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DECAYING FUNGI AFFECTING SUSTAINABLE PRODUCTION OF WOODEN BIOMASS AS RENEWABLE SOURCE OF ENERGY

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ABSTRACT: *The wood is important renewable resource of raw material and energy. Its` rational management and utilization lead to the sustainable production of wooden biomass. A numerous of factors affect normal production, quantity and quality of biomass as like wood decaying fungi, xylophages insects etc. Decaying fungi destroy the wooden mass due to their nutritional requirements. As consequence it appears significant loss of wooden mass as potential raw material or energy resource, although the wood is renewable resource of energy. In this article it has been estimated mass loss of two Oak wood species due to impact of four decaying fungi.*
KEYWORDS: *decay, fungi, mass loss, Basidiomycetes, wood, biomass*

INTRODUCTION

The basic built materials of wood - cell walls are cellulose (40 - 50%), hemicelluloses (15 - 35%) and lignin (20 - 35%), which create together some 97 - 99% of wood substance [1].

Wood decaying fungi, depending to their enzymatic activity, can utilize for nutrition each of this constituents, but in amount which in quantitative and qualitative sense define them as causers of brown -, soft - or white rot [2]. Among this group of fungi extremely important are those species with the both parasitic and saprophytic characteristics. Their destructive activity can start in stems and continue (or start) in felled timber. The effects of their activity are previously visible through the changes on elements of anatomical structure of wood. In that process, as a consequence of fungal development it appears the changes of chemical -, physical -, mechanical - and technological wood properties, what leads to the final effect - death of stem and decomposition of wood mass. The differences in chemical structure of the most important anatomical elements of certain wood species, as well as enzymatic systems of wood decaying fungi, are responsible for appearance of different types of decay and different amount of damages.

Among the broad - leaved trees of Balkan peninsula, the Oaks are the most important species - especially Sessile Oak (Quercus petraea agg.) and Pedunculate Oak (Quercus robur L.) not only due to its` role as edificatory in forest stands, but also due to its` mechanical -, physical - and esthetical properties [3, 4, 5].

These two species are especially endangered in almost all Balkan countries. A number of scientists are still involved in scientific research relating to the problem of dieback of Oak stands, injuries and deterioration of Oak wood, searching causers of that phenomenon.

The endangering of Oak is emphasized just immediately after felling of stems and sapwood - zone is especially sensitive [6]. The heartwood - zone, which lost a basic physiological functions is significantly more resistant owing to the presence of inhibitors (like as tannins), as well as the deficiency of moisture, oxygen and easy consumable nutrients. Nevertheless, some species of fungi also attack and destroy exclusively this zone regardless of weather they are resistant to those polyphenols, or they are defined as tanninophyllic species as like Xylobolus frustulatus, Laetiporus sulphureus etc.

Impact of wood decaying fungi on sustainable production of wooden biomass is a part of actual investigating project in Serbia which is in progress at moment. These investigations are financially supported by Ministry of Science and Technology of Republic of Serbia in the frame of project: TR 37008. This preliminary results show how high loss of wooden biomass could appear due to impact of wood decaying fungi in certain conditions. The main two reasons why the Oak - wood has been tested as substrate are the fact that Oak wood use to be very expensive among European wood species, as well as the fact that, due to presence of certain inhabiting substances as like tannins, Oak wood has its` high natural durability against wood deteriorating fungi.

MATERIAL AND METHOD

Deteriorating impact on the mass of Sessile- and Pedunculate Oak has been investigated by mass - loss test, with four common decaying Basidiomycetes fungi as follows: Stereum hirsutum (Wild. ex Fr.), S. F. Gray. (Figure 1), Chondrostereum purpureum (Pers. ex Fr.) Pouz. (Figure 2), Stereum rugosum (Pers. ex Fr.) Fr. (Figure 3) and Xylobolus frustulatus (Pers. ex Fr.) Karst. (Figure 4). Mycelia of tested fungi have been isolated from fresh fruit bodies growing on oak wood and collected from forest stand in locality of Majdanpek, so that tests have been carried out with dicariotic mycelia. Tests have been performed with two geographically different strains of fungus Stereum hirsutum, due to its` importance and common appearance on Oaks. Second strain of this fungus originated from fungi culture collection of Institute for Wood biology and Wood protection in Hamburg – Germany. Cultivation of fungi have been performed in sterile plastic Petri – dishes (D = 90 mm) in standard clima conditions of temperature (21 ± 1°C) and humidity (70 ± 5 %). All tested fungi are very common on Oak trees and logs in forests as well as storages since they appear as saprophytes as well as weakened parasitic micro-organisms. Fungus Sternum hirsutum causes white rot of death wood of broad leaf trees, with- or without bark, but also attacks physiologically weakened trees and branches. It attacks sapwood zone of Oak extremely common. It is very common and wide spread in Europe, North America and Asia. Fungus Chondrostereum purpureum use to be causer of Silver leaf disease and white rot of sapwood on more than 150 wood species, especially on stone - fruits. It appears as saprophyte on death broad leaf trees (Oak, Beech and Birch), rarely on conifers. This fungus is wide spread in Europe, North America and Asia. Fungus Stereum rugosum appears on death, upstanding or felled timber (with or without bark) of broad leaf trees (Beech, Oak, Birch, and Hazel – wood) as saprophyte, but also as parasitic. It is dangerous causer of Oak cancer and white rot of sapwood. This dangerous fungus is wide spread in Europe, Asia and North America. Fungus Xylobolus frustulatus appears exclusively in heartwood of Oak felled or upstanding stems as saprophyte. In upstanding stems spread several meters in vertical direction above earth, but also attacks inbuilt wood. It causes white pocket rot of heartwood zone of Oak (so called Partridge wood). Fungus Xylobolus frustulatus is wide spread in Europe, North America and Asia. As test microorganism, one of the most destructible white rot fungus - Trametes versicolor has been also used in test for comparison. This fungus attacks a numerous of broad leaf trees causing very fast deterioration of wood. This is the reason why it is usually used as test fungus in testing of decaying capability of the other wood - decaying fungi.

Figure 1: Stereum hirsutum – fruit body

Figure 2: Ch. purpureum – fruit body

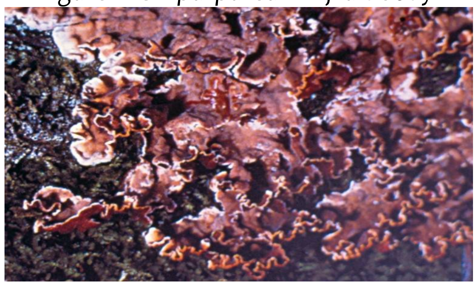

Figure 3: Stereum rugosum – fruit body

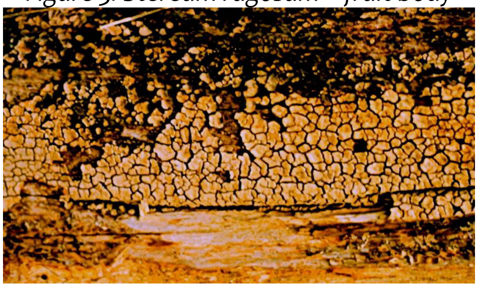

Figure 4: Xulobolus frustulatus – fruit body

Pedunculate Oak (Quercus robur L.) wood samples originated from locality in Croatia (Slatinske nizijske šume) near city of Podravska Slatina (section 31 – department D), assotiation Querco – Fraxinetum, altitude 0 m o/s, flat earth surface: no exposition (datas from forest management plan: GJ Slatinske nizijske šume – šumski predjel „Trešnjevo polje“). Wood samples have been colected out from sound health tree (h = 32 m, $D_{1,30}$ = 49 cm) from the trunk part on breast hight. Wood samples from Croatia have been colected by courtesy of dipl. eng. Vojislav Pavlović, director of Forest section Podravska Slatina of that time - in 1988. (period of ex SFRJ) and stored as part of wood sample collection of Forestry Faculty of University in Belgrade. The samples of Sessile Oak (Quercus petraea agg.) have been colected from two sites in Serbia. Locality Slačina is situated near city of Majdanpek , *department 60, assotiation Querco – Carpinetum, south exposition, altitude of 540 m o/s. Wood samples have been also colected out from sound health tree (h = 19 m, $D_{1,30}$ = 44 cm) from the trunk part on breast hight. The seccond locality in Serbia is Krčanik on mountain Goč, department 89, assotiation Querco – pinetum typicum, altitude of 980 m o/s, exposition north / north – east. Wood samples have been colected out from sound health tree (h = 18 m, $D_{1,30}$ = 40 cm) from the trunk part on breast hight. The samples dimensions 15 x 15 x 5 mm have been extracted separately from the sapwood as well as from the hartwood zone of the logs. After marking, all samples have been kiln drying till absolutely dry state at 103 ±1°C and measured with accurasy of 0,001 g, as like at the end of the test. The mass loss has been calculated using formula:*

$$G_m = (m_1 - m_2) : m_1 \times 100\ (\%),$$

where is: G_m = Mass loss (%); m_1 = Mass of absolutely dried wood before fungal attack (g); m_2 = Mass of absolutely dried wood after fungal attack (g).

Samples of Oak sapwood and heartwood, in aseptic conditions, have been placed in Petri dishes (D= 90 mm) and exposed to impact of dicarion - mycelia of tested fungi in laboratorial climate chamber for 8 weeks (Figure 5). Two geographically different strains of fungus Stereum hirsutum have been tested due to its' very frequent appearance and importance of this species (Figure 6). After incubation at 21 ± 1°C and 75 ± 5% of relative humidity, wood samples were cleaned of surfaced mycelia, dried till absolutely dry mass and measured with accuracy of 0,001g. Mass - loss have been estimated based on difference between masses before and after fungal attack. For each fungus, wood species, and wood zone eight replicates have been tested, and whole test has been repeted three times in the same conditions. Obtained results represent everige values of all measures for certan series.

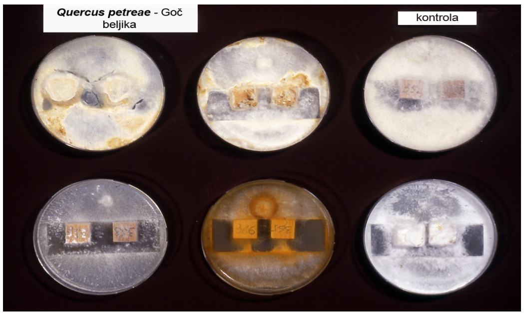

Figure 5: Samples of Q. petraea exposed to tested fungi

Figure 6: Fruit bodies of S. hirsutum on Oak log in forest

RESULTS AND DISCUSSION

Gained results are shown in table 1. The heartwood zone showed higher natural resistance against tested fungi in all cases in comparison with sapwood zone.

Table 1- Average mass loss (%) of Pedunculate- and Sessile Oak wood due to impact of 5 tested fungi and control species T. versicolor after 8 weeks

Wood species	Wood zone	Stereum hirsutum German strain	Stereum hirsutum Domestic strain	Chondrostereum purpureum	Stereum rugosum	Xylobolus frustulatus	Trametes versicolor
Q. robur P. Slatina	sapwood	1.72	1.16	0.97	0.49	0.83	11.2
	heartwood	1.72	0.59	0.82	0.51	0.55	1.48
Q. petraea lok. Slačina	sapwood	19.28	14.82	1.88	2.79	0.49	20.56
	heartwood	1.3	1.82	0.67	3.48	1.07	5.09
Q. petraea lok. Krčanik	sapwood	17.64	14.64	3.89	2.14	1.66	36.3
	heartwood	1.02	1.18	0.70	0.44	0.91	7.53

Mass loss of wood from the sapwood zone used to be higher in the case of Sessile- than in the case of Pedunculate Oak wood. The highest mass loss occurred in the case of sapwood of Sessile Oak from locality of Slačina under the impact of S. hirsutum – German strain (19,28%), while the sapwood of Sessile Oak from locality of Krčanik (Goč) showed 17,64 %. Domestic strain of S. hirsutum caused mass loss of sapwood of Sessile Oak from the both localities very similar: 14,82 and 14,64%.

The fungus Ch. purpureum caused mass loss of Sessile Oak sapwood of 1,88 % originated from locality Slačina and 3,89% from mountain Goč, while the heartwood showed approximately similar mass loss in the both cases: 0,67 and 0,70%. S. rugosum caused mass loss of Sessile Oak sapwood originated from locality Slačina of 2,79%, and from Krčanik of 2,14%.

In the case of heartwood, wood from Goč showed higher natural resistance (just 0,44% of mass loss) in comparison with wood from Slačina (mass loss was 3,84%). Excluding the control fungus T. versicolor, it is obvious that heartwood of all tested Oak species showed high degree of natural *resistance against stereoid fungi, but it is also visible capability of tested fungi to decompose heartwood zone in certain degree as well. An emphasized low resistance showed Sessile Oak sapwood against control fungus T. versicolor with mass loss of 20,55 and 36,3% (Tab. 1).*

According to Liese J. [7] fungus Polyporus sulphureus in laboratorial conditions for 4 months causes mass loss of Oak wood of about 16%, and Pine -, Beech - and other wood species up till 14%. The same author obtained that fungus Fomitopsis pinicola in laboratorial conditions is capable to decrease wood mass up to 40% while in the case of fungus Lenzites abietina it goes up to 36% of Pine sapwood. For comparison Poria Vaillantii Fr. in 4 months can causes mass loss of Pine sapwood and Beech wood of about 37%, and Pine heartwood up to 30%.

Fungus Fomes fomentarius (L. ex Fr.) F. in 4 months can decrease wood mass for 24% [8]. For comparison, one of the most destructible brown rot fungus Serpula lacrymans (Schum. Ex Fr.) S.F. Gray, in laboratorial conditions can decrease wood mass up to 60%, while in 3 months it decreases up to 40% [9]. Fungus Lenzites trabea (Pers.) Fr. after 4 months in laboratorial conditions can cause mass loss of wood up to 40% [10].

According to Krstić [11], fungus Xylaria polymorpha (Pers. ex Mér) Grey. which use to be one of pioneer species on felled trees in forests as like Stereum hirsutum, in period of 4 months decrease wood mass for 14%, while Gleophyllum sepiarium (Wulf.: Fr) Karst. can cause mass loss of Pine sapwood of 20%.

Petrović [12] obtained that Lentinus lepideus Fr. - for period of 4 months can decompose about 16 - 20% wood mass, while in the case of Paxillus panuoides Fr. it can reach some 16%. Small wood particles are decayed much faster so that after 6 and 12 months mass loss can decrease for 29 - 56%. One of most destructible fungus Lenzites saepiaria (Wulf) Fr. - in laboratorial conditions in 4 months can decrease wood mass for some 40%.

Above mentioned results indicate that certain measures should be used in protection of Sessile Oak wood if one has the maximum quantitative as well as qualitative consumption as a main task in wood working, regarding that sapwood zone of this Oak species is very sensitive against tested wood decaying Basidiomycetes fungi, which are very wide spread in Oak forest stands.

Actual problem of sustainable management and utilization of wooden biomass opens several serious questions relating to its` quantity and quality. Decaying fungi have certain impact on both aspects so that consequence of their metabolism and destructive activity use to affect the aim of wooden bio-mass utilization. But there is one more serious question which is not enough lightened among consumers who utilize wooden biomass. This is relating to the whole role that wood waste and biomass that stay in forest after felling play in such complex biogeocenose like as the forest use to be.

It is necessary to be emphasized that this question is not so simple and that it is of extraordinary importance, so that it has to be clearly understood. Among many consumers there is an approach that in collecting of wood waste it should be the main task to collect all waste and biomass from forests which left after felling of trees, and convert to briquettes, pellets or any other product that could be utilize for different purposes as like for burning, heat, etc. It is important that one understand that forest soil surface can not and must not be as a soil surface of parks and green areas in urban environment. All leafs, branches, and particles of felled timbers after cutting of trees are of enormous importance for forest biocenose itself as a source of further nutritive substances for upstanding stems. As one knows, the period of degradation of clay - minerals and rocks that exist under the soil layer use to be very long so that main source of nutrients lays in forest soil itself. This layer is creating threw the years by processes of humification and mineralization of organic maters that rest on earth surface after felling of trees. If one removes these wood waste materials, the microbiology of forest soil should be badly affected and the consequence should be debalanced in nutritive content in very near future. It is already well known that after industrial revolution consumers use to extract wooden biomass out of forests, and minor quantity of organic material as like branches and leafs stayed on soil surfaces. In that way threw the time, forests become hungry and much more sensitive against forest pests and diseases. In the case that one force utilization of almost all wood waste and rest of biomass from surface of forest soil, it should be a dangerous and very risk activity that could cause enormous damages for forests ecosystem itself. In that sense it should be necessary that all participants involved in utilization of wooden biomass originated from forests have in their mind that wood waste in natural environment is just situated on the right place – on the surface of forest soils, and use to be very useful and necessary for biogeocenose like forests are.

CONCLUSIONS

The heartwood zone of Oaks showed higher natural resistance against tested fungi in all cases in comparison with sapwood zone. Mass loss of wood from the sapwood zone used to be higher in the case of Sessile- than in the case of Pedunculate Oak wood. Excluding the control fungus T. versicolor, it is obvious that heartwood of all tested Oak species showed high degree of natural resistance against tested Basidiomycetes - fungi, but it is also visible capability of tested fungi to decompose heartwood zone in certain degree as well.

Regarding to obtain results of our investigation it is obvious that tested fungi caused much more damages in the case of Sessile Oak wood than in Pedunculate one. Sapwood zone of the both wood species was much more damaged than heartwood zone

Excluding fungus Xylobolus frustulatus, in literature it hasn't been published so far that other mentioned stereoid fungi could decompose in any amount heartwood zone of Oak wood, what is actually now discovered for the very first time.

Wood decaying fungi seriously decrease amount of wooden biomass in forests by their metabolic activity. All wooden material resting on the surface of forest soil use to be colonized and infected by decaying fungi due to very high level of inocula in forest air. As wood decaying fungi consume basic constitutive substances i.e. lignin, cellulose and hemicelluloses as sources of carbon, nitrogen, phosphorus etc. for their metabolic processes, as consequence it appears significant mass loss of this type of biomass. After activity of humicole micro-organisms, and process of mineralisation, the forest itself provide nutrients for growing plants. In that process, microbiology of forest soil use to be of extraordinary importance.

Sustainable production of wooden biomass in such natural circumstances is in accordance with sustainable feeding of living plants, but nevertheless in the same time in opposition with sustainable providing of biomass for utilisation in production of briquets, pellets etc. in the aim of total consumption of wooden biomass and wood waste. This aspects should be taken in serious consideration in the aim of protecting forest ecosystems and environmental in the widest sense.

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REFERENCES

[1.] Grosser, D.: Pflanzliche und tierische Bau- und Werkholz- Schädlinge, DRW- Verlag, Leinfelden – Echterdingen, 1985.

[2.] Schmidt, O., Kerner - Gang, N.: Natural Materials (in: Biotechnology, Vol 8: H. J. Rehm and G. Reed - Edit.), Weinheim, 1986

[3.] Jovanović, B.: Dendrologija, Naučna knjiga, Beograd, 1991

[4.] Wagenführ, R., Scheiber, C. H. R.: Holzatlas, Veb. Fachbuchverlag, Leipzig, 1974

[5.] Ugrenović, A.: Tehnologija drveta, Nakladni zavod Hrvatske, Zagreb, 1950, 9

[6.] Mirić, M.: Bioekološka istraživanja najvažnijih gljiva iz roda Stereum izazivača truleži hrastovog drveta, Doktorska disertacija, Šum. Fak. Uni. Bgd. 1993

[7.] Liese J.: Verhalten Holzserstörenden Pilze gegenüber verschiedenen Holzarten und Giftstoffen. Eeberswald, 1929, 193, 196, 210. 213

[8.] Marinković P, Šmit S.: Zaštita šuma i drveta od štetočina i bolesti. Elaborat IZDI SRS, Bgd. 1971, 195

[9.] Segmüller J., Walchli O.: Monographic Information on S. (M.) lacrymans (Schum. Ex Fr.) S.F. Gray, acording to the „Model Questinaire for Reparation of Monographic cards for wood destroying Fungi". IRG/WP-133-1975, 216

[10.] Walchli O.: Resistance of variosus wood spegies against decay C. cerebella (Pers.) Duby and L. trabea (Pers.) Bres. IRG/WP-142-76, 211

[11.] Krstić, M.: Zaštita šuma- II deo Prouzrokovači truleži i obojenosti drvetra. Naučna knjiga- Beograd, 1962,113, 136

[12.] Petrović, M.: Zaštita drveta, Šumarski fakultet, Institut za preradu drveta, Beograd, 1987, 210, 213, 214