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FOIL STORAGE FOR CONSERVATION OF BEETLE-INFESTED SPRUCE LOGS – A FEASABILITY STUDY

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Abstract:
Recently, increasing quantities of calamity timber led not only to sales difficulties on the European market, but brought forest enterprises at their capacity limits during felling and forwarding. At many places, spraying of stored roundwood was also limited due to a shortfall of water after a series of dry summers. Therefore, foil storage as developed in the 1990s was rediscovered. Experience with foil storage of beetle-infested roundwood is rather limited. While living parenchyma cells of freshly felled timber reduce the oxygen content inside a foil tent and thus inhibit fungal growth and decay, it is uncertain whether this principle can be applied for beetle-infested and partly dead and dry timber. Within this study, Norway spruce (Picea abies) was submitted to conditions representing foil storage. Stem segments, which were (1) uninfested, (2) slightly infested by bark-breeding beetles, but still green, or (3) severely infested and already dead were stored in plastic boxes, which were either airtight ('Baden-Württemberg procedure') or open at the bottom allowing direct access of moisture from the ground ('Swiss procedure'). Changes in O_2 and CO_2 content were monitored and growth wood decay of different brown and white rot fungi were observed. The lack of living parenchyma cells in severely infested 'beetle wood' was significantly reducing the protective effectiveness of the foil store. It became evident that only an airtight foil wrapping leads to an effective reduction of the oxygen content.

Key words: *Bark-breeding beetles; foil storage; fungal decay; log conservation; storm-felled trees.*

INTRODUCTION

On January 18, 2018, winter storm Friederike hit Central Europe and caused billions in damage. Solely in Germany, 9.1 million bank meter - mainly Norway spruce (*Picea abies*) - were felled within a few hours (Pöschel 2018). Subsequently, the price for roundwood dropped, and after the two dry summers 2018 and 2019 with a bark-breeding beetle disease, the market for Norway spruce roundwood in Germany and its neighbouring countries collapsed. In total, 171 million bank meter calamity timber accumulated on a total area of 277.000 hectares, and large amounts have not been harvested yet (BMEL 2021). Free areas for storage at the saw mills become increasingly unavailable and wet storage through permanent spraying (Fig.1a) is limited due to dryness and water scarcity. Foil storage, which had been used in the 1990s for the conservation of storm-felled trees (Mahler 1992, Bues and Weber 1998, Schüler and Wurster 2000), was brought back on the agenda. Its mode of protective action is simple: Freshly felled timber is stored in an air-tight foil tent (Fig. 1b). The living parenchyma cells reduce the oxygen content inside the tent and thus inhibit fungal growth and decay in the logs (Schüler and Wurster 2000, Rademacher et al. 2011, Rademacher and Hapla 2012, Solar et al. 2015). The main concern about this technique is its applicability for beetle-infested and partly dead and dry timber.

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a. *b.*

Fig. 1.
Storage of calamity timber.
a – Wet storage through spraying; b – Foil storage according to the 'Baden-Württemberg Procedure'.

Earlier studies (Gerencsér et al. 2007, Rademacher et al. 2011, Rademacher and Hapla 2012, Solar et al. 2015) showed that the so-called 'Baden-Württemberg Procedure' has a higher protective effect compared to the 'Swiss Procedure'. Solely, complete closure of the wood from the ambient air can prevent fungal growth and wood degradation. This is only the case with the 'Baden-Württemberg Procedure', since according to the 'Swiss Procedure' the wood is not closed off from the ground. Nevertheless, both methods are still used in practice today. Even for short-term storage (up to one year), the 'Swiss Procedure' appears less suitable. However, only the 'Baden-Württemberg Procedure' can be used, particularly for desired storage periods of several years, as might be required by the current situation on the raw wood market.

Most of the wood that is currently not immediately saleable is not freshly felled by a storm, but damaged by bark-breeding beetles and showing very different degrees of vitality. The new question arises to what extent damaged 'beetle wood' is able to reduce the oxygen content in a foil store in such a way that wood-destroying fungi are deprived of their livelihood.

Foil storage was developed and used in several regions of Germany to protect wood from storms. When fresh, wood is rich in still living parenchymal cells, which use up the residual oxygen in a foil pile and reduce it so much that it is not sufficient for wood-destroying fungi to respire. The prerequisite for avoiding fungal wood degradation is that the oxygen content remains permanently low. For this it is essential that the foil tent remains tightly closed, for which a number of expensive measures have to be taken. Storage areas must be levelled and cleared of sharp stones, water drainage must be ensured, mouse protection fabric put out, and logs´ cut edges rounded. In addition to a not inconsiderable expense for the preparation of a foil tent, there is the monitoring of the store with regard to the tightness of the foil tent, which up to now has mainly been done by manual measurements of the oxygen content. All in all, this means a high logistical effort, especially with regard to the timely delivery of the wood to be stored. Information on the costs for the foil storage of logs vary greatly and depend on the storage method in addition to the local conditions. By the example of a 300 bank meter foil covered log stack, costs per bank meter may vary between 11 – 18 EUR/m³, including costs for the preparation of the storage place, material costs and salary costs for the installation and monitoring (4 weeks interval) of the foil storage (Wald und Holz NRW 2020).

Basically, a distinction is made between two procedures, the 'Baden-Württemberg Procedure' - also known as the 'Woodpacker Procedure' - and the 'Swiss Procedure'. Foil conservation was developed in principle at the 'Forestry Experimental and Research Institute Baden-Württemberg' in cooperation with the Institute of Forest Utilization at the Technical University Dresden between 1995 and 1999. For this purpose, the wood is stored in an airtight, sealed envelope made of polyethylene film (Fig. 1b). The Swiss Procedure, on the other hand, lacks a bottom foil. The wood, which is covered by foils on the sides and from above, is kept permanently moist due to the exclusion of air from the outside and should in this way be protected from devaluation.

OBJECTIVE

This study aimed at examining the potential of foil storage for conservation of Norway spruce wood, which had been infested and damaged by bark-breeding beetles to varying extent. Therefore, storage conditions in foil tent according to both, the 'Baden-Württemberg Procedure' and the 'Swiss Procedure' were simulated and the oxygen and carbon dioxide within a foil tent should be examined. In addition, the ability of decay fungi to grow and degrade wood under respective conditions should be investigated.

METHODS

Wood material and storage conditions

Three assortments of Norway spruce (*Picea abies*) were submitted to conditions representing foil storage, i.e. sections of 35cm length were cut each from three trees (DBH = 17-20cm), which were (1) uninfested (MC = 120 ± 83%), (2) slightly infested by bark-breeding beetles, but still green (MC = 62 ± 41%), or (3) severely infested and already dead (MC = 24 ± 4%). The trees were harvested in Haus Ilster in the Northeast of Lower Saxony, Germany. Sections were stored in plastic boxes, which were either airtight ('Baden-Württemberg procedure') or open at the bottom allowing direct access of moisture from the ground ('Swiss procedure'). Three replicate boxes were prepared for both procedures and the three different spruce assortments, i.e. in total 18 boxes (Fig. 2). In addition, six boxes were filled with expanded polystyrene as reference (data not presented). Oxygen and CO_2 content were monitored during a period of 8 weeks using an oxygen meter (Greisinger GOX 100, Regenstauf, Germany) and a carbon dioxide meter (7755AZ, Taichung City, Taiwan), respectively.

Fig. 2.
Exposure of storage boxes according to the 'Baden-Württemberg Procedure' (two top rows) and to the 'Swiss Procedure' (bottom row). Boxes filled with stem sections of Norway spruce plus reference boxes filled with inert expanded polystyrene (data not presented).

Fungal growth and wood degradation tests

In addition to the O_2 and CO_2 measurements, different basidiomycete fungi were grown in Petri dishes (Ø = 150mm) and exposed inside the storage boxes. Mycelial growth of the following test fungi was measured: *Coniophora puteana* = (Schum.: Fr.) P. Karsten BAM Ebw. 15, *Gloeophyllum trabeum* = (Pers.: Fr.) Murrill FPRL 108 N and *Trametes versicolor* = (L.:Fr.) Pilat CTB 863A. Each storage box contained two Petri dishes per test fungus.

In addition, mini-block test specimens (5 x 10 x 30mm³) according to Bravery (1978) were cut from Norway spruce and European beech (*Fagus sylvatica*) and incubated with *T. versicolor* in Petri dishes on malt agar, which were stored for 66 days in airtight boxes (n = 3) and either filled with freshly felled or severely infested Norway spruce wood. The specimens were oven-dried and weighed to the nearest 0.001g before and after incubation. Mass loss due to fungal decay ML_F was calculated according to Eq. 1.

$$ML_F = \frac{m_{0,L} - m_{0,F}}{m_{0,L}} \cdot 100 \quad [\%] \qquad (1)$$

where: $m_{0,L}$ is the oven-dry mass before incubation after leaching;
$m_{0,F}$ is the oven-dry mass after incubation.

RESULTS & DISCUSSION

The 'Swiss Procedure' did neither lead to a significant reduction of the oxygen content nor to an increase in CO_2 compared to atmospheric conditions (Fig. 3). As expected, agar plates were overgrown during two (*C. puteana* and *T. versicolor*) and five weeks (*G. trabeum*). Thus, independent from the type of stored wood no protective effect was observed. In contrast, the entire exclusion of air oxygen according to the 'Baden-Württemberg Procedure' reduced O_2 and increased CO_2 in the storage boxes (Fig. 3). Within a few hours O_2 dropped below 5% when fresh and non-infested or slightly infested wood was stored; after one day it was below 1% and fungal growth was significantly inhibited. Severely infested wood also led to a decrease in O_2, but the effect was only temporary.

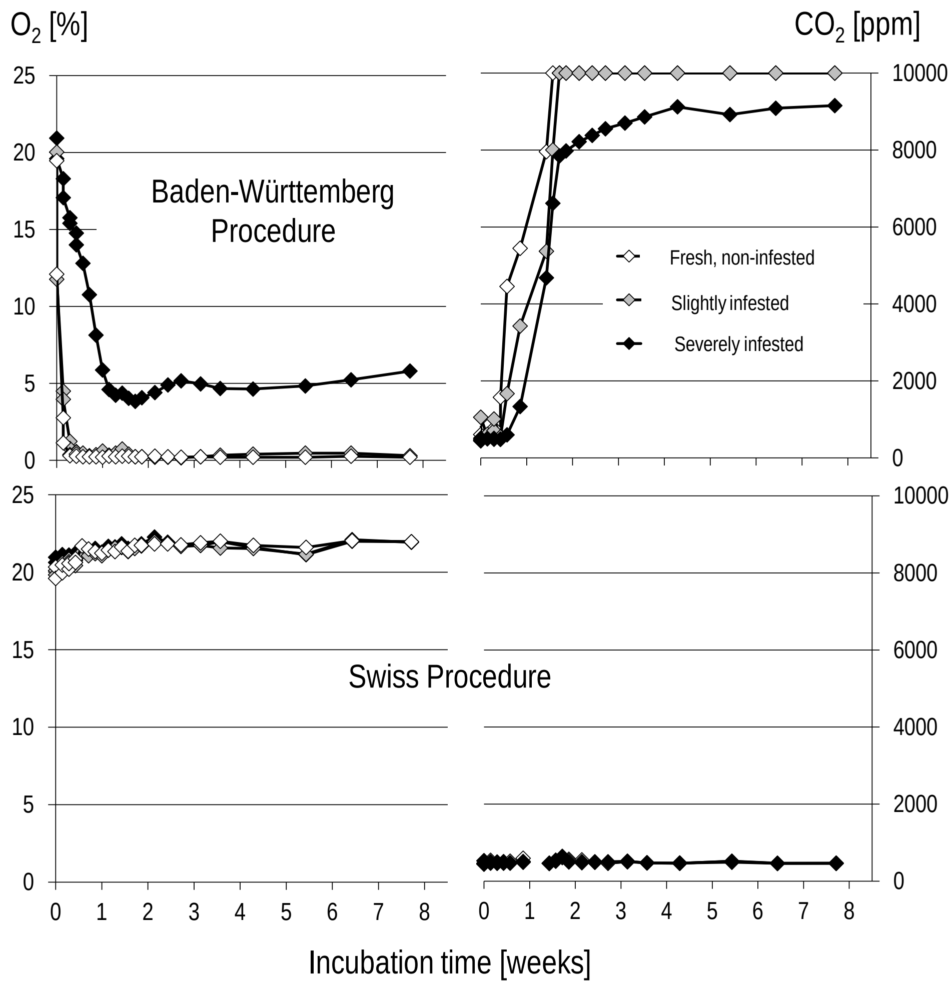

Fig. 3.
Oxygen and CO_2 content during 8 weeks of 'foil storage' of Norway spruce wood differently infested by bark-breeding beetles. Note: the upper limit of CO_2 measurements was 10.000 ppm.

The brown rot fungi *C. puteana* and *G. trabeum* stopped growing almost immediately when incubated in boxes filled with fresh or slightly infested wood. Agar plates were fully grown with mycelium when they were incubated in boxes with severely infested wood. In contrast to the brown rot fungi, the growth of the white rot fungus *T. versicolor* was slightly inhibited, but it was able to fully grow the agar plates even when it was incubated together with freshly felled wood. Different authors reported on the high tolerance of white rot fungi against lacking oxygen (Metzler et al. 1993, Rabe 2008).

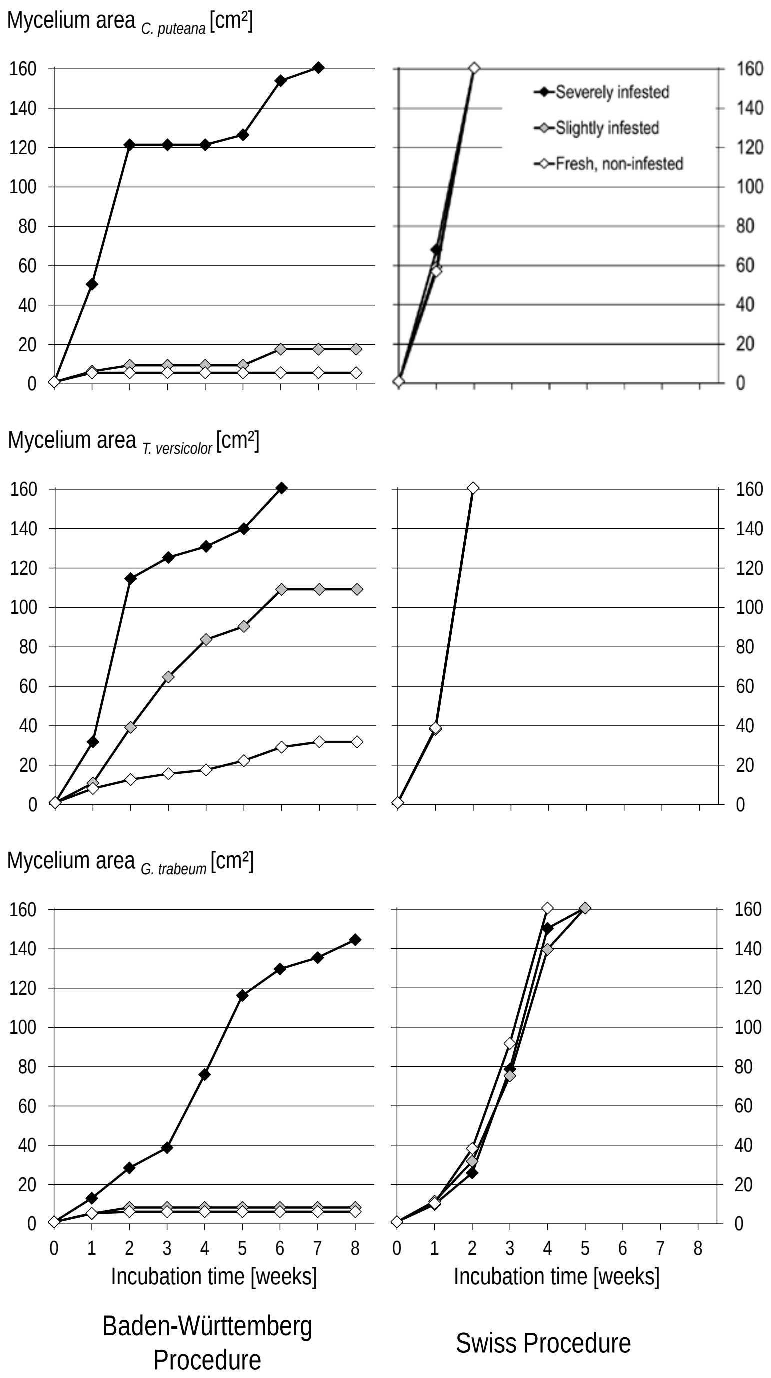

Fig. 4.
Growth of the brown rot fungi Coniophora puteana and Gloeophyllum trabeum and the white rot fungus Trametes versicolor in storage boxes according to the 'Baden-Württemberg Procedure' and 'Swiss Procedure' for foil conservation of Norway spruce roundwood logs.

The decay tests revealed that solely storage of freshly felled wood led to conditions inhibiting wood degradation. Beech wood specimens incubated with *T. versicolor* and severely infested Norway spruce wood showed significant decay and an average mass loss of 10 % (Fig. 5). *T. versicolor* did not lose its ability to degrade wood, despite the significantly reduced O_2 content. Only the storage of fresh wood did not lead to degradation of the wood under the experimental conditions given here. Further investigations over longer incubation periods are necessary in order to prove a long-term protective effect of the storage of 'beetle wood' with different degrees of damage.

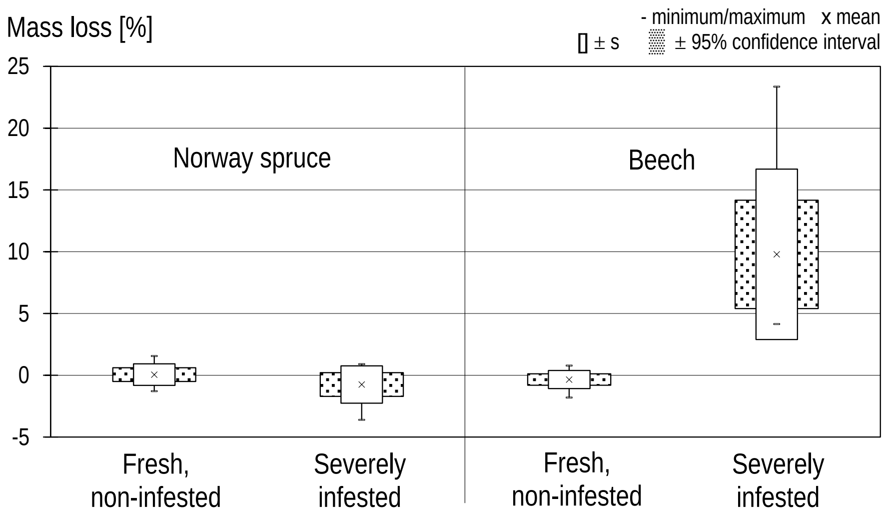

Fig. 5.
Mass loss of mini-block specimens after 66 days of incubation with Trametes versicolor in conservation boxes according to the 'Baden-Württemberg Procedure'.

CONCLUSIONS

Independent of economic considerations, foil storage can be used for temporary conservation of calamity timber. The lack of living parenchyma cells in severely infested 'beetle wood' is significantly reducing the protective effectiveness. It became evident that only an airtight foil wrapping leads to an effective reduction of the oxygen content.

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