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Full Length Research Paper

The effect of protective dye layer applied with different thicknesses on the paper coated blockboard to the roughness and color characteristics

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This study is carried out for determining the changes occurring on the amount of the material used on the protective layer when polyurethane and acrylic (lacquered) dye is applied on the test samples prepared from sandwich type composite (blockboard) boards with their surface coated or uncoated with paper, which are used for the yacht furniture and interior decoration. After applying polyurethane and acrylic dye on the 10 test samples prepared as coated or uncoated with paper with 10 x 10 x 1.6 cm sizes from blockboard, the average surface roughness (*Ra*) values of the protective layer as applied in TS 6956 (2004) have been determined and the total color differences have been determined according to the essentials specified in ASTM- D2244-07e1. According to the result of the study, concealing dyeing is obtained with less roughness and no color difference by using less lacquer dye on the boards coated with paper. With this study, it is possible to suggest that coating with paper before lacquer dyeing can be a preferable application in terms of cost and time saving.

Key words: Composite board, blockboard, dye, layer, surface roughness, color.

INTRODUCTION

Wooden based boards are indispensible materials of decoration and construction components for indoor and outdoor. Wooden material has been an indispensable raw material for the human being throughout the history and today, due to the decreasing forestry existence, it is required to process them more effectively and to use them for longer periods.

Several furniture components are used in wet volumes of houses, recreation, entertainment and sports facilities, land and sea vehicles (Kureli, 1996). Composite materials such as particleboard, fiberboard, blockboard and plywood obtained from massive tree or tree products are used in furniture production (Yildiz and Ozgan, 2009).

Coating the surfaces of the furniture used in wet volumes, as well as the walls and ceilings with coating components such as varnish and dye increases their strength to humidity effect. For the furniture used in these places, massive tree material and derivatives (particleboard, fiberboard, melamine coated chipboard, laminate coated boards etc.) are used (Keskin, 2004).

The long-term strength of the wooden material surfaces to the external effects depends on the strength against possible effects exposed by the protective layer. The protective layers are prepared and applied by coating the wooden material surfaces with the use of coating materials in order to protect the furniture and decoration components against physical, mechanical and chemical effects, outdoor weather conditions and biological pests (Sonmez, 2000). In order to extend the esthetic and economic life of the wooden material surfaces, the materials mostly used for the fluid surface treatments in creating protective layer are dyes and varnishes (Kurtoglu, 2000).

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The wooden material surface can be exposed to various effects depending to the place it is used. Possible effects are mechanical (friction, abrasion, stroke etc.), physical (dust, dirt, oil etc.), chemical (acid, base, household chemicals etc.), microorganisms, temperature, light, heat and air's deteriorating effects. The strength of the protective layer against the deteriorating effects mainly depends to the adhesion strength of the layer with the material surface and the cohesion strength among its own molecules. The hardness, brightness and surface adhesion strength of the varnishes on these layers, where the varnishes with different characteristics are applied on different tree types by creating different layer thicknesses, have been studied. It is been determined according to Budakci (1997) that the layer thickness increase in polymeric based varnishes has a strength increasing effect on the surface adhesion strength.

The opaque dyes prepared for wooden surfaces with different characteristics are applied to the wooden material surfaces with different types and the hardness, brightness, scratching and surface adhesion strengths have been studies. According to Kaygin (1997), it is been determined that the wooden material has no effect on differentiation of surface adhesion strength, but the type of dye has and it is been reported that the best result is obtained with the synthetic dye.

Coating the surfaces of the wooden materials used in furniture and decoration with varnish does not necessarily mean that they are always coated with a protective layer. Therefore, when it is requested to create a protective layer with varnish, it is required to consider the possible effects at the place where the wood will be used, to choose the type of varnish displaying the highest strength against these effects and to apply it in accordance with the relevant technique. Furthermore, the requirement on announcing the information related to the characteristics of the varnish layer and the usage instructions to the consumers by performing regular maintenance and repairing must be considered (Sonmez, 2000).

In order to perform a successful upper surface treatment, it is required to know the characteristics of the wooden material and the upper surface material which might affect each other and to apply the upper surface material with suitable method (Sonmez, 2000).

Today, wooden material has different usage areas in various products with its specific anatomic structure and physical and mechanical characteristics. Wood is a renewable organic material comprised of cellulose, hemicelluloses and lignin and abundantly found in the nature. Wooden material is one of the rare materials that can be intervened physically, mechanically, chemically and biochemically. It can be used either as massive or by being converted into composite products. Although, its density is less compared to other structural materials, its strength is significantly high. It can be easily treated with tools and machines. It can be used as an insulating material and also has desired acoustic characteristics (Bozkurt, 1986).

It is been reported that the wooden material has approximately 10.000 usage areas (Ors and Keskin, 2001). This high amount of usage areas for the wooden material is due to its anatomic structure, physical and mechanical characteristics and chemical structure (Bozkurt and Erdin, 1997).

As a general rule, if the other conditions are available, the microbiological degradation in wood starts when the wood humidity is higher than 20%. In order to prevent the damages on the wooden material and to extend its usage life, treating it with protective chemical substances (impregnating) and protecting it against the indoor and outdoor effects and increasing its esthetic as a second treatment (surface works) gain importance. No significant change occurs in the size of the wooden material dried according to the balance humidity at the place where it will be used (Yalinkilic, 1993). Defects affecting the working and consequently wetting ability such as cracking and deformation as a result of this occur on the wood under atmospheric conditions due to the changes in the humidity amount of the air. In order to protect the wood effectively against different atmospheric conditions, it is required to coat the entire surface of the wood with surface treatment systems preventing humidity (Bufkin and Wildman, 1980).

It is required to use, however, wooden material suitable in terms of size, shape and quality according to the place of use (Bozkurt and Goker, 1986). Therefore, choosing the suitable material, considering the standards and evaluating matters such as engineering, mastery and experience have significant importance (Bozkurt et al., 1993).

In this study, the changes, which may occur on the protective layer and in the amount of the dye used when polyurethane and acrylic dye are applied in order to create a protective layer as coated or uncoated with paper on the surface of the sandwich structure composite board used in furniture and decoration, are determined.

MATERIALS AND METHODS

Blockboard

Blockboard composite board material, a sandwich structure material used in producing yacht furniture and interior decoration furniture, has been chosen as the test material. The test samples are obtained form a private company producing yacht and boat furniture in Turkey by being imported from Moralt Tischlerplatten GmbH and Co KG company located at Germany. The samples are prepared with random selection among the boards.

Total 40 test materials, which 10 from each as coated or uncoated with paper prepared by cutting with 0.5 mm sensitivity with 100 x 100 x 16 mm size from blockboard, are prepared (Figure 1).

Used before fiberboard and MDF with primitive methods by the furniture makers, blockboard has been converted into a material

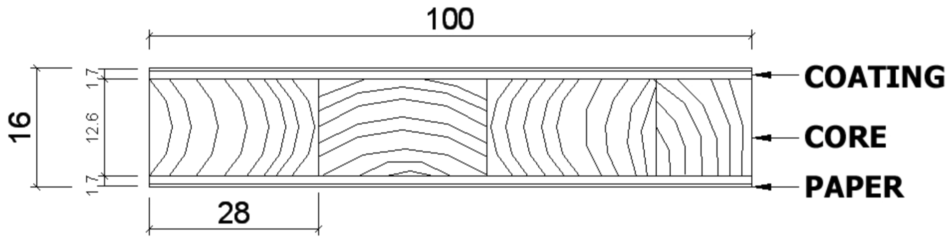

Figure 1. Blockboard sizes.

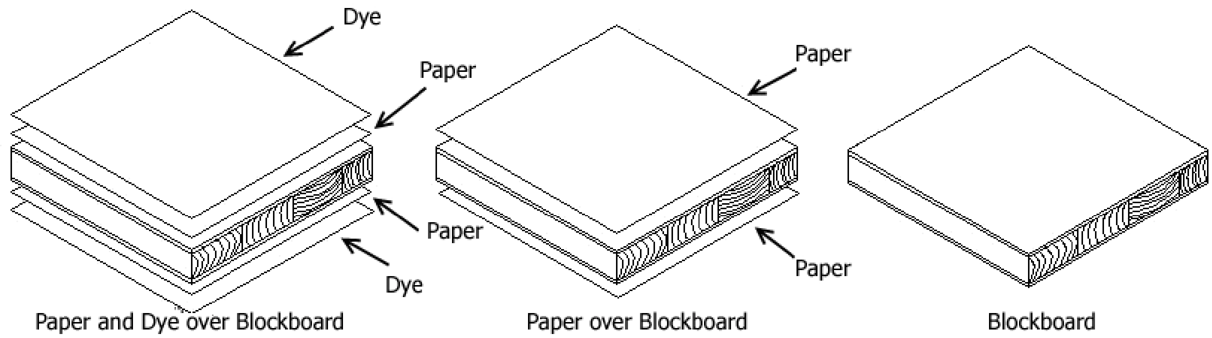

Figure 2. Blockboard layers.

more suitable to purpose by using advanced tree technology. It is produced by coating the sub- and upper surfaces with peeling coating pupil, oven drying its interior with soft trees such as pine, fir and maple and pressing the trees arranged as short and thin laths as end-to-end and next to each other. In hot press applications, Melamine and Urea formaldehyde glue (E2 norm) is used (Figure 2).

Coloring materials

During the tests, before applying acrylic white and polyurethane black lacquer on the paperless board, hardener and filling varnish mixture (Sayerlack XT 4028) + varnish (Sayerlack TR 4027) have been applied as barrier layer and dried for 4 h. After leveling the dry layer with no. 220 emery, polyester primer dye (PU-0377-13) has been applied and dried for 8 h. After being leveled with no. 120 and 180 emery, the layer is dyed with primer lacquer dye (Glasurit Universal Primer filler AB 285-650) and dried for 4 h. After the dried layer is leveled with no. 220 and 320 emery, inspection paste (Dyo Polyester Paste) is applied, rubbed with no. 320 and 400 emery, dyed with Glasurit 22 Series Acrylic Finish Mat Dye (Color: White, Code: U8x02x21.50) and dried for 8 h. While applying acrylic white and polyurethane black lacquer on the boards coated with paper, it has been applied without barrier layer and polyester primer dye.

Preparation of test samples

Coloring

Coloring treatments applied with spraying guns on surfaces, which are cleaned by brush, by considering the recommendations of the manufacturer company. Dye has been applied as 3 layers for boards coated with paper and as 5 layers for board uncoated with paper.

Test method

The varnished samples are dried for three weeks for full curing under laboratory conditions of 20 ± 2°C temperature and 65 ± 5% relative humidity in order to provide full drying. After this, before surface roughness and color differences measurements, the samples are conditions for 16 h under the air conditioning environment of 23 ± 2°C temperature and 65 ± 5% relative humidity by complying with the basis of TS 642 (1997) and prepared for the tests.

Determination of surface roughness

Surface roughness of the samples was measured by using a profilometer (Mitutoyo Surftest SJ-301). The surface roughness of the samples was measured with the profile method using a stylus device standard. The measuring speed, pin diameter, and pin top angle of the tool were 10 mm/min, 4 μm, and 90°, respectively. The points of roughness measurement were randomly marked on the surface of the samples. Measurements were made in the direction perpendicular to the fiber of the samples.

Roughness parameter, mean arithmetic deviation of profile (Ra) was commonly used in previous studies to evaluate surface characteristics of wood and wood composites including veneer. Therefore, such parameter which is characterized by (ISO 4287,

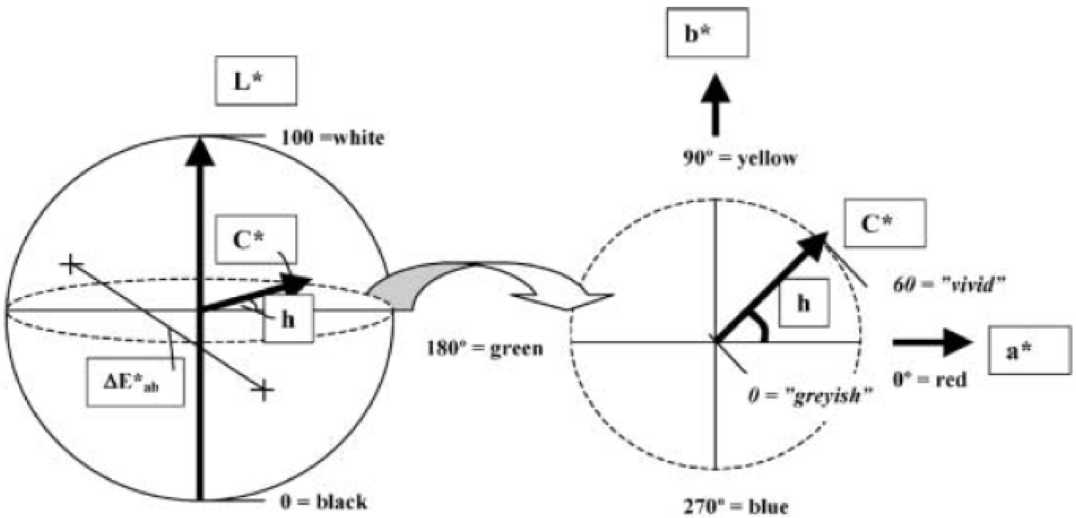

Figure 3. CIEL*a*b* color space and the transformation to cylindrical color space L*C*h*.

1997) and (DIN 4768, 1990) were recorded. Roughness values were measured with a sensitivity of 0.5 µm. The length of scanning line (Lt) was 15 mm and the cutoff was λ=2.5 mm. The measuring force of the scanning arm on the surfaces was 4 mN (0.4 g), which did not put any significant damage on the surface according to Mitutoyo Surftest SJ-301 user manual (Anonymous, 2002). Measurements were performed at room temperature and the pin was calibrated before the tests.

Determining the surface brightness

After the treatments applications, using light reflections, sample brightness were measured with the aid of Elrepho Spectrophotometer according to TS 4318 EN ISO 2813 (2002) standards. For the same samples, colors were also measured with the aid of Elrepho Spectrophotometer according to ASTM D2244-07e1 (2007) standards.

Determining the color difference

Color measurements were made using a tristimulus photoelectric colorimeter, Elrepho, with a measuring head 50 mm in diameter. The Elrepho measures the color as three coordinates in three-dimensional color space (Figure 3). This system is called CIE L*a*b* and works according to the CIE Standard. The part of the coordinate system that is of interest in this work is the first quadrant; that is, positive values of a* and b* (Hunt, 1995).

To the left: The color sphere, where the circle of cross section at L*=50 is donated. The color difference (ΔE) is the distance between two colors (points) within the color sphere. To the right: Cross section at L*=50 showing the axis from green to red (a*) and from blue to yellow (b*), and the co-ordinates chrome (C*) and hue (h=arctan (b*/a*)) is the hue of a color; 0 or 360° is red, 90 is yellow, 180 is green and 270 is blue. L* is the lightness; 0=black and 100=white. C* is the chrome or saturation; 0 represents only grayish colors and 60, for instance, represents very vivid colors (Sundqvist, 2002). The three measured co-ordinates, L*a* and b*, were transformed to L*, C* and h co-ordinates and ΔE values, according to the equations below (Temiz et al., 2005).

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

The L*C*h system was chosen since only one color variable is needed to denote hue, that is red, green, blue or yellow, and furthermore, this system is easy to refer to our experience of color characteristics such as lightness, saturation and hue. Each color parameter, L*, C*, h and ΔE, was measured for each material, time and temperature. The average color values, standard deviations and 95% confidence intervals (5% significance level), based on t-distribution, were calculated assuming normal distribution. The lower value of Δ*E** indicates that the color is either not changed or the changes is negligible.

Statistic method

For all parameters, all multiple comparisons were first subjected to an Analysis of Variance (ANOVA) and significant differences between mean values of control and treated samples were determined using Duncan's multiple range test.

RESULTS AND DISCUSSION

The statistical data of surface roughness values are given in Table 1. The variance analysis results displaying whether there are any differences between the surface roughness (Ra) values are given in Table 2. DUNCAN test was used to show the difference determined with ANOVA. The test results are given in Table 3.

According to Table 3; it will be seen that there is a statistical difference, with a confidence interval of 95% and 99%, between the surface roughness (Ra) values of acrylic samples with paper and the surface roughness (Ra) values of acrylic, polyurethane with paper and polyurethane samples and between the surface

Table 1. Statistical data of surface roughness values (Ra).

	Acrylic	Acrylic with paper	Polyurethane with paper	Polyurethane
Arithmetic mean	0.646	0.678	0.749	0.820
Standard deviation	0.059	0.075	0.057	0.088
Variance	0.003	0.006	0.003	0.008
Coefficient of variance	9.107	11.063	7.680	10.768
Max.	0.870	1.000	0.990	1.140
Min.	0.530	0.570	0.640	0.620

Table 2. One-way analysis of variance (ANOVA) test of surface roughness values (Ra).

Analysis of variance						
Source of variation	Degree of freedom	Total variance	Variance	F-ratio 95%	F-ratio 99%	Confidence level
Between groups	3	1.795	0.598	58.658	58.658	
Within groups	396	1.999	0.010	>	>	(95%) S*
Total	399	3.793504		2.680	3.949	(99%) S**

As $F_{calculation} = 58.658 > F_{0.01;}$ 3;396 = 3.949 and $F_{calculation} = 58.658 > F_{0.05;}$ 3;396 = 2.680, there are differences among the surface roughness (Ra) values with 99% and 95% confidence interval.

Table 3. Duncan test results belonging to surface roughness values (Ra).

	Duncan test		
	Acrylic	Polyurethane with paper	Polyurethane
Acrylic with paper	0.071	0.142	0.174
Rp	0.040	0.048	0.053
Acrylic		0.071	0.102
Rp		0.040	0.048
Polyurethane with paper			0.032
Rp			0.040

Table 4. Statistical data of brightness values.

	Polyurethane	Polyurethane with paper	Acrylic	Acrylic with paper
Arithmetic mean	7.214	7.854	71.015	71.065
Standard deviation	0.166	0.083	0.090	0.139
Variance	0.027	0.007	0.008	0.019
Coefficient of variance	2.294	1.063	0.127	0.195
Max.	7.570	7.990	71.190	71.250
Min.	6.920	7.570	70.790	70.730

roughness (Ra) values of acrylic samples and the surface roughness (Ra) values of polyurethane with paper and polyurethane samples. The statistical data related to brightness values are given in Table 4.

The variance analysis results displaying whether there any differences between the brightness values are given in Table 5. DUNCAN test was used to show the difference determined with ANOVA. The test results are given in Table 6.

According to Table 6; it will be seen that there is a

Table 5. One-way analysis of variance (ANOVA) test of brightness values.

Analysis of variance						
Source of variation	**Degree of freedom**	**Total variance**	**Variance**	**F-ratio 95%**	**F-ratio 99%**	**Confidence level**
Between groups	3	201657.730	67219.243	4356281.312	4356281.312	
Within groups	196	3.024	0.015	>	>	(95%) S*
Total	199	201660.75		2.680	3.949	(99%) S**

As $F_{calculation}$ = 4356281.312 $F_{0.01;}$ 3;396 = 3.949 and $F_{calculation}$ = 4356281.312 $F_{0.05;}$ 3;396 = 2.680, there are differences among the brightness values with 99% and 95% confidence interval.

Table 6. Duncan test results belonging to brightness values.

	Duncan Test		
	Acrylic	**Polyurethane with paper**	**Polyurethane**
Acrylic with paper	0.050	63.211	63.851
Rp	0.049	0.059	0.065
Acrylic		63.160	63.800
Rp		0.049	0.059
Polyurethane with paper			0.640
Rp			0.049

Table 7. Statistical data of color difference (ΔE),one-sample statistics.

	N	Mean	Std. deviation	Std. error mean
Acrylic	50	0.2248	0.12628	0.01786
Polyurethane	50	1.2345	0.38762	0.05482

statistical difference, with a confidence interval of 95 and 99%, between the brightness values of acrylic samples with paper and the brightness values of acrylic, polyurethane with paper and polyurethane samples, between the brightness values of the acrylic samples and the brightness values of polyurethane with paper and polyurethane samples and between the brightness values of polyurethane with paper samples and the brightness values of polyurethane samples. The statistical data related to color difference (ΔE) values are given in Table 7.

T-test results belonging to color difference (ΔE) values are given in Table 8. According to Table 8; it will be seen that there is a statistical difference, with a confidence interval of 95%, as a result of T-test performed to see whether there are any differences between the color difference values of the acrylic and polyurethane samples.

Conclusions

According to the result of the study, concealing dyeing is obtained with less roughness and no color difference by using less lacquer dye on the boards coated used in yacht furniture and interior decoration and with its surface coated with paper. In the study performed by Richter et al. (1995), it is been reported that the dye and varnish absorption on wood surfaces, which the preliminary treatments are not performed well, causes more consumption, that the best surface roughness performance is obtained on the wood surfaces with good preparation and the varnish and dye consumption amount is reduced by fifty percent.

In the study performed by Kaygin (1997), the acrylic dye has achieved a better results compared to cellulosic dye and much better results compared to synthetic dye in terms of the strength against brightness and scratching. It is been reported that despite all these advantages, the cellulosic dye is preferred more compared to the acrylic dye in the furniture industry due to its low cost.

In the study performed by Nemli (2000), it is been determined that there is a significant decrease in the water-taking amount and thickness-increase rate between 2 to 24 h as a result of coating the surfaces of

Table 8. T-test for color difference.

	One-sample test					
	Test value = 0					
	t	df	Sig. (2-tailed)	Mean difference	95 % confidence interval of the difference	
					Lower	Upper
Acrylic	12.587	49	0.000	0.22477	0.1889	0.2607
Polyurethane	22.520	49	0.000	1.23450	1.1243	1.3443

the fiberboard with lacquer dye, melamine absorbed papers, wooden coating boards and roll laminates.

Kopecky et al. (1997) found that the surface microroughness of about 0.6 nm with simultaneous preservation of the underlying optical figure may be achieved in the case of optimal lacquer concentration. Asa result, it can be recommended that coating the board surfaces with paper before lacquer dyeing can be preferred in terms of costs and time saving.

REFERENCES

Anonymous (2002). Mitutoyo surface roughness tester. Mitutoyo Surftest SJ-301. Product no. 99MBB035A 1. Series No. 178, Mitutoyo Corporation, 20-1, Sakado 1-chome, Takatsu-ku, Kawasaki, Kanagawa Japan, 213-0012.

ASTM D2244-07e1. (2007). Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates, American Society for Testing and Materials.

Bozkurt Y (1986). Tree Technology, İ.Ü. Faculty of Forestry, Department of Forest Products Engineering, Istanbul.

Bozkurt Y, Erdin N (1997). Tree Technology, İ.Ü. Faculty of Forestry Publications, Istanbul. Issue No: 3998, Faculty Publication No: 445-372.

Bozkurt Y, Göker Y (1986). Utilization of Forestry Products, İ.Ü. Faculty of Forestry Publications, Istanbul. Issue No: 3402 / 379.

Bozkurt Y, Göker Y, Erdin N (1993). Impregnation Technique, İ.Ü. Faculty of Forestry Publications, Istanbul, Issue No: 3779: 425-429.

Budakçi M (1997). “Effect of Layer Thickness in Wooden Varnishes on Hardness, Brightness and Surface Adhesion Strength”, Gazi Uni., Institute of Science and Technology, Postgraduate Thesis, Ankara, 1997.

Bufkin BG, Wildman GC (1980). Environmentally Acceptable Coatings for The Wood Industry, For. Prod. J., 30: 37-44.

DIN 4768, (1990). Determination of values of surface roughness parameters Ra, Rz, Rmax using electrical contact (stylus) instruments, concepts and measuring conditions. Berlin, Deutsches Institut fur Norming, Germany.

Hunt R (1995). Measuring color, second edition. (Ellis Horwood series in applied science and industrial technology): Ellis Horwood Limited.

International Standard ISO 4287 (1997). Geometrical product specifications (GPS)–surface texture: profile method–terms, definitions, and surface texture parameters. International Organization for Standardization, Geneva, Switzerland.

Kaygin B (1997). “Strength Characteristics of Opaque Dyes Used on Wooden Surfaces”, Karaelmas Uni. Institute of Science and Technology, Postgraduate Thesis, Bartin, 1997.

Keskin H (2004). "Technological Properties of Laminated Wood Materials Made Up With the Combination of Oak (*Quercus Petraea* Liebl.) Wood and Scots Pine (*Pinus sylvestris* Lipsky) Wood And Possibilities of Using Them", Gazi University J. Sci. (GUJSCI), 17/ 4: 121-131.

Kopecky M, Inneman A, Franc F, Pina L (1997). Surface finishing by lacquer-coating technique Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 395(2): 281-286.

Küreli İ (1996). Studies on Possibilities of Using Chipboard and Fiberboard in wet places, Doctoral Thesis, GÜ, Institute of Science and Technology.

Kurtoğlu A (2000). Wood material surface treatments, General information, Volume.1, Istanbul University Publication No: 4262, Faculty of Forestry Publication No: 463, ISBN 975-404-590-9.

Nemli G (2000). “Effects of Surface Coating Materials and Application Parameters of Technical Specifications of Fiberboard”, Karadeniz Technical Uni.. Institute of Science and Technology, Doctoral Thesis,, Trabzon, 2000.

Örs Y, Keskin H (2001). Tree Material Knowledge, KOSGEB, Kale Matbaacilik, Ankara.

Richter K, Feist WC, Knaebe MT (1995). The Effect of Surface Roughness on The Performence of Finishes, For. Prod. J., 45(7): 91-97.

Sonmez A (2000). Upper Surface Treatments in Trees I, Çizgi Matbaacilik, Ankara.

Sundqvist B (2002). Color Response of Scots Pine (*Pinus sylvestris*), Norway Spruce (*Picea abies*) and Birch (*Betula pubescens*) Subjected to Heat Treatment in Capillary, Holz Roh. Werks., 60: 106-114.

Temiz A, Yildiz UC, Aydin İ, Eikenes M, Alfredsen G, Çolakoğlu G (2005). Surface Roughness and Color Characteristics of Wood Treated With Preservatives After Accelerated Weathering Test, Appl. Surface Sci., 250: 35-42.

TS 4318 EN ISO 2813 (2002). Paints and varnishes - Determination of specular gloos of non-metallic paint films at 20, 60 and 85, Turkish Standards Institution, Ankara, Turkey.

TS 642 (1997). Standard Atmospheres-Characteristics for Conditioning and/or Testing, *T.S.E.,* Ankara.

TS 6956 (2004). Geometrical product specifications (GPS) - Surface texture: Profile method –Terms, definitions and surface texture parameters, Ankara-Turkey.

Yalinkiliç MK (1993). Changes Caused by Various Impregnation Materials on Burning, Hygroscopicity and Dimensional Stability Characteristics of the Wooden Material and Washability of These Materials on Woods, K.T.Ü. Faculty of Forestry, Associate Professor Thesis, Trabzon.

Yildiz K, Özgan E (2009). Review of Engineering Characteristics of Some Wooden Based Boards Exposed to Different Environments, Selçuk University Technical Sciences Vocational High School, Teknik-Online Magazine, ISSN 1302/6178, 8(1).