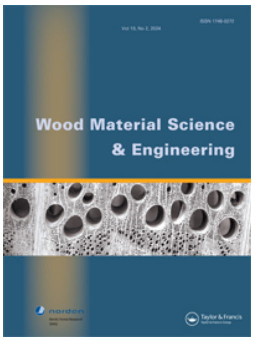

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Accelerated decay tests with miniaturised wood specimens – critical assessment of suitability for durability classification

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ABSTRACT
The biological durability of ten wood species was determined on the basis of results from laboratory agar block tests. The experiment utilised two specimen formats: standard EN 113-2 specimens (15 × 25 × 50 mm) and mini-blocks (5 × 10 × 30 mm) exposed to two fungi (*Coniophora puteana* and *Trametes versicolor*) for varying incubation periods. Mini-block tests yield dissimilar outcomes compared to the European standard test at six, eight, ten or 16 weeks of incubation. This discrepancy extended to both durability classifications based on median percentage mass loss and those based on relative mass loss (*x*-values). It was therefore concluded that laboratory tests with miniaturised specimens are not advisable as a substitute for conventional durability classification assessments.

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Durability classes; incubation time; mass loss; natural durability; wood-destroying fungi; *x*-values

1. Introduction

Wood durability can be tested under laboratory conditions with the help of monoculture incubation experiments of wood-destroying fungi. Since long, such tests are used for screening and preliminary classification of the biological durability of wood against decay fungi. Furthermore, the protective effectiveness of wood preservatives can be tested in similar test-set ups. One major advantage of such laboratory experiments is that their duration is significantly shorter compared to field tests. In contrast to a minimum exposure time of five years in the field, common incubation times with basidiomycetes are 16 weeks as used in the EN 113-2 standard (CEN 2021).

The decay process can be further accelerated through the use of feeder blocks. Alternatively, specimens for laboratory decay tests have been reduced in size with the aim of shortening the incubation time needed to achieve a requested mass loss. Globally, the most often used miniaturised specimen format is 5 × 10 × 30 (long.) mm, the so-called mini-blocks and sometimes "Braveries" named after Dr. Anthony Bravery, who suggested the format (Bravery 1978). A mini-block has only 60% of the length, and 28% of the volume of a standard specimen, i.e. 15 × 25 × 50 mm according to the EN 113-2 standard. Bravery (1978) also pointed out that besides the mass of the specimen its surface-to-volume ratio and the proportion of end grain influences the decay rate, which has later been confirmed by Brischke *et al*. (2020). Finally, Bravery (1978) gave preference to the mini-blocks, because they showed rapid decay, fit well into Petri dishes, and were at the time considered for inclusion in a European standard. Furthermore, toxic values of different wood preservatives obtained after six weeks incubation period compared well with those obtained after 12 weeks using the British standard specimens of 15 × 25 × 50 (long.) mm.

The method was subsequently used many times by various authors, but deviating incubation periods of eight weeks and twelve weeks were applied. Several authors pointed on the effect of incubation time and suggested incubation periods longer than six weeks to achieve more similar mass loss data compared with standard specimens and the standard incubation period of 16 weeks (e.g. Pohleven *et al*. 2000).

The aim of this study was to compare mass losses and the resulting durability classifications for mini-blocks and standard test specimens after different incubation times. This is intended to contribute to the ongoing discussion about the comparability of durability classes that have been determined under varying test conditions.

2. Materials and methods

Wood specimens of 15 × 25 × 50 (long.) mm were prepared according to the EN 113-2 standard and specimens of 5 × 10 × 30 (long.) mm according to Bravery (1978). The number of replicates for each wood species, specimen format, test fungus, and incubation time was $n = 10$. The wood species under test were Scots pine (*Pinus sylvestris*) sapwood and heartwood, Norway spruce (*Picea abies*), European larch (*Larix decidua*), Douglas fir (*Pseudotsuga menziesii*), Lebanon cedar (*Cedrus libani*), European beech (*Fagus sylvatica*), English oak (*Quercus robur*), black locust (*Robinia pseudoacacia*), and flooded gum (*Eucalyptus grandis*).

The specimens for each specimen format, test fungus, and incubation time were axially matched to diminish the effect of natural variability on the comparison of the different test conditions.

Laboratory decay resistance tests were conducted according to a modified EN 113-2 standard protocol as follows: All

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specimens were oven-dried at 103 ± 2 °C for 48 h, weighed to the nearest 0.001 g, and afterwards conditioned at 20 °C/65% RH until constant mass. After sterilisation in a steam pot for 20 min, the specimens were placed on fungal mycelium in Kolle flasks. To avoid direct contact between wood and overgrown malt agar (4%) stainless steel washers were placed in between.

Specimens according to the EN 113-2 standard: Two specimens of the same wood species were placed on fungal mycelium in one Kolle flask. The incubation times were eight and 16 weeks.

Mini-block specimens according to Bravery (1978): five specimens of the same species were placed on fungal mycelium in one Kolle flask. The incubation times were six, eight, ten, and 16 weeks.

The following test fungi were used: *Coniophora puteana* = (Schumach) P. Karsten, strain BAM Ebw. 15 and *Trametes versicolor* = (L.) Lloyd, strain CTB 863A. After incubation, the specimens were cleaned from adhering mycelium, weighed to the nearest 0.001 g, and mass loss (ML_F) was calculated according to:

$$ML_F = \frac{m_{0,i} - m_{0,F}}{m_{0,i}} \tag{1}$$

$m_{0,i}$ = oven-dry mass before incubation; $m_{0,F}$ = oven-dry mass after incubation.

The durability of the different wood species was classified according to the EN 350 standard (CEN 2016) based on x-values and on the median ML_F for the different specimen dimensions and incubation periods as follows:

- DC 1 (very durable): $ML_F \leq 5\%$; $x \leq 0.10$
- DC 2 (durable): $5\% < ML_F \leq 10\%$; $0.10 < x \leq 0.20$
- DC 3 (moderately durable): $10\% < ML_F \leq 15\%$; $0.20 < x \leq 0.45$
- DC 4 (less durable): $15\% < ML_F \leq 30\%$; $0.45 < x \leq 0.80$
- DC 5 (non durable): $ML_F > 30\%$; $x > 0.80$

For calculation of the x-value from the median ML_F, beech was used as a reference species for hardwoods, and Scots pine sapwood was used for softwoods (i.e. ML_F for timber test specimens / ML_F for reference timber test specimens).

Regression curves were established using the method of least squares based on linear fitting functions to evaluate the interrelationship between ML_F obtained by the two methods. All fitting lines were straight from the origin. The quality of fitting has been assessed based on the degree of determination R^2.

3. Results and discussion

Mass loss (ML_F) data are presented for all wood species, both test fungi, both specimen formats, and the different incubation periods as median values (Table 1). *T. versicolor* caused generally higher ML_F of mini-block specimens compared to EN 113-2 specimens at a given incubation period. In contrast, ML_F due to *C. puteana* was higher or similar in EN 113-2 specimens compared to mini-block specimens. The latter is somewhat surprising and contradicts findings from previous studies showing that smaller specimens showed higher ML_F (Brischke *et al*. 2020). However, the test was considered valid, since after 16 weeks of incubation the median

Table 1. Median percentage mass loss (ML_F), durability classes (DC) based on ML_F and on x-values referring to ML_F of mini-block and EN 113-2 standard specimens after different incubation periods.

	T. versicolor						*C. puteana*					
	EN 113-2		Mini-block				EN 113-2		Mini-block			
Wood species	8 w	16 w	6 w	8 w	10 w	16 w	8 w	16 w	6 w	8 w	10 w	16 w
Median percentage mass loss ML_F (%)												
European beech	17.1	30.2	20.5	35.5	41.1	56.6	20.9	26.8	41.9	40.7	21.4	40.9
English oak	6.3	13.7	11.1	18.0	21.1	36.4	1.2	1.7	−0.5	0.7	1.7	2.0
Black locust	1.3	4.0	1.5	2.8	3.5	10.8	0.4	0.6	−0.3	0.2	0.7	0.6
Flooded gum	6.1	15.4	7.8	15.0	20.3	35.1	1.9	5.4	−1.5	−0.3	0.6	0.3
Scots pine sw	9.3	20.4	8.0	10.4	15.4	31.0	18.8	23.3	15.5	18.8	20.0	28.4
Scots pine hw	8.9	13.3	7.4	12.1	16.7	37.4	18.3	24.9	24.8	31.8	19.4	30.3
Norway spruce	10.8	19.5	11.0	13.2	23.5	42.1	17.5	22.1	1.1	2.2	9.1	10.9
European larch	3.7	8.1	4.5	6.2	8.9	17.6	4.0	9.4	1.4	1.9	2.9	2.1
Douglas fir	1.5	3.8	1.0	1.0	3.1	9.1	11.4	20.9	−1.5	−1.2	0.3	−0.1
Lebanon cedar	1.9	6.0	1.9	4.5	7.0	13.9	9.2	31.2	1.7	1.2	3.8	4.3
Durability classes based on the median percentage mass loss (ML_F)												
English oak	**2**	**3**	**3**	**4**	**4**	**5**	1	1	1	1	1	1
Black locust	**1**	**1**	**1**	**1**	**1**	**3**	1	1	1	1	1	1
Flooded gum	**2**	**4**	**3**	**4**	**4**	**5**	1	2	1	1	1	1
Scots pine hw	2	3	2	3	4	5	**4**	**4**	**4**	**5**	**4**	**5**
Norway spruce	3	4	3	3	4	5	**4**	**4**	**1**	**1**	**2**	**3**
European larch	1	2	1	2	2	4	**1**	**2**	**1**	**1**	**1**	**1**
Douglas fir	1	1	1	1	1	2	**3**	**4**	**1**	**1**	**1**	**1**
Lebanon cedar	1	2	1	1	2	3	**2**	**5**	**1**	**1**	**1**	**1**
Durability classes based on *x*-values												
English oak	**3**	**4**	**4**	**4**	**4**	**4**	1	1	1	1	1	1
Black locust	**1**	**2**	**1**	**1**	**1**	**2**	1	1	1	1	1	1
Flooded gum	**3**	**4**	**3**	**3**	**4**	**4**	1	3	1	1	1	1
Scots pine hw	5	4	5	5	5	5	**5**	**5**	**5**	**5**	**5**	**5**
Norway spruce	5	5	5	5	5	5	**5**	**5**	**1**	**2**	**4**	**3**
European larch	3	3	4	4	4	4	**3**	**3**	**2**	**2**	**3**	**2**
Douglas fir	2	2	2	1	3	3	**4**	**5**	**1**	**1**	**1**	**1**
Lebanon cedar	3	3	3	3	4	3	**4**	**5**	**2**	**1**	**2**	**2**

Notes: Bold = Fungus with the highest ML_F under standard conditions, i.e. 16 weeks of incubation according to EN 113-2. sw = sapwood, hw = heartwood.

ML_F of European beech and Scots pine sapwood virulence control specimens exceeded the thresholds of minimum 20% and a median ML_F of at least 30% with one of the test fungi (EN 113-2).

Durability classes (DC) were assigned to the eight different test timbers on the basis of median ML_F according to the EN 113-2 standard, and on the basis of *x*-values referring to median ML_F data (Table 1). Per definition, the reference wood species European beech and Scots pine sapwood were considered not durable (DC 5). As expected, the white rot fungus *T. versicolor* generally caused higher ML_F on hardwoods, and the brown rot fungus *C. puteana* on softwoods. Hence, different test fungi were relevant for the durability classification as indicated through bold font in Table 1. Accordingly, based on the median ML_F and the standard conditions according to EN 113-2 the tested timbers were assigned to DCs as follows:

- Very durable (DC 1): Black locust
- Durable (DC 2): European larch
- Moderately durable (DC 3): English oak
- Less durable (DC 4): Flooded gum, Norway spruce, Scots pine heartwood, and Douglas fir
- Non durable (DC 5): Lebanon cedar

A durability classification based on median ML_F of mini-block test specimens after eight and ten weeks of incubation with *T. versicolor* led to remarkably similar results with those obtained under standard conditions. In contrast, DCs based on mini-block tests with *C. puteana* deviated severely from those based on standard tests.

The use of normalised ML_F data, i.e. in form of *x*-values (Table 1), for durability classification did not lead to more matches between mini-block specimens after different incubation times and standard conditions. Only Scots pine heartwood and English oak were assigned to the same DCs using ML_F data obtained in mini-block tests. None of the DCs of the other six wood species matched with those obtained under standard conditions.

It has previously been hypothesised that the variability in ML_F is increasing with decreasing specimen volume (Brischke *et al*. 2020). In general, this hypothesis is supported by the obtained data. The majority of data sets from mini-block tests showed higher coefficients of variation (COVs) compared to those obtained under standard conditions (data not shown). The relationship between median ML_F of mini-block specimens after different incubation times and standard EN 113-2 specimens after 16 weeks of incubation is given for *T. versicolor* and *C. puteana* in Figure 1. Hence, this is a method comparison, not a comparison between wood species. *T. versicolor* nearly had a 1:1 ML_F relation between mini-blocks after eight weeks and EN 113-2 specimens ($y = 0.9862x$) while the closest to a 1:1 ML_F for *C. puteana* was found for mini-blocks after six and 16 weeks and EN 113-2 specimens ($y = 0.821x$). The best goodness of fit for *T. versicolor* was for mini-blocks after 16 weeks and EN 113-2 specimens ($R^2 = 0.9674$) while for *C. puteana* it was found for mini-blocks after six weeks and EN 113-2 specimens ($R^2 = 0.9545$). Hence, we saw that the best overlap between the methods with regard to ML_F strongly depended on the fungus. Similar relationships became evident between *x*-values and median ML_F of mini-block specimens after different incubation times and standard EN 113-2 specimens after 16 weeks of incubation (data not shown).

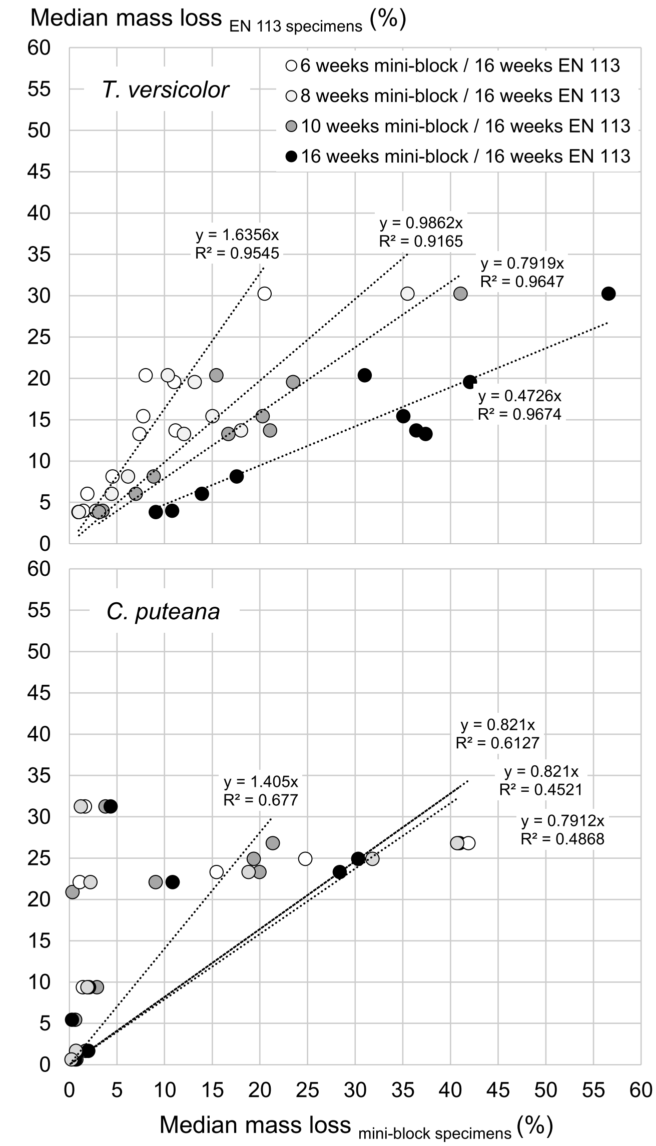

Figure 1. Relationship between median mass (ML_F) loss by *T. versicolor* and *C. puteana* of mini-block specimens after different incubation times and standard EN 113-2 specimens after 16 weeks of incubation. Each dot represents the median of ten replicate specimens per wood species.

4. Conclusions

The following was concluded from this comparative study:

- Mini-block tests do not produce similar results to the European standard test, i.e. EN 113-2, at either six, eight, ten or 16 weeks. This includes both durability classes based on the median percentage mass loss and durability classes based on *x*-values.
- The data based on incubation with *T. versicolor* gave a more consistent picture when comparing the two methods than incubation with *C. puteana*.

- The mini-block test has value as a fast initial screening test, e.g. for new wood protection systems, but should be avoided for durability classification because it can cause misleading results.

The main conclusion from this study is that the mini-block test is not recommended as an alternative to standard tests for durability classification.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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