Effect the site, heartwood and sapwood on some chemical characterization composition of *Quercus aegilops* L. naturally growing in Kurdistan region of Iraq

By
Hadar Sami Saeed[1], Ahmed Saieed Abdullah[2], and Aree Adel Abdulqader[3]

[1]*PhD student. Dept. of Forestry, College of Agricultural Engineering Sciences, University of Duhok, Kurdistan Region-Iraq*

[2]*Assist. prof /supervisor. Dept. of Forestry, College of Agriculture and Forestry Sciences, University of Mosul, Region-Iraq*

3 Office of the president, Duhok polytechnic University, Duhok, Kurdistan Region, Iraq.

* Corresponding author: hadar.sami@uod.ac

Abstract

Oaks are one of the important trees, distributed in many regions of temperate zone in the world. The Valonia oak tree (*Quercus aegilops* L.) comprises ~ 70% of the oak forests in the Kurdistan Region of Iraq. Besides its ecological importance as the residence for various endemic and migratory species, also has socio-economic values. The study aims to investigate the effect of site, heartwood and sapwood chemical properties wood of *Q. aegilops* tree to knowledge to increase the efficiency of their utilization. Nine mature trees with tree height ranged from 8.10 to 8.90 m and tree diameter are between 21.10 and 24.50cm at breast height were randomly selected and harvested from three naturally regenerated and unmanaged sites within the natural geographic distribution area. Lignin, ash, and total extractive content were determined from the sapwood and heartwood of species in each site. Significant difference effects noted among the sites, wood type, and their interactions on some wood chemicals of tree studies. Trees of the Zakho content more chemical extractive in hot-water (29.972%), chloroform (5.583%), acetone (4. 667%), lignin (31.70%), and ash content (2.79%). Makes the trees of this site more survive by fighting off pests and diseases, and they provide valuable raw materials for medicines, building products, and everyday industrial, compare to the trees of both Imedi and Safin. The results indicated that heartwood content more extractive than the sapwood. The sapwood generally had higher chemical extractive content in ethanol and acetone solvent, while the heartwood had a greater amount of lignin (34.956%), ash (2.66%) and extractives dissolved in hot-water (26.781%), and chloroform (3.917%). This may affect the higher durability and color of heartwood.

Keywords: *Quercus aegilops* L. wood extractive, site, heartwood, sapwood

Introduction

Forests, one of the most complex and diverse ecosystems on earth, play a crucial role in maintaining global ecological balance and biodiversity. Oak is an angiosperm belonging to the Fagaceae family. Approximately 600 species of the genus *Quercus* (*Quercus* spp.) is one of the most valuable hardwood tree species because of its high-quality timber, durability, and wide range of industrial applications. Have wide distribution through Europe, Asia and North America,

ISSN 2072-3857

representing half of all forest cover [1],and [2] and are ecologically, economically and culturally relevant [3]. Oaks are also economically important for the Kurdistan forestry due to the variety of oak species and the extent of the area they occupy.

The chemical composition of oak wood plays a crucial role in determining its physical, mechanical, and durability properties. It is the basic composition of oak does not significantly differ from one species to another. Cellulose (40%) and hemicellulose (25%), which provide the framework and matrix of the woods, are the main compounds of oak woods, and lignin, another large polymer mainly present in the cell walls, also comprises 20% of dried oak wood [4] and [5].

Q. Aegilops L. commonly known as Valonia oak is an important deciduous hardwood species naturally distributed throughout the eastern Mediterranean region, including Iraq, Turkey, Syria, Greece, and neighboring countries [6]. In the Kurdistan Region of Iraq is considered one of the most important, widespread, and native tree species. It covers as much as 70 % of the total Oak area which constitutes about 90% of the region's forest [7]. The species has large ecological adaptability landscape and socioeconomic importance, in which is the most important source of wood that is hard, heavy, dense, strong and resistant to pressure and fungi diseases. Its wood used for construction, furniture, mine timbers, plywood, pulp chips and production of coal[8] and [9]. Also, it plays a vital role for preserving soil and water, providing shelter and food for hundreds of animal and plants species thus contributing to the enhancement of the biodiversity and wildlife of the region. Kurdish farmer's make the shank of plough from its branches, Different parts of oak are used in folk medicine [10]. Oaks are valuable timber species is highly considered for indoor joinery and furniture due to its mechanical properties and aesthetical value. Size and absence of defects such as knots or grain direction are also important aspects for acceptance of oak timber for higher value products [11]. The wood of oak is very resistant to insect and fungal attack because of its content high amount of tannin. Moreover, has very interesting grain markings, mainly when quarter sawn [6].

Wood is a biopolymer composite existing in three-dimensional space essentially composed of an interconnected matrix of cellulose, hemicelluloses, and lignin interrupted by a small percentage of various extractives and inorganic materials. The chemical composition of wood is a fundamental factor determining its overall properties. The content and arrangement of cellulose within cell wall directly influence the mechanical strength of wood [12]. Chemically, wood is composed primarily of carbon, hydrogen, and oxygen, with carbon and oxygen being the major elements, with their respective average units of 49% and 44% by weight. Approximately 7% of the remaining composition consists of hydrogen with some nitrogen and inorganic metallic ions (ash) in trace amounts [13]. Site condition may at times vary from being moderate to a strong effect with respect to the characteristics of wood;[14].and [15] a variation of extractive content in heartwood and sapwood on *Eucalyptus globulus*, concluded having differences among sites statistically; however, the greatest amount of variation came from differences within trees between sapwood and heartwood.

Oaks contain about 25-28 chemical compounds. These include tannic acid, egallic acid, ellagic acid, monoterpens, pcoumarin, vanillic acid, tolune and kaempferol[16]. These Quercus species contain secondary products such as poly phenolic compounds; tannins are ellagic

ISSN 2072-3857

acids which are considered to be a great importance in medicinal, pharmaceutical, antimicrobial and anti-disease [17]. A chemical characterization of *Q. Aegilops* has not been made, namely considering the differences between heartwood and sapwood. In fact, the transformation of sapwood to heartwood is accompanied by accumulation of solvent extractible compounds (the so-called extractives) and their proportion and properties may have a significant impact on the wood utilization. For instance, the heartwood in oaks shows high concentrations of phenolic extractables (up to 10%), that may have multiple biological effects, including antioxidant properties, and has small amounts of lipids that vary according to the species and other factors such as geographical origin and tree [18]. Knowledge of the chemical composition of timber species is necessary in the search for alternatives to forest exploitation. The chemical composition of wood is not static but exhibits considerable variability across species, within the same species, and even within individual trees. This variability arises from factors such as genetic differences, growth conditions, tree age, and anatomical location (sapwood versus heartwood) [19]. Sapwood and heartwood, the two primary components of the woody tissue, play critical roles in tree growth. Sapwood functions as the active zone for water and nutrient transport, while heartwood primarily provides structural support and stores nutrients and water [20] and [21]. While both sapwood and heartwood contribute to the tree's overall functionality, heartwood is generally less phenotypically adaptable to environmental fluctuations compared to sapwood, which is more directly involved in physiological processes such as water and nutrient transport. Nonetheless, the formation and density of both heartwood and sapwood are influenced by environmental factors, particularly water availability, which is crucial for the tree's growth and survival in varying conditions [22]. Heartwood formation involves physiological and biochemical changes that lead to chemical difference in cellulose, hemicellulose, lignin, and extractives between heartwood and sapwood [23]. Analyzing these differences provides valuable insights for elucidating the mechanisms underlying heartwood formation and is crucial for understanding wood properties and tailoring utilization strategies. A chemical characterization of *Q. Aegilops* has not been made, namely considering the differences between heartwood and sapwood. In fact, the transformation of sapwood to heartwood is accompanied by accumulation of solvent extractible compounds (the so-called extractives) and their proportion and properties may have a significant impact on the wood utilization. For instance, the heartwood in oaks shows high concentrations of phenolic extractables (up to 10%), that may have multiple biological effects, including antioxidant properties, and has small amounts of lipids that vary according to the species and other factors such as geographical origin and tree [24] and [18]. Miranda et al., [25] observed that the heartwood and sapwood of *Q. faginea* are clearly outsingled with a well-established border. Chemically, heartwood and sapwood differ considerably in their extractives content, namely in polar extractives e.g. compounds soluble in ethanol and water, which are approximately two-fold in heartwood in relation to sapwood. The ethanol-water extracts are rich in phenolics, especially the heartwood extracts. Understanding these chemical properties is crucial for timber conversion, as sapwood requires preservative treatments and different drying (seasoning) strategies than the naturally durable heartwood.

Material and Methods:

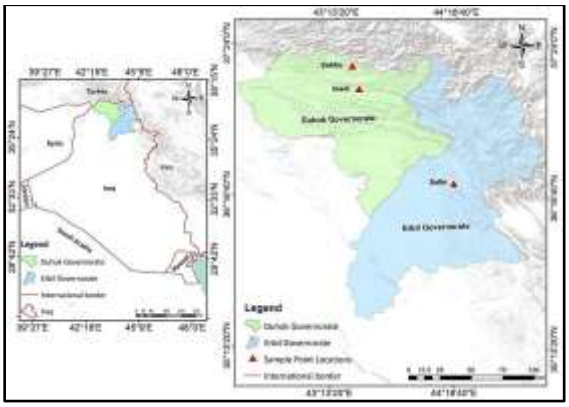
Location of examination

ISSN 2072-3857

The current study was carried out in the laboratory of forest department and laboratory centers in College of Agricultural Engineering Sciences/University of Duhok.

Site characterization and sampling

A total of nine *Q. aegilops* mature trees were randomly selected and harvested from three naturally regenerated and unmanaged sites (3 trees per site) within the natural geographic distribution area of the species in the Kurdistan Region of Iraq. Tree selection was based on criteria such as straight stem form, normal branching patterns, and absence of visible disease or pest infestation. The locations and detailed characteristics of the three sites are presented in the (Table 1 and Figure 1). The tree height ranged from 8.10 to 8.90 m and tree diameters are between 21.10 and 24.50cm.



(Figure 1): Study area map with specific locations for wood sample collection from different locations.

(Table 1: Site and physiographic data of location surveyed

Precipitation rate (ml) 2015-2025	Stand Density (Tree/100m2)	Aspect	Altitude (m)	Latitude (E)	Longitude (N)	Site
822.9727	85 trees/100m2	N	1070	37.083225°	43.439623°	Amedy
565.2818	70 trees/100m2	N	597	37.248170°	43.374643°	Zakho
659.7364	75 trees/100 m2	N	1028	36.40655°	44.296426°	Safin

Wood Chemical Analysis:

The chemical determinations were performed on a stem disc collected at breast height with approximately 15 cm thickness. The sapwood and heartwood were separated with a chisel and the samples were ground in a knife mill and sieved. The 40–60 mesh fractions were kept for analysis. Chemical summative analysis included determination of ash, soluble extractible compounds in dichloromethane, ethanol and water, Klason and acid-soluble lignin. All determinations were made with duplicate samples.

The heartwood and sapwood samples of *Q. Aegilops* were kept to measure and analyses the chemical composition, from pith to the bark, as per [26] standards. Proper preparation of the wood material into small particles preceded the test procedure. The oven-dried specimen was ground and sieved to pass through a 0.4 mm (40-mesh) screen and retained on a 0.6 mm (60-mesh) screen. The samples were conditioned under sealed bags at 5 °C in a cold room until further analysis could be done. The wood samples were first oven dried before conducting chemical testing at a constant weight under 60 ± 2 °C for 48 hours. Subsequently, each sample of 2g

was subjected to Soxhlet extraction for 8 hours with each of the four solvents: Hot-water, ethanol, chloroform, and acetone, whereby the extractives were left with the remaining material being the lignocellulosic fraction of the wood [27] and [28]. Using a two-step acid hydrolysis process, lignin content was analyzed across the radial section of the wood from pith to bark. In the first step, 15 ml of 72% sulfuric acid (H_2SO_4) was added to 1 g of each extractive sample and stirred every 15 min for a period of 2 hours at 20 °C using a glass rod to thoroughly dissolve the sample. In the second step, the concentration of the acid was downgraded to 3% by adding 560 ml of distilled water to each sample and heating them in a 100-degree water bath for 4 hours to complete the hydrolysis. The flasks were covered with aluminum foil and stirred periodically.

The acid-insoluble residue (Klason lignin), was washed with hot water again to remove residual acid from the filtered samples after hydrolysis through pre-weighed glass crucibles and were oven-dried at 105 ± 2 °C until a constant weight is obtained as demonstrated in (Figure 3.9). The weight of Klason lignin was determined by subtracting the initial crucible weight from the final weight after drying the residue [29]. Lignin content (%) was calculated for every sample according to [30] by using the following equation.

Lignin (%) = (A/W) *100

Where: A = Weight of lignin (g) and W = Oven-dry weight of the test sample (g)

The determination of ash content for wood samples was done as per [31] standard. Five grams of dried wood powder unextracted from each sample taken radially from pith to bark and was added to pre-weighed crucibles. They were then burnt in a muffle furnace for four hours at a temperature of 550 ± 25 °C until the saw dust was completely converted into white. After burning, the crucibles were placed in a desiccator to cool to room temperature. The final mass of each crucible was recorded, and the ash content was calculated as the difference between the initial and final masses, expressed relative to the oven-dry weight of the sample. The ash content was calculated using the following formula:

Ash Content (%) = (A/B) ×100

Where: A = Weight of ash (g) B = Oven-dry weight of the test specimen (g), moisture-free.

A descriptive statistical tool was used to summarize the data numerically. The results were expressed as mean and standard deviation (ST.D). The significance of differences (p 0.05) among the corresponding mean values was determined using one-way analysis of variance (ANOVA) followed by Duncan's multiple-comparison test.

Results and Discussion

Chemical properties of wood are major determining factors for its performance and suitability for different wood-based applications. Chemical analysis sheds light on the structural composition of wood that governs its functional behavior. The chemical composition of the heartwood and sapwood of the *Q. Aegilops* trees from the three sites is given in (Tables 2, 3, 5, and 6) regarding the monosaccharide composition. There were considerable chemical differences between heartwood and sapwood as regards solvent extractible compounds content (Table 2). Heartwood contained significantly higher amounts of extractible compounds than sapwood.

- **Hot Water Extractable Contents (%):**

The hot water extractable substances are of great importance when identifying the

ISSN 2072-3857

different types of water-soluble compounds present in lignocellulosic materials, such as tannins, starches, calories, pectin, and phenolic substances [32]. High variability in hot water extractives across the sites studied (Table 3). The overall mean was 24.687± 4.671%. The effects of sites, wood type, and the interaction between site and wood type were high on chemical properties dissolved in hot water at the 1% probability level (Table 2). Analysis of variance and Duncan's multiple range tests in Table (2 and 3) revealed the highest value on hot water extractable content was recorded at Zakho site (29.972%), and differed significantly with other sites, while the lowest extractive dissolved in hot-water in trees of the Safin site by the value (21.111%). However, there was a difference between the proportions of the water and other soluble compounds in the studies between sites, heartwood and sapwood ethanol-soluble compounds represented the largest proportion of total extractives (70%). Comparative studies of heartwood—sapwood solvent extractible compounds in hot water shown in table (4) that there was high significant variation among these two types of wood and the heartwood content more extractive by the ratio (26.781 %), while the sapwood have less amount by the value (22.593**%)**. Moreover, the heartwood and sapwood of trees from the Zakho content maximum extractive compare to the wood types of other sites by amount ratio (30.244 and 29.700%) respectively (Table 5).

Morais&Pereira [32]. who carried out a study on a variation of extractive content in heartwood and sapwood on *E. globulus*, concluded having differences among sites statistically; however, the greatest amount of variation came from differences within trees between sapwood and heartwood. The higher content in solvent extractible compounds of heartwood in relation to sapwood is considered a heartwood specific feature [33]. However the magnitude of the difference between sapwood and heartwood differs greatly between species e.g. respectively 3.5% and 5.7% or 2.4% and 3.8% in *E. globulus* [24] and [32], 4.0–4.2% and 7.4–9.5% in *A. melanoxylon* [34], 9.2% and 10.0% in *T. grandis* [35]. Moreover, [36] reported that *Q. rubra* contained 6.2% and 8.2% total extractables in sapwood and heartwood, respectively, which included sixteen phenolic compounds. Herna´ndez and Salazar [37] reported the chemical composition of sapwood and heartwood of four oak species: respectively 6.1% and 7.2% in *Q. coccolobilofia,* 8.3% and 8.9% in *Q. durifolia*, 9.2% and 11.6% in *Q. rugose,* and 8.2% and 10.6% in *Q. oleoides*. Ruiz-Aquino et al., [38] found no differences between sapwood and heartwood solvent extractible compounds content: respectively 5.3% and 5.4% in *Q. laurina*, and 8.2% and 8.9% in *Q. crassifolia*.

- **Ethanol and Acetone Extractive Content (%):**

Statistical details, as described in (Table 3), the total average with ST.D of amount of extractive in this solvent was 5.189 ± 2.326%, and show that there is a variability concerning the percentage of wood extractives extracted by the ethanol solvents among sites. Similarly, Ahmed [39] reported that the relative value of ethanol-benzene extractives in Platanus species was 2.75%. Gao et al., [40] also noted that the content of ethanol and acetone extractives in wood varies significantly with tree species, age, and the particular portion being analysed. From the analysis of variance results presented in (Table 2), it may be seen that there were significant differences affect observed between sites and wood kind (heartwood and sapwood) on amount of extractive dissolved in the ethanol solvent. Duncan's multiple range test in (Table 3) also

ISSN 2072-3857

demonstrated relative volumes in ethanol wood extractives are statistically equivalent across survey sites-Amedi, Safin, and Zakho. Data shown the maximum percentage of extractive observed in the trees in the Safin locations (7.417%), and the minimum mean percentage values were recorded as 2.775% among trees of Amedi site. Examining the environment, [41] witness substantial differences in the extractive content of trees within a given species and in some different regions due to influences of climate and altitude.

Remaining data from this study indicated that radial position has had very effect on extractive content in ethanol. Duncan's mean comparison test also proved that there were significant differences in the radial direction between heartwood and sapwood. However, the results pointed out that higher percentage of ethanol-soluble extractives occur in the growth rings nearer to the bark (sapwood) by the amount (6.550%), while lower percentages are reported in the heartwood region near to the pith of the tree in the ratio (3.828%) (Table 4). Usually, extractive content increases with the age of the tree, more so in those species having durable heartwood rich in polyphenolic compounds. Similarly to [42] on *P. orientalis* wood. the results pointed out that higher percentages of ethanol- and acetone-soluble extractives occur in the growth rings nearer to the bark, while lower percentages are reported in the middle region of the tree. Contrary to [24] what he found a significant variation between sites on *Q. faginea* and the extractives in sapwood ethanol-soluble was higher from heartwood ethanol-soluble.

Data of this study indicated that also there were significant differences effect of heartwood and sapwood among the sites (Table 5). Duncan's mean comparison test show the higher ratio of ethanol-soluble extractives occur in heartwood and sapwood of trees from the Safin site by the vale (5.500 and 9.333%) and the lowest in the Imedi location by the value (2.183%) for heartwood and (3.367%) to sapwood ethanol-soluble extractives.

- **Chloroform Extractive Content (%):**

Chloroform is a moderately polar, lipophilic organic solvent used to isolate non-polar and semi-polar wood extractives—such as fats, waxes, free fatty acids, resin acids, sterols, and low-molecular-weight phenols—from wood tissue [42]. (Table 3) shows the average and standard deviation values (2.667 ± 2.209%) for the yield and composition of chloroform extracts regarding total wood extractive among the sites. analyses of variance (Table 2) and Duncan's means test proved significant effect of site on amount of extractive dissolved in chloroform soluble compounds. Wood of trees from the Zakho recorded higher percentage (5.583%) and differed significantly with trees of Imedi site which content lower ratio of extractive dissolved in chloroform soluble (1.250 %), data shows in the (Table 3).

Generally, non-significant effect of heartwood and sapwood on the amount extractive dissolved in chloroform soluble, also the results appearance that there was slight difference between heartwood and sapwood of amount chloroform solvent extractable compounds by the proportion (3.917 and 3.417%) respectively (Table 4). The heartwood region of the xylem generally contains more extractives than the sapwood region. Heartwood formation and extractive accumulation are critical adaptive strategies that improve tree protection against environmental stress.

As for as, the interaction between site and heartwood and sapwood the Duncan's

ISSN 2072-3857

multiple range test (Table 5) indicated the heartwood and sapwood of trees from Zakho site have higher extractive dissolved in chloroform by the ratio value (6.167 and 5.000%) respectively, compare the heartwood and sapwood in cross sections of tree of the Imedi locations which have less quantity of extractive dissolved in chloroform solvent in percentage value (1.083 and 1.417%). The radial distribution of extractives in European larch was investigated by [41] sing microsampling with subsequent FTIR analysis. Their results found that, in mature larch, the wood extractive amount increased linearly from the pith toward the heartwood–sapwood boundary. The heartwood region of the xylem generally contains more extractives than the sapwood region. Heartwood formation and extractive accumulation are critical adaptive strategies that improve tree protection against environmental stress [43].

- **Acetone Extractive Content (%):**

Statistical details, as described in Table (3), show that there is a degree of variability concerning the percentage of wood extractives extracted by the acetone solvents between trees from different sites. Overall mean of the wood extractives obtained of *Q. Aegilops* tree from acetone solvent was (3.899 ± 1.033%). Acetone extractive content in wood typically ranges from 1% to 5% of the dry wood mass for many common tree species, though it varies widely by species, tissue type (heartwood vs. sapwood), and geographic origin. Acetone efficiently isolates lipophilic and moderately polar compounds like fats, waxes, resin acids, sterols, and low-molecular-weight phenolic compounds [44]. Gao et al. [45] also noted that the content of ethanol and acetone extractives in wood varies significantly with tree species, age, and the particular portion being analysed.

From the analysis of variance results presented in (Table 2), it may be seen that there were no significant differences effects observed between sites, wood types (heartwood and sapwood), and the interactions between site and wood types on amount of wood extractive in acetone solvent. Typically, it can be seen that post-Duncan's multiple range test in (Table 3) also demonstrated relative volumes in acetone wood extractives there were a significant difference across survey sites (Imedi, Safin, and Zakho). Data measured noted that the highest mean percentage values of extractive were recorded by 4. 667% in the Zakho and 4.500% in the Safin site, while the least values were observed in Imedi location with values of (2.800%). Acetone effectively dissolves polar and medium-polarity lipophilic and phenolic compounds, showing clear differences across geographic or environmental sites. Acetone extracts different amounts of wood compounds from trees depending on where the trees grow, soil types, local weather, and sunlight change how much extractives form in the wood, the different sites cause these chemical amounts to go up or down [46].

The study indicated that the heartwood and sapwood in radial position has had very little effect on extractive content dissolved in the acetone solvent. Duncan's mean comparison test also proved there were no significant differences between these wood types. But the result indicated that the amount of extractives in sapwood (4.394%) was higher than that in heartwood (3.583%) (Table 4). Contrary to the [47] the results showed that the difference in content of the main components between heartwood and sapwood was not obvious. However, the amount of extractives in heartwood was higher than that in sapwood, especially for phenols, quinones, and ketones of teak (*Tectona grandis* L.F.), they concluded

ISSN 2072-3857

The acetone extractives in heartwood were higher in composition and content than those in sapwood; 49 components were detected in the acetone extractive of the heartwood, and 26 components were detected in the sapwood. The high content in the teak heartwood was mostly detected in the sapwood.

However, the results pointed out that higher percentages of acetone-soluble extractives occur in the growth rings nearer to the bark (sapwood), while lower percentages are reported in the near of pith region (heartwood) of Q. *Aegilops* tree in different sites. Duncan's mean comparison test also (Table 5) displays the great amount acetone-soluble extractives in heartwood and sapwood were from tree of the Zakho and Safin by the value (4.167 and 3.833%) and (5.167%) respectively, In the other side, also the maximum acetone-soluble extractives quantity recorded in the Imedi location by the value percentage (2.750% in heartwood) and (2.850% in sapwood). From the differences in compositions, it can be assumed that phenols, quinones, and ketones in *Q. aegilops* may be the main extractives that caused heartwood to be darker than sapwood.

(Table 2): Analysis of Covariance for Sum of Sequares of Wood chemical properties *Quercus aegilops* L wood

Ash content (%)	Lignin (%)	Acetone Extractive (%)	Chloroform Extractive(%)	Ethanol Extractive (%)	Hot Water Extractive (%)	D.F	S.O.V
1.71 *	125.14	12.80	58.58 **	64.95 **	261.85 **	2	Sites (S)
0.86 *	1098.92 **	2.96	1.125	33.35 *	78.96 **	1	Wood Type (WT)
2.21 **	120.53	1.22	1.750	2.84	67.57 **	2	S * WT
5.76	1718.18	23.43	50.35	48.61	30.11	12	Error
10.54	3062.77	40.418	111.809	152.587	438.496	17	Total

- **(**) Significant at (0.01) level of probability, (*) Significant at (0.05) level of probability**

(T**able 3): Influence the site on some chemical properties of *Quercus aegilops* L. wood**

Total Mean ± ST.D	Sites			Wood Extractive Material
	Zakho	Safin	Imedi	
24.687± 4.67	29.972 a	21.111 b	22.978 b	Hot Water Extractive (%)
5.189 ± 2.326	5.375 a	7.417 a	2.775 b	Ethanol Extractive (%)
2.667 ± 2.209	5.583 a	4.167 a	1.250 b	Chloroform Extractive%)
3.899 ± 1.033	4. 667 a	4.500 ab	2.8000 b	Acetone Extractive (%)
29.430 ± 2.284	31.700 a	29.458 a	27.133 a	Lignin (%)

ISSN 2072-3857

2.507 ± 0.267	2.79 a	2.26 b	2.47 ab	Ash content (%)

(Table 4): Influence the wood zone (heartwood and sapwood) on some chemical properties of *Quercus aegilops* L. wood

Wood Type		Wood Extractive Material
Sapwood	Heartwood	
22.593 b	26.781 a	Hot Water Extractive (%)
6.5500 a	3.828 b	Ethanol Extractive (%)
3.4167 a	3.9167 a	Chloroform Extractive%)
4.3944 a	3.5833 a	Acetone Extractive (%)
23.906 b	34.956 a	Lignin (%)
2.35 b	2.66 a	Ash content (%)

(Table 5) Influence the interaction among the site with heartwood and sapwood on some chemical properties of *Quercus aegilops* L. wood

Sites						Wood Extractive Material
Zakho		Safin		Imedi		
Sapwood	Heartwood	Sapwood	Heartwood	Sapwood	Heartwood	
29.700 a	30.244 a	16.333 d	25.889 b	21.744 c	24.211 bc	Hot Water Extractive (%)
6.950 ab	3.800 bc	9.333 a	5.500 bc	3.367 bc	2.183 c	Ethanol Extractive (%)
5.000 ab	6.167 a	3.833 ab	4.500 ab	1.417 b	1.083 b	Chloroform Extractive (%
5.167 a	4.167 a	5.167 a	3.833 a	2.850 a	2.750 a	Acetone Extractive (%)
28.067 ab	35.333 a	24.157 b	34.40 a	19.133 b	35.133 a	Lignin (%)
2.29 b	3.28 a	2.20 b	2.31 b	2.55 b	2.38 b	Ash content (%)

- Lignin Content (%):

Lignin's mean average value among the sites of Q. aegilops wood was 29.430 ± 2.284 % this study revealed that lignin content denoted low variation among sites as illustrated in (Table 3). In oak trees (Quercus species), total lignin content typically ranges between 20% and 30% of dry wood mass. Differences in absolute lignin percentage between heartwood and sapwood are generally minimal or statistically similar when calculated on an extractive-free basis, though heartwood often exhibits a more condensed, cross-linked lignin structure [24]. Comparatively, other hardwood species exhibit lignin contents in the following ranges: (15 to 28)% in *E. globulus* [48];

ISSN 2072-3857

(22 to 25)% in *B. pendula* (silver birch) [49]; (32 to 43)% in *T. grandis* (teak) [50]; and (21.00 to 29.50%) in *P. orientalis* [43].

Analysis of variance results indicated high significant differences (more of 1% probability level) between heartwood and sapwood regarding to lignin content. In the other site, site and site interaction with wood type not influenced significantly on the variations in amount of lignin in wood of Valonia oak. The data is presented in (Table 2).

Duncan's multiple range test results in (Table 3) also confirmed no-significantly differences among sites. But the trees in Zakho had the highest lignin contents, being 31.700% then Safin (29.458%), and Imedi trees (27.133%) pleased the lower mean lignin. therefore, environmental factors operating at a site are critical determinants of lignin content and composition as lignin biosynthesis is usually stress responsive. Temperature, light intensity, water stress, soil characters, and nutrient availability could enhance or suppress lignin accumulation in trees [43].

Lignin usually varies in a predictable pattern within an individual tree, more specifically along with the radial axis from the centre pith outward into the bark. Strong significant variation observed between heartwood and sapwood of amount lignin content, and the total lignin amount was slightly higher in heartwood (34.956%) than in sapwood (23.906%) (Table 4). Miranda et al., [24] observed the site did not influence the chemical composition.in *Q. faginea* and the heartwood had approximately two times more solvent extractible compounds than sapwood (on average 19.0% and 9.5%), were the lipophilic extractible compounds were below 1%, and most of them were polar e.g. ethanol-soluble compounds corresponded to 65% of total extractives in heartwood and 43% in sapwood. Lignin content was similar in sapwood and heartwood (28.1% and 28.6% of extractive-free wood respectively) as well as the sugar composition. The lignin content reported [38] for *Q. laurina* (25.1% in sapwood and 25.5% in heartwood) and *Q. crassifolia* (24.9% in sapwood and 25.2% in heartwood), and by [46] for *Q. suber* sapwood (23.8%).

Moreover, the wood of trees from the Zakho site content more lignin in heartwood (35.333%) and sapwood (28.067%) compared to the trees of other sites was studies (Table 5). Apparent increases in heartwood lignin can partly result from the relative loss or degradation of polysaccharides (cellulose and hemicellulose) and the accumulation of polyphenolic extractives that cross-link with the lignin network. During the transition from sapwood to heartwood, chemical transformations alter the wood matrix, modifying both the quantity and structural properties of the lignin polymer. This would be of importance in choosing sites with reduced lignin content, particularly in the field of pulp and paper manufacture or bioethanol, where isolation of lignin is important. Moreover, the strength of the paper formed is reduced because of the higher lignin content as it resists hydrogen bonding that occurs during the formation of fibers. Wood is the primary source of lignin on the global scale, which is a complex organic polymer and acts like a natural "glue", binding cellulose and hemicellulose fibers to confer structural integrity, rigidity, and mechanical strength. Lignin comprises about 18-35% of the total mass of a tree and helps in waterproofing the cell walls, aids in water transport, and provides resistance to microbial degradation[52].

In the study by [50], they mentioned that the percentage of lignin varies a lot from tree species to tree species, between any number of individual trees, or even from the pith to the bark in a single tree. All of

ISSN 2072-3857

these variations are influenced by genetic, environmental, and developmental factors, among others. In the same way, [53] reported on significant variation in total lignin content and chemical composition of trees belonging to the same species. According to their findings, most variation found among individual trees is caused by to genetic differences.

- **Ash Content (%):**

Ash content is one of the most important parameters to evaluate the energy potential of wood. Ash originates from inorganic materials (silicone, aluminium, iron, calcium, magnesium, sodium, potassium, titanium and manganese) and does not participate in energy production [54] and [55]. As it is an inorganic material, ash corresponds to the residues of the complete wood combustion. (Table 3) shows the mean ash contents and standard deviation for *Q. Aegilops* wood, according to site, wood type position, and the interaction between site and wood type (heartwood and sapwood of the trees was (2.507 ±0.267). Recognizing of ash content in wood is importance to quantify wood quality, and the relevance of understanding variations in ash content at different ages, tree positions and growing regions. [24] reported that in oak tree species, the total ash content (representing inorganic mineral residue) tends to be slightly higher in the sapwood or shows variable patterns depending on specific mineral accumulations, though overall wood ash remains low (typically under 1% of dry mass). Studies on various oak species show that individual tree maturity and local soil chemistry heavily influence mineral uptake rather than a universal heartwood-sapwood rule.

According to the analysis of variance (Table 2) significant differences were observed of ash contents among the site, heartwood and sapwood and the interaction between these sources. Analyzes and Duncan's means test (Table 2 and 3) were performed the wood from Zakho plantation showed higher ash content (2.79) than from the Imedi (2.470) and Safin (2.260). High ash content in wood increase cleaning frequency and reduce the useful life of combustion equipment [56]. Moreover, as documented by [57], variations in plant species, local parent rock and anthropogenic activities could also cause differences in elemental composition of wood ash. But these environmental, factors such as moisture content of wood, burning conditions, and soil chemistry will also influence the composition of ash from its geographical environment; therefore, a detailed chemical characterization of ashes is necessary as long as it is compliant with the permissible limits in soil.

In radial position, the site had a significant effect on variation of ash content in heartwood samples and sapwood (Table 4). Studied from the ash content was higher in heartwood (2.66) than in sapwood (2.35). As for as, the interaction between site with wood type (Table 5), Duncan's test analysis indicated the heartwood of trees the Zakho have higher she content (3.280), While, the sapwood of trees from the Safin site have maximum ash content (2.200) compare to the trees of other sites. Compare to [43] observed considerable variation in the responses from the ash content analysis across the radial direction of the *P. orientalis* tree, noted the ash content increased from the pith toward the bark, as the highest value was for wood samples nearest to the bark 1.26%, and the lowest was in the inner wood 1.00%. This trend is consistent with the general pattern in trees, where sapwood, located closer to the bark, typically contains higher ash concentrations compared with heartwood near the pith. Also, [52] found the heartwood samples had smaller ash content than sapwood samples of E. grandis. It is results show that for sapwood, the ash

ISSN 2072-3857

content decreases with the age of the trees, they indicated that ash content can be a considerable parameter to assess the quality of the wood of Eucalyptus spp. as a fuel. The results show that for sapwood, the ash content decreases with the age of the trees, which corroborates with the findings of several authors. Sapwood can sometimes exhibit slightly higher or comparable total inorganic ash levels (e.g., around 0.8%–1.0% in *Q. faginea* sapwood versus 0.4%–0.5% in heartwood) due to active ion transport of macro-nutrients, whereas other studies find minimal overall statistical variance for basic combustion ash [24]. Sapwood is the physiologically active part of wood, containing living cells through which various compounds are transported for subsequent deposition in the heartwood [59] and [60].

Conclusion:

The present study attempted to expand our understanding of the changes in the wood chemical and extractive in heartwood and sapwood of *Quercus aegilops* trees growing in different sites in Kurdistan ragion of Iraq.

1. The chemical characterization and composition of *Q. aegilops* are heavily influenced by the wood zone (heartwood vs. sapwood), while the specific growth site primarily impacts physical proportions rather than altering fundamental chemical structures
2. Significant variation observed in the concentration of Valonia oak extractives between the sites.
3. The trees growing in Zakho site content more extractive, lignin, and ash compare the trees growing of other sites. Wood chemical and extractive composition varies greatly based on growth site factors like soil, climate, and geography. These environmental stresses change how a tree makes secondary metabolites, altering extractives (tanin, fats, phenolics) and polymers (cellulose, lignin).
4. Chemically, heartwood and sapwood differ considerably in their extractives content. For radial variation, the sapwood *of Q. aegilops* recorded a greater value of extractive substance in ethanol and acetone solvent content than the heartwood. However, the heartwood recorded a greater amount of lignin, ash, and total extractive content than the sapwood, make the heartwood more durability.

References:

[1] Haavik, L. J., Billings, S. A., Guldin, J. M.,&Stephen, F. M. (2015). Emergent insects, pathogens and drought shape changing patterns in oak decline in North America and Europe. Forest Ecology and Management, 354, 190–205.

[2] Tulik, M.,&Bijak, S. (2016). Are climatic factors responsible for the process of oak decline in Poland? Dendrochronologia, 38, 18–25**.**

[3] Sallé, A., Nageleisen, L. M., &Lieutier, F. (2014). Bark and wood boring insects involved in oak declines in Europe: Current knowledge and future prospects in a context of climate change. Forest Ecology and Management, 328, 79–93.

[4] Fernández de Simón, B., Cadahía, E., Conde, E.,&García-Vallejo, M. C. (1996). Low molecular weight phenolic compounds in Spanish oak woods. *Journal of Agricultural and Food Chemistry, 44*(6), 1507–1511.

[5] Nonier, M. F., Vivas, N., De Gaulejac, N. V., Absalon, C., Soulié, P.,&Fouquet, E. (2006). Pyrolysis–gas chromatography/mass spectrometry of

Quercus sp. wood: application to structural elucidation of macromolecules and aromatic profiles of different species. *Journal of Analytical and Applied Pyrolysis*, *75*(2), 181–193.

[6] Aree, A. A., Suliman, H. H., Saeed, H. S.,&Dawod, N. A. (2021). Some of phenotypic, physical and anatomical wood properties of valonia oak trees in Kurdistan-Iraq. *The Iraqi Journal of Agricultural Science*, *52*(3), 589–600.

[7] Shahbaz, S. E. (2010). Trees and Shrubs, A field guide to the trees and shrubs of Kurdistan region of Iraq. *Journal of University of Duhok*, *602*, 212–214.

[8] Stein, W. I. (1990). Quercus garryana Dougl. ex Hook. Oregon white oak. *Silvics of North America*, *2*, 650–660.

[9] Niemiec, S. S., Ahrens, G. R., Willits, S.,&Hibbs, D. E. (1995). Hardwoods of the Pacific Northwest. Research Contribution 8. *Collage of Forestry, Research Laboratory, Oregon State University*.

[10] Shahbaz, S. E., Balo, A. H.,&J MT, H. (2005). Phenotypic variation in natural stands of *Quercus aegilops* (Fagaceae) in Duhok province. *Journal of Duhok University*, *8*, 1–9.

[11] Kuzsella, L.,&Szabó, I. (2007). The effect of the compression on the mechanical properties of wood material. *Materials Science Forum*, *537*, 41–46.

[12] Ruiz-Aquino, F., Bautista, L. L., Bautista, A. E. L., Santiago-García, W., Pintor-Ibarra, L. F.,&Rutiaga-Quiñones, J. G. (2020). Anatomical characterization, physical, and chemical properties of wood of *Quercus macdougallii* Martínez, endemic species of the Sierra Juárez of Oaxaca, Mexico. *BioResources*, *15*(3), 5975.

[13] Young, R. (2008). Historical developments in wood chemistry. *Turkish Journal of Forestry*, *9*(1), 1–15.

[14] Wu, F., Zhang, P., Pei, J., & Kang, X. (2013). Genotypic parameters of wood density and fiber traits in triploid hybrid clones of *Populus tomentosa* at five clonal trials: F. Wu et al. *Annals of Forest Science*, *70*(7), 751–759.

[15] Scherbath, L.L. (2002). A survey of Allelopathic and other chemical interaction of oak (Quercus Spp.) http://colostate.edu/depts/Entomology/ courses/papers-2002/scher barth-polf-62k. 2002

[16] Cown M.M. (1999). Plant product as antimicrobial agents. Clinical microbiology reviews, 1999, 12(4), 564-582.

[17] Zhang, B., Cai, J., Duan, C.-Q., Reeves, M. J.,&He, F. (2015). A review of polyphenolics in oak woods. *International Journal of Molecular Sciences*, *16*(4), 6978–7014.

[18] Liu, H., Yang, B., Jiang, Z., Tang, J., Chen, D., Hao, J., Deng, X.,&Li, L. (2026). A Comparative Study of the Chemical Compositions of Heartwood and Sapwood in *Erythrophleum fordii*. *BioResources*, *21*(1), 903

[19] Ma, R.K.; Luo, J.; Wang, W.; Fu, Y.L. (2023). Changes in the physiological activity of parenchyma cells in *Dalbergia odorifera* xylem and its relationship with heartwood formation. BMC Plant Biol., 23, 559.

[20] Fan, J., Ding, C., Wang, S., Ma, C., Zhang, C., Li, Y., Wang, J., Yang, M., & Su, X. (2023). Effects of site conditions on growth and wood properties of *Populus* × *euramericana* cv.‘74/76’ J. Fan et al. Journal of Forestry Research, 34(2), 401–414.

[21] Chen, T., Aishan, T., Wang, N., Halik, Ü., & Yao, S. (2025). Heartwood/Sapwood Characteristics of *Populus euphratica* Oliv. Trunks and

ISSN 2072-3857

Their Relationship with Soil Physicochemical Properties in the Lower Tarim River, Northwest China. Plants, 14(2), 154.

[22] Ma, R., Luo, J., Qiao, M., Fu, Y., Zhu, P., Wei, P.,&Liu, Z. (2022). Chemical composition of extracts from *Dalbergia odorifera* heartwood and its correlation with color. Industrial Crops and Products, 180, 114728.

[23] Sanz, M., de Simón, B. F., Cadahía, E., Esteruelas, E., Muñoz, Á. M., Hernández, M. T.,&Estrella, I. (2012). Polyphenolic profile as a useful tool to identify the wood used in wine aging. Analytica Chimica Acta, 732, 33–45.

[24] Miranda, I., Sousa, V., Ferreira, J.,&Pereira, H. (2017). Chemical characterization and extractives composition of heartwood and sapwood from *Quercus faginea*. PLoS One, 12(6), e0179268.

[25] ASTM, E. (2017). Standard specification for woven wire test sieve cloth and test sieves. ASTM International.

[26] Diehl, B. G., Watts, H. D., Kubicki, J. D., Regner, M. R., Ralph, J., & Brown, N. R. (2014). Towards lignin-protein crosslinking: amino acid adducts of a lignin model quinone methide. Cellulose, 21(3), 1395–1407.

[27] Hassan, K. T. S., Kandeel, E., Kherallah, I. E. A., Abou-Gazia, H. A., & Hassan, F. M. M. (2020). *Pinus halepensis* and *Eucalyptus camaldulensis* grown in Egypt: a comparison between stem and branch properties for pulp and paper making. BioResources, 15(4), 7598–7614.

[28] Browning, B. L. (1967). Methods of wood chemistry. Volumes I&II.

[29] TAPPI standards. (2006). TAPPI-222: Regulation and guidelines.

[30] TAPPI 211 om-85 (1992) Ash in wood and pulp. TAPPI Test Methods, Atlanta 23.

[31] Jamaludin, K. (2006). Properties of particleboard and thermoplastic board from Buloh Semantan (*Gigantochloa scortechinii*). University Publication Centre (UPENA), Universiti Teknologi Mara, Shah Alam.

[32] Morais, M. C., & Pereira, H. (2012). Variation of extractives content in heartwood and sapwood of *Eucalyptus globulus* trees. Wood Science and Technology, 46(4), 709–719.

[33] Sjostrom E. (1993). Wood chemistry. Fundamentals and applications. 2nd ed. San Diego Academic Press. 1993.

[34] Lourenço, A., Baptista, I., Gominho, J., & Pereira, H. (2008). The influence of heartwood on the pulping properties of *Acacia melanoxylon* wood. Journal of Wood Science, 54(6), 464–469.

[35] Miranda I, Sousa V, Pereira H. (2011). Wood properties of teak (*Tectona grandis*) from a mature unmanaged stand in East Timor. J Wood Sci.; 57: 171–178. https://doi.org/10.1007/s10086-010-1164-8

[36] Seikel, M. K., Hostettler, F. D., & Niemann, G. J. (1971). Phenolics of *Quercus rubra* wood. Phytochemistry, 10(9), 2249–2251.

[37] Hernández, R. B.,&Salazar, J. A. H. (2005). Composición química de la madera de cuatro especies del género Quercus. *Revista Mexicana de Ciencias Forestales*, *30*(98), 25–49.

[38] Ruiz-Aquino F, Gonza´lez-Peña MM, Valdez-Herna´ndez JI, Revilla US, Romero-Manzanares A. (2015). Chemical characterization and fuel properties of wood and bark of two oaks from Oaxaca, Mexico. Ind Crops Prod. 2015; 65: 90–95.

[39] Ahmed, O. I. (2018). Some

physical and chemical characteristics of charcoal produced from forest trees in north of Iraq. Kirkuk University Journal for Agricultural Sciences (KUJAS), 9(1), (96-104).

[40] Gao, C., Cui, X.,&Matsumura, J. (2024). Multidimensional exploration of wood extractives: a review of compositional analysis, decay resistance, light stability, and staining applications. *Forests*, *15*(10), 1782

[41] Gierlinger, N., Jacques, D., Schwanninger, M., Wimmer, R.,&Pâques, L. E. (2004). Heartwood extractives and lignin content of different larch species (Larix sp.) and relationships to brown-rot decay-resistance. *Trees*, *18*(2), 230–236.

[42] Santos, A., Anjos, O., Amaral, M. E., Gil, N., Pereira, H.,&Simões, R. (2012). Influence on pulping yield and pulp properties of wood density of Acacia melanoxylon. *Journal of Wood Science*, *58*(6), 479–486.

[43] Abdullah. H. A. (2026). Effects of Site, Trees and Within Tree Variations on Some Wood Properties of *Platanous orientalis* L. Growing Naturally in Duhok Province. A thesis . Forest department / College of Agricultural Engineering Sciences / University of Duhok.

[44] Keržič, E., Humar, M., Oven, P.,&Vek, V. (2023). Development of extraction methodology for identification of extractive-compounds indexing natural durability of selected wood species. *Wood Material Science&Engineering*, *18*(6), 1940–1950.

[45] Gao, C., Cui, X., & Matsumura, J. (2024). Multidimensional exploration of wood extractives: a review of compositional analysis, decay resistance, light stability, and staining applications. Forests, 15(10), 1782.

[46] Haag, V., Koch, G., Richter, H.-G., Evans, R., Guzmán, J. A. S., & Schmitt, U. (2019). Wood anatomical and topochemical analyses to characterize juvenile and adult wood of lesser-known species from Central America (Mexico). *IAWA Journal*, *40*(4), 785–803.

[47] Qiu, H., Liu, R., & Long, L. (2019). Analysis of Chemical Composition of Extractives by Acetone and the Chromatic Aberration of Teak (*Tectona Grandis* L.F.) from China. Molecules, 24(10), 1989. https://doi.org/10.3390/molecules24101989

[48] Kojima, Y., Isaji, S., Yoon, S.-L.,&Ona, T. (2008). Selection criteria of *Eucalyptus globulus* Labill. for production of chemithermomechanical pulps (CTMP).

[49] Fagerstedt, K. V, Saranpää, P., Tapanila, T., Immanen, J., Alonso Serra, J. A., & Nieminen, K. (2015). Determining the composition of lignins in different tissues of silver birch. Plants, 4(2), 183–195.

[50] Lourenço, A., Neiva, D. M., Gominho, J., Marques, A. V.,&Pereira, H. (2015). Characterization of lignin in heartwood, sapwood and bark from *Tectona grandis* using Py–GC–MS/FID. *Wood Science and Technology*, *49*(1), 159–175.

[51] Lourenço, A., Rencoret, J., Chemetova, C., Gominho, J., Gutierrez, A., Del Río, J. C.,&Pereira, H. (2016). Lignin composition and structure differs between xylem, phloem and phellem in *Quercus suber* L. *Frontiers in Plant Science*, *7*, 1612.

[52] Tribot, A., Amer, G., Alio, M. A., de Baynast, H., Delattre, C., Pons, A., Mathias, J.-D., Callois, J.-M., Vial, C.,&Michaud, P. (2019). Wood-

lignin: Supply, extraction processes and use as bio-based material. *European Polymer Journal*, *112*, 228–240.

[53] Alves, A.,&Rodrigues, J. (2025). Variation of *Eucalyptus globulus* lignin content and composition within and between countries. *Journal of Wood Chemistry and Technology*, *45*(3), 142–152.

[54] Afonso CI (2012). Uso da antracologia como instrumento de fiscalização do carvão vegetal em Moçambique. [Use of anthracology as a tool for charcoal inspection in Mozambique]. Universidade Federal do Paraná.

[55] Kajda-Szcześniak, M. (2014). Characteristics of ashes from fireplace. *Archives of Waste Management and Environmental Protection*, *16*(3), 73–78.

[56] Oliveira AC, Carneiro A de CO, Vital BR, Almeida W, Pereira BLC, Cardoso MT (2010). Parâmetros de qualidade da madeira e do carvão vegetal de Eucalyptus pellita F. Muell. [Quality parameters of *Eucalyptus pellita* F. Muell wood and charcoal]. Scientia Forestalis 38: 431–439.

[57] Asare, M. O., & Hejcman, M. (2022). Effect of tree species on the elemental composition of wood ashes and their fertilizer values on agricultural soils. GCB Bioenergy, 14(12), 1321–1335.

[58] Mogeia, S., Manhiça, A. A.,&Egas, A. F. (2023). Wood ash content variation in *Eucalyptus grandis* clones in Mozambique. *Silva Fennica*, *57*(1).

[59] Pereira, B. L. C., Oliveira, A. C., Carvalho, A. M. M. L., Carneiro, A. de C. O., Vital, B. R.,&Santos, L. C. (2013). *Correlações entre a relação Cerne/Alburno da madeira de eucalipto, rendimento e propriedades do carvão vegetal*.

[60] Silveira, L. H. C., Rezende, A. V.,&Vale, A. T. do. (2013). Moisture content and basic wood density of nine commercial Amazonian tree species. *Acta Amazonica*, *43*, 179–184

ISSN 2072-3857