Apiterapi ve Doğa Dergisi
Journal of Apitherapy and Nature
www.dergipark.gov.tr/jan

Determination of some surface properties in wax coatings applied on mulberry (Morus alba) wood

Dut (Morus alba) ahşabına uygulanmış balmumu katmanlarında bazı yüzey özelliklerinin tespit edilmesi

Ümit AYATA[1*]

[1]Department of Interior Architecture and Environmental Design, Faculty of Arts and Design, Bayburt University, Bayburt, TURKEY. *umitayata@yandex.com

Received/Geliş Tarihi: 03/07/2024
Accepted/ Kabul Tarihi: 08/11/2024
***Corresponding author** /Yazışılan yazar
Doi: 10.35206/jan.1509658
e-ISSN: 2667-4734

Abstract

In this study, the surface properties of mulberry (*Morus alba*) wood treated with wax layers of varying coat numbers were identified and compared. The obtained data were analyzed in a statistical program, revealing generally different results. Except for the *h*° value, the number of coats factor was found to be significant for all tests in the variance analyses. As the number of coats increased, decreases were observed in the *L** value, while increases were found in the *b**, *C**, and *a** values. Increases in the number of coats resulted in a reduction in *WI** values in both directions. The highest results in color parameters were observed in the control samples for *h*° and *L** values, whereas for *a**, *b**, and *C** values, they were found in the experimental samples treated with three coats of wax. The Δ*E** values measured were 7.65 for one coat, 9.68 for two coats, and 12.02 for three coats of application. Increases in glossiness values were achieved in both directions at 60 and 85 degrees. The application of wax has been found to change certain optical properties of the wood.

Keywords: Mulberry, Waxes, Colour, Glossiness, Whiteness index

Özet

Bu çalışmada dut (*Morus alba*) ahşabına uygulanmış farklı kat sayılarına ait balmumu katmanlarında elde edilen bazı yüzey özellikleri tespit edilmiş olunup, sonuçlar birbirleri ile karşılaştırılmıştır. Elde edilen veriler bir istatistik programında değerlendirilmiş olunup, genelde farklı sonuçların elde edildiği görülmüştür. *h*° değeri dışında bütün testler üzerinde varyans analizleri için kat sayısı faktörünün anlamlı olarak bulunduğu görülmüştür. Kat sayısının artması ile *L** değerlerinde azalışlar tespit edilirken, *b**, *C** ve *a** değerlerinde artışlar bulunmuştur. Kat sayısının artması ile her iki yönlerde yapılan *WI** değerlerinde azalışlar görülmüştür. Renk parametrelerinde en yüksek sonuçlar *h*° ve *L** değerleri için kontrol örneklerinde görülrken, *a**, *b** ve *C** değerleri için 3 kat balmumu uygulanmış deney örnekleri üzerinde bulunmuştur. Δ*E** değerleri 1 kat uygulama ile 7.65, 2 kat uygulama ile 9.68 ve 3 kat uygulama ile 12.02 olarak bulunmuştur. 60 ve 85 derecelerde her iki yönelerde yapılan parlaklık değerlerinde artışlar elde edilmiştir. Uygulanan balmumu ile ahşabın sahip olduğu bazı optik özelliklerinin değiştiği görülmüştür.

Anahtar Kelimeler: Dut, Balmumu, Renk, Parlaklık, Beyazlık İndeksi

Abbreviations: *WI**: Whitness index; *a**: Red colur, *b**: Yellow color, *L**: Lightness; *C**: Chroma, *h*°: hue tone

1. INTRODUCTION

Wax is commonly described as a solid material resembling plastic at room temperature, transitioning into a liquid state when heated. Due to its plasticity, wax can often deform under pressure even in the absence of heat. The chemical makeup of waxes is intricate, typically comprising various chemical components and a diverse array of reactive functional groups (Warth, 1946; Letcher, 1984; Sequeira, 1994).

Wax serves as a versatile material with various applications, including its use as a waterproofing agent in candle making, ointments/lubricants, pharmaceuticals, soaps, and polishes, manufacturing of electronic components and CDs, modeling and casting, grafting, and the creation of artificial honeycombs. Its primary significance is observed in apiculture, particularly in the production of artificial honeycomb foundations. These foundations, made from cast or pressed wax sheets with embossed cells, are swiftly and economically transformed into honeycomb structures by bees. Excess wax tends to accumulate in regions where artificial honeycomb foundations are not utilized (Marieke et al., 2005; Alemu and Girma, 2019).

Traditional beehive wax production typically results in an output equivalent to about 8-10% of the weight of the honey. In contrast, modern methods yield approximately 1-2% of the honey's weight in wax. Transitional beehive wax production falls in between, yielding approximately 8% of the honey’s weight in wax (Gezahegne, 2001).

A prevalent method for processing beeswax typically entails melting it using hot water, steam, or sunlight, and then proceeding with either filtration or centrifugation (Bogdanov, 2016).

Waxes and wax emulsions are also used for protecting wood surfaces in outdoor applications without relying on biocides. They are known to improve water resistance and reduce the extent of photochemical degradation. Additionally, beeswax exhibits biocidal properties when applied to wood surfaces exposed to soil burial degradation conditions (Teacă et al., 2019; Németh et al., 2015).

In the literature, it has been reported that various waxes and derivatives were applied to wood surfaces, and tests were conducted to investigate the interaction between the applied wax chemicals and the wood material [lemon (*Citrus limon* (L.) Burm.) (Çamlıbel and Ayata, 2024b), poplar and beech (Németh et al., 2015), Siberian pine (*Pinus sibirica*) (Çamlıbel and Ayata, 2024c), mahogany (*Swietenia mahagoni* (L.) Jacq.) (Ayata et al., 2024b), pine, elm, and ash (Rozanska and Beer, 2013), magnolia (*Magnolia grandiflora* L.) (Ayata et al., 2024a), cocobolo and African padauk (Qian et al., 2019), plum (*Prunus domestica* L.) (Ayata et al., 2024c), black dargon (Yata et al., 1995), olive (*Olea europaea* L.) (Peker et al., 2024a), Norway spruce (Lesar et al., 2010), balau red (*Shorea guiso*) (Peker et al., 2024b), Macassar ebony (*Diospyros celebica* Bakh.) (Kaplan et al., 2024), Norway spruce and beech (Humar and Lesar, 2013), African ebony (*Diospyros crassiflora* Hiern.) (Çamlıbel and Ayata, 2024a), pine (Chau et al., 2015)]. However, it has been observed in the literature that after applying wax at different layer thicknesses to mulberry wood, tests on various optical properties were not conducted. This research is envisaged to fill this gap.

Mulberry (*Morus alba*) is a perennial tree that can grow up to 10-20 meters tall and is widely distributed across Asia, Europe, Africa, and North America. In southern Europe and the United States, it is commonly used in landscaping due to its drought tolerance and suitability for urban environments (Tipton, 1994).

Cavus et al., (2019) reported a thermal conductivity coefficient of 0.155 W/m·K for mulberry wood. According to Ayata et al., (2018), the Janka hardness values for the same wood species were found to be 73.24 N/mm² on the radial surface, 77.69 N/mm² on the tangential surface, and 93.71 N/mm² on the transverse surface.

In this study, some surface properties obtained from wax layers with different coat numbers applied to mulberry (*Morus alba*) wood were determined, and the results were compared with each other. The aim is to identify the interaction between the obtained results for both mulberry wood and the application of wax, with the expectation that the findings will contribute valuable information to the body of literature.

2. MATERIALS AND METHODS

This research employed *Morus alba* (mulberry) wood as the primary experimental material. The specimens, measuring 100 mm x 100 mm x 20 mm and classified as first-class quality, were sourced from a commercial supplier. Rigorous selection criteria were applied to ensure the integrity of the experimental samples: they were free of cracks and knots, exhibited smooth and straight fibers, displayed uniform color and density, and maintained consistent properties. Following this, the specimens were prepared according to the guidelines specified in TS ISO 13061-1 (2021).

In the study, an oil mixture containing natural and synthetic waxes (appearance: paste, color: neutral, odor: characteristic, solubility in water: dispersible but not soluble, dry residue: 30%, pH value: 7.6) was used. The wax compound was acquired by purchasing it from a supplier specializing in wood preservative chemicals. The oil mixture containing natural and synthetic waxes was applied to wooden surfaces in 1, 2, and 3 layers using a brush.

Glossiness measurements were performed at angles of 20°, 60°, and 85° relative to the fibers using the ETB-0833 model glossmeter device (Vetus Electronic Technology Co., Ltd., CN), following ISO 2813 (1994) standards. This study employed the Whiteness Meter BDY-1 device to evaluate the whiteness index (WI^*) values in both parallel and perpendicular fiber orientations, following the procedures specified in ASTM E313-15e1 (2015). Color changes in the samples were quantified using a CS-10 device (CHN Spec, China) with CIE 10° standard observer and CIE D65 light source, utilizing an illumination system of 8/d (8°/diffuse illumination), in accordance with ASTM D 2244-3 (2007) standard and employing the CIELAB color system. The overall color variation outcomes were calculated using the equations described in Ayata et al., (2021a;b).

$$\Delta a^* = (a^*_{\text{wax applied wood}}) - (a^*_{\text{control wood}}) \quad (1)$$

$$\Delta L^* = (L^*_{\text{wax applied wood}}) - (L^*_{\text{control wood}}) \quad (2)$$

$$\Delta b^* = (b^*_{\text{wax applied wood}}) - (b^*_{\text{control wood}}) \quad (3)$$

$$\Delta E^* = ((\Delta L^*)^2 + (\Delta b^*)^2 + (\Delta a^*)^2)^{1/2} \quad (4)$$

$$C^* = ((a^*)^2 + (b^*)^2)^{1/2} \quad (5)$$

$$\Delta C^* = (C^*_{\text{wax applied wood}}) - (C^*_{\text{control wood}}) \quad (6)$$

$$h^{\circ} = \arctan\,(b^*/a^*) \quad (7)$$

$$\Delta H^* = [(\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*)^2]^{1/2} \quad (8)$$

Δ*C**: Represents the alteration in chroma or saturation, for a positive sample, it exhibits heightened vibrancy and luminance compared to the reference, conversely, for a negative sample, it displays reduced vividness and distinction relative to the reference, Δ*H**: Denotes variations in hue angle or shading, Δ*L**: In the case of a positive sample, it signifies a lighter shade compared to the reference, while a negative sample indicates a darker shade, Δ*a**: A positive sample leans towards a more pronounced red tone than the reference, whereas a negative sample leans towards a greener hue, and Δ*b**: For a positive sample, there is a shift towards increased yellowness compared to the reference, and for a negative sample, a shift towards heightened blueness is observed (Lange 1999). Furthermore, the color alteration benchmarks outlined in Table 1, as established by Barański et al. (2017), have been juxtaposed and contrasted with the findings presented in Table 4.

Table 1. Color change criteria by Barański et al., (2017)

Color change criteria	►	Δ*E** value
Invisible color change	►	Δ*E** < 0.2
Slight change of color	►	2 > Δ*E** > 0.2
Color change visible in high filter	►	3 > Δ*E** > 2
Color change visible with average quality of filter	►	6 > Δ*E** > 3
High color change	►	12 > Δ*E** > 6
Different color	►	Δ*E** > 12

This study utilized the SPSS software to compute various metrics, such as homogeneity groups, minimum and maximum values, standard deviations, percentage variations (%), multivariate coefficient of variations, and mean results.

3. RESULTS AND DISCUSSION

The results of the multivariate analysis of variance are presented in Table 2. According to these results, all tests were found to be statistically significant except for the *h*° value. The results of the color parameters determined before and after wax application are given in Table 3. The highest result for the *L** value was observed in the control experiment samples (62.82), while the lowest result (55.86) was seen on surfaces treated with 3-layers of wax. In terms of the *L** parameter, decreases were observed with an increase in the number of layers applied. The lowest decrease rate was found to be 7.64% with the application of 1-layer of wax, whereas the highest decrease rate, at 11.08%, was observed with the application of 3-layers of wax (Table 3).

Table 2. The results of the multivariate analysis of variance (*: significant)

Test	Sum of Squares	df	Mean Square	F	Sig.
*L**	280.661	3	93.554	69.137	0.000*
*a**	109.008	3	36.336	238.634	0.000*
*b**	426.998	3	142.333	94.414	0.000*
*C**	528.275	3	176.092	132.942	0.000*
h°	30.390	3	10.130	2.085	0.119**
⊥20° glossiness	0.206	3	0.069	42.621	0.000*
⊥60° glossiness	39.813	3	13.271	290.075	0.000*
⊥85° glossiness	370.128	3	123.376	892.592	0.000*
ǁ20° glossiness	0.069	3	0.023	6.395	0.001*
ǁ60° glossiness	40.405	3	13.468	196.856	0.000*
ǁ85° glossiness	474.143	3	158.048	349.555	0.000*
*WI** (⊥)	443.889	3	147.963	410.723	0.000*
*WI** (ǁ)	720.684	3	240.228	689.650	0.000*

For the *a** value, the lowest result was obtained in the control experiment group samples (8.08), while the highest result (12.46) was determined on samples treated with 3-layers of wax. An increase in the number of layers applied resulted in higher *a** values. The smallest increase rate, at 37.62%, was observed with 1-layer application, whereas the highest increase rate of 54.21% was recorded with 3-layers applied (Table 3).

For the *b** value, the control samples exhibited the lowest result (23.49), while the highest result (32.27) was observed on surfaces treated with 3- layers of wax. The application of more layers led to higher *b** parameters. The lowest increase rate, at 21.80%, was observed with 1-layer application, while the highest increase rate of 37.38% was recorded with 3-layers applied (Table 3).

As for the *C** parameter, the lowest result was detected in the control experiment samples (24.84), while the highest result (34.59) was obtained on samples treated with 3-layers of wax. The augmentation in the number of layers led to elevated *C** values. The lowest increase rate, at 23.59%, was noted with the application of 1-layer, while the highest increase rate, reaching 39.25%, was observed with 3-layers applied (Table 3).

In terms of the *h*° value, the control experiment samples yielded the highest result (70.99), whereas the lowest value (68.73) was recorded on surfaces treated with a single layer of wax. The highest decrease rate, at 1.58%, was found with the application of 1-layer of wax, while the lowest decrease rate, also at 1.58%, was observed with 3-layers of wax applied. In terms of the *h*° parameter, decreases were observed with an increase in the number of layers applied (Table 3).

Table 3. Results of color parameters determined before and after wax application

Test	Wax Application	N	Mean	Change (%)	*HG*	*SD*	Mini-mum	Maxi-mum	COV
*L**	Control	10	62.82	-	A*	0.51	62.31	63.64	0.82
	1 layer	10	58.02	↓7.64	B	1.82	54.46	60.44	3.13
	2 layers	10	57.01	↓9.25	B	0.88	55.83	58.28	1.54
	3 layers	10	55.86	↓11.08	C**	1.04	54.62	57.49	1.87
*a**	Control	10	8.08	-	D**	0.27	7.65	8.44	3.33
	1 layer	10	11.12	↑37.62	C	0.29	10.60	11.44	2.63
	2 layers	10	11.60	↑43.56	B	0.32	11.19	12.37	2.77
	3 layers	10	12.46	↑54.21	A*	0.59	11.11	13.05	4.73
*b**	Control	10	23.49	-	D**	1.20	21.68	25.49	5.11
	1 layer	10	28.61	↑21.80	C	1.29	26.56	30.36	4.50
	2 layers	10	30.39	↑29.37	B	1.31	28.62	32.03	4.30
	3 layers	10	32.27	↑37.38	A*	1.11	29.50	33.19	3.44
*C**	Control	10	24.84	-	D**	1.21	22.99	26.86	4.88
	1 layer	10	30.70	↑23.59	C	1.23	28.81	32.31	4.01
	2 layers	10	32.53	↑30.96	B	1.17	30.86	34.06	3.58
	3 layers	10	34.59	↑39.25	A*	0.98	32.09	35.52	2.83
h°	Control	10	70.99	-	A*	0.47	70.43	71.78	0.66
	1 layer	10	68.73	↓3.18	B**	0.90	67.21	70.01	1.31
	2 layers	10	69.07	↓2.70	AB	1.18	67.02	70.65	1.70
	3 layers	10	69.87	↓1.58	AB	4.12	66.81	81.24	5.90

SD: Standard Deviation, N: Number of Measurements, *HG*: Homogeneity Group, COV: Coefficient of Variation, *: Highest value, **: Lowest value

The results for total color differences (Δ*E**) are provided in Table 4. According to these results, an increase in the number of layers applied led to an increase in Δ*E** values (Δ*E** for 1 layer: 7.65, for 2 layers: 9.68, and for 3 layers: 12.02). All wax applications resulted in negative Δ*L** values (darker compared to the reference), while Δ*a** (redder than the reference), Δ*b** (yellower than the reference), and Δ*C** (clearer, brighter than the reference) values were found to be positive. When evaluating the results based on the color change criteria (Barański et al., 2017), it was observed that applying 1 and 2 layers of wax met the criterion for "high color change (12 > Δ*E** > 6)," while applying 3 layers of wax achieved the criterion for "significant color difference (Δ*E** > 12)" (Table 4).

Table 4. The results of the total color differences

Wax Application	Δ*L**	Δ*a**	Δ*b**	Δ*C**	Δ*H**	Δ*E**	Color change criteria (Barański et al., 2017)
1 layer	-4.80	3.04	5.12	5.86	1.07	7.65	High color change (12 > Δ*E** > 6)
2 layers	-5.81	3.53	6.90	7.69	0.93	9.68	
3 layers	-6.96	4.38	8.77	9.75	1.02	12.02	Different color (Δ*E** > 12)

Table 5 presents the results for the whiteness index (*WI**) values measured perpendicular and parallel to the fibers. Decreases in measurements were observed in both directions as the number of layers applied increased. The control experimental samples yielded the highest results (⊥: 18.22 and ‖: 17.42), while samples treated with 3 layers of wax showed the lowest results (⊥: 9.24 and ‖: 6.46) (Table 5).

Table 5. Results of whiteness index (*WI**) values determined before and after wax application

Test	Wax Application	N	Mean	Change (%)	*HG*	*SD*	Minimum	Maximum	COV
*WI** ⊥	Control	10	18.22	-	A*	0.96	17.00	19.70	5.26
	1 layer	10	12.95	↓28.92	B	0.60	12.00	13.90	4.65
	2 layers	10	11.26	↓38.20	C	0.31	10.90	11.60	2.75
	3 layers	10	9.24	↓49.29	D**	0.25	9.00	9.70	2.76
*WI** ‖	Control	10	17.42	-	A*	0.81	16.00	18.30	4.66
	1 layer	10	10.70	↓38.58	B	0.74	9.10	11.90	6.92
	2 layers	10	7.70	↓55.80	C	0.24	7.40	8.10	3.12
	3 layers	10	6.46	↓62.92	D**	0.36	6.00	6.90	5.52

SD: Standard Deviation, N: Number of Measurements, *HG*: Homogeneity Group, COV: Coefficient of Variation, *: Highest value, **: Lowest value

The results for glossiness values are presented in Table 6. Increases in glossiness values were observed at both 60 and 85 degrees in both directions. The lowest results in glossiness measurements at three different angles in both directions were found on samples from the control experimental group (⊥: 0.33, ⊥: 1.49, ⊥: 0.10, ‖: 0.38, ‖: 1.91, and ‖: 0.35). At 85 degrees in both directions, the highest results were found on samples treated with 3 layers of wax (⊥: 7.90 and ‖: 9.26). Increases in glossiness values were observed with an increase in the number of layers applied parallel to the fibers at both 60 and 85 degrees. Additionally, similar results were observed in measurements perpendicular to the fibers at 85 degrees (Table 6).

In studies reported in the literature on wax application, changes in color, glossiness, and whiteness index values due to wax have been documented [African ebony (*Diospyros crassiflora* Hiern.) (Çamlıbel and Ayata, 2024a), mahogany (*Swietenia mahagoni* (L.) Jacq.) (Ayata et al., 2024b), magnolia (*Magnolia grandiflora* L.) (Ayata et al., 2024a), Siberian pine (Pinus sibirica) (Çamlıbel and Ayata, 2024c), Macassar ebony (*Diospyros celebica* Bakh.) (Kaplan et al., 2024), lemon (*Citrus limon* (L.) Burm.) (Çamlıbel and Ayata, 2024b), olive (*Olea europaea* L.) (Peker et al., 2024a), balau red (*Shorea guiso*) (Peker et al., 2024b), plum (*Prunus domestica* L.) (Ayata et al., 2024c)].

Table 6. Results of glossiness values determined before and after wax application

Test	Wax Application	N	Mean	Change (%)	*HG*	*SD*	Mini-mum	Maxi-mum	COV
⊥20°	Control	10	0.33	-	C**	0.05	0.30	0.40	14.64
	1 layer	10	0.32	↓3.03	C	0.04	0.30	0.40	13.18
	2 layers	10	0.50	↑51.52	A*	0.00	0.50	0.50	0.00
	3 layers	10	0.37	↑12.12	B	0.05	0.30	0.40	13.06
⊥60°	Control	10	1.49	-	D**	0.09	1.40	1.60	5.88
	1 layer	10	2.58	↑73.15	C	0.08	2.50	2.70	3.06
	2 layers	10	3.97	↑166.44	A*	0.19	3.70	4.20	4.76
	3 layers	10	3.77	↑153.02	B	0.37	3.30	4.20	9.69
⊥85°	Control	10	0.10	-	D**	0.00	0.10	0.10	0.00
	1 layer	10	3.82	↑3720.00	C	0.17	3.50	3.90	4.42
	2 layers	10	6.90	↑6800.00	B	0.33	6.50	7.30	4.83
	3 layers	10	7.90	↑7800.00	A*	0.64	7.10	8.80	8.14
‖20°	Control	10	0.38	-	B**	0.09	0.30	0.50	24.18
	1 layer	10	0.43	↑13.16	AB	0.05	0.40	0.50	11.23
	2 layers	10	0.48	↑26.32	A*	0.04	0.40	0.50	8.78
	3 layers	10	0.48	↑26.32	A*	0.04	0.40	0.50	8.78
‖60°	Control	10	1.91	-	C**	0.21	1.70	2.20	11.16
	1 layer	10	3.39	↑77.49	B	0.07	3.30	3.50	2.18
	2 layers	10	4.32	↑126.18	A	0.43	3.90	5.10	9.93
	3 layers	10	4.41	↑130.89	A*	0.20	4.10	4.60	4.47
‖85°	Control	10	0.35	-	D**	0.11	0.20	0.50	30.86
	1 layer	10	3.84	↑997.14	C	0.63	3.10	4.70	16.48
	2 layers	10	7.56	↑2060.00	B	0.99	5.70	8.20	13.16
	3 layers	10	9.26	↑2545.71	A*	0.64	8.40	10.30	6.89

SD: Standard Deviation, N: Number of Measurements, *HG*: Homogeneity Group, COV: Coefficient of Variation, *: Highest value, **: Lowest value

4. CONCLUSION

As the number of coats increased, decreases were observed in the *WI** values measured in both directions. With an increase in the number of coats, there were decreases noted in the *L** parameter, alongside increases observed in the *C**, *b**, and *a** parameters. Glossiness values showed increases in both orientations at temperatures of 60 and 85 degrees. For achieving high Δ*E** values, it is recommended to apply three coats of wax, while for lower desired values, one coat of wax application is suggested. The study demonstrates that applying three coats of wax on mulberry wood produces varying color tones depending on its usage. It is suggested to explore the changes in surface properties by subjecting the wax-coated test samples to salt spray corrosion tests, artificial or natural aging, or thermal aging processes.

DECLARATIONS

There is no conflict of interest between the authors.

AUTHORS' CONTRIBUTIONS

The author contributes the study on his/her own.

REFERENCES

Alemu, T., & Girma, M. (2019). Size of beeswax foundation sheet and productivity of honeybee colonies in northeastern Ethiopia. *Animal Health and Production*, 67, 255-263.

ASTM D 2244-3, (2007). Standard practice for calculation or color tolerances and color, differences from instrumentally measured color coordinates, ASTM International, West Conshohocken, PA.

ASTM E313-15e1, (2015). Standard practice for calculating yellowness and whiteness indices from instrumentally measured color coordinates, ASTM International, West Conshohocken, PA.

Ayata, U., Cakicier, N., & Gurleyen, L. (2021a): Determination of the artificial aging performance of the apricot wood applied with UV system parquet varnish used indoors. *Furniture and Wooden Material Research Journal*, 4, 40-50. DOI: 10.33725/mamad.922311.

Ayata, U., Cakicier, N., & Gurleyen, L. (2021b): Determination of some surface properties of UV curable varnish-applied cedar wood after artificial aging application. *Furniture and Wooden Material Research Journal*, 4, 145-154. DOI: 10.33725/mamad.1005120.

Ayata, Ü., Bilginer, E. H., & Çamlıbel, O. (2024a). Applications of natural and synthetic wax blends on wood surfaces of magnolia (*Magnolia grandiflora* L.). *Wood Industry and Engineering,* 6(1): 9-17.

Ayata, Ü., Çamlıbel, O., Efe, F. T., Tonguç, F., & Kaplan, Ş. (2024b). Maun (*Swietenia mahagoni* (L.) Jacq.) odununa uygulanmış modifiyeli arı balmumlarında seçilmiş bazı yüzey özelliklerinin incelenmesi, Tarım, Orman Ve Su Bilimlerinde Popüler Yaklaşımlar, Duvar Yayınları, 67-79.

Ayata, Ü., Çavuş, V., Bal, B. C., & Efe, F. T., (2018). Dut, doğu çınarı, kızılçam ve sedir ağaç türlerinde janka sertlik değerinin belirlenmesi, *2. Uluslararası Bilimsel Çalışmalarda Yenilikçi Yaklaşımlar Sempozyumu* (pp.1490-1494), Samsun, Türkiye.

Ayata, Ü., Peker, H., Bilginer, E. H., Çamlıbel, O., & Gürleyen, L. (2024c). Balmumu uygulanmış erik (*Prunus domestica* L.) odununda bazı yüzey özellikleri üzerine farklı kat sayılarının etkileri. *Sivas Cumhuriyet Üniversitesi Mühendislik Fakültesi Dergisi*, 2(1), 2-8.

Barański, J., Klement, I., Vilkovská, T., & Konopka, A. (2017): High temperature drying process of beech wood (*Fagus sylvatica* L.) with different zones of sapwood and red false heartwood. BioResources, 12, 1861-1870. DOI: 10.15376/biores.12.1.1861-1870

Bogdanov, S. (2009). Harmonised methods of the International Honey Commission. *Bee Product Science,* 1-63.

Cavus, V., Sahin, S., Esteves, B., & Ayata U. (2019). Determination of thermal conductivity properties in some wood species obtained from Turkey. *Bioresources*, 14(3), 6709-6715. DOI: 10.15376/biores.14.3.6709-6715.

Chau, T., Ma, E., & Cao, J. (2015). Moisture adsorption and hygroexpansion of paraffin wax emulsion-treated southern pine (*Pinus* spp.). *BioResources,* 10(2), 2719-2731.

Çamlıbel, O., & Ayata, Ü. (2024a). Ebony Afrika (*Diospyros crassiflora* Hiern.) ahşabında seçilmiş bazı yüzey özellikleri ile farklı kat sayılarına sahip balmumu uygulamaları arasındaki etkilerinin araştırılması, *Latin Amerika 8. Uluslararası Bilimsel Araştırmalar Kongresi,* (pp. 730-737), Havana, Küba.

Çamlıbel, O., & Ayata, Ü. (2024b). Limon (*Citrus limon* (L.) Burm.) odunu yüzeylerine uygulanmış balmumu katmanlarında seçilmiş bazı yüzey özellikleri üzerine farklı kat sayılarının etkileri, *European Conferences 5. Uluslararası Sağlık, Mühendislik ve Uygulamalı Bilimler Kongresi*, Roma, İtalya.

Çamlıbel, O., & Ayata, Ü. (2024c). Sibirya çamı (*Pinus sibirica*) odununda seçilmiş bazı yüzey özellikleri üzerine modifiye edilmiş arı balmumunun etkileri, *Latin Amerika 8. Uluslararası Bilimsel Araştırmalar Kongresi* (pp. 748-755). Havana, Küba.

DIN 5033, (1979). Deutsche Normen, Farbmessung. Normenausschuß Farbe (FNF) im DIN Deutsches Institut für Normung eV, Beuth, Berlin März.

Gezahegne, T. (2001). Beekeeping (In Amharic), Mega Printer Enterprise: Addis Ababa, Ethiopia.

Humar, M., & Lesar, B. (2013). Efficacy of linseed-and tung-oil-treated wood against wood-decay fungi and water uptake. *International Biodeterioration & Biodegradation*, 85, 223-227. DOI: 10.1016/j.ibiod.2013.07.011.

ISO 2813, (1994). Paints and varnishes - determination of specular gloss of non-metallic paint films at 20 degrees, 60 degrees and 85 degrees, International Organization for Standardization, Geneva, Switzerland.

ISO 554, (1976). Standard atmospheres for conditioning and/or testing, International Standardization Organization, Geneva, Switzerland.

Kaplan, Ş., Çamlıbel, O., Bilginer, E. H., & Ayata, Ü. (2024). Ebony Macassar (*Diospyros celebica* Bakh.) odununda balmumu uygulaması üzerine bir çalışma. *Journal of Green Technology and Environment*, 2(1), 1-8. DOI: 10.5281/ze-nodo.11097705.

Lange, D. R. (1999). Fundamentals of Colourimetry - Application Report No. 10e. DR Lange: New York, NY, USA.

Lesar, B., Kralj, P., & Humar, M. (2010). Influence of polyethylene and oxidized polyethylene wax emulsions on leaching dynamics of boric acid from impregnated spruce wood. *Drvna industrija,* 61(4), 213-221.

Letcher, C. S. (1984). "Waxes," Encyclopedia of Chemical Technology, 3rd Ed., Vol. 24, John Wiley & Sons, New York, pp. 466481.

Marieke, M., Blitterswijk, H., Leven, L., Kerkvliet, J., & Waerd, J. (2005). Bee products (properties, processing and marketing). *Agrodok*, 42, 33-35.

Németh, R., Tsalagkas, D., & Bak, M. (2015). Effect of soil contact on the modulus of elasticity of beeswax-impregnated wood. *BioResources*, 10(1), 1574-1586.

Németh, R., Tsalagkas, D., & Bak, M. (2015). Effect of soil contact on the modulus of elasticity of beeswax-impregnated wood, *BioResources* 10(1), 1574-1586. DOI: 10.15376/biores.10.1.1574-1586.

Peker, H., Bilginer, E. H., Ayata, Ü., Çamlıbel, O., & Gürleyen, L. (2024a). Zeytin (*Olea europaea* L.) ahşabında bazı yüzey özellikleri üzerine balmumum uygulamasının etkileri. *Journal of Marine and Engineering Technology*, 4(1), 1-10. DOI: 10.58771/joinmet.1406915.

Peker, H., Bilginer, E. H., Ayata, Ü., Çamlıbel, O., & Gürleyen, L. (2024b). Ahşap ağartma kimyasalları uygulandıktan sonra balmumu ile muamele edilmiş balau red (*Shorea guiso*) odununda bazı yüzey özelliklerinin belirlenmesi. *Türk Bilim ve Mühendislik Dergisi*, 6(1), 14-21. DOI: 10.55979/tjse.1407845.

Qian, J., Li, J., Wang, Z., Qu, L., Ding, Y., Yi, S., & He, Z. (2019). Effects of wax and dimethyl silicone oil mixed impregnation on dimensional stability of two hardwoods. *Wood Research*, 64(1), 165-176.

Rozanska, A., & Beer, P. (2013). Sustainable wood parquet finishing by means of oils and waxes. *Science for Sustainability*, 19, 60-67.

Sequeira, A. (1994). Lubricant base oil and wax processing. CRC press.

Teacă, C. A., Roşu, D., Mustaţă, F., Rusu, T., Roşu, L., Roşca, I., & Varganici, C. D. (2019). Natural bio-based products for wood coating and protection against degradation: A Review. *BioResources*, 14(2), 4873-4901. DOI: 10.15376/biores.14.2.Teaca.

Tipton, J. L. (1994). Relative drought resistance among selected southwestern landscape plants. Arboriculture & Urban Forestry (AUF), 20(3), 150-155. DOI: 10.48044/jauf.1994.028.

TS ISO 13061-1, (2021). Physical and mechanical properties of wood - Test methods for small clear wood specimens - Part 1: Determination of moisture content for physical and mechanical tests, Turkish Standards Institution, Ankara, Turkey.

Warth, A. H. (1946). The chemistry and technology of waxes, 2nd Ed., Reinhold, New York.

Yata, S., Tamoto, S., & Tamura, T. (1995). Water proofing of wood by paraffin wax. *Mokuzai Hozon (Wood Protection)*, 21(3), 113-118. DOI: 10.5990/jwpa.21.113.