Radovan Despot, Jelena Trajković, Bogoslav Šefc, Marin Hasan[1]

Influence of coating and colour on bacterial colonisation of fir-wood L-joints

Utjecaj vrste premaza i boje na bakterijsku kolonizaciju jelovih L-spojeva

Original scientific paper • Izvorni znanstveni rad
Prispjelo - received: 20. 11. 2002. • Prihvaćeno - accepted: 04. 02. 2004.
*UDK 630*841, 630*844.3*

ABSTRACT • *Silver-Fir (Abies alba,* Mill*.) sapwood L-joints coated with high build alkyd paint (HAP) and medium build alkyd stain (MAS) in white, brown and black colour were exposed in Zagreb and examined after 1, 2, 3, 4, 6, 12 and 36 months of exposure. The highest bacterial colonisation was recorded in HAP L-joints. Significantly lower bacterial colonisation always occurred in MAS L-joints. This is particularly evident during the first three months of exposure. Water vapour permeability of stains and the fact that black stain surfaces absorbed much more heat from the sun provided accelerated seasoning, lower moisture contents and lower bacterial colonisation. The possible influence of coating colour only occurred during the first three months of exposure, and later on it was more or less insignificant. In general, L-joints coated with dark colour were less infected and colonised by bacteria. The intensity of bacterial activity (BA) varied significantly within the same group of L-joints due to well-known non-homogenous structure of Silver-Fir wood.*

Key words: *Fir-wood, L-joints, high build alkyd paint, medium build alkyd stain, bacterial activity*

SA□ETAK • *Važnost bakterija u redoslijedu razgradnje mikroorganizama drvene građevne stolarije jest u tome što one prve započinju enzimski razarati drvo te prethode ksilofagnim gljivama. Bakterije povećavaju poroznost i vlažnost inficiranog drva, koje time postaje podložnije zarazi i razgradnji gljivama. Prikazani su rezultati trogodišnjeg istraživanja provedenoga prema EN 330: 1993 na L-spojevima od bjeljike domaće jele (Abies alba, Mill.), naše najvažnije drvne sirovine za proizvodnju građevne stolarije. L-spojevi izlagani u Zagrebu podijeljeni su u dvije osnovne skupine. Prva je trostruko premazana debeloslojnim alkidnim pigmentnim lakom (lak), a druga je trostruko premazana srednjoslojnom alkidnom lazurom (lazura) (tabl. 1). Svaka osnovna skupina dalje je podijeljena u tri podskupine prema boji premaza: na bijelu, smeđu i crnu.Po tri L-spoja svake podskupine uzimana su nakon 1, 2, 3, 4, 6, 12 i 36 mjeseci izlaganja. Iz svakoga od njih uzeti su uzorci drva (prema EN 330), a njihov razmaz (bris) stavljen je na hranjivu podlogu. Nakon četverodnevne inkubacije vizualno je procijenjena i u postocima zabilježena jačina bakterijske aktivnosti (BA) (prema Carey, 1979). Jakost BA prikazana je s obzirom na vrstu premaza, poziciju u L-spoju, duljinu izlaganja i boju premaza. Rezultati*

[1]Authors are assistant professor, asisstant, assistant and young scientist respectively, at Faculty of Forestry, Zagreb University, Croatia.

[1]Autori su redom docent, asistent, asistent i znanstveni novak na Šumarskom fakultetu, Sveučilište u Zagrebu, Hrvatska.

su pokazali da razvoj bakterija i njihovo djelovanje u drvu jelovih L-spojeva ponajprije ovise o vrsti premaza, o njegovoj boji te o interaktivnom djelovanju gljiva i bakterija. BA je uvijek bila najjača blizu samog spoja, odnosno na pozicijama 1, 2 i 3, neovisno o vrsti premaza i duljini izlaganja (sl. 1a i 2a). U lakiranim L-spojevima tijekom izlaganja zamjećen je blagi pad BA, a u L-spojevima premazanim lazurom blagi porast BA. Općenito, znatno niži BA uvijek je bio u L-spojevima premazanim lazurom, i to na svim pozicijama, a posebice u prva tri mjeseca izlaganja. Istodobno je na poziciji 4 BA manji nego blizu spoja i varira ovisno o količini vode u drvu u trenutku analiziranja uzoraka (sl. 1b i 2b). Bez obzira na vrstu i ton premaza, tijekom prvih šest mjeseci izlaganja na pozicijama 5 i 6 BA je znatno slabiji (sl. 1c i 1d, 2c i 2d). Međutim, u svim L-spojevima nakon 12, a pogotovo nakon 36 mjeseci izlaganja, zamjetan je blagi rast BA na poziciji 4, odnosno povećan rast na poziciji 5, a poglavito na poziciji 6 (sl. 1 i 2). To su grupe L-spojeva premazanih crnim lakom i bijelom lazurom, u kojima je istodobno ustanovljeno djelovanje gljiva truležnica. Dva su razloga takve pojave. Prvi je činjenica da su L-spojevi nakon 12, a osobito nakon 36 mjeseci bili cijelom duljinom razoreni simultanim djelovanjem gljiva i bakterija, a drugi je razlog djelomična raspucanost bitumenske zaštite čela. Sitne pukotine i djelomično ljuštenje bitumenske zaštite čela bilo je vidljivo na četiri od ukupno 18 L-spojeva. S obzirom na građu i strukturu jelovine i usporedbom ovih rezultata s dosadašnjim rezultatima ispitivanja BA u drvu bijelog bora, jelovina je kao slabije permeabilna vrsta drva i nakon tri godine izlaganja pokazala katkada snažnu, a često neujednačenu otpornost na prodiranje vode, a time i bakterija. Zbog specifično nehomogene građe jelovine nekoliko je puta zamijećen nerazmjer između dužine izlaganja i jakosti BA. Naime, unutar iste ekspozicije bilo je skupina bez BA i onih s maksimalnim BA. To je, bez obzira na vrstu i ton premaza, najočitije bilo u L-spojeva izlaganih 3, 6 i 12 mjeseci. Zbog poznate vodoodbojnosti i paropropusnosti srednjoslojne su se alkidne lazure za ovo podneblje pokazale prikladnijima od debeloslojnih alkidnih pigmentnih lakova.

Ključne riječi: *jelovina, debeloslojni alkidni pigment lak, srednjoslojna alkidna lazura, L-spojevi, bakterijska aktivnost*

1 INTRODUCTION
1 UVOD

During out-door service, wooden products particularly external joinery, are simultaneously exposed to abiotic and biotic factors. Silver-Fir wood (*Abies alba*, Mill.) is a traditional primary raw material in Croatian joinery industry. However, it is well known that Silver-Fir wood is a less durable and a less permeable wood species. In order to extend service life of Fir-wood joinery it has to be well protected against microorganisms particularly against fungi. On the other hand, due to low permeability, the penetration of liquids including water and preservatives is complicated and depends on the surface of wood. The duration of microbiological infection and rotting is very long and depends on many factors. It is very difficult to follow decaying process on the infected external windows and doors. This problem was solved by use of a method with simulated window joinery components, named L-joint method (EN 330: 1993). In this method destructive examination prior to obvious failure of the samples can give early indications of the mechanism of infection and the relative efficacy of preservative treatments (Carey, 1979).

Colonisation occurs in the following sequence: bacteria, followed by moulds and blue stain fungi, soft rot fungi and Basidiomycetes. In the above succession, the intensity of bacterial attack and colonisation is very important. If the bacterial degradation is stronger, and the porosity and permeability are higher, then the following wood degradation caused by fungi is stronger and faster (Despot, 1996).

Bacteria invading the L-joints appear to have entered through the joint, since they were first isolated close to the joint, and then spread along the length of members (Carey, 1983; Miller et al, 1987). Till now the experimental trials were carried out mainly with L-joints made of Scots Pine sapwood (*Pinus sylvestris*, L.), and hence the author's intention in this article was to establish the presence of bacteria and its possible influence on later fungal colonisation on the Silver-Fir sapwood L-joints.

2 MATERIALS
2 MATERIJALI

L-joints were made of homegrown Silver-Fir sapwood (*Abies alba*, Mill.) and prepared in accordance with EN 330: 1993.

There were two main groups of L-joints. The first group was coated with high

build alkyd paint system (HAP) and the other one with medium build alkyd stain (MAS). Both types of coating were in three different colours: white (Wh), brown (Br) and black (Bl), and made in Croatia ("Chromos" Zagreb). Each coating system consisted of three layers as presented in Table 1.

There were three L-joints coated with the same type of coating and colour for each period of exposure: 1, 2, 3, 4, 6, 12 and 36 months.

The end grain, remote from the joint, of both members of each L-joint was sealed by use of an epoxy resin. The vertical member of each L-joint was labelled with a numbered aluminium tag.

All L-joints were exposed in Zagreb on south facing plywood racks, 900 mm above ground, sloping at 10 degrees to provide a water trap in the joint area.

Oxoid nutrient agar produced in Great Britain (Code CM3) was used for culture plates.

3 SAMPLING
3 IZRADA UZORAKA

Upon expiry of the exposure period, each of three replicates was observed for visible signs of deterioration and examined in accordance with EN 330.

According to Carey (1979, 2002) strips from all six positions were streaked across and then planted onto a plate of solid nutrient medium to assess the relative numbers of bacteria present. All the plates were incubated at 22 °C and observed after four days. Bacterial activity (BA) was evaluated through the intensity of its appearance on the surface of nutrient medium and for each position under each L-joint. The surface under the streaked area was: completely full of bacteria (evaluation 100 %); partly or weakly colonised (evaluation 50 %) or no bacteria occurred (evaluation 0 %).

4 RESULTS
4 REZULTATI

The patterns in the sequence of colonization were investigated and deterioration by bacteria is summarized in Figures 1, 2 and 3. The examination of all L-joints showed that bacteria and other organisms invaded L-joints and appeared to enter through the joint. As explained above, bacteria were isolated, first close to the joint, and then spread along the length of the members.

In the first four months of exposure, regardless of the type of coating, bacteria mainly colonised the first three positions, frequently colonised position 4 and very rarely positions 5 and 6. The exception was found in a three months exposed black HAP L-joint (Figure 1.b) and a six months exposed white MAS L-joint (Figure 2). In those two L-joints strong BA was followed by high moisture contents and strong fungal activity, which means that those L-joints were completely decayed.

	Type of coating - *Vrsta premaza*			
Layers *Slojevi*	**HAP -** *Lak*	**Quantity** *Količina*	**MAS -** *Lazura*	**Quantity** *Količina*
First *prvi*	alkyd low lead wood primer – white *alkidni temelj - bijeli*	13 g/L-joint cca 220 g/m^2 13 g/L-spoju oko 220 g/m^2	alkyd stain - white, brown (teak) or black (ebony) *lazura - bijela, smeđa (tikovina) ili crna (ebanovina)*	9 g/L-joint cca 150 g/m^2 9 g/L-spoju oko 150 g/m^2
Second *drugi*	alkyd undercoating – white, brown-red or black *pigmentni lak - bijeli, smeđocrveni ili crni*		adequate to first layer *odgovarajuće prvom sloju*	
Third *treći*	adequate to second layer *odgovarajuće drugom sloju*		adequate to first two layers *odgovarajuće prvim dvama slojevima*	

Table 1
Coating systems
Tablica 1.
Sustavi premaza

4.1 High build alkyd paint (HAP)
4.1 Debeloslojni alkidni pigmentni lak

As shown in Figure 1 during all exposure periods it was obvious that the highest BA occurred at the first three positions of L-joint. During the first three months of exposure at the first three positions BA was between 60 and 100 %. The highest BA was recorded in one-month exposed white L-joints (100 %) and the lowest in three-year exposed brown L-joints (only 30 %). At the position 4 the highest BA of 100 % occurred in three months exposed black L-joints, but interestingly there were no BA in six-month exposed black L-joints. BA at the positions 5 and 6 tended to increase during the exposure period.

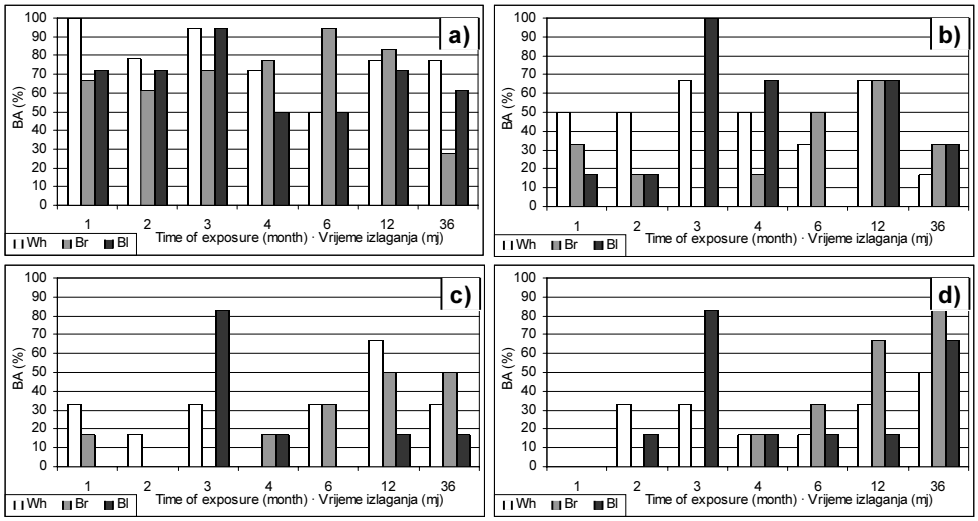

Figure 1
BA in HAP L-joints (positions relative to the joint): a) Position 1, 2, 3; b) Position 4; c) Position 5; d) Position 6
Slika 1.
BA u lakiranim L-spojevima prema pozicijama: a) pozicija 1, 2, 3; b) pozicija 4; c) pozicija 5; d) pozicija 6

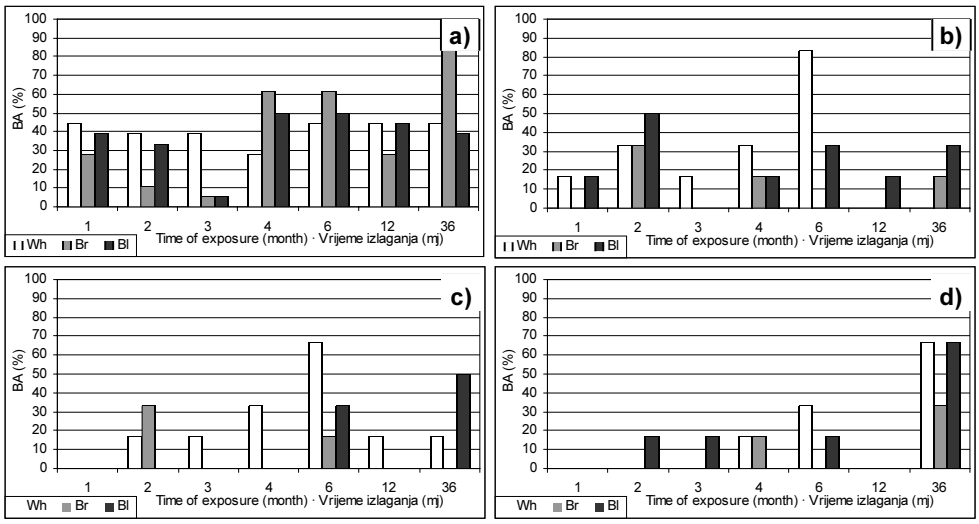

Figure 2
BA in MAS L-joints (positions relative to the joint): a) Position 1, 2, 3; b) Position 4; c) Position 5; d) Position 6
Slika 2.
BA u lazuriranim L-spojevima prema pozicijama: a) pozicija 1, 2, 3; b) pozicija 4; c) pozicija 5; d) pozicija 6

4.2 Medium build alkyd stain (MAS)
4.2 Srednjoslojna alkidna lazura

The main characteristic of bacterial colonisation among all MAS L-joints was that there were no 100 % BA and colonisation in any position (4, 5 and 6) or group of position (positions 1, 2 and 3 together) (Figure 2).

The highest average BA of about 83 % was recorded among six-month exposed white L-joints at position 4 (Figure 2b). The lowest average BA occurred in brown and black L-joints. BA of all exposed L-joints at positions 5 and 6 was insignificant (Figures 2c, 2d) probably due to the well-known water vapour permeability of stain.

With regard to the coating colour, L-joints proved again to be colonised to a larger extent than brown and black ones.

4.3 HAP and MAS coatings
4.3 Lak i lazura

Significantly different BA was observed between HAP and MAS L-joints (Figure 3). BA in MAS L-joints at positions 1, 2, and 3 was significantly lower than in HAP L-joints (Figure 3a). This can be seen particularly well on three-month exposed brown and black L-joints (Figure 1 and 2). During that period the insolation was the highest. Dark surfaces absorbed more heat than white ones, but the heating effect reflected differently on BA in HAP and MAS coated L-joints depending on water vapour permeability of the coating. In the dark MAS L-joints faster heating provided accelerated seasoning, lower moisture contents and finally lower potential BA. In this case the well-known water vapour permeability constantly caused lower moisture contents again (Turkulin, 1990). In the dark HAP L-joints faster heating could only cause increase of temperature but not seasoning due to low permeability of the HAP coatings. Such conditions provided stronger BA as it is known that bacterial growth is faster when the moisture content is higher.

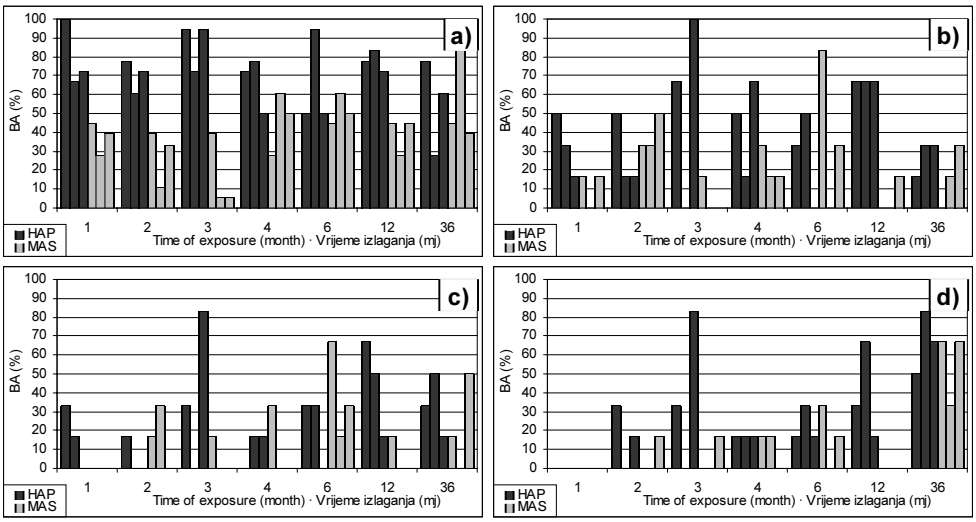

Figure 3
Comparison between BA in HAP and MAS L-joints (positions relative to the joint): a) Position 1, 2, 3; b) Position 4; c) Position 5; d) Position 6
Slika 3.
Usporedba BA u lakiranim i lazuriranim L-spojevima prema pozicijama: a) pozicija 1, 2, 3; b) pozicija 4; c) pozicija 5; d) pozicija 6

5 DISCUSSION
5 DISKUSIJA

Regardless of the coating types, bacteria that were significantly present very close to the joint, after only a month, rapidly colonised untreated material. Comparing the results from the earlier research on the pine-sapwood L-joints (Carey, 1983; Mendes, 1982) it is obvious that the bacterial colonization on fir-wood L-joints was slower.

Due to the fir-sapwood low permeability (Petrić, 1971; Despot, 1991) during the first three months of exposure, bacteria mainly colonised the first three positions and did not colonise significantly the positions 4, 5 and 6. Later, particularly after 6, 12 and 36 months of exposure, bacterial colonisation at those positions was greater. There are two possible explanations.

The first explanation is more acceptable. It lies on well-known direction of bacterial penetration and activity. Bacteria first attacked and invaded the first three positions and then proceeded through the tenon. They produced the increase of porosity in naturally low permeable fir sapwood, water uptake became increasingly stronger, and bacteria kept penetrating by water. After 36 months of exposure almost all positions of L-joints were infected (Figure 3). It is can be seen particularly well in brown and black L-joints. But due to the very known non-homogenous structure of Silver-Fir wood, the exceptions were very frequent, particularly in three- and six-month exposed L-joints.

The other explanation could be in slow water penetration through the cracks in the end grain sealing into the tenon towards position 6. This explanation could be acceptable especially for brown L-joints (Figures 2 c, d).

During the 4th and 6th month of exposure, although the average temperatures were low (between -1 and -6 ^{o}C), BA was very strong regardless of the coating type. The ice and snow covering L-joints might have provided a kind of thermal isolation and protection against low temperatures.

6 CONCLUSION
6 ZAKLJUČAK

The occurrence of bacteria on untreated L-joints made of Silver-Fir (*Abies alba*, Mill.), coated with two different coating types, appears to depend upon a number of factors. This paper demonstrates the need to incorporate the bacteria and other colonization sequence into any method for assessing the performance of new coatings and preservatives for joinery.

Coating type and colour affect the bacterial colonisation of Silver-Fir L-joints. Generally, medium build alkyd stains performed better than high build alkyd paints. The joinery producers in Croatia are suggested to produce joinery coated with stains especially for exposition in the sites with rather moderate continental climate (Zagreb). On the other hand, the highest bacterial colonisation was recorded on L-joints coated with alkyd paint coating. The possible influence of coating colours only occurred during the first three months of exposure. Generally L-joints coated with dark colours were less infected and colonised by bacteria.

7 REFERENCES
7 LITERATURA

1. Carey, J. K. 1979: A possible method for enumerating Bacteria in wood. Int. Biodeterioration Bull. 15, (4): 119 - 123.
2. Carey, J. K. 1983: Colonisation of Wooden Joinery. Biodeterioration 5, 1983: 13 - 25.

3. Carey, J. K. 2002: L-joint trials: Part 1: Observations on the process of colonisation and decay, IRG 33rd Annual Meeting Cardiff UK.
4. Despot, R. 1991: Poboljšanje permeabilnosti jelovine djelovanjem bakterija, MSc thesis, Forestry Faculty of Zagreb, pp 89.
5. Despot, R. 1996: Prilog poznavanju mehanizma infekcije i truljenja jelove građevne stolarije, PhD thesis, Forestry faculty of Zagreb, pp 386.
6. Mendes, F. 1982: Microflora associated with treated exterior joinery. PhD Thesis, University of London.
7. Miller, E. R, Boxall, J., Carey, J. K. 1987: External joinery: end grain sealers and moisture control. Building Research Establishment Information Paper IP20 /87.
8. Petrić, B. 1971: The Influence of Wood Structure on Permeability of Softwoods. Šumarski list 95, 5-6: 125 - 140.
9. Turkulin, H. 1990: Postojanost lamelirane građevne stolarije, MSc thesis, Forestry Faculty of Zagreb, pp 312.
10. *** EN 330: 1993: Wood preservatives Field-test method for determing the relative protective effectiveness of a wood under a coating and exposed out-of-ground contact: L-joint method, pp 14.

Corresponding address:

Doc. dr. sc. RADOVAN DESPOT
Department of Wood Science
Faculty of Forestry
University of Zagreb
Svetošimunska 25
HR-10000 ZAGREB
CROATIA
E-mail: radovan.despot1@zg.hinet.hr