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The Utilization of Tea Waste Extract Dyes with Different Mordant-Water Solvent-Borne Varnishes on Wood and Impact on Gloss Change

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Abstract

Natural colorants are obtained from the residues of the tea that is the most consumed drink in Turkey, which come into existence during processing in accordance with ISO 1574/TS 1563 standards as extracts. For this purpose, tea dye that has been developed as a surface material and waterborne varnish have been applied on the surface of Scotch pine (Pinus sylvestris), oriental beech (Fagus orientalis) wood surfaces. The values for the changes that have occurred with respect to gloss have been calculated. According to the results of the experiment, while the highest gloss value was obtained from waterborne varnish (33.02 Gloss) Scotch pine wood application, the least gloss alteration value (0.80 Gloss) was obtained in the application of tea dye with aluminium sulphate on Scotch pine. The dye that has been developed from waste tea extracts, has the aesthetic appearance that could be used in surface applications for the furniture industry.

Keywords: Natural wood dye, tea extract, furniture, gloss

INTRODUCTION

Due to furniture and decoration, wooden materials and wood composites have become the mostly used semi-finished products and unless they are coated with a protective coating, their lifetime is fairly short. Dyes/varnishes are commonly used in furniture and decoration elements manufactured with wooden materials in order to prepare a protective coating [1,2]. Environmental pressures and restrictions imposed against wood preservative materials that are commonly used, due to the poisonous components have made the use and development of environment friendly materials mandatory [3]. The Turkish tea, which has one of the highest quality levels among different teas manufactured worldwide, has also become a strategic product for the national economy. The tea factories established in the Black Sea region manufacture around 40.000 tons of waste tea products each year [4,28]. As the human and environmental health awareness come even more to the fore, states started introducing new protective standards, therefore they are also demanded by the society as significant alternatives to natural colorants, synthetic based and harmful dyes 1 [5, 6, 7]. Particularly, in the fields of catering and textile, with the increase of interest towards environment friendly, antioxidant, anticarcinogenic, antibacterial and antiallergenic natural colorants that do not have any toxic effects and that are extracted from plants, a "green wave" has been initiated [8]. The most significant reason for the diversity in the use of and the accelerated increase in the production and consumption of water solvent dyes/varnishes is the development and diversification of the properties of resins that are used as coating [9].

According to a research conducted by Salthamer et al. [10]. They have indicated that there are approximately 150 sources in the oscillation of volatile compounds to modern internal venues and they have stated that the majority of these result from furniture and wood products. Considering the damages inflicted by the synthetic colorants within the industry that manufactures wood and wood products; the chemical materials that preserve the wooden materials should have poisonous effects against tree pests. However, once these chemicals are applied on wooden materials as dyes and preservatives, they are harming other creatures despite this is unwanted, as they pass onto the soil and water and diffuse into the air when the wooden products are disposed and burnt at the end of their utilization period and during their use. Moiz et al. have highlighted that while wool fabrics are being dyed, the tea plant had given positive results in terms of colour stability after conducting several tests while Angelini has obtained positive results by using wild mignonette (Reseda luteola L.) for dying cotton, wool and silk threads in comparison to synthetic products [11, 12].

The study has determined the surface (gloss) properties provided that an extract has been obtained from tea, which is a natural product, the procurement and development of natural and water based wood preservatives (dye) and colorants that do not harm environmental and human health and in order to attain long-term aesthetic-preservative properties by conducting various experiments.

MATERIAL and METHOD

Wood Materials

Scotch pine (Pinus sylvestris L.), which is among the common species in our country and is commonly used within the furniture-construction industry and oriental beech (Fagus orientalis Lipsky) woods have been used [13].

Waste Tea

Waste teas have been procured from Rize (Fındıklı) tea factory. According by ISO 1573/TS 1562 standard [14], the waste tea sample has not undergone any chemical processes and the samples procured were particularly selected among those that were not affected by harmful factors such as mold, fungus etc. (biotic-abiotic-humidity).

Varnish

During the trials, water solvent-borne wood varnish has been used and ASTM D 3023 [18] principles have been followed. The properties of the varnish are provided in Table 1 below.

Table 1. Water Solvent (Borne) Varnish

Solvent	Temperature	pH	Density	Viscosity	Solid Material (%)	Applied Amount (g/m²)
(DIN Cup4mm)	Solid Material (%)	Applied Amount (g/m²)				
Pure water	23 °C	8.5	1.020	18	34	67

Preparation of the Tea Extract

The sample amount envisaged in the experiment has been heated for an hour with a temperature below boiling point, in a condenser apparatus by putting it inside a 200 ml hot demineralized water or an equivalent water of at least the same level of purity and by mixing it at certain intervals, then after it has been filtered in the presence of a vacuum within a porous capsule that has been previously prepared, the process continued with the washing of the balloon with demineralized water a few times so that there aren't any traces of the sample left and the part that has not been dissolved was put back into the porous capsule. Finally, the residue was washed with 200 ml of hot demineralized water and after the water left in the residue was discharged with a pump or another device that would fulfil the suction requirements, the porous capsule and its contents were dried in a drying oven at 103oC by keeping them in the oven for 16 hours, followed by their cooling off in the desiccator and the weighing was done with 0.001 g sensitivity [2,13,14, 15, 26, 27].

$$\%Extract = \frac{(m_0.w).(m_1.100)}{(m_0.w)}.100$$

m_o: Initial sample amount (g)
m_1: Dried non-dissolving part, residue (g)
w: Dry matter content where the sample's mass is expressed in percentage

Preparation of Experiment Samples

According by TS 2471 standards, the samples in the air-dried moistness were cut as roughcast with dimensions 110×110×12 mm and they were kept in the air conditioning unit at a temperature of 20±2 oC and relative humidity 50±5% until they reached fixed weight. The roughcasts were brought to the dimensions 100×100× 10 mm and following this, they were rubbed with sandpaper no. 80 and 100 consecutively. The dusts on the sample surfaces were first cleaned by using a soft hair brush and a vacuum before they were varnished [15, 16].

Extract Dye Application (Impregnated)

The tea extract dye that has been prepared was subjected to impregnation beyond the classical brushing application in order to measure the penetration depth on wood, to ensure long-term sustainability and to determine the adherence amount. The impregnation process was realized under the conditions specified within ASTM–D 1413-76 [17]. The experiment samples that have been prepared were firstly applied with pre-vacuuming for 60 minutes that is equivalent to 60 cm Hg-1 (Hg-1:Vacuum), and then they were left into the solvent at normal atmosphere pressure for 60 minutes.

$$R = \frac{G.C}{V}.10(kgm/3) \qquad G = T_2 - T_1$$

T_2: Sample weight after impregnation
T_1: Sample weight before impregnation
C: Concentration V: Sample volume

$$R(\%) = \frac{Moes - Moeö}{Moeö}.100(\text{Re}tention\%)$$

Moes= Sample's exact dry weight after impregnation(g)
Moeö= Sample's exact dry weight before impregnation(g)

Varnish Application

During the varnishing of the samples, ASTM D 3023-3924 principles and manufacturer company suggestions were followed. In order to ensure that the varnish layers applied to the experiment samples are completely dried, they were waited under the laboratory conditions with 20±2°C temperature and 65±3 % relative humidity for three weeks. Prior to the experiments, the samples were air-conditioned for 16 hours under 23±2°C temperature and 50±5 % relative humidity . The amount of varnish that has been applied was determined by weighing in an analytical scale that has a sensitivity level of 0,01g. Dried samples were rubbed with water sandpaper no. 220 and 320 [18, 19,20].

Gloss Measurement

The term gloss refers to the measurement of the coming light in terms of its reflection rate and angle. Therefore, in order to determine how much the surface reflects, a device called glossmeter was used. Gloss measurement procedure is generally conducted at 20°, 60° and 85° temperature, in order to send the light beams and to measure the light density that returns in the same degree [21].

Mordant (Aluminium sulphate)

The substances that are used to maintain the colour of the dyes extracted from plants, to ensure that they hold on the material they are painted to and to establish colour alternatives are called mordants. Colorant extracts obtained from plants are either with or without mordants. It is one of the two most commonly used coagulants that are shown with the formula of aluminium sulphate (AlSO4) and are used together with iron sulphate. It is a highly efficient purification chemical. The working range of aluminium sulphate is accepted as the range between 5.5 – 7.8 pH depending on values such as cloudiness of water and waste water [29].

RESULTS and DISCUSSION

Tea Extract (Solvent) Characteristics

The properties of the solvent are provided in Table 1.

Table 1 . Tea Extract (Solvent) Characteristics

Tea Extract Concentration(%)	Solvent Substance	pH		Density (gr/ml)		Temperature ºC	
		EÖ	ES	EÖ	ES	EÖ	ES
15%	Pure Water	5.32	5.3	0.997	0.996	23 ºC	23 ºC

EÖ: Before Impregnation, **ES:** After Impregnation

Tea plan extract has been used as an impregnation substance and due to the properties of the solvent as it has been used as a fresh solvent, there had not been significant changes in the pH and density values measured before and after impregnation. As the solvent's pH is acidic, the possibilities of acidic solvents causing a change in the resistance of the wood should be taken into consideration.

Total Retention (kg/ m3) and Retention % Rate

The Simple Variation Analysis (SVA) results related to the retention values are provided the Dunan test results related to these are presented in Table 2.

Table 2. BVA Results Related to Retention Values Retention Values (Kg m/3)

Source of Variance	Sum of Squares	Degree of Freedom	Average Squares	F value	Significance Level(P<0.05)
Intra groups	60487.57	5	12097.51	176.672	0.000***
Inter group	5751.852	84	68.474		
Total	66239.425	89			
Retention Values (kg/ m3)					
Type of Wood	Average		St. Sp.		HG
Scotch pine	68.18		11.38		B
Oriental Beech	100.65		8.04		A
LSD ±2.379					

When the tables have been examined, the highest retention value has been observed for the oriental beech (100.65 kg/m3), while the lowest has been observed for the scotchpine (68.18 kg/m3); at 0.05 significance level, it was found to be highly statistically significant. In relation to % retention rates, SVA result have been presented Duncan test results are presented in Table 3.

Table 3. % Simple Variance Analysis Results In Relation to % Retention Rates

Source of Variance	Sum of Squares	Degree of Freedom	Average Squares	F value	Level of Significance (P<0.05)
Intra groups	244.763	5	48.953	2.432	0.041***
Intergroup	1690.448	84	20.124		
Total	1935.211	89			
Retention Rates (%)					
Type of Wood	Ave.		St. Sp.		HG
Scotch pine	5.61		3.33		B
Oriental Beech	6.75		5.73		A
LSD ±4.251					

Ave: Average **St. Sp.:** Standard Deviation **HG :** Homogeneity Group leaved ***: 0.05 significance level

When Table 3 are examined; the highest % retention rate was observed in oriental beech (% 6.75), while the lowest was observed for scotchpine (% 5.61); and a statistically significant difference was found between the different tree species at 0.05 significance level in terms of % retention rates.

Peker et al.(1999) carried out a study where they impregnated the oriental beech and the scotch pine wood with boron compounds, ammonium compounds, phosphorus compounds and organic solvent substances .They have determined the retention values for the oriental beech wood experiment samples that were impregnated with (borax+boric acid) mixture as 10.57 kg/m3, while this was 41.64 kg/m3 for scotch pine experiment samples; for the beech % retention rate was % 2.11, for the scotch pine they have reported this value as % 1.60 [22].. Toker (2007) determined that the highest retention rate in the oriental beech wood were attained in those samples that were processed with % 6 SP and in those calabrian pine wood samples that were processed with % 6 BX [23]. Atılgan et al.(2009) reported that the highest % high retention value was observed in oriental beech wood with ammonium tetra flu borate (% 3.91), and the lowest in oriental beech wood was observed in %6 cement mixture (% 0.19) [24]. Şimşek and Baysal (2012) Ammonium tetrafluoroborate (AFB), sodium tetrafluoroborate (SFB), and ammonium pentaborate octahydrate (APB) were used as borates. Total retention value of the highest ammonium pentaborate octahydrate (17.49 Kg/m3), the lowest value Ammonium tetrafluoroborate (7.53 Kg/m3) were determined [30]. Türkoğlu et al (2015)

The highest retention amounts determined in Scots pine and Oriental beech impregnated with TN-E were 35.5 and 28.8 kg.m3, respectively. The lowest retention amounts determined in Scots pine and Oriental beech impregnated with AD-KD 5 were 30.7 and 23.1 kg.m3, respectively [33].

Gloss Measurement Values

Surface gloss measurement values are presented in Tables 4, while the related graphic is presented in Figure 1.

Table 4. Simple Variance Analysis (SVA) Results Related to Gloss Value and Duncan Test Results Related to Gloss Change

Source of Variance	Sum of Squares	Degree of Freedom	Average Squares	F value	Level of Significance (P<0.05)
Intra groups	7713.70583	11	701.246	55.86282	.000***
Intergroup	602.544	48	12.553		
Total	8316.24983	59			
Wood Type	Tea Extract Dye and Variations		Average	Standard Deviation	HG
SCOTCH PINE	Control		4.02	0.54	F
	Tea Extract Dye		1.46	3.50	H
	Tea Extract Dye +Waterborne Varnish		18.32	0.18	D
	Tea Extract Dye + Aluminium sulphate		0.80	0.12	I
	Tea Extract Dye + Aluminium sulphate + Waterborne Varnish		13.32	15.50	E
	Waterborne Varnish		33.02	10.57	A
BEECH WOOD	Control		2.52	0.47	G
	Tea Extract Dye		1.30	4.72	H
	Tea Extract Dye +Waterborne Varnish		18.8	0.12	D
	Tea Extract Dye + Aluminium sulphate		0.74	0.05	I
	Tea Extract Dye + Aluminium sulphate + Waterborne Varnish		20.18	9.35	C
	Waterborne Varnish		29.74	9.72	B

HG : Homogeneous groups Aluminium sulphate (**Alum**) AL2(SO4)3(16,42-14,33)H2O

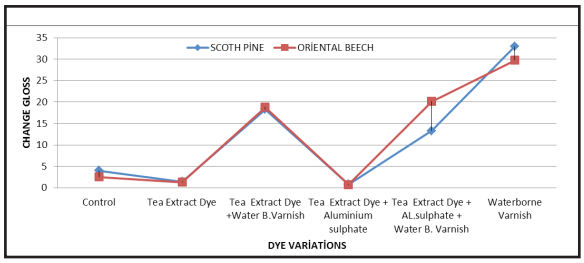

Figure 1. Gloss Change Values in Scotch pine and Beech Wood

The type of wood has been determined as highly significant for the application of tea extract dye, water based varnish to both types of wood. The highest gloss value was observed for the application of water based varnish in Scotchpine wood (33.02 Gloss), while the lowest was observed in beech with tea extract dye+aluminium sulphate application (0.74 Gloss). Tea extract + varnish application had positive results on both types of wood. The type of wood that was found statistically significant at the 0.005 significance level, was the one that was applied with tea extract and acrylic varnish.

Sönmez et al. conducted research on the impact of different application methods on the rigidity, gloss and surface adherence resistance of water solvent-borne varnishes and they found that the variation in the application methods were not effective on scotch pine (Pinus silvestris L.),oriental beech (Fagus orientalis L.), and oak (Qercus petreae L.) wood, while the spraying method was effective on gloss values [1]. They have also reported that the gloss of varnish layers was mostly dependent on surface smoothness and light reflection capabilities. For the spray gun application, with the influence of the air pressure, the pores of the wood were completely filled with varnish and a smooth layer was attained therefore this application was reported as having an effect towards increasing the gloss of the layer [25].

Baysal et al. (2014) reported that the lowest gloss loss was observed to be 50.84 and 65.59 % in Scots pine and Oriental beech impregnated with TN-E before PV coating, respectively, after six months of natural weathering ; the impregnation with copper-based preservatives before PV coating protected the wood surface against gloss loss. They also found that the lowest gloss loss observed was in TN-E pretreatment before PV coating. Before and after natural weathering, our result showed that the gloss values of PV coating wood specimens were higher than wood specimens coated with SV [34].

Şimşek and Baysal (2012) They were designed to determine colour changes and gloss values of wood impregnated with some borates. Results showed that borate treatments darkened the both wood species. Total colour differences of Scots pine were higher than Oriental beech. Borate treatments remarkably decreased gloss values of Oriental beech and Scots pine [30]. Forintek Canada Corporation (2002) While research on the effects of preservative treatment on gloss of wood is rather limited, many researches have focused on colour of preservative impregnated wood. For instance; borate– treated wood looks and handles just like untreated [31]. Yalınkılıç et al. (1999) The gloss values remarkably decreased around 28-37 % and 32-45 % for Oriental beech and Scots pine,

respectively. It may be due to the dispersion effect of the salt crystals deposited in the large lumens of the wide early wood sections within grains [32]. Baysal et al(2014) The gloss values of impregnated and coated, and untreated (control) wood specimens after 3 months of natural weathering were dramatically lower, and after 6 months, gloss values of all wood specimens had decreased considerably. The gloss values of PV coated wood specimens were higher than wood specimens coated with SV [34].

CONCLUDING COMMENTS

Tea plan extract has been used as an impregnation substance and due to the properties of the solvent as it has been used as a fresh solvent, there had not been significant changes in the pH and density values measured before and after impregnation. The highest retention value has been observed for the oriental beech (100.65 kg/m3), while the lowest has been observed for the scotchpine (68.18 kg/m3); at 0.05 significance level, it was found to be highly statistically significant. the highest % retention rate was observed in oriental beech (% 6.75), while the lowest was observed for scotchpine (% 5.61); and a statistically significant difference was found between the different tree species at 0.05 significance level in terms of % retention rates. The type of wood has been determined as highly significant for the application of tea extract dye, water based varnish to both types of wood. The highest gloss value was observed for the application of water based varnish in Scotchpine wood (33.02 Gloss), while the lowest was observed in beech with tea extract dye+aluminium sulphate application (0.74 Gloss). Tea extract + varnish application had positive results on both types of wood. The type of wood that was found statistically significant at the 0.005 significance level, was the one that was applied with tea extract and acrylic varnish. Especially water-based varnish application has a positive effect on gloss.

The dye extract obtained from tea and tea wastes have given positive results in terms of their retention on wood within the water based systems. Both the impregnation application and the brush-gun applications to the surface can be easily used for tea dye extracts. Particularly the furniture for outside mediums (garden, city etc.), the impregnation application and again with the water based varnish systems secondary applications have also given positive results. In terms of human and environmental health, the dye acquired is the most ideal and due to its natural structure, it can be used in any field comfortably. In terms of costs, water based structure is particularly suitable compared to the synthetic and cellulose based structure system. For internal fittings and for all wooden artefacts that would be restored, tea extract dye has the ideal structure due to its colour tone structure; and again with the water system, various different colour tones could be attained. These have also given positive results in terms of gloss in general.

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