# Valorisation de différentes espèces méditerranéennes

# Characteristics and technological properties of the wood of mediterranean evergreen hardwoods

*by Elias V. VOULGARIDIS* and Costas N. PASSIALIS**

## I - Introduction

The forests in Greece cover 18.6% of the total area that is about 2.5 million hectares. High forests cover only 0.9 million ha whilst the rest part of the forested area (about 2/3) consists of coppice forests and shrubs.

Evergreen hardwoods include a number of different species of shrubs rather than trees that are growing together in almost all Mediterranean countries at low altitudes. This category of the forests cover 18.6% of the total forest area whilst the rest of it consists of cold-climate conifers, Mediterranean conifers and deciduous hardwoods (Tsoumis 1980, see Tab. I).

The total production of wood from the forests of Greece is about 3 millions m$^3$ yearly, but most (~ 70-75%)

| Category of the forests (Species) | Area 1000 ha | Area % |
|---|---|---|
| 1. Cold-climate conifers (fir, black pine, other pines, spruce) | 486,6 | 19,7 |
| 2. Mediterranean conifers (Aleppo pine hard pine, cypress) | 462,0 | 18,7 |
| 3. Decidous hardwoods (oak, beech, chestnut, other) | 1061,4 | 43,0 |
| 4. Evergreen hardwoods | **460,0** | **18,6** |
| **Total** | **2470,0** | **100,0** |

**Tab. I. Classification of the forests and forest area**

*Aristotelian University, School of Forestry and Natural Environment, 54006 Thessaloniki, Greece

is fuelwood. Evergreen hardwoods (evergreen broadleaved forests), although cover significant area (see Tab. I), produce small quantities of wood (about 300,000 $m^{3}$) that is mostly fwelwood and raw material for charcoal. This is because of two main reasons :

a - From the 460,000 ha of evergreen hardwoods only about 70,000 ha are exploited for wood production while the rest forest area is utilized mostly as grazing land. Clear cutting in small forest areas is applied every 25-30 years. *Quercus ilex* may produce small quantities of short-length roundwood (d > 12 cm, l > 0,8 m) (Tsoumis 1987).

b - Evergreen hardwoods are usually shrubs, slow-growing and not wood productive species.

The main species of evergreen hardwoods (evergreen broadleaved forests) are shown in Tab. II. The wood of almost all these species have high density and is characterized hard or very hard and heavy.

The structure, properties and utilization of the wood produced by various species of evergreen hardwoods have not been thoroughly investigated. In this paper, a first approach to this biological material is attempted aiming to better and complete utilization of the renewable biomass produced by the above mentioned species.

| a/a | Species: Latin name | Species: Common name+ | Dry wood density* g/cm3 |
|---|---|---|---|
| 1 | *Quercus ilex* L. | Hom Oak | 0,90 |
| 2 | *Quercus coccifera* L. | Kermes or Holly Oak | 0,92 |
| 3 | *Arbutus andrachne* L. | Greek Strawberry Tree | 0,77 |
| 4 | *Arbutus unedo* L. | Strawberry Tree | 0,82 |
| 5 | *Pistacia lentiscus* L. | Mastic Tree, Lentisc | 0,83 |
| 6 | *Pistacia terebinthus* L. | Terebinth, Turpentine Tree | 0,79 |
| 7 | *Erica arborea* L. | Tree Heath | 0,84 |
| 8 | *Phillyrea media* L. | | 0,76 |
| 9 | *Olea europaea* L. | Olive Tree | 1,00 |
| 10 | *Myrtus communis* L. | Myrtle | 0,82 |
| 11 | *Rhamnus alaternus* L. | Mediterranean Buckthorn | 0,76 |

+ Polumin 1976
* Voulgaridis 1993

**Tab. II : Main species of Mediterranean evergreen hardwoods**

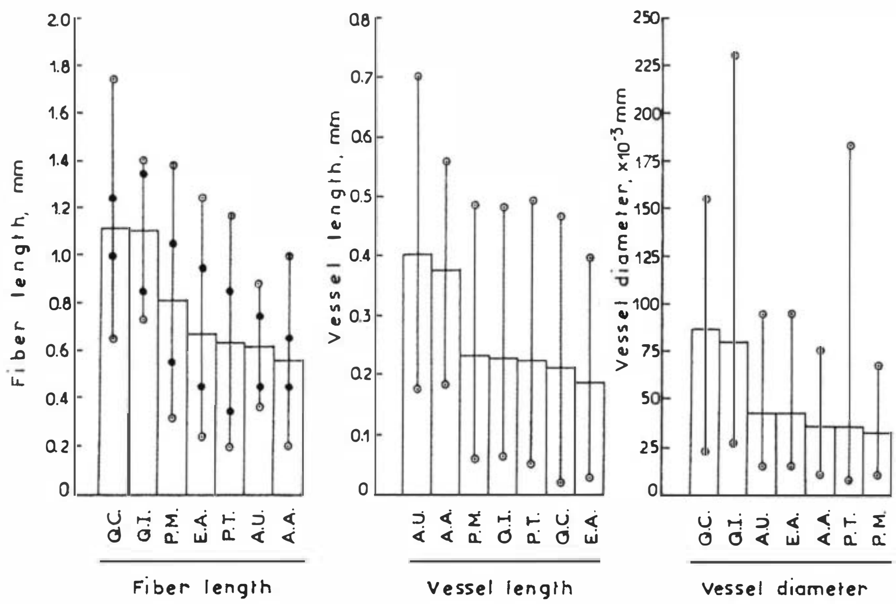


**Fig. 1 : Mean values and minimum and maximum values (○) of fiber length, vessel member length and diameter of evergreen hardwood species (● Range of fiber length for more than 90% of the number of fibers. The initials on the horizontal axis refer to the Latin names of hardwood species tested).**

# II - Wood cell morphology characteristics

Cell dimensions (fiber length, vessel length and diameter) for seven species of evergreen hardwoods were measured at 30 cm of the stem height above

**Tab. III : Mean values of fiber length and vessel member length and diameter*** ▶

* Three trees of each species with age ranging between 12 and 49 years and three-ring wood pieces in radial direction were used. Sixty cells for each three-ring wood piece were measured (totally about 12,000 fibers or vessel members).

| No | Species | Fiber length (mm) | Vessel length (mm) | Vessel diameter (mm) |
|---|---|---|---|---|
| 1. | *Quercus ilex* | 1,103 | 0,230 | 0,080 |
| 2. | *Quercus coccifera* | 1,116 | 0,220 | 0,087 |
| 3. | *Arbutus andrachne* | 0,560 | 0,377 | 0,036 |
| 4. | *Arbutus unedo* | 0,619 | 0,403 | 0,043 |
| 5. | *Erica arborea* | 0,672 | 0,189 | 0,043 |
| 6. | *Phillyrea media* | 0,816 | 0,233 | 0,033 |
| 7. | *Pistacia terebinthus* | 0,635 | 0,225 | 0,036 |

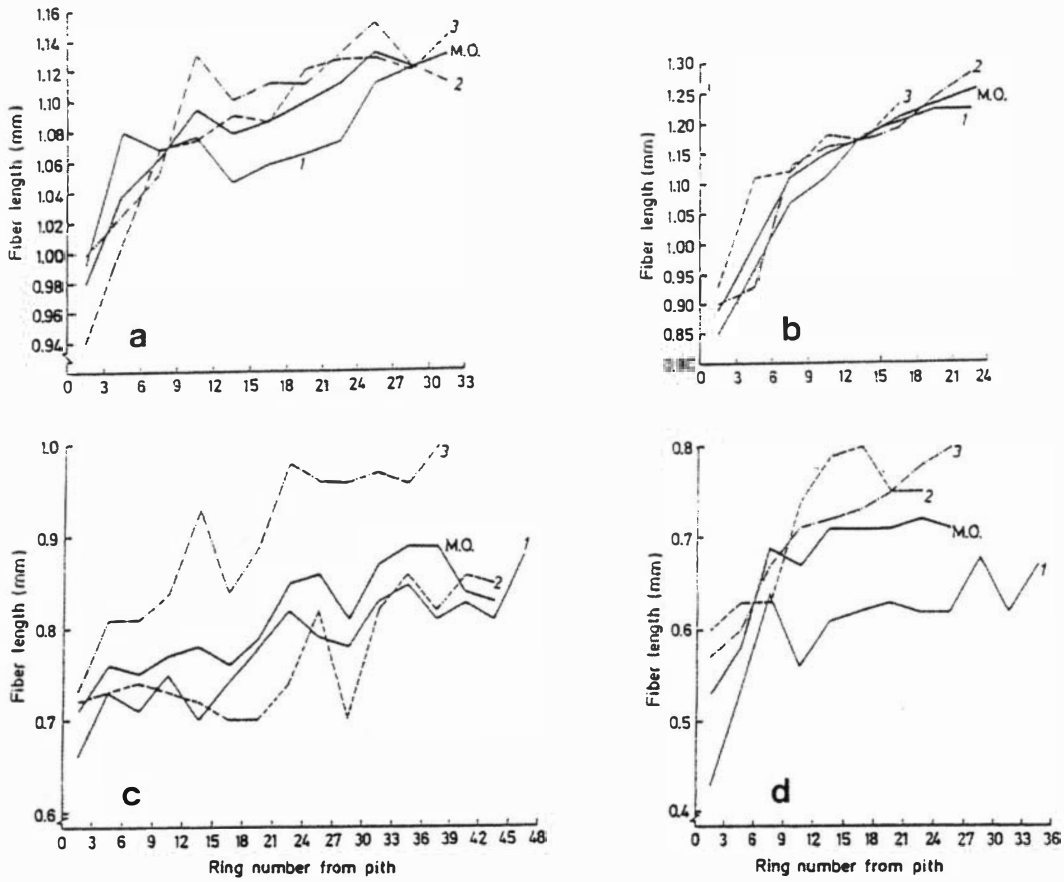


**Fig. 2 : Pith to bark variation of fiber length at 30 cm height above ground for *Quercus ilex* (a), *Quercus coccifera* (b), *Phillyrea media* (c) and *Erica arborea* (d). (1, 2, 3 : three different trees, M.O.: Average) (Voulgaridis 1990).**

ground. Average values and range are shown in Table III and Fig. 1 (Voulgaridis 1990).

Most of the evergreen hardwood species are short fibered (mean values range between 0.56 and 0.82 mm), and only the mean fiber length of the two *Quercus* species tested was found to be above 1 mm (see Tab. III).

The pith to bark variation of fiber length of all species follows the general pattern variation, i.e. fiber length increases for a number of years and then changes slightly (Fig. 2). The maximum increase of fiber length in radial direction was relatively small ranging between 1.1-1.4 times for all species tested when compared to the mean value of the first three growth rings (see Fig. 2) (Voulgaridis 1990).

The patterns of horizontal variation for the length and diameter of vessel members were not consistent among the species. An increase, permanence or decrease of vessel length or diameter was observed in various cases (see Fig. 3).

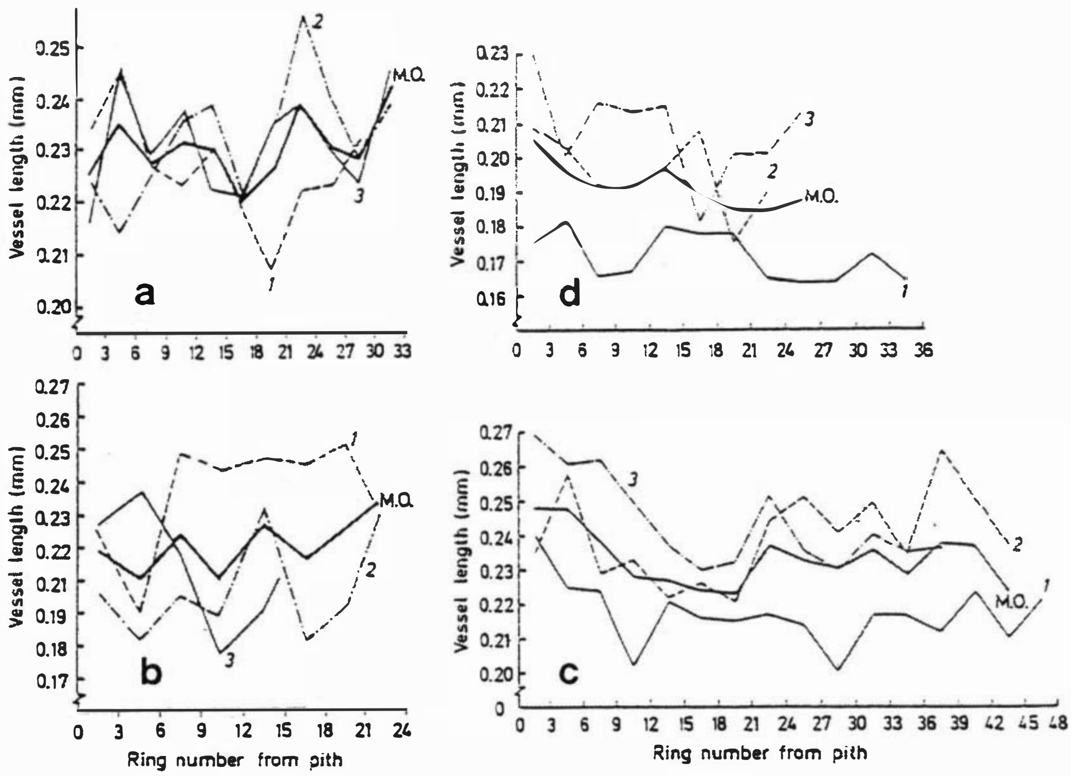


**Fig. 3 : Pith to bark variation of vessel member length at 30 cm height above ground for several evergreen hardwood species as in Fig. 2 (Voulgaridis 1990).**

# III - Physical and mechanical properties

Some physical (density, shrinkage) and mechanical (static bending, compression strength, toughness, hardness) properties of eight evergreen hardwood species are shown in Tab. IV (Voulgaridis/Passialis 1993). The wood of all above species tested is dense (do = 0.74-1.00 g/cm³) and hard. Average values of total volumetric shrinkage range between 14.7% and 18.7%, whilst static bending (MOR) and axial compression strength (ACS) of most species are comparable to those of the local deciduous oak species *Quercus conferta*. Toughness values are very high for *Quercus ilex*, *Quercus coccifera* and *Olea europaea* (18.4-20.7 x 10-2 J/mm²).

Hygroscopicity (adsorption and desorption isotherms, equilibrium moisture content) and dimensional (radial, tangential) changes of the species *Quercus ilex* L. were investigated in relation to changes of relative humidity of the athmosphere ( from 0 % to 97 % ) at constant temperature (23 ± 1°C).

Wood specimens were cross-sectional, 5 mm of thickness, with true radial and tangential faces. The results

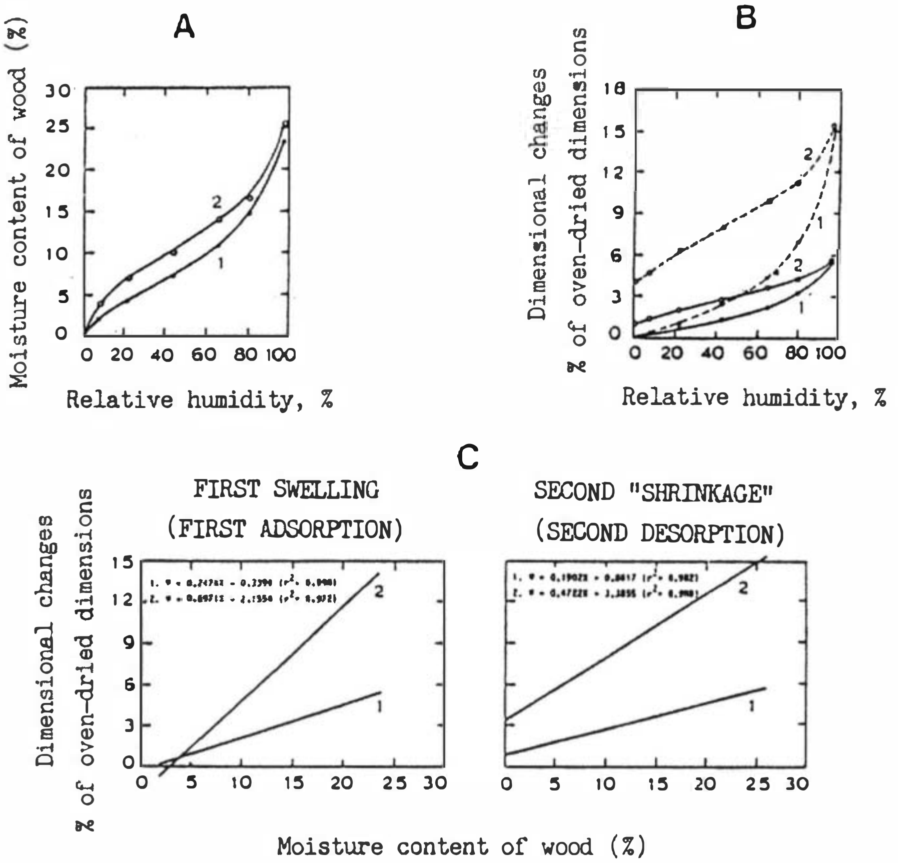


**Fig. 4 : Characteristics of hygroscopicity and dimensional changes of oak wood (*Quercus ilex* L.). A. First absorption (1) and second desorption (2) isotherm, B. First swelling (1) and second "shrinkage"* (2). —, Radial direction, -- - , Tangential direction. C. Linear relationship between dimensional changes and moisture content of wood (1. radial direction, 2. tangential direction) (Voulgaridis 1987).**

* Shrinkage values in this case are based on the dried dimensions after the complete 1st desorption of wood specimens and express how much swollen is the wood at certain relative humidity or moisture content of wood during the 2nd desorption.

| a/a | Species | Dry density g/cm³ | Total vol. shrinkage % | Static bending MOR N/mm² | Compression strength (axial) N/mm² | Hardness N/mm² Axial | Hardness N/mm² Lateral | Toughness J/mm² x 10-2 |
|---|---|---|---|---|---|---|---|---|
| 1. | *Quercus ilex* | 0,93 | 18,7 | 146,1 | 64,0 | 136,7 | 114,3 | 18,84 |
| 2. | *Quercus coccifera* | 0,95 | 16,6 | 134,9 | 55,3 | 131,1 | 124,8 | 18,44 |
| 3. | *Arbutus andrachne* | 0,75 | 15,4 | 135,1 | 61,0 | 109,3 | 79,6 | 8,06 |
| 4. | *Arbutus unedo* | 0,74 | 14,7 | - | - | 103,4 | 77,7 | - |
| 5. | *Erica arborea* | 0,76 | 14,7 | - | 56,4 | 119,4 | 95,7 | 6,05 |
| 6. | *Phillyrea media* | 0,91 | 14,9 | - | 57,1 | 134,6 | 114,9 | 11,09 |
| 7. | *Olea europaea* | 0,99 | 16,6 | - | 62,87 | 138,4 | 129,9 | 20,69 |
| 8. | *Pistacia terebinthus* | 0,89 | 15,4 | 105,2 | 52,5 | 119,0 | 97,7 | 10,82 |
| 9. | *Quercus conferta* | 0,80** | 16,8** | 135,9 | 59,4 | - | - | 10,36 |

* Mean values of n specimens (n=5-32)

** Voulgaridis et al. 1980

**Tab. IV : Physical and mechanical properties of wood of eight evergreen hardwoods* (Voulgaridis, Passialis 1993)**

are shown in Fig. 4. The shape of sorption isotherms is the typical "sigmoid" curve for wood and cellulose materials (Fig. 4A). Swelling and "shrinkage" values, both based on dry dimensions, are different under the same conditions (Fig. 4B). The higher "shrinkage" values can be atributed 1) to hysteresis of equilibrium moisture content and 2) to hysteresis of dimensions due to "loosening" of wood structure. Relationship between swelling or shrinkage values and moisture content of wood (between 0 and 30%) are shown in Fig. 4C.

| Species | Moisture content (%)* Branches + leaves | Moisture content (%)* Stem | Percentage (%)** Leaves | Percentage (%)** Branches |
|---|---|---|---|---|
| *Q. ilex* | 74 | 62 | 31 | 69 |
| *Q. coccifera* | 71 | 59 | 40 | 60 |
| *Q. europaea* | 66 | 43 | 40 | 61 |
| *P. terebinthus* | 79 | 52 | 28 | 72 |
| *A. unedo* | 93 | 70 | 28 | 72 |
| *A. andrachne* | 107 | 73 | 42 | 59 |
| *E. arborea* | 61 | 58 | 28 | 72 |
| *Ph. media* | 63 | 49 | 24 | 76 |

* Mean values of five samples
** Based on oven-dry mass

**Tab. V : Moisture content and mass proportion (Passialis 1985)**

# IV - Moisture content, calorific value and chemical properties

| Species | Higher calorific value (cal/g)* Stem | Higher calorific value (cal/g)* Branches | Higher calorific value (cal/g)* Leaves | Calorific value of air-dry biomass (cal/g) Stem | Calorific value of air-dry biomass (cal/g) Branches + Leaves |
|---|---|---|---|---|---|
| *Q. ilex* | 4,603 | 4,623 | 5,108 | 3,924 | 4,086 |
| *Q. coccifera* | 4,583 | 4,613 | 4,837 | 3,907 | 4,011 |
| *Q. europaea* | 4,785 | 4,794 | 5,379 | 4,083 | 4,289 |
| *P. terebinthus* | 4,553 | 4,612 | 4,756 | 3,881 | 3,967 |
| *A. unedo* | 4,747 | 4,680 | 5,025 | 4,050 | 4,072 |
| *A. andrachne* | 4,714 | 4,709 | 5,059 | 4,021 | 4,141 |
| *E. arborea* | 4,985 | 4,975 | 5,728 | 4,257 | 4,431 |
| *Ph. media* | 4,802 | 4,965 | 5,162 | 4,097 | 4,237 |

* Mean values of five samples

**Tab. VI : Higher calorific value and calorific value of air-dry biomass (Passialis 1985)**

The production of wood from evergreen hardwoods (200,000 ton) corresponds to 12,5% of the total production of fuelwood while the proportion "Green biomass of branches and leaves/Green mass of fuelwood" was found to be 1.1/1 (Barboutis 1991). Better utilization of evergreen hardwoods for energy needs information on moisture content, calorific value and certain chemical properties either for wood or for branches and leaves.

It was found (Passialis 1985) that the moisture content of green stem wood was lower than that of branches and leaves for all species tested. It is interesting that the mass of brances is 1.5-3 times more than the mass of leaves for the various species of evergreen hardwoods (see Tab. V).Calorific values of absolutely dry stem wood were found to be almost equal to those of branches but lower than the values of leaves (see Tab. VI). These higher calorific values can not be utilized in practice because green material consumes significant energy for removal of its moisture. In order to keep energy consumption at low level, it is necessary, first to dry the green material to a certain level, and, then, to utilize its calorific value. Calorific values of air-dried material have been calculated by substracting the energy consumption for drying the green material to a moisture level of 15% and presented in Tab. VI.

The range of mean values of ash and inorganic constituents are shown in Tab. VII. The content of ash and inorganic constituents for stem was found to be lower than branches and leaves. The highest values refer to leaves. The content of inorganic constituents of all species together is also shown in Tab. VII (Passialis 1985).

The acidities of suspensions in distilled water on a 1: 20 mass/volume basis of the three biomass components (leaves, branches, stems) for the species investigated are shown in Tab. VIII. All the pH values ranged in the acid region, from pH 4.19 to 4.68 for leaves, from pH 4.05 to 4.45 for branches, and from pH 3.96 to 4.57 for stems. Figure 5 shows that acid and base buffering capacities of aqueous extracts of various species and biomass components tested vary considerably. From Tab. VIII it can be seen that buffering capacities (both acid and alkaline equivalent) of leaves are greater than those of branches for the species tested. The acid equivalent of branches is greater than that of stems, but the alkaline equivalent is lower in most species (except in *A. unedo* and *A. andrachne*). Between leaves and stems, the alkaline equivalent is greater in leaves (except in *Q. ilex* and *Q. coccifera*).

The differences in acidity values among species and biomass components seem to be relatively low. Hence, the utilization of mixed material in the manufacture of products by using pH-sensitive adhesives is possible by proper selection of the glue. However, the great differences which exist in buffering capacities may cause difficulties in industrial processing of mixed material where the adjustment of acidity in various levels is necessary.

Removal of hot water (100 °C) soluble extractives from stem (7.1-16.7%), branches (12.2-24.3%) and leaves (27.1-45.0%) were found to affect their calorific value and inorganic constituents in all species tested. After extraction, the calorific value of leaves increased to a certain degree (0.8-10%) in all species but for branches and stems it was increased or decreased slightly dependent on the species. The ash content of hot water extracted biomass was found to be lower than that of non-extracted material in most cases (Passialis 1987).

| Material | Ash (%) | Inorganic constituents, mg/g K | Ca | Mg | Mn | Fe |
|---|---|---|---|---|---|---|
| **Range of mean values of eight evergreen hardwoods** | | | | | | |
| Stem | 0,69-2,43 | 0,78-2,19 | 0,39-9,48 | 0,42-0,90 | 0,02-0,45 | 0,01-0,04 |
| Branches | 1,96-5,87 | 2,05-6,55 | 1,31-17,94 | 1,07-2,35 | 0,03-0,35 | 0,04-0,62 |
| Leaves | 4,54-8,87 | 5,10-9,72 | 1,83-23,22 | 2,01-9,18 | 0,07-0,95 | 0,12-0,97 |
| **All species together** | | | | | | |
| Stem | | 1,3 | 4,0 | 0,6 | 0,1 | 0,02 |
| Branches | | 3,7 | 8,8 | 1,4 | 0,1 | 0,3 |
| Leaves | | 5,5 | 9,4 | 3,5 | 0,3 | 0,4 |

**Tab. VII : Ash and inorganic constituents for eight evergreen hardwoods**

# V - Briarwood

The evergreen shrub *Erica arborea* is very well known because of its tumor-like outgrowths that develop

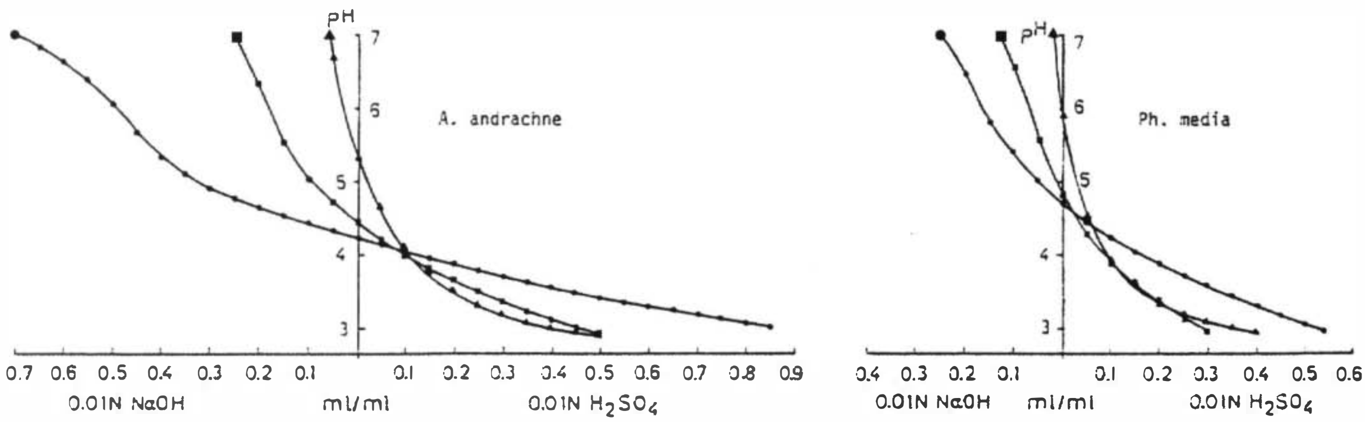


**Fig. 5 : Striking differences of acid and base buffering capacities of aqueous extracts between the two evergreen hardwood species *Arbutus andrachne* and *Phillyrea media* (● Leaves, ■ Branches, ▲ Stems) (Passialis 1985).**

| Species | Acidity (pH)* Leaves | Branches | Stems | Buffering capacity (ml/ml)** Alkaline equivalent Leaves | Branches | Stems | Acid equivalent Leaves | Branches | Stems |
|---|---|---|---|---|---|---|---|---|---|
| *Q. ilex* | 4,55 | 4,05 | 4,07 | 0,0041 | 0,0029 | 0,0070 | 0,0026 | 0,0018 | 0,0012 |
| *Q. coccifera* | 4,38 | 4,24 | 4,57 | 0,0051 | 0,0033 | 0,0059 | 0,0049 | 0,0008 | 0,0006 |
| *Q. europaea* | 4,91 | 4,45 | 4,32 | 0,0073 | 0,0037 | 0,0045 | 0,0024 | 0,0013 | 0,0003 |
| *P. terebinthus* | 4,19 | 4,12 | 4,53 | 0,0080 | 0,0048 | 0,0055 | 0,0065 | 0,0023 | 0,0006 |
| *A. unedo* | 4,34 | 4,11 | 4,15 | 0,0082 | 0,0045 | 0,0038 | 0,0047 | 0,0028 | 0,0006 |
| *A. andrachne* | 4,36 | 4,25 | 4,36 | 0,0085 | 0,0047 | 0,0046 | 0,0070 | 0,0025 | 0,0006 |
| *E. arborea* | 4,27 | 4,20 | 3,96 | 0,0063 | 0,0024 | 0,0036 | 0,0043 | 0,0008 | 0,0008 |
| *Ph. media* | 4,68 | 4,39 | 4,53 | 0,0054 | 0,0030 | 0,0038 | 0,0025 | 0,0013 | 0,0002 |

* Mean values of five samples and standard deviations
** Mean values of two replicate measurements

**Tab. VIII : Acidity (pH) and buffering capacity of leaves, branches, and stems (Passialis 1985)**

between root and stem and consist the source of briarwood. Fiber length and certain properties of tumor wood are shown in Tab. IX, in comparison to stem wood. Striking characteristics of tumor wood are: (a) high amount of extractives, (b) high volumetric shrinkage values but isometric directional shrinkage (c) very dense and hard wood, (d) short-length fibered (Tsoumis et al. 1988).

| Material* | Fiber length mm | Density (dry) g/cm³ | Shrinkage (%) Axial | Radial | Tangential | Volume | Hardness (end, Janka) N/mm² | Extra-ctives % |
|---|---|---|---|---|---|---|---|---|
| Tumor | 0.363 | 0.97 | 5.45 | 5.67 | 6.64 | 18.39 | 90.0 | 27.36 |
| Stem | 0.477 | 0.84 | 0.57 | 6.49 | 8.81 | 15.30 | 84.8 | 10.32 |

* Number of measurements or specimens (tumor-stem): fiber length 300-300, density and hardness 10-10, shrinkage 19-10, and extractives 3-3. Size of specimens: 2 x 2 x 2 cm (density, shrinkage, hardness) and wood flour (extractives). Extractives (total) are based on oven-dry weight of wood flour.

**Tab. IX : Fiber length, properties and extractives of tumor and stem wood of *Erica arborea***

| No | Species | Vol. shrinkage % A | Vol. shrinkage % B | Density (ro)* g/cm³ A | Density (ro)* g/cm³ B | Extractives** % A | Extractives** % B |
|---|---|---|---|---|---|---|---|
| 1 | *Erica (tumor)* | 15,00 | 10,24 | 0,890 | 0,787 | 27,36 | 4,29 |
| 2 | Olive tree *(Olea)* | 16,82 | 18,73 | 1,034 | 0,994 | 15,74 | 4,35 |
| 3 | Oak (*Q. coccifera*) | 14,77 | 20,20 | 0,941 | 0,972 | 8,78 | 2,55 |

* A : natural condition, B : boiled in water

** Extractives: A : based on oven-dry weight of wood flour (tumor : total extractives) and B : removed from 2 x 2 x 2 cm specimens.

Number of specimens : tumor and oak (A-B) 22-22, olive tree 13-13; Dimensions : density and B extractives 2 x 2 x 2 cm.

**Tab. X : Effects of boiling in water on shrinkage, density and removal of extractives (Tsoumis et al. 1988)**

Light microscope and SEM observations revealed that fibers are usually irregular (crooked, bent, in parts dilated fibers) along their length and not normally arranged resulting in a characteristic microscopic appearance and attractive figure of briarwood. Amorphus or crystal enclosures were observed in cell cavities.

Boiling is a treatment applied in making pipe bowls. Boiling tumor wood in water reduced significantly the extractive content but this removal of extractives resulted unexpectedly in a lower shrinkage, while the normal behaviour of wood is opposite (Tab. X). Boiled pieces of tumor wood did not show checks and deformations after air-drying as non-boiled did.

Boiling did not appreciably affect the rate of air-drying of tumor wood but splitting and checking did not occur. The above results justify the boiling (or steaming) applied in practice.

Ash and silica content in tumor wood are at low level (0.75% and 0.04% respectively) and, therefore, thay can not be considered responsible for its good resistance to high temperatures tested (from 150°C to 600°C) that develop inside a smoked pipe bowl (maximum values measured : 615°C). Interesting results were found for the extractives of tumor wood. They showed good resistance to high temperatures. Impregnation of poplar wood with tumor wood extractives increased considerably the resistance of poplar wood to high temperatures (Tsoumis et al. 1988). These results suggest that the extractives may play a "fire-retardant" role in briarwood.

It must be noticed that good resistance to high temperatures was also found for the two species of evergreen hardwoods *Olea europaea* and *Quercus coccifera.*

# VI - Experimental production of particleboards

Biomass from five species of evergreen hardwoods (stem wood, branches, foliage) was used for particleboard production on laboratory scale. The categories of experimental particleboards that were made and assessed are shown in Tab. XI (Barboutis 1991). All boards were tested for density, internal bond (I.B.) static bending (M.O.R.), thickness swelling (T.S.) and water absorption (W.A.).

All boards had internal bond within the DIN requirements. M.O.R. of boards made from material of evergreen hardwoods was very low but for boards made from the mixtures "evergreen hardwoods-fir or poplar wood" it was within the DIN standards. Veneered boards had high bending strength (about 2 times higher) compared with one-layer particleboards. The wood species, the mixture ratio between species and the density had a profound effect on the properties of the boards.

Boards based on chip-material of evergreen hardwoods had better hygroscopic properties than those based on industrial chip-material. Boards from evergreen hardwoods and fir +

| No | Material | Species | Screened (S) or Unscreened (U) particles | Density g/cm3 | Results (MOR : Modulus of rupture, IB : Internal bond, TS : Thickness swelling, WA : Water absorption) |
|---|---|---|---|---|---|
| 1 | Wood | Each species of E.H. separately | U or S | 0,65-0,75 0,67 | Compared to 3a : (1) U : MOR lower and mostly under DIN requirements, IB lower but above DIN requirements, TS and WA lower values. (2) S : Improvement of MOR, IB and TS (except *Quercus ilex, Q. coccifera*), WA Higher values |
| 2 | "Branches"** | All species | U or S | 0,65-0,75 0,67 | Compared to 3a : (1) U : MOR under DIN requirements, IB lower but above DIN requirements, TS lower in most cases, WA higher. (2) S : Improvement of all properties |
| 3 | Wood | a. Industrial material | S | 0,65-0,75 | Compared to 1 and 2 : Best MOR and IB, TS and WA higher values |
| | | b. Fir and poplar | S | 0,67 | Compared to 3a : MOR equal, IB slightly lower WA higher |
| 4 | Wood | Each species of E.H. separately with fir and poplar | S | 0,67 | Compared to 3a, 3b : MOR and IB slightly lower and above DIN requirements, TS and WA lower values than 3b, within DIN requirements |
| 5 | "Branches" | All species of E.H. with wood of fir and poplar | S | 0,67 | Compared to 3b : MOR and IB lower, they increase with increasing fir and poplar wood percentage, TS and WA lower values |
| 6 | Wood | | S | 0,67 | Compared to 3b : As No. 5 (MOR and IB higher than No. 5, Generally, lower TS and WA than No. 5) |
| 7 | Wood or "Branches" | All species of E.H. with wood of industrial chip material | S | 0,67 | Compared to industrial material : MOR and IB lower, TS and WA higher. Between "wood" and branches similar values |
| 8 | Wood or "Branches" | All species of E.H. and with wood of fir and poplar | S (for core), Fines (for surface) | 0,67 | Compared to 1 (S) : MOR lower (below DIN), IB lower (above DIN). TS and WA higher in boards including fir and poplar |
| 9 | Wood or "Branches" | a. Two species of E.H. separately (wood), b. All species (wood or branches) in mixture or not with fir and poplar c. Industrial material | Veneered | 0,58 | Compared to industrial material : MOR and IB lower, better stability<br>Compared to non-veneered boards (d=0,67) : MOR higher, IB lower, WA and, mostly, TS higher |

* *Quercus ilex, Quercus coccifera, Arbutus unedo, Erica arborea, Phillyrea media.* + All experimental boards were 1-layer except of the 3-layer No. 8 boards
** The term "Branches" includes small diameter stems, branches and foliage that are abandoned in the forest after felling

**Tab. XI : Experimental particleboards from biomass of evergreen hardwoods (E.H.)* (Data from Barboutis 1991)**

poplar wood in proportion 1: 3 had very good mechanical properties. Increase of addition of evergreen hardwoods reduces the mechaical properties but improved the hydroscopic properties. Reduction of the percentage of fine particles improved, generally, the properties of the boards.

Generally, wood of evergreen hardwoods may be utilized in particleboard production but boards of good properties may be produced in mixture with other more suitable wood species (such as fir and poplar in proportion 1 : 3).

Wood of evergreen hardwoods can be used either alone or in mixture with other wood species for production of veneered particleboards. Branches and foliage gave low quality boards.

# VII - Conclusions

The general conclusions for characteristics and technological properties of the wood of evergreen hardwoods may be summarised as follows :

- Evergreen hardwoods can be characterized as short fibered species (fiber length <0.82 mm) except the evergreen oaks (fiber length >1mm). Fiber length increases from pith to bark and follows the general pattern variation for all species but horizontal variations for vessel member length and diameter were not consistent among the species tested.

- The wood of evergreen hardwoods is hard and dense (d=0.74-1.00 g/$cm^3$) with total volumetric shrinkage about 15-19% and mechanical properties (MOR, axial compression strength) comparable to those of the deciduous broadleaved oak. Toughness values are very high for evergreen oaks and olive tree.

- Water sorption isotherms for wood of *Quercus ilex* are of typical "sigmoid" form, whilst during shrinkage a hysteresis of radial or tangential dimensions is observed.

- Moisture content of green stem wood of eight species (43-73%) is lower than branches + leaves (61-107%). The green mass proportion "stem: branches + leaves" is 1 : 1,1.

- Between stem and branches of eight species no differences of calorific values (4.553-4.985 cal/g) were found, whilst these values in leaves were the highest (4.837-5.756 cal/g). The content of ash and inorganic constituents for stem was found to be lower than branches and leaves.

- All acidity values for leaves, branches and stems were found to be within the acid region (pH 3.96-4.68). Acid and base buffering capacities of aqueous extracts of various species and biomass components (stem, branches, leaves) vary considerably.

- Tumor wood of *Erica arborea* that consist the source of briarwood, is characterized by irregular and not normally arranged fibers, high but isometric shrinkage, good resistance to high temperatures and it seems that the high amount of extractives may be fire-retardant substances in briarwood. Boiling of tumor wood in water reduces its shrinkage, checks and deformations and, therefore, as treatment applied in practice before fabrication of pipe bowls can be justified.

- Wood of evergreen hardwoods can be utilized in particleboard production but boards of good properties may be produced either in mixture with fir, poplar and other suitable wood species or alone but veneered. Boards based on branches and leaves are of low quality.

- Further investigations are needed for complete and more effective utilization of the wood or biomass of evergreen hardwoods that cover significant areas in Mediterranean region.

**E.V., C.P.**

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## Résumé

### Caractéristiques et propriétés technologiques du bois de feuillus méditerranéens sempervirents

*Un certain nombre de feuillus sempervirents tels que* Quercus ilex, Quercus coccifera, Arbutus, Rhus, Erica, Pistacia, Phillyrea, *etc... domine dans le maquis et couvre 18,6 % de la surface forestière grecque. Les feuillus produisent environ 300 000 m³ de bois, surtout du bois de chauffage.*

*Les caractéristiques anatomiques du bois, les propriétés physiques (degré d'humidité, densité, sorption, retrait, travail du bois), les propriétés mécaniques (flexion statique, résistance à la compression, dureté, ténacité), les propriétés thermiques (valeur calorifique) et chimiques (éléments minéraux, acidité, pouvoir tampon) sont présentées dans ce travail et concernent le bois ou les tiges et feuilles des principales essences de feuillus sempervirents.*

*Une mention est faite sur les caractéristiques de la souche et du bois de fût de* Erica arborea *dont l'utilisation pour la fabrication de pipes est importante.*

*L'utilisation du bois de fût et de houppier provenant de feuillus sempervirents est possible dans la production de panneaux composites.*

*Des panneaux de particules expérimentaux fabriqués à partir d'un mélange de bois des principales essences de feuillus sempervirents et de bois de faible densité de sapin et de peuplier satisfaisaient aux exigences des normes européennes.*

*D'autres recherches sont nécessaires, portant sur les propriétés et les potentialités d'utilisation du bois de feuillus sempervirents qui couvrent de très importantes surfaces dans les régions méditerranéennes et qui produisent de grandes quantités de biomasse et de bois de petite dimension et de forte densité.*



## Summary

### Characteristics and technological properties of the wood of mediterranean evergreen hardwoods.

*A number of evergreen hardwoods such as* Quercus ilex, Q. coccifera, Arbutus, Rhus, Erica, Pistacia, Phillyrea, *etc. dominating Maquis ecosystem cover 18,6% of the total Greek forest area and produce about 300.000 m³ wood, mostly fuelwood. Characteristics of wood cell morphology, physical properties (moisture content, density, sorption, shrinkage, movement), mechanical properties (static bending, compression strength, hardness, toughness), thermal (calorific value) and chemical properties (inorganic constituents, acidity, buffering capacity) are presented in this work and refer to wood or branches and leaves of the main species of evergreen hardwoods. A reference is made for the characteristics of tumor and stem wood from* Erica arborea *that are important in utilizing this species for smoking pipes. Utilization potentials of stem- and branch wood from evergreen hardwoods exist in composite board production. Experimental particleboards from mixtures of wood from main species of evergreen hardwoods and of low density wood from fir and poplar were found to satisfy European standard requirements.*

*Further inverstigations on properties and utilization potentials of the wood of evergreen hardwoods that cover significant areas in Mediterranean countries and produce relatively large quantities of biomass and wood of small dimension and high density are needed.*