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An influence of contemporary oil coatings on the aesthetical properties and abrasion resistance of oak wood parquets

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Abstract: *An influence of contemporary oil coatings on the aesthetical properties and abrasion resistance of oak wood parquets.* The article analyses the influence of oil coatings on the colour, gloss, and abrasion resistance of parquets made of oak wood. Popular oil coatings of the same brand were compared: two-ingredient oil, single-ingredient oil and wax oil. A comparison of properties of several different kinds of oil manufactured by the same brand reveals that they do have influence on the changes in wood properties, when comparing to wood without finish. Single-ingredient and two-ingredient oil darken the colour, increase in red colour and in yellow colour to a similar extent, while wax oil darkens it and increase the share of red and yellow colour less. As to gloss, there are no statistically significant differences between the influence of the different oils. Two-ingredient oil practically does not change resistance to abrasion at all, while single-ingredient oil and wax oil reduce the rate of abrasion, and wax oil reduces abrasion 4 times less efficiently than single-ingredient oil.

Keywords: oak wood, resistance, properties, single-ingredient oil, two-ingredient oil, wax oil

INTRODUCTION

Oil is one of the oldest kinds of finish applied to wooden surfaces. Most surfaces finished with oil are easy to maintain and repair, resistant to water vapour, water and alcohol (Swaczyna 1995, Krajewski, Witomski 2005). Oils are produced as liquids that are ready to use and easy to apply.

Oils used on floors have the following advantages: they penetrate deeply into the wood and protect it against scratches, they allow air and moisture to pass through the coating, they create an elastic layer preventing the appearance of cracks as a result of wood swelling and shrinking, they permit to repair one area of the floor, without the necessity to sand the entire parquet.

In spite of their many benefits, oils also have some drawbacks: comparing to lacquers, their resistance to dirt and stains is low; they require regular maintenance with proper substances, it is impossible to apply lacquer later on.

Another substance that has been used for ages to finish the surface of wooden floors is wax. Wax is a substance that can be obtained from animals (beeswax), minerals (paraffin) or plants (carnauba). Paste wax is made by dissolving wax in petrol or turpentine. It is applied on the surface of wood along the fibres with the use of a sponge or a brush, after which it is left for the solvent to evaporate. Wax is flammable, fusible and impenetrable for liquids and gases. Most of the waxes of animal origin contain esters of saturated higher fatty acids and saturated or unsaturated alcohols. Considering the type of solvents, we distinguish: water, turpentine and petroleum waxes (Swaczyna 1995).

Oils and waxes are gaining popularity as means of providing finish to wooden floors, thanks to their properties protecting wooden surfaces against destructive factors, as well as their natural and ecological character and good aesthetical characteristics that give the impression that a natural, uncoated surface of wood has been preserved.

Recently, due to the above-mentioned properties of oil and wax, a mix of those two has been created and is called wax oil or hard wax oil. Wax oil creates a coating on top of the wood that is resistant to scratches and to the activity of water, and can be easily applied and refreshed. The most frequently used is yellow wax oil that provides wood with a honey-like hue, and white wax oil that slightly whitens the colour.

Oil and wax are perfect for highlighting the colour of wood, as well as its natural growth ring patterns, but oil also intensifies the visibility of stains and discolorations, which can be a problem in antique wood applications. Favourable values of the wettability angle and surface energy confirm that both substances are hydrophobic and (if applied correctly) protect the surface against dirt. The oil and wax coating increases the abrasion resistance and does not affect hardness and scratch resistance. (Rozanska et al 2012, Rozanska et al.2013).

In contemporary parquet-making, the most popular types of coat-forming oils used for oil finish on wooden parquet floors are: single-ingredient oil, two-ingredient oil, wax oil, oil hardened with infrared rays, and oil hardened with UV.

AIM OF STUDY

Considering the wide variety of oils available on the market, within the range of products of several well-known brands, both investors and contractors who install wooden floors find it difficult to choose a product appropriate for their needs. Especially, in case of large parquet surfaces, this choice may have significant financial and ecological consequences, if the chosen coating proves to be inappropriate for the particular application or in case of complaints.

The aim of our paper is to present selected properties of different kinds of oil coatings offered within the same brand. The research was conducted on oak wood parquets with the use of single-ingredient oil, two-ingredient oil and wax oil. We analysed the appropriateness of different kinds of oils for the parquet industry, taking into account the changes in colour, gloss and abrasion resistance. The properties of contemporary synthetic oils have been compared with the properties of wood without coating.

METHODOLOGY

Investigated Material The wood species used in the research was European oak (*Quercus Sp.* L). The number of samples was 10. Similarly to oak parquets, the samples were machine-polished with sand paper, grit 100 and 120. The first parameters tested on samples without finish were colour, gloss and resistance to abrasion, and then the same tests were repeated on the same samples covered with a single-ingredient oil, Arboritec Millic Comfort; two-ingredient oil, Arboritec Miracle Oil; and wax oil, Arboritec Hard Wax Oil.

Single-ingredient oil and then two-ingredient oil were applied in two layers, according to manufacturer recommendations, using a roller with short hair. The time interval between the two layers was 24h, and after drying, the wood was polished with sandpaper, grit 120. Before applying the second coating, the previous one was polished with sandpaper, grit 100.

Wax oil was applied twice. The time interval between oil applications was 2 days (48h). After drying, the samples were polished with sandpaper, grit 120.

Before the tests, samples were seasoned for 3 weeks in laboratory conditions, at the temperature of ca. 20 degrees C and humidity of 50%.

Colour examination was carried out with the portable spherical spectrophotometer X-Rite, model SP64, in the L* a* b* system, based on the PN-N 01262:1971 standard. Measurements were carried out four times, on each corner of a sample without finish, and then covered with oil coatings. To assess the total colour change, we applied the following scale: $0 < \Delta E < 1$ – unperceivable difference, $1 < \Delta E < 2$ – difference that can be noted by an experienced observer, $2 < \Delta E < 3.5$ – difference noted by an inexperienced observer, $3.5 < \Delta E < 5$ – a clear difference of colour, $5 < \Delta E$ – two different colours.

Gloss measurements were carried out with the use of a gloss meter manufactured by Erichsen, model PICOGLOSS 503, for the angle of 60 degrees, 2 measurements in parallel and in perpendicular to the fibres, based on the PN–EN ISO 2813:2014-11 standard.

Tests of abrasion resistance were performed with the use of the Taber machine, model 5135, as a mass loss, with the precision of 0.001 g, based on the PN–EN ISO 5470-1:2001 standard.

The statistical significance was assessed on the basis of the standard deviation. The statistics was based on the thesis, proven below, that algorithms used in Excel programmes are correct for the purpose of assessing general differences and conservative in case of lack of differences.

In the procedure, the average values $\mu_1, \mu_2, \ldots, \mu_k$ are compared in pairs. Two average values μ_i, μ_j in the Tukey-Kramer procedure are considered different if for the corresponding sample means it is true that: $\left|\bar{y}_i - \bar{y}_j\right| > LSD_{ij}$ (*LSD*– Least Significant Difference, in Polish: NIR). We've got the formula: $LSD_{ij} = q(\alpha, k, N-k)\sqrt{0{,}5 \cdot 1\left(1/n_i + n_j\right)} \cdot \sqrt{MSE}$, where n_i, n_j are sample dimensions, N is the number of all observations in k samples, i.e. $N = n_1 + n_2 + \ldots + n_k$, *MSE* is the Mean Squared Error in the classical one-way analysis of variance, and $q(\alpha,k,N-k)$ is the critical value of studentized range. In most cases, in the comparisons presented in this paper, the value of $q(\alpha,k,N-k)\sqrt{0{,}5 \cdot \left(1/n_i + 1/n_j\right)}$ is not larger than 2. In very few cases it is slightly higher than 2. It can be assumed that in the experiment, in general, $LSD_{ij} \leq 2\sqrt{MSE}$. Considering that the standard deviations (S_j , S_i - for any, freely chosen bars), as well as $\sqrt{MSE}$, are estimations of the same value, it can be assumed that $\sqrt{MSE} \approx \frac{S_i + S_j}{2}$. This means that $LSD_{ij} \leq (S_i + S_j)$. If intervals on the bars (whose heights correspond to the sample means) are not repeated, then we know that for these means: $\left|\bar{y}_i - \bar{y}_j\right| > S_i + S_j \geq LSD_{ij}$. Therefore, the difference is significant. On the other hand, if the intervals (bins) on the bars do overlap, it can be concluded only very carefully that there are no differences, because the Tukey-Kramer procedure can still reveal significant differences in many of such cases.

The discussion of results was strictly comparative and takes into account results of tests carried out with the same procedures, devices and identical research tools.

RESULTS

Chart no. 1 presents the colour lightness of raw samples and then samples covered with three kinds of oil; and Table no. 1 presents the differences between their lightness. Single-ingredient and two-ingredient oil darkened the oak sample to a similar extent (two-ingredient oil darkened the coating by 18%, and single-ingredient oil by 19%). Wax oil caused the smallest change in colour lightness, darkening it by only 5%.

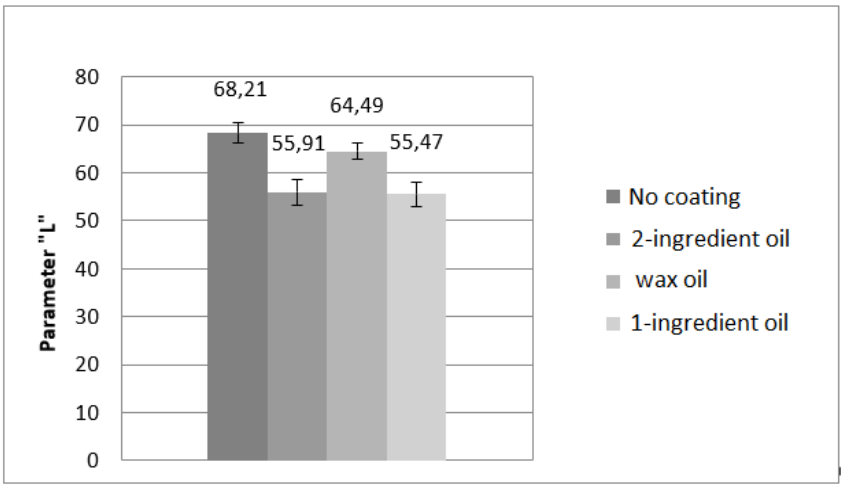

Chart 1. Change of the L* parameter for the coatings under research

Table 1. Differences in sample lightness for the coatings under research expressed in percentage, in comparison with wood without coating

L* - colour lightness parameter

Two-ingredient oil	Wax oil	Single-ingredient oil
82%	95%	81%

The standard deviation was comparable for all the sample groups and amounted to: 2.12 units for raw wood, 2.64 units for two-ingredient oil, 1.65 units for wax oil and 2.58 units for single-ingredient oil.

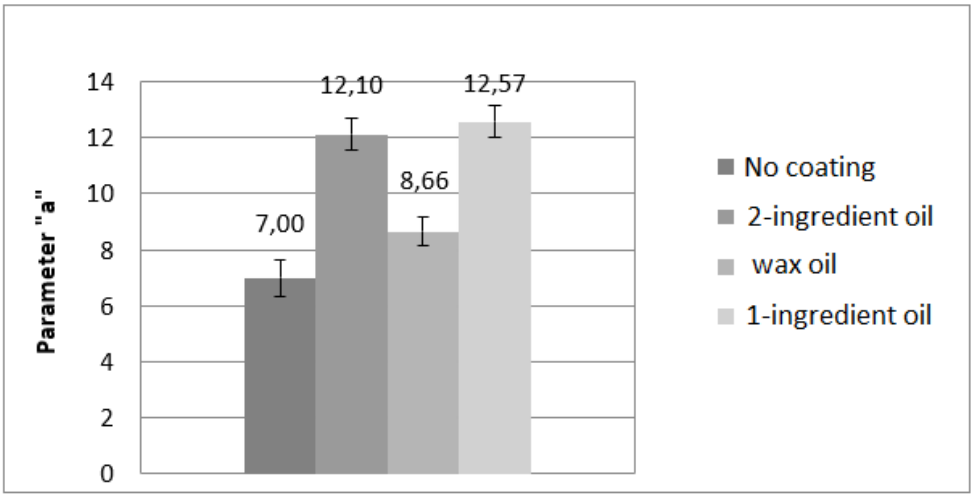

Chart 2. Change of the a* parameter for the coatings under research

On the basis of the standard deviation, we can conclude with a high degree of certainty that the application of coating to the wood surface changes its lightness in a statistically significant way (wax oil, at the limit of significance) and that the differences in lightness between wax oil and the remaining coatings are statistically significant. The differences in lightness between single-ingredient and two-ingredient oil are not statistically significant.

Chart no. 2 presents the share of red colour, and Table no. 2 presents the percentual difference of its share comparing with raw samples. Applying an oil finish to wood caused an increase in the share of red colour. The smallest increase of the share of red happened in case of samples covered with wax oil (only by 24%). The use of two-ingredient and single-ingredient oil had a significant impact on the increase of red colour share (increase by 73% for two-ingredient oil and by 80% for single-ingredient oil).

Table 2. Differences in the share of red colour for the coatings under research expressed in percentage, in comparison with wood without coating

a* - share of red colour

Two-ingredient oil	Wax oil	Single-ingredient oil
173%	124%	180%

The standard deviation was comparable for all the sample groups and amounted to: 0.64 units for wood without coating, 0.57 units for two-ingredient oil, 0.50 units for wax oil and 0.56 units for single-ingredient oil.

On the basis of the standard deviation, we can conclude with a high degree of certainty that the differences between wood without coating and wood with all kinds of finish are statistically significant. Moreover, there are also statistically significant differences between wood coated with wax oil and single-ingredient and two-ingredient oils. The differences between single-ingredient and two-ingredient oil coatings are not statistically significant.

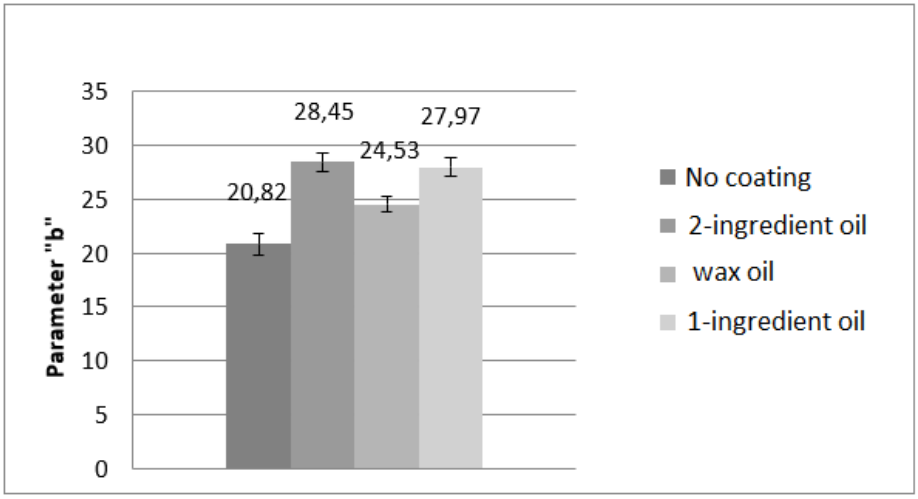

Chart 3. Change of the b* parameter for the coatings under research

Chart no. 3 presents the share of yellow colour, and Table no. 3 shows the percentual differences in the share of yellow colour in samples with finish compared to wood without coating. Applying an oil finish to wood caused an increase in the share of yellow colour. The smallest difference was observed for wax oil, which increased it by 18%. The highest difference was seen for two-ingredient oil (by 37%) and single-ingredient oil (by 34%).

Table 3. Differences in the share of yellow for the coatings under research expressed in percentage, in comparison with wood without coating

b* - share of yellow colour		
Two-ingredient oil	Wax oil	Single-ingredient oil
137%	118%	134%

The standard deviation was comparable for all the sample groups and amounted to: 0.95 units for samples without coating, 0.86 units for two-ingredient oil, 0.76 units for wax oil and 0.88 units for single-ingredient oil.

On the basis of standard deviation, we can assume that all kinds of oil coatings have a significant impact on the change in the share of yellow colour. Moreover, there are also statistically significant differences between wood coated with wax oil and single-ingredient and two-ingredient oils.

Table 4. Total colour change Δ E

ΔE		
Two-ingredient oil	Wax oil	Single-ingredient oil
7.77	2.12	8.28

The oils used in the research influenced the colour of oak wood samples (see: total change in colour Δ E - Table 4). Two-ingredient and single-ingredient oil influenced the colour of samples in a way that was noticeable at first glance, because the observed results exceeded 7 units (5 < ΔE), which means that these are two different colours. An inexperienced viewer can notice a difference in colour after applying a coating of wax oil.

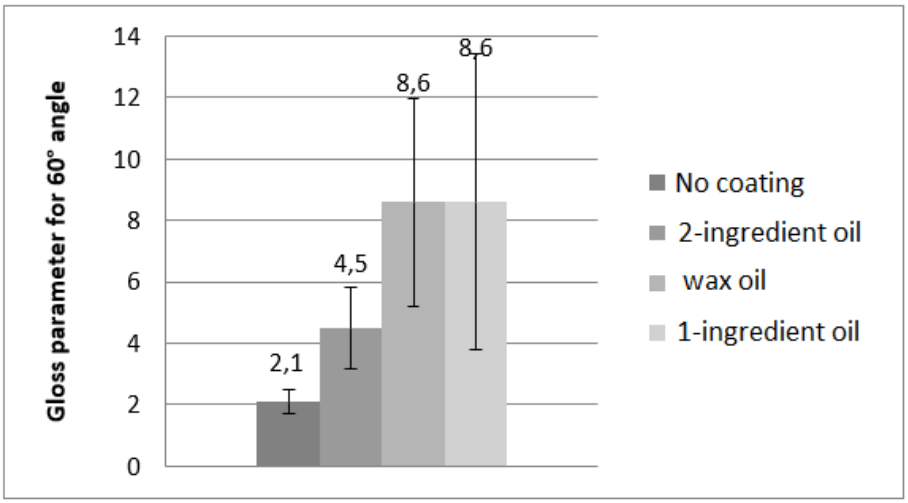

Chart 4. Average changes in gloss in parallel and in perpendicular to grain for a 60° angle.

Chart no. 4 presents the average gloss values measured in parallel and in perpendicular to the grain, and Table 5 shows the percentual effects of oils, comparing with wood without coating. Oil coatings increase wood's gloss. The smallest increase in gloss was observed for two-ingredient oil (by 113%), while wax oil and single-ingredient oil increase gloss by 310%.

The standard deviation for individual sample groups amounted to: 0.40 units for samples without coating, and 1.33 units for two-ingredient oil. In case of wax oil, the observed standard deviation was two times higher: 3.38 units, and in case of single-ingredient oil: 4.81 units.

Table 5. Percentual differences in gloss, in comparison with raw wood

Gloss at 60° angle		
Two-ingredient oil	Wax oil	Single-ingredient oil
213%	410%	410%

By analysing standard deviation, it can be assumed with high level of certainty that the statistical differences between the coatings under research and wood without finish are statistically significant, and there is no significant difference between the individual types of finish.

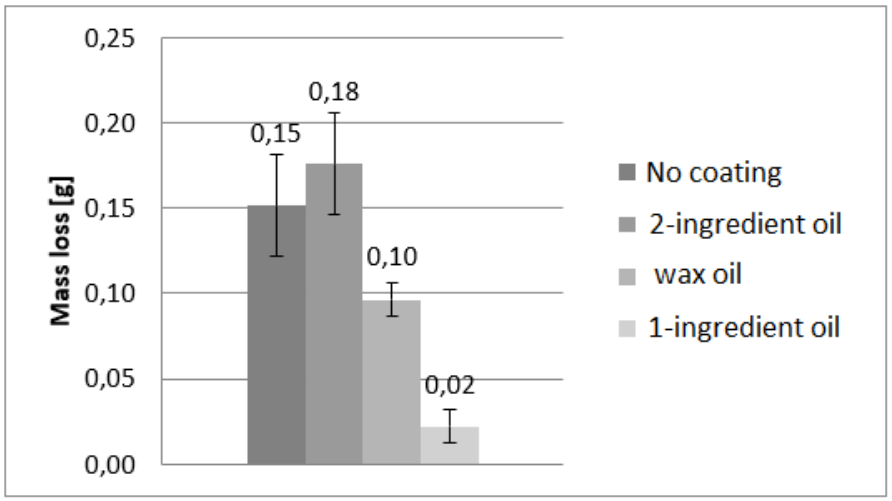

Chart 5. Mass loss in oak samples

The abrasion resistance measured as mass loss has been presented in Chart no. 5. Wax oil and single-ingredient oil caused an increase in resistance to abrasion. The highest abrasion resistance was observed in case of single-ingredient oil: reduction of abrasion by 85% comparing to wood without coating; and in case of wax oil: reduction of abrasion by 34%. The smallest resistance to abrasion was observed for two-ingredient oil, and that value was lower than the abrasion resistance of samples without finish by 23%.

Table 6. Percentual difference in mass loss, comparing with raw wood

Mass loss difference		
Two-ingredient oil	Wax oil	Single-ingredient oil
123%	66%	15%

Samples covered with wax oil and single-ingredient oil showed a smaller dispersion of test results than samples of wood without coating or coated with two-ingredient oil. Taking into account the standard deviation, it can be assumed with high level of certainty that the application of single-ingredient oil and wax oil to wood significantly changes its resistance to abrasion. The application of two-ingredient oil does not significantly change the abrasion resistance of oak wood. There are statistically significant differences between the effects of all kinds of finish.

SUMMARY

A comparison of properties of several different kinds of oil manufactured by the same brand reveals that they do have influence on the changes in wood properties, when comparing with wood without finish (Chart 6).

From the point of view of coating durability, the best properties have been observed for single-ingredient oil. Moreover, single-ingredient oil also had the largest overall influence on the change of the tested properties. Our study has confirmed that this kind of oil provides the highest resistance to abrasion (abrasion reduction by 85% comparing to wood without finish) and the highest gloss increase (by 310%), which can, but doesn't have to, be a desirable phenomenon.

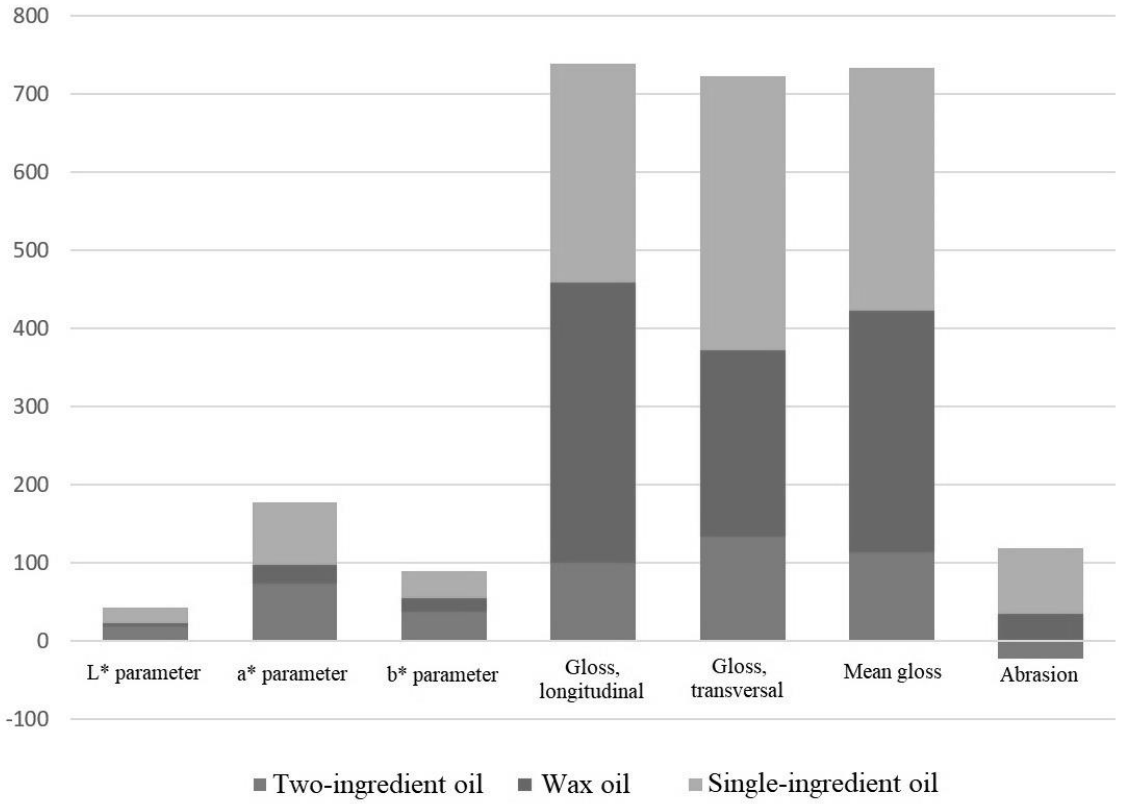

Chart 6. Percentual changes in the properties of samples with coatings, comparing to raw wood samples

A possible drawback of the single-ingredient oil can be the fact that it darkened the samples under research by 18% comparing to wood without finish, it increased the share of red colour by 80%, and yellow by 34%. Comparing to wood without finish, we noticed the biggest total change in colour precisely for this kind of oil, ΔE with the value of 8.28 units - which results in perceiving it as a completely different colour.

For people who prefer to preserve the appearance of raw wood after applying the finish coating, wax oil can be an interesting option, as it produces the smallest change in colour parameters, although the colour change can still be noticed even by an inexperienced observer. Out of all the tested finish coatings, wax oil caused the smallest colour darkening (only by 5%), increased the share of red by 24%, and yellow by 18%. The total change in colour ΔE amounted to 2.12 units comparing with raw wood.

The influence of wax oil on the tested properties was comparable with single-ingredient oil in case of gloss (it also increased by 310%), but significantly smaller in case of resistance to abrasion. Moreover, wax oil increased resistance to abrasion, but only by 34% in comparison with wood without finish.

The smallest total influence on the tested properties was observed for two-ingredient oil, although the distribution of influence among properties was unfavourable for usage.

Coating finish made of two-ingredient oil did not produce statistically significant changes in the resistance to abrasion, but it did change wood colour.

Two-ingredient oil darkened the wood slightly (to a similar extent as single-ingredient oil). After its application, the share of yellow colour increased by 37%, and red by 73%. Total colour change ΔE amounted to 7.77 units.

CONCLUSIONS

A comparison between the tested oils revealed that single-ingredient and two-ingredient oil darken the colour to a similar extent, while wax oil darkens it ca. 16% less.

The same happens with the increase in red colour (single-ingredient and two-ingredient oils increase the share of red to a similar degree, while wax oil ca. 30% less), and in yellow colour (similar change for both single-ingredient and two-ingredient oils, while wax oil produces a change smaller by ca. 13%).

As to gloss, there are no statistically significant differences between the influence of the different oils, so the gloss caused by the oils under research is comparable.

Each of the tested oils produces a different change in resistance to abrasion: two-ingredient oil practically does not change this property at all, while single-ingredient oil and wax oil reduce the rate of abrasion, and wax oil reduces abrasion 4 times less efficiently than single-ingredient oil.

DISCUSSION OF RESULTS

Abrasion reduction. The reduction of abrasion rate seems to be the most important advantage of oil coatings, considering usage properties. The reduction of abrasion by 85% after applying single-ingredient oil is a spectacular effect. Wax oil is perfect considering the aesthetics of appearance of wooden floors with patterns, and it reduces abrasion by 34%. The lack of effect of two-ingredient oil on abrasion is slightly puzzling.

Other studies on traditional finish coatings do indicate a desirable wood abrasion reduction after their application. In the case of furniture coatings, wax reduces wood abrasion by 40%, French polish only by 33%, and popular lacquer, by 31% (Górski, 2016).

It is interesting and confusing that substances that increase the resistance to abrasion of contemporary wood, at the same time worsen this property when applied to antique wood, which has been proven by the research of Kieblesz and Majka (Kieblesz, 2017; Majka, 2017). A comparison of mass loss between wood covered with coatings and wood without finish shows that the biggest percentual difference in mass loss happens in case of using the "Oil 90" coating. When this coating is applied to contemporary wood, it increases resistance to abrasion by 58%; however, when used on antique wood, resistance to abrasion drops drastically (mass loss is by 98% higher than in case of wood without finish) (Majka, 2017). Majka's research on antique wood also shows that there is no positive effect of the use of linen varnish and "Oil 90", as far as the abrasion resistance of oak is concerned (Majka, 2017).

Hardness. Literature provides data concerning a very small influence of finish coatings on the hardness of oak wood. The biggest increase in hardness, according to Górski's research, happened in case of contemporary oak wood covered with French polish (wood hardness increased by 7%). The lacquer tested by him increased hardness by 4%. In case of wax, the differences between wood with and without coatings amounted to around 1% (Górski, 2016). Similarly, the research conducted by Majka also proves that linen varnish and "Oil 90" do not change oak hardness (no statistically significant influence) (Majka, 2017).

Colourand gloss changes. In case of wooden parquets made of several different wood species, excessive darkening caused by finish leads to a loss of colour hues and the pattern becomes less visible. For this reason, a recommended substance for such parquets

would be wax oil, as it darkens the colour (in the presented research) by only 5%, increases the share of red by 24%, and yellow by 18%.

A comparison of the influence of oils used in parquet making with the coatings that have also been used for oak, we can notice that the smallest change in colour darkness is caused by wax (only 3% darker) and lacquer (5% darker). Lacquer also causes the smallest change in the share of red colour, reducing it by 7%, and yellow colour, increasing it by 9%, in comparison with wood without finish (Szczuka, 2016). Wax increases the share of red (by 17%) and yellow (by 16%) and significantly increases gloss (Szczuka, 2016).

Coating durability and the method of application. A big advantage of oils consists in the fact that they are film-forming substances, and they penetrate deeply into the wood. The oiled surface can be easily refreshed by applying another layer of oil. Wax oil is also a film-forming substance, and during long-term usage its coating on top of the parquet can become worn (Sandak et al.2015). Removing the worn coating requires scraping the floor.

The disadvantage of oils is the long process of their application to the wood surface (at least three times application at intervals of several weeks) and the need to temporarily refresh the coating. Oil wax is applied in two or three layers immediately after drying the previous layer.

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Streszczenie*: Wpływ współczesnych powłok olejowych na właściwości estetyczne i ścieralność posadzek z drewna dębowego*. Porównanie właściwości poszczególnych rodzajów oleju, produkowanych przez tą samą markę, dowodzi różnego ich wpływu na zmiany właściwości drewna wykończonego w porównaniu do drewna niewykończonego. Olej jedno i dwuskładnikowy przyciemniają barwę oraz zwiększają udział barwy czerwonej i

żółtej w podobnym stopniu, a olejowosk w stosunku do w mniejszym stopniu. W przypadku połysku nie ma ewidentnie istotnych statystycznie różnic pomiędzy wpływem poszczególnych olejów. Olej dwuskładnikowy praktycznie nie ma wpływu na zmianę ścieralności, a olej jednoskładnikowy i olejowosk zmniejszają ścieralność, lecz w stosunku do oleju jednoskładnikowego olejowosk zmniejsza ścieralność czterokrotnie mniej.

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