicated in chronic diseases like cardiovascular disorders and neurodegenerative conditions. Other metabolites like ketones and phenols were also detected which acts as natural durability against insects. The study revealed that higher the age class higher will be the wood metabolites. Hence, higher age classes are considered as biochemically strong wood.

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## Conflict of interest

The authors declare no conflict of interest relevant to this article.

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