

THE INFLUENCE OF STERILISATION BY GAMMA RADIATION ON NATURAL DURABILITY OF WOOD

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ABSTRACT

Gamma-radiation-induced depolymerisation causes significant changes in wood properties that could influence on wood natural durability. Therefore, *Pinus sylvestris* sapwood, sterilised by gamma irradiation and steam was exposed to white rot fungus *Schizophyllum commune* and brown rot fungus *Poria placenta*. According to EN 113 Cobalt ^{60}Co was used at the dosage of 30 and 150 kGy. Control specimens were steam sterilised. Significant differences in mass loss between gamma irradiated and autoclaved specimens were determined after four weeks of exposure to *S.commune*. Irradiated specimens lose higher percentage of their masses than non-irradiated ones. During further exposure, differences decreased until they became insignificant. On the other hand, sterilization method doesn't have significant influence on specimens' mass loss after 4 weeks of exposure to *P. placenta*. However, after 8, 12 and 16 weeks of exposure, irradiated specimens lose higher percentages of their masses than autoclaved ones. With increasing of exposure time, this difference became more and more significant.

KEY WORDS: natural durability, *Poria placenta*, *Schizophyllum commune*, wood sterilisation, *Pinus sylvestris*

INTRODUCTION

Wood as a natural organic material is susceptible to biodeterioration by insects, fungi, and bacteria. Therefore, depending on in-service conditions, it must be adequately preserved, particularly if used in wet conditions. Sterilization of wood is necessary for testing the effectiveness of wood preservatives. All European standard methods prescribes that wood specimens need to be sterilized before exposure to the test fungi. In general there are two methods of sterilization available; steam and gamma sterilisation.

Gamma radiation, as a high energy, ionising electromagnetic radiation, is known to be a very effective and fast sterilisation method (Shuler 1971). Since alpha and beta rays are stopped and in this way neutralised at the surface or in surface-close layers of irradiated objects, gamma radiation fully penetrates the wooden object ionising molecules or changing their chemical structure in the pest's living cells (Tišler and Medved 1997). Such modified molecule structure leads to either inexpedient function of the cells or to a complete loss of their function.

Kunstadt (1998) mentioned that insects do not withstand dosages between 0.7 and 1.3 kGy, while elimination of fungi requires significantly higher dosages. Freitag and Morrell (1998) reported on a gamma radiation dosage of 15 kGy to be adequate for mitigating pests in wood. The Standard EN 113 (1996) requires dosages between 25 and 50 kGy for wood sterilisation in lab testing procedures. Sterilisation by gamma radiation is very easy, fast and effective, but in the same time gamma radiation changes the molecular structure not only of pest's living cells, but also of wooden cell walls. It was found in the early 1950s that treatment of wood with gamma rays causes random break-up of cellulose chains. Seifert (1964), Tabith et al. (1977) and Cutter et al. (1980) found that the holocellulose portion of wood cell walls was degraded by gamma irradiation. Loss (1962), Shuler et al. (1975) and El-Osta et al. (1985) verified that gamma-radiation-induced depolymerisation causes a significant decrease in wood strength. Divos and Bejo (2005) stated a linear correlation between dynamic MOE and gamma radiation dosage.

Seifert (1964) found an increasing amount of free radicals in wood after gamma radiation, which could support further destruction of polysaccharides chains. Fengel and Wegener (1989) and Tišler and Medved (1997) mentioned that the cellulose chains are continuously breaking down for at least 100 days after gamma treatment.

Seifert (1964), Klimentov et al. (1981), Ardica et al. (1984), Šimkovic et al. (1991), Magaudda et al. (2001), Struszczyk et al. (2004), Despot et al. (2006, 2007) reported gamma irradiated wood to be more susceptible to chemical and enzymatic degradation. Therefore, we were interested in, whether gamma and steam sterilisation of pine specimens resulted in different performance of untreated wood against white and brown rot fungi.

MATERIAL AND METHODS

The present work attempts to assess the effect of gamma radiation on natural durability of wood against biological degradation. Control non-irradiated specimens were sterilised by autoclaving. The applied gamma radiation dosages were 30 and 150 kGy. The intensity of degradation as a function of exposure was assessed after 4, 8, 12 and 16 weeks of exposure to fungi according to EN 113, 1996 procedure.

Material and methods

All specimens were made from sapwood of one eighty years old pine tree (*Pinus sylvestris* L.) grown in Croatia. Three central planks were sawn out of a 4.2 m long log and air dried for 152 days up to a moisture content (MC) of 24.5 %, kiln-dried below 65 °C to MC = 12 %. After kiln drying, sapwood laths were sawn from each board. Specimens of 25 × 15 × 50 [± 0.2 mm] (R×T×L) were cut and successively-axially selected from sapwood lattices and exactly assorted to each group of parameter combination for each test (Tab. 1).

All specimens were stored and conditioned in standard climate of 20 °C and 65 % relative humidity before and after radiation. Specimens were exposed to fungi 10 days after radiation.

Groups of specimens for each parameter combination were packed into polyethylene (PE) plastic bags (Tab. 1). All plastic bags for the same gamma dosage were packed together in one larger PE bag. Cobalt ^{60}Co was used as a gamma radiation source at the Institute of Ruđer Bošković, Zagreb, Croatia. A standard dosage of 30 kGy and five times greater dosage of 150 kGy were applied for sterilisation, as proposed by standard EN 113 procedure (1996). As a control, non-irradiated specimens were sterilised by autoclaving (123 °C, 1.8 ± 0.1 bar, 30 min).

Tab. 1: Number of specimens for each parameter combination.

Fungus	Gamma radiation dosage, G [kGy]	Time of exposure, weeks [w]			
		4	8	12	16
<i>Schizophyllum commune</i>	0	7	7	7	7
	30	7	7	7	7
	0	7	7	7	7
	150	7	7	7	7
<i>Poria placenta</i>	0	7	7	7	7
	30	7	7	7	7
	0	7	7	7	7
	150	7	7	7	7

Determination of natural durability

White rot fungus *Schizophyllum commune* Fr.: Fr. and brown rot fungus *Poria placenta* (Fries) Cooke sensu J. Erikson. were used in this research. As a relatively easy and fast method for determination of natural durability in laboratory conditions, a standard EN 113 (1996) method was used. The mass loss (Δm) caused by fungal decay was measured after 4, 8, 12 and 16 weeks of exposure and calculated as follows:

$$\Delta m = \frac{m_1 - m_3}{m_1} \times 100[\%] \quad (1)$$

where:

Δm is mass loss of specimen,

m_1 is oven-dry mass of specimen before exposure to fungi and

m_3 is oven-dry mass of specimen after exposure to fungus.

M of specimens exposed to fungal degradation was calculated at the end of each exposure period as follows:

$$MC = \frac{m_2 - m_3}{m_3} \times 100[\%] \quad (2)$$

where:

MC is moisture content of specimen after exposure to fungus,

m_2 is wet mass of specimen after exposure to fungus and

m_3 is oven-dry mass of specimen after exposure to fungus.

Experiment was performed in seven individual replicates (Tab. 1).

RESULTS AND DISCUSSION

After ten days of exposure of the wood specimens to wood decay fungi, it was clearly visible, that irradiated specimens were more overgrown, than control steam sterilised specimens. This observation is the first prove that the irradiated wood is more susceptible to biodegradation than non-irradiated one.

Durability against *Schizophyllum commune* Fr.: Fr.

Almost no difference in appearance between irradiated and autoclaved decayed wood even after 16 weeks of exposure was established (Fig. 1).

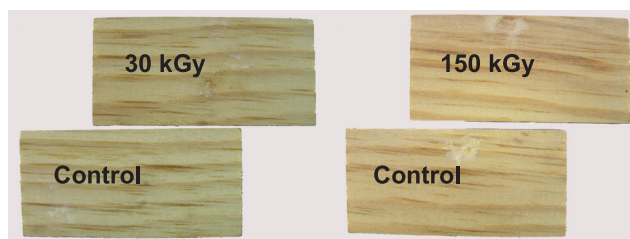


Fig. 1: Appearance of irradiated and autoclaved specimens after 16 weeks of exposure to fungus *S. commune*.

On the other hand, significant difference in Δm between autoclaved and with 30 kGy irradiated specimens was established after 4 weeks of exposure. During further exposure, the difference decreased and became less significant until the end of exposure when no significant difference was determined (Fig. 2). If considering the type of decay and decay preferences of the *S. commune* observed tendency and changes of mass loss between autoclaved and gamma irradiated wood became reasonable. Namely, in the beginning of decay white rot fungus uses simple carbohydrates – the ones incurred during gamma radiation. Therefore, the mass loss of wood irradiated with 30 kGy was significantly greater after fourth week of decay than mass loss of steam sterilised specimens. As the fungus grows and spend all the simple sugars is starts decaying lignin mainly. Consequently, Δm became less and less significant over exposure time. During all exposure time mass loss of wood irradiated with 150 kGy was smaller or equal to mass loss of the controlled ones due to very high sampler carbohydrates content as reported by Despot et al. (2006, 2007) (Fig. 2). Another possible reason for lower mass losses of specimens sterilised with the highest dosage are free radicals formed (Divos and Bejo 2005). These radicals on the first place causes depolymerisation of polysaccharides, and on the other hand negatively influence on the development and decay processes of wood decay fungi. This consumption is further supported by, fact that particularly, white rot fungi uses radical mechanisms to degrade lignin. These radical mechanisms can be disturbed if there are other radicals present in wood (Kirk and Cullen 1998).

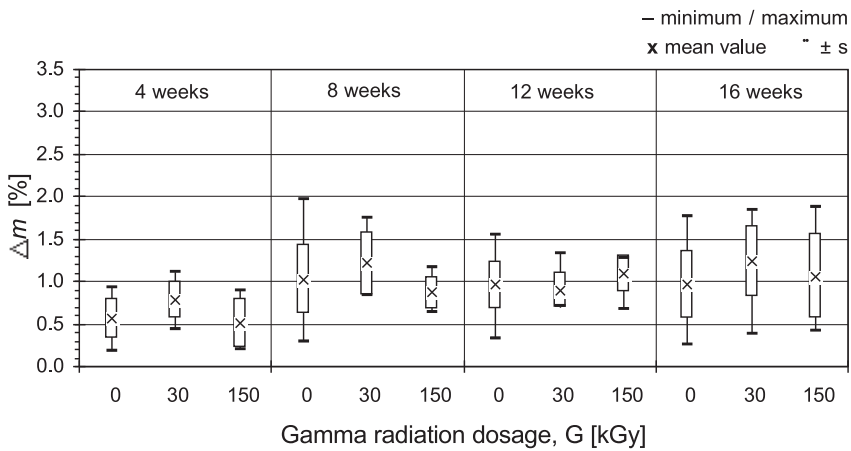


Fig. 2: Mass loss (Δm) of autoclaved and irradiated specimens during exposure to fungus *S. commune* for different periods of exposure; (for irradiated specimens $n=7$; for autoclaved specimens $n=14$)

The dependency between mass loss and time of exposure to fungus tend to be logarithmic. The difference in mass loss between irradiated and control autoclaved specimens decreased and became less significant during exposure time as stated above what is clearly visible in the Figure 3.

However, it has to be considered, that white rot fungi predominantly decays hardwood, but in this experiment softwood specimens were used. Therefore, even more prominent influence of sterilisation method could be observed on the specimens made of beech exposed to white rot fungi.

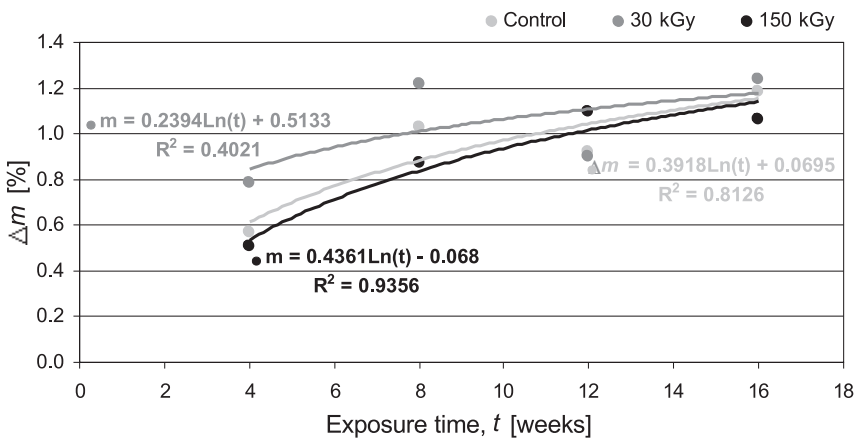


Fig. 3: Correlation between mass loss (Δm) of autoclaved (control) and irradiated groups of specimens and exposure time to fungus *S. commune*

Average MC of each group of irradiated specimens was equal or higher than the MC of controls during all exposure time, except after 16 weeks where 30 kGy irradiated specimens had significantly lower MC than the control ones. It confirms the increased concentration of simpler carbohydrates incurred during radiation (Fig. 4). This data further supported fact, that gamma radiation resulted in depolymerisation of wood polysaccharides. It is well known, that glucose and other simple sugars makes wood considerably more hygroscopic (Fengel and Wegener, 1989).

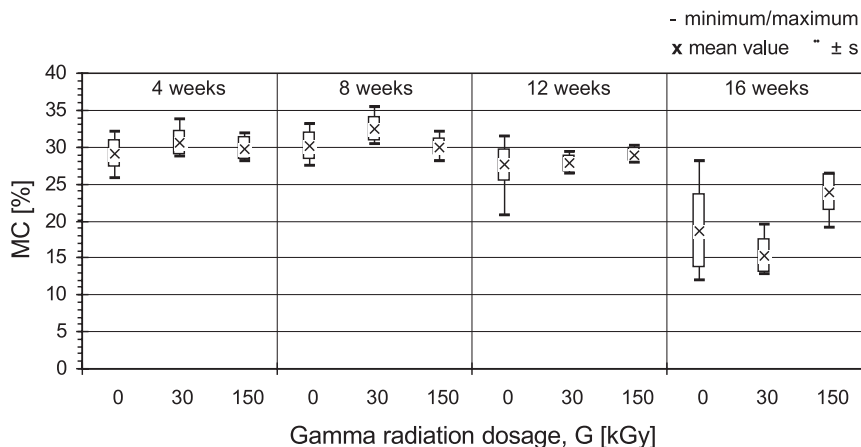


Fig. 4: Moisture content (MC) of autoclaved and irradiated specimens during exposure to fungus *S. commune* for different periods of exposure; (for irradiated specimens $n=7$; for autoclaved specimens $n=14$).

Durability against *Poria placenta* (Fries) Coke sensu J. Erikson.

Fungus *P. placenta* causes brown cubic rot with broad and deep cracks. Clearly visible difference in appearance (cracks and irregular shape) between irradiated and autoclaved specimens after 16 weeks of exposure has been shown in the Figure 5.

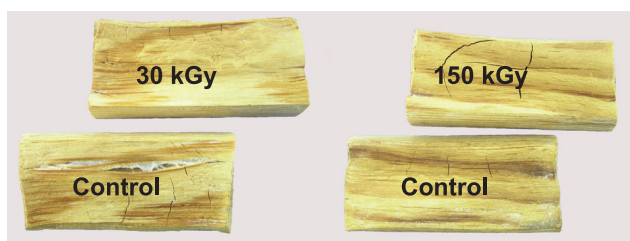


Fig. 5: Appearance of irradiated and autoclaved specimens after 16 weeks of exposure to fungus *P. placenta*.

The difference in mass loss between 30 kGy irradiated and autoclaved specimens is slight and not significant after 4 weeks of exposure, while specimens irradiated with 150 kGy had significantly greater mass loss. Since *P. placenta* mainly uses carbohydrates, it was expected that mass loss of

irradiated specimens increased faster than mass loss of autoclaved ones during exposure time due to easier accessibility of simpler carbohydrates (Fig. 6).

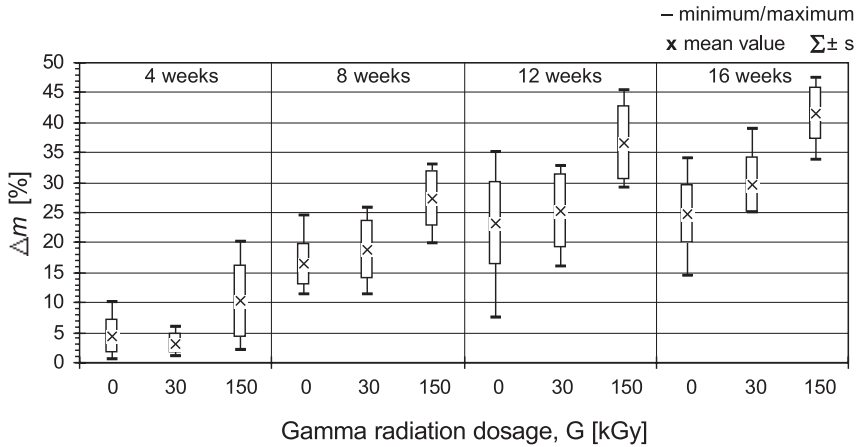


Fig. 6: Mass loss (Δm) of autoclaved and irradiated specimens during exposure to fungus *P. placenta* for different periods of exposure; (for irradiated specimens $n=7$; for autoclaved specimens $n=14$).

The dependency between mass loss and time of exposure to fungus tend to be logarithm. The difference in mass loss between irradiated and autoclaved (control) specimens increased and became more significant during exposure time (Fig. 7). As brown rot decay mechanisms, particularly decay mechanism of *P. placenta*, are less radical dependent, higher irradiation does not influence on the decay patterns of this brown rot fungus. On contrarily, higher irradiation resulted in higher degree of depolymerization, what makes wood significantly more susceptible (Despot et al. 2006, 2007).

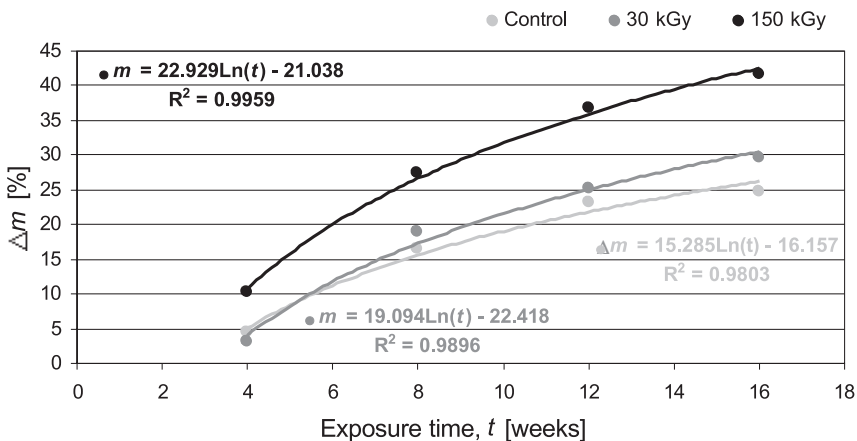


Fig. 7: Correlation between mass loss (Δm) of autoclaved (control) and irradiated groups of specimens and exposure time to fungus *P. placenta*

Increased MC of irradiated specimens during fungal nutrition has been observed as well. 150 kGy irradiated specimens had the greatest MC, while autoclaved controls had the smallest MC (Fig. 8). We presume that there are two important reasons for increased MC; higher mass loss and higher percentages of simple sugars what make decayed wood more hygroscopic.

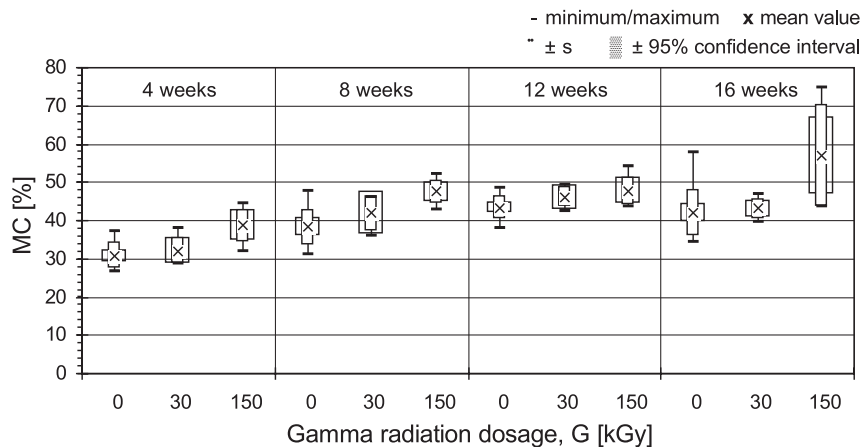


Fig. 8: Moisture content (MC) of autoclaved and irradiated specimens during exposure to fungus *P. placenta* for different periods of exposure; (for irradiated specimens $n=7$; for autoclaved specimens $n=14$).

However, it has to be taken into consideration that depolymerization of wood components by gamma irradiation is one aspect that could explain us differences in natural durability of pine wood. On the other hand, we have to be aware, that steaming of wood in the autoclave could have some effect on natural durability as well, as we are all familiar with different modification methods using heat.

CONCLUSIONS

Method of sterilisation has considerable influence on the natural durability of pine wood. However, method of sterilisation has different influence on white rot and brown rot fungal species.

Significantly greater mass loss of gamma irradiated than autoclaved specimens have been established after 4 weeks of exposure to fungus *S. commune*. During exposure, the difference decreased and became less significant.

After 4 weeks of exposure to *P. placenta*, autoclaved specimens lost more mass. During further exposure, mass loss of irradiated wood became greater than autoclaved ones and these differences became more and more prominent.

It is obvious that gamma irradiated wood is more susceptible to fungal degradation than autoclaved wood, particularly to brown rot fungi. Gamma radiation at a level of 30–150 kGy causes irreversible and permanent changes in chemical structure in wood cell wall. Degradation of gamma-irradiated wood is greater and faster due to easier accessibility of simpler carbohydrates to fungi.

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