



Decay Resistance of Scots Pine Wood Treated with Water and Oil Extracts of Various Plants

Çeşitli Bitkilerin Su Ekstraktları ve Doğal Yağları ile İşlem Görmüş Sarıçam Odununun Mantar Çürüklüğüne Karşı Direnci

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ABSTRACT

The bioactivities and antioxidant properties of natural oils and water extractives from various plants have been proven to be safe for use in food applications, pharmaceutical research, and many other utilization areas for years. The objective of this study is to evaluate the decay resistance of wood treated with various natural plant oils or water extracts. Scots pine wood specimens (*Pinus sylvestris* L.) treated with fourteen plant oils and water extracts of nineteen plant species were subjected to brown rot fungus, *Coniophora puteana*, for two months. As a result, cinnamon, mint, garlic, thyme, and onion oils provided better protection than the other tested oils. Water extracts of fennel were able to protect wood specimens against decay fungus, and treated wood showed the weight loss of less than 5% relative to the initial oven-dry weight. Nearly all treated specimens showed greater efficiency against fungal decay compared to control groups; however, the preservation effect was not measured within the range required efficiency for a successful wood preservative according to EN standards.

ÖZET

Çeşitli bitkilerin doğal yağları ve su ekstraktlarının biyoaktiviteleri ve antioksidan özellikleri yıllardır gıda uygulamaları, ilaç araştırmaları ve diğer birçok kullanım alanında güvenli bir şekilde kullanıldığını kanıtlamaktadır. Bu çalışmanın amacı çeşitli doğal bitkisel yağlar veya su ekstraktları ile işlenmiş ahşabın mantar çürüklük dayanımını değerlendirmektir. On dört bitkisel yağ ve on dokuz bitki türüne ait su özütleri ile işlenmiş Sarıçam odun örnekleri (*Pinus sylvestris* L.) iki ay boyunca esmer çürüklük mantarı *Coniophora puteana*'ya tabi tutuldu. Sonuç olarak, tarçın, nane, sarımsak, kekik ve soğan yağları test edilen diğer yağlardan daha iyi koruma gösterdi. Rezenenin su ekstraktı, odun örneklerini çürüklük mantarına karşı koruyabildi ve işlenmiş odun, başlangıç fırın kuru ağırlığına göre %5'ten daha az ağırlık kaybı gösterdi. İşlenmiş örneklerin neredeyse tamamı kontrollerle karşılaştırıldığında mantar çürüklüğüne karşı daha iyi etkinlik gösterdi; ancak koruma etkisi, EN standartlarına göre başarılı bir ahşap koruyucu için gereken etkinlik aralığında ölçülemedi.

1. Introduction

Wood is a sustainable, renewable, and natural organic material that requires less energy to process and maintenance than other construction materials. However, under outdoor conditions, it can decompose rapidly due to decay by fungal micro-organisms in the presence of adequate moisture, light, water, mechanical forces, and heat subsumed under the blanket term weathering (Koski, 2008). Suitable wood preservatives can ensure a long service life for wood. Regarding environmental issues, traditional wood preservatives containing heavy metals have been

banned for some applications due to their mammalian toxicity and adverse environmental impact (Gezer et al., 2006). Since the new regulations of other common wood preservatives (zinc, copper, chromium, etc.) and the concerns about environmental contamination, new, eco-friendly, yet still effective protection systems are needed in order to protect wood. Natural plant extracts may be one possible approach to protect wood against wood-decay organisms (Shultz & Nicholas 2000; Sen et al., 2002; Goktas et al., 2007). Essential oils containing monoterpenes, diterpenes, and hydrocarbons with various functional groups have been used for many years in preservation and medicinal antimicrobial production as antimicrobial

agents in addition to their use in perfumes (Voda et al., 2003; Yang & Clausen 2007).

Kartal et al. (2006) suggested that essential oils and plant extracts might be used to develop new wood preservatives that were less harmful to the environment and humans than those recently available. Antifungal effect of essential oils such as ajowan, dill weed, Egyptian geranium, lemongrass, rosemary, tea tree, and thyme on southern yellow pine was reported by Yang and Clausen (2007). Antifungal efficacy of natural poisonous plant extract from *Oleander* (*N. oleander* L.) against *P. placenta* and *T. versicolor* was reported on Scots pine and beech by Goktas et al. (2007). Chittenden and T. Singh (2011) tested the antifungal properties of essential oils against common wood fungus. The effectiveness of two pure essential oil extracts -cinnamaldehyde and eugenol- on the durability of radiata pine wood was then assessed. The antifungal properties of eugenol and cinnamonaldehyde were validated in a wood durability test, but it also showed that these chemicals leached from treated wood when exposed to moisture. When exposed to all three test fungi - *Oligoporus placenta*, *Coniophora puteana*, and *Antrodia Xantha* - blocks treated with 3% w/v eugenol without being exposed to damp conditions, showed a 1% weight loss. Blocks exposed to water, however, saw weight losses ranging from 13.4% to 23.1%. Recently, Abd El-Kareem et al. (2025) reported that the essential oils derived from umbel and leaves of various fennel plants showed possible antifungal activity against *A. solani* and *F. oxysporum* growth based on the values of minimal inhibitory concentrations and decreases in fungal growth.

The objective of this study was to screen the fungal resistance of Scots pine specimens treated with fourteen commercially available essential oils and nineteen water extracts of plants. Wood specimens were first impregnated with extracts and oils, then subjected to *Coniophora puteana* attack in petri dishes for 2 months.

2. Materials and Methods

2.1. Material and treatment process

Defect-free kiln-dried Scots pine sapwood specimens (*Pinus sylvestris* L.) with dimensions of 5x15x30 mm (R, T, L) were used in this study. Before impregnation, the specimens were conditioned at 65% relative humidity and 20°C until they reached constant weight.

Natural oils of various plants were obtained from Industrial companies in Turkey. Plant leaves for water extraction were obtained from the market. Water extracts of ground plant leaves were prepared by the hot-water extraction method using a hot plate at approximately 100°C for 30 min. The ratio of ground plant leaves in distilled water was 25%. All extracted solutions were filtrated after cooling for the impregnation process. The plant extracts tested in the study are presented in Table 1 and 2 along with their retention (kg/m^3) and fungi test results (Equation 1).

$$R (\text{kg}/\text{m}^3) = \left[\frac{G \times C}{V} \right] \times 10 \quad (1)$$

Where G is the amount of impregnation solution absorbed by the sample (g), C is the concentration (%) of the impregnation solution, and V is the volume of the samples (cm^3).

The specimens were first vacuum impregnated with the plant extract oils and water extracts at 760 mm-Hg for 10 min at 20 °C. Following this, they remained immersed in the solutions for 10 min at atmospheric pressure. The treated specimens were subsequently conditioned for two weeks at 20 °C and 65% relative humidity (Figure 1).



Figure 1: General schema of the experimental process.

2.2. Decay resistance test

The decay test was carried out according to the EN 113 (1997). Petri dishes containing 25 ml 4.8% (w/v) malt agar were inoculated with *C. puteana* (Mad-515). A plastic mesh was used to avoid direct contact between the specimens and the medium. Four replicates for each extract were used. The brown-rot fungus (*C. puteana*) was used as a degradation organism because the timber used in construction is mainly preferred from coniferous species, and brown-rot fungi preferentially degrade softwood timber (Goodell et al.,

2003). In addition, brown-rot wood decay represents a significant problem in the storage and preservation of wooden structures inside buildings (Voda et al., 2003). The incubation time was eight weeks at 22°C and 65±5% relative humidity. After the incubation period, the fungal mycelium was removed from the specimens and dried at 103±2°C to constant weight (Çs). The extent of fungal attack was expressed as the percentage of weight loss before (D_b) and after (D_a) decay test (Equation 2).

$$WL (\%) = \left[\frac{D_b - D_a}{D_b} \right] \times 100 \quad (2)$$

3. Results and Discussion

Retention values were greater for specimens treated with water extracts than specimens treated with plant oils (Table 1, 2). This could be due to viscosity differences between the oil and water. Relatively high retention values obtained with both water and oil extracts. In many cases, high retention values and deep oil penetration into the wood are necessary in order to provide good long-term performance (Temiz et al., 2008a).

Table 1: Retentions (kg/m³) and weight losses (%) in specimens treated with plant extract oils after decay test.

Oil-type Plant Extracts	Retention (kg/m ³)	Weight Loss (%)		
		Test	Control	Change (%)
Cinnamon	362.2 (28.56)*	5.98 (0.25)	35.01 (11.29)	82.92
Garlic	322.2 (3.14)	9.28 (1.83)	25.40 (5.70)	63.46
Mint	473.3 (23.7)	6.71 (1.18)	28.29 (5.30)	76.28
Daphne	304.4 (17.14)	25.98 (1.10)	36.97 (7.76)	29.73
Rosemary	480 (19.14)	10.43 (6.17)	37.96 (3.85)	72.52
Stinging nettle	235.5 (18.86)	16.17 (4.04)	37.46 (8.98)	56.83
Thyme	417.7 (18.8)	9.41 (0.62)	32.92 (6.15)	71.42
Sage	431.11 (22.9)	19.83 (7.57)	40.75 (13.26)	51.34
Onion	362.96 (25.27)	8.49 (5.16)	24.82 (9.32)	65.79
Apricot	302.2 (32.04)	16.63 (4.27)	22.15 (5.96)	24.92
Fennel	388.8 (19.9)	12.87 (2.57)	33.75 (11.31)	61.87
Walnut	300 (19)	16.92 (0.77)	27.96 (1.18)	39.48
Lemon	296.3 (17.76)	18.82 (4.18)	34.07 (3.75)	44.76
Eucalyptus	325.9 (37.7)	17.86 (0.81)	41.02 (2.28)	56.46

*Values in parentheses are standard deviations

Untreated (control) specimens showed weight losses of more than 20%, verifying that the decay test in petri dishes was valid according to EN 113 (1997) standard

(Figure 2). Depending on oil type, the weight loss of treated specimens decreased 25-83% compared to controls. In the case of water-type plant extracts, weight loss of treated specimens decreased by 7-88% except for walnut, apricot, and sage extracts.

Table 2: Retentions (kg/m³) and weight losses (%) in specimens treated with plant extract oils after decay test.

Water-type Plant Extracts	Retention (kg/m ³)	Weight Loss (%)		
		Test	Control	Change (%)
Walnut	118.9 (8.7)	36.97 (1.10)	32.81 (7.71)	-12.68
Stinging nettle	165 (9.6)	28.15 (6.81)	30.25 (6.99)	6.94
Onion	172.8 (8.1)	27.44 (4.07)	36.38 (1.90)	24.57
Apricot	149.2 (9.8)	27.76 (2.96)	26.37 (4.34)	-5.27
Eucalyptus	141.1 (23.6)	11.29 (4.02)	36.41 (2.92)	68.99
Marjoram	167.2 (9.1)	29.90 (7.82)	35.43 (5.18)	15.61
Mint	139.7 (15.7)	27.48 (8.40)	39.53 (2.05)	30.48
Thyme	87.8 (5.9)	25.86 (4.86)	39.57 (4.86)	34.65
Rosemary	148.6 (11.2)	28.57 (6.49)	35.56 (9.37)	19.66
Cinnamon	144.2 (15.2)	30.41 (10.71)	33.23 (7.65)	8.49
White rosebay	169.2 (17.7)	24.15 (9.12)	32.35 (5.20)	25.35
Daphne	146.4 (18.4)	25.22 (10.11)	30.66 (11.14)	17.74
Sage	135.8 (7.1)	29.83 (5.55)	27.56 (5.53)	-8.24
Coriander	103.6 (15.5)	17.10 (7.78)	38.20 (3.49)	55.24
Fennel	153.6 (30.6)	4.22 (1.71)	36.02 (5.11)	88.28
Salix bark	149.2 (37)	29.96 (7.72)	42.98 (0.86)	30.29
Acacia branch	182.8 (9.8)	26.35 (1.16)	39.02 (3.35)	32.47
Salix branch	97.8 (11.8)	32.11 (5.01)	35.83 (5.33)	10.38

Improvement in the biological resistance of test specimens was greater for oil-type plant extracts than water-type plant extracts. Two possible reasons for this might be due to antifungal and antimicrobial activity of the main components of essential oils (Bansod & Rai 2008), and filling the lumens with oil, and thus providing physical protection by acting as water repellents that inhibited the catalytic action of the fungal enzymes (Temiz et al., 2008b). In the oil extract type, the lowest weight losses were 5.98%, 6.71% and 8.47% for cinnamon, mint and onion, respectively. Wood specimens treated with a water extract of fennel showed less than 5% weight loss, and this extract was able to protect wood specimens against brown rot decay caused by *C. puteana*. The major components of the different parts of fennel (*F. Vulgare*) are estragole,

fenchone, α -phellandrene, and γ -terpinene (Ozcan et al., 2006).

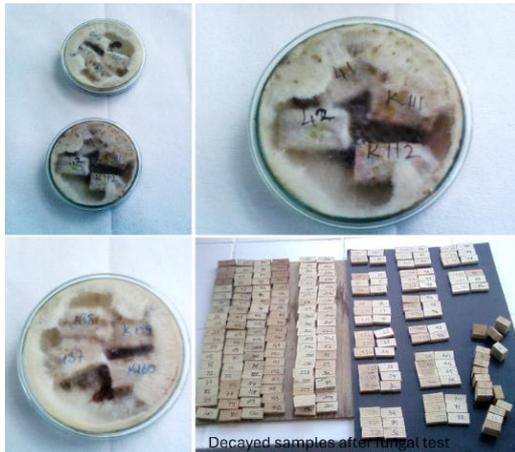


Figure 2: Decay test samples in a petri dish during fungal degradation, and decayed samples after the test.

The nature and position of the functional groups in these components were supposedly the factors that influence biological performance against *C. puteana*. A detailed investigation on the structure of fennel components could reveal the key factors underlying their superior antifungal activity against *C. puteana* attack. Kartal et al. (2006) studied various essential oils and extracts from plants for their ability to inhibit wood decay and termite attack. Formulations containing cinnamaldehyde, cassia oil, wood tar, and dodecanal were found to be effective against brown rot fungus, *Tyromyces palustris*, and white-rot fungus, *Trametes versicolor*. Thymol, carvacrol, trans-anethole, methyl chavicol, and cuminaldehyde, as the main constituents of thyme, oregano, anise, basil, and cumin oils, were found the most effective compounds in inhibiting the growth of both wood-decaying fungi, *T. versicolor* and *C. Puteana* by Voda et al. (2003). Seven essential oils (ajowan, dill weed, Egyptian geranium, lemongrass, rosemary, tea tree, and thyme) were evaluated for their ability to inhibit the growth of *Aspergillus niger*, *Trichoderma viride*, and *Penicillium chrysogenum* on pine stakes by Yang and Clausen (2007). Thyme, Egyptian geranium, and dill weed oil inhibited the growth of all test fungi for 20 weeks.

According to EN 113, for a chemical to be effective against test fungi, the weight loss of treated specimens should be less than 3%. Nevertheless, it was found that the biological effectiveness of the plant extracts used in this study was not within the range required for a wood preservative. This may be due to the high nutritional content of the plant extracts. A low concentration of *N. oleander* extract was more

effective than a high concentration against *T. versicolor*, and it was attributed to the content of organic materials such as sugar, protein, etc., in the extract at high concentration levels (Goktas et al., 2007). Different concentration levels of both water and oil plant extracts on wood applications are needed to understand the antifungal effectiveness better.

4. Conclusions

The study evaluated the decay resistance of Scots pine wood treated with various plant extracts and essential oils against the brown rot fungus *Coniophora puteana*. The results demonstrated that certain plant extracts, particularly cinnamon, mint, garlic, thyme, and onion oils, significantly reduced weight loss in treated wood specimens compared to untreated controls. Among water extracts, fennel exhibited notable antifungal properties, achieving a weight loss of less than 5%. However, despite these promising results, the overall efficacy of the tested extracts did not meet the stringent requirement of less than 3% weight loss as specified by the EN 113 standard for wood preservatives.

The findings suggest that while plant extracts and essential oils can enhance wood's resistance to fungal decay, their performance may be limited by factors such as the nutritive content of the extracts or the need for optimized concentrations. Further research is recommended to explore the synergistic effects of combining different extracts, refining concentration levels, and identifying the specific bioactive compounds responsible for antifungal activity. Such advancements could pave the way for the development of eco-friendly wood preservatives that balance effectiveness with environmental safety.

In conclusion, this study highlights the potential of natural plant extracts as sustainable alternatives to traditional wood preservatives. However, additional investigations are necessary to achieve the desired level of protection for practical applications.

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