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IMPACT OF *LAETIPORUS SULPHUREUS* (BULL. EX FR.) MURRILL ON DESTRUCTION OF OAK WOOD

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Abstract

Samples for the research have been taken from the heart wood zone of a sound tree of *Quercus petraea agg.* from the area of East Serbia, from association *Quercetum montanum* (Cer. et Jov., 1953). In the periods of 2, 4 and 6 months, the samples have been exposed to the impact of the mycelia of the brown rot fungus on oak tree: *Laetiporus sulphureus* (Bull. ex Fr.) Murrill (Sulphur Polypore). In order to determine the effect of *L. sulphureus* on decrease of the properties of oak wood, the following has been investigated: wood mass loss and hardness (according to Brinell). It has been concluded that mass loss of *Q. petraea agg.* wood under the impact of the fungus *L. sulphureus* after for 2, 4 and 6 months have been 0.90, 1.66 and 4.29% respectively. The hardness of the wood of *Q. petraea agg.* under the impact of *L. sulphureus* after 2, 4 and 6 months decreased to 96.44, 91.74 and 41.00%. In addition to separately displayed comparative review of the loss of mechanical properties in relation to mass loss, depending upon the duration of the impact of *L. sulphureus,* based on the review, the respective percentages of hardness of wood of *Q. petraea agg.* have been determined for the recorded mass losses in the period after 2, 4 and 6 months.

Key words: Laetiporus sulphureus, hardness; wood properties

Introduction

Development of the wood processing industry is causing growing demand for high-quality wood raw materials. This calls for preservation and extension of wood durability, which is directly linked to preservation of physical, chemical, mechanical, aesthetical and other properties, according to Miric & Popovic (1993) and Karadzic (2006).

Basic structural constituents of wood (cellulose, hemicellulose and lignin) are distributed in different percentages in different species and parts of trees, as discussed by Markovic *et al* (2011). There is thus more cellulose in soft than hard species of trees, in bolewood more than in branchwood, in early successional species more than in late ones, as discussed by Knezevic (1975) and Miric & Schmidt (1992). Moreover, the presence of cellulose determines the modulus of rupture, whereas the presence of lignin determines the bulk modulus and hardness (Miric *et al*, 2012). Through its enzyme system, the epixylous fungi break down the constituents of wood cell walls, modify the percentage of their participation and thus directly induce changes of the wood properties (Markovic *et al.*, 2011). The agents of brown prismatic rot (to which the researched fungus *L. sulphureus* belongs*)* disintegrate primarily cellulose, while the disintegration of lignin occurs in a far smaller extent. This paper presents the course of alteration (decrease) of the presence of lignin in the cell wall, reflected in the decrease of wood bulk modulus of *Q. petraea* agg. under the influence of the fungus *L. sulphureus* after 2, 4 and 6 months of the incubation.

Material and method

The substrate used in the research was a 110-year-old healthy tree of Sessile oak *Q. petraea agg*. The tree had been cut in Eastern Serbia, at the altitude of 550 m in association *Quercetum montanum* (Tomic, 1992). As the fungus *L. sulphureus* attacks the first bole (technically the most valuable part of a tree), the analyses were conducted on a log 3.5 m in length (from the lower part of the trunk to the first live branch), which was according to the relevant pattern cut into specimens using the standard prescribed dimensions 2x2x4cm, in accordance with method by SRPS D.A1.040:1979.
Dikaryotic mycelia *L. suphureus* was isolated from the sporocarp and resown into plastic Petri dishes containing malt-agar growing medium of standard concentration. The Petri dishes served as glass carriers in order to prevent excessive soaking of moisture from the growing medium, onto which wood specimens of Sessile oak were placed. On the top of the stack were Petri dishes with 5% water solution of boric acid intended to induce high relative air humidity, as the fungus *L. sulphureus* is known not to attack a tree under 20% of moisture, according to Karadzic (2010).
The dishes were kept in a closed sterilized chamber in the total darkness, and the temperature was controlled by thermograph throughout the experiment. Over most of the duration of the research the temperature in the chamber was at about 20°C, with brief time intervals at about 28°C, which are roughly optimal temperatures for the development of the researched species, in accordance with method by SRPS D.A1.058.
All data obtained were processed by applying the standard statistical methods; destruction results were compared using the single factor analysis of variance and the least significant difference test for the control group and the duration of the fungus impact (2, 4 and 6 months).

Results and discussion

Effect of *l. Sulphureus* on the wood mass loss – Based on the analysis of the basic parameters presented in Table 1, it is evident that a great variability in data has occurred as a result of the non-homogenous structure of wood as a material and exposure to the influence of the fungus. The wood mass loss of *Q. petraea* agg. ranged from 0.76 to 1.02% in the sample group exposed to the influence of the fungus *L. sulphureus* for 2 months; from 1.07 to 3.49% in the sample group exposed for 4 months; and from 1.32 to 8.80% in the sample group exposed for 6 months. The values of the variation coefficient also demonstrate the existence of data variability; the variation coefficient is very high, particularly after 4 months - 41.68 and after 6 months - 57.54.

Table 1. Wood Mass Loss (%) under the Influence of Fungus *L. sulphureus*

	0 months	2 months	4 months	6 months
Number of measurements	30	30	30	30
Minimum amount	0.0	0.76	1.07	1.32
Maximum amount	0.0	1.02	3.49	8.80
Arithmetic mean	**0.0**	**0.90**	**1.66**	**4.29**
Standard deviation	0.0	0.07	0.69	2.47
Variation coefficient	0.0	7.83	41.68	57.54

Due to the evident dispersion of data, the percentages were calculated and differences thereof from the basic parameters, based on the arithmetic mean, i.e. average amounts; thus the average wood mass loss *Q. petraea agg.* after 2 months of exposure to the influence of fungus *L. sulphureus* amounts to 0.90%, after 4 months of exposure to 1.66%, and after 6 months of exposure to 4.29%.This means that the greatest mass loss occurred between 4 and 6 months of exposure, when it increased by 2.63%. The mass loss in this period is by 0.97% larger that the total loss over the first four months of exposure to the fungus (1.66%), and three times as great as the loss occurred in the first 2 months (0.90%). According to the aforesaid, the most intensive mass loss occurred after 4 months although statistically significant differences, resulting from the influence of the fungus, were observed as early as within the first 2 months of exposure (Table 2).

Table 2. Wood Mass Loss (g) under the Influence of *L. sulphureus*

	0 months	2 months	4 months	6 months
0 months	-	-0.792667	-1.457	-3.92133
2 months		-	-0.66433	-3.12867
4 months			-	-2.46433
6 months				-

- Significant difference at the level of 0.05

Based on the aforesaid, it may be concluded that the decomposition of wood under the influence of the fungus *L. sulphureus* commences in the first 2 months yet it is most intensive in the period from 4 to 6 months of exposure.

Effect of *l. Sulphureus* on the wood hardness reduction (by brinell) – It is well known that the hardness of healthy Sessile at the standard humidity of 12% amounts to minimum 42.0, 69.0 on the average and maximum 99.0 N/mm^2 (Soskic, 1994). Based on the results presented in Table 3, the hardness of the control sample group of *Q. petraea agg.*, equaled minimum 60.57. 80.10 on the average and maximum 104.5 N/mm^2. The samples that had been exposed to the impact of the fungus *L. sulphureus* for 2 months exhibited average hardness of 77.25; after 4 months of exposure the average hardness was 73.48 and after 6 months - 32.84 N/mm^2.

Table 3. Wood Hardness Reduction (N/mm^2) under the Influence of *L. sulphureus*

	0 months	2 months	4 months	6 months
Number of measurements	30	30	30	30
Minimum amount	60.57	55.12	51.87	22.30
Maximum amount	104.50	104.50	96.33	89.08
Arithmetic mean	**80.10**	**77.25**	**73.48**	**32.84**
Standard deviation	9.95	14.14	11.29	13.36
Variation coefficient	12.42	18.69	15.37	40.68

From the results presented in Table 3, it is evident that the least data dispersion occurred in the control sample group, which is demonstrated by the variation coefficient amounting to 12.42. Slightly higher variability in data was observed after 4 months of exposure to the influence of the fungus *L. sulphureus* (with variation coefficient of 15.37) and after 2 months (18.69). extremely high variability in data was recorded after 6 months of exposure to the influence of the fungus (40.68). This indicates that in the period between 4 and 6 months of exposure, the wood hardness reduction under the influence of the researched fungus *L. sulphureus*, progresses rapidly and amounts to 32.84 N/mm^2 (probably due to uneven colonization of the wood, variation coefficient increases substantially).

Percentages and difference in the wood hardness of *Q. petraea agg.* under the influence of fungus *L. sulphureus,* depending on the time of exposure to the influence of the fungus, calculated as compared to the control sample group, demonstrate that the wood hardness reduction of *Q. petraea agg.* under the influence of fungus *L. sulphureus* in the first 4 months of exposure is rather weak (8.26%) in contrast to the reduction occurring between 4 and 6 months of exposure (50.74%), with the total wood hardness loss of 59.00% after 6 months.
Significant wood hardness reduction in the period between 4 and 6 months of exposure to the influence of the fungus *L. sulphureus* is evident from the least significant difference test presented in Table 4.

Table 4. Wood Hardness Reduction (N/mm^2) under the Influence of *L. sulphureus*

	0 months	2 months	4 months	6 months
0 months	-	2.85209	6.62043	47.2596
2 months		-	3.76834	44.4075
4 months			-	40.6391
6 months				-

[shaded] - Significant difference at the level of 0.05

Based on the results of T-test presented in Table 4, it is evident that all the respective differences between the 6 month-period and other groups compared are significant, with high amounts (differences range from 40.6391 to 47.2596), whereas the difference between the control group and 4-month period group is also significant but exhibits a far lower amount (6.62043), indicating that the wood hardness reduction commences in the period between 4 and 6 months of exposure to the fungus (differences between 0-month and 2-month groups as well as between 2-month and 4-month groups are random). Significant differences between the control group and 4-month group are only a result of the longer period of comparison between the two groups of data).
According to the literature, the wood hardness has proved to be the best indicator of the changes in the inner structure of wood. This is why by means of this property, destruction due to the impact of epixylous fungi is most rapidly and most clearly observed (Jankovsky *et al*, 2002). Given the fact that wood hardness depends on the quantity of lignin, it is clear that the researched fungus (although it causes brown rot, i.e. primarily disintegrates hemicellulose and cellulose), also disintegrates lignin in the period after 4 months of impact.
Table 5 presents wood hardness reduction in comparison to wood mass loss after 2, 4 and 6 months of exposure to the fungus impact. The loss of mechanical properties of wood is presented as the difference against the control group (100%).

Table 5. Differences in Property Decrease (%) under the Influence of the Fungus

Wood Property	Time of exposure to the fungus		
	2 months	4 months	6 months
Mass loss	0.90	1.66	4.29
Hardness by Brinell	3.56	8.26	59.00

Table 5 above shows the percentage of decrease in the tested mechanical property as compared to the mass loss after each respective incubation period.

Correlation analysis of the wood properties and time of exposure to the fungus - The correlation analysis was conducted in order to establish a correlation link between the tested properties of wood *Q. petraea agg.* depending on the time of exposure to the fungus (Table 6).

Table 6. Correlation analysis of Exposure time to Fungus and Wood Properties

Tested property	Model type	Correlation coefficient (r)	Regression equation
Mass loss (G_m)	Square function (y)	0.98582	$G_m = (0.094068 + 0.327671\ xT)^2$
Hardness (H_b)	Linear model	-0.84574	$H_b = 87.75 - 7.2775\ x\ T$

The performed correlation analysis of changes in mechanical properties of wood *Q. petraea agg.,* depending on the time of exposure to the fungus *L. sulphureus,* has led to the conclusion that there is a strong correlation link between the variables. Under the influence of the fungus *L. sulphureus,* the correlation coefficient is the highest (indicating the strongest correlation link between the variables) with the mass loss (0.98582). The correlation coefficient under the influence of the fungus *L. sulphureus* is the lowest with the wood hardness (-0.84574), which is a consequence of a rapid decrease in wood hardness in the period from 4 to 6 months of exposure to the impact of the fungus. The presented regression equations open the possibility to forecast modifications in wood properties over certain time periods of exposure to the fungus, under unaltered environmental conditions. This is significant for practical purposes, i.e. for undertaking proper measures of protection, as well as from the standpoint of usability of wood.

Conclusions

Based on the research presented, the following most relevant conclusions can be inferred:
Wood mass loss of *Q. petraea,* under the influence of the fungus *L. sulphureus* after 2, 4 and 6 months of incubation amounted to 0.90%, 1.66% and 4.29%, respectively, which suggests that the greatest mass loss due to the impact of *L. sulphureus* occurs between 4 and 6 months.
Wood hardness of *Q. petraea,* under the influence of the fungus *L. sulphureus* after 2, 4 and 6 months of incubation amounted to 96.44%, 91.74% and 41.00%, respectively, which suggests that the greatest wood hardness reduction due to the impact of *L. sulphureus* occurs between 4 and 6 months.
Correlation analysis showed a strong correlation link between the changes (decrease) in wood properties of *Q. petraea.* and the time of the influence of the fungus *L. sulphureus.* This opens the possibility to forecast modifications in wood properties depending on the time of exposure to the fungus under unaltered environmental conditions.
If a future research would carry out similar experiments on our most significant tree species against the greatest and most dangerous wood destructors, over a larger number of monitoring periods, the obtained results could serve as basis for creation of relevant tables (standards). By cross-referencing the obtained data and conducting their statistical analysis, we would arrive at the closest approximation of values to be inserted into relevant tables and applied in practice.

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