FACTORS AFFECTING MOULD GROWTH ON KILN DRIED WOOD

Hannu Viitanen,
hannu.viitanen@vtt.fi
VTT Building and Transport,
P.O. Box 1806, Fin 02044 VTT,
Finland

ABSTRACT

Several studies on the factors known to affect the development of mould fungi on wood has been carried out at VTT. It was shown that mould growth is significantly more rapid and vigorous on the original kiln dried wood surface than on the resawn surface. Spruce sapwood proved to be slightly less suscepectible to mould than pine sapwood. The amount of low-molecular nutrients in wood affected the initiation and rate of fungal growth. Moreover, relative humidity (RH), temperature, fluctuation of humidity and exposure time contributed to mould growth. Regression and other mathematical models for simulation of growth of mould fungi on wood were generated based on the experimental work. Effective solutions or remedies should be developed in order to prevent the problem. If wood is coated, fungicides in all coating layers improve durability against mould and blue-stain fungi as was proved in one ot the studies.

1. INTRODUCTION

Kiln drying is an essential process in manufacturing forest products. Moisture content of wood is a basic critical factor for the use of wooden products and for the durability of wood. The critical limit for mould growth on wood is around RH 75 - 80 % (constant ambient air humidity), but mostly higher relative humidity, around 90 % (wood moisture content around 20 %) is required for growth. The actual limit depends on temperature, exposure time, material and fungal species (Wang 1994, Viitanen 1996, Ritschkoff and Viitanen 2000). The durability of wood material is also dependent on the quality of wood, e.g. the amount and quality of primary metabolites, storage compounds and the extractives of wood. The amount of primary metabolites such as sugars, lipids, peptides and starch varies in pine and spruce sapwood (Fengel and Wegener 1989, Theander et al. 1993, Saranpää et al. 1995). The extractives are waxes, fats, free fatty acids and alcohols, steroids, higher carbon compounds and resins. During kiln drying, the content, composition and distribution of soluble components and extractives can be changed (King et al. 1976, Terziev 1996). This affects mould resistance of wood during the use of wooden products.

This paper is based on the litterature survey and on the studies performed at VTT. Several factors known to have effect on the development of mould fungi on wood: relative humidity (RH), temperature, fluctuation of humidity, exposure time and surface quality were studied (Viitanen and Ritschkoff 1992, Viitanen and Bjurman 1997, Viitanen 1996). The test material was kiln dried pine and spruce sawood. Also a study of the effect of drying scedules on the mould growth was performed (Tarvainen and Viitanen 2001). The effect of fungicides in a paint film on pine and spruce was studied (Viitanen and Ahola 1999).

The mould growth was analysed under constant or fluctuating humidity and temperature conditions during different exposure periods in climatic chambers. Regression and mathematical models were generated on the basis of the experimental work (Viitanen 1996, Hukka and Viitanen 1999, Viitanen et al. 2000). These models describe the development of mould or decay in pine and spruce sapwood in relation to humidity, temperature and the duration of exposure

2. CRITICAL CONDITIONS FOR THE GROWTH OF MOULD FUNGI

Common discolouring fungi on wood are e.g. *Aspergillus*, *Cladospoirum*, *Penicillium* and *Trichoderma* -fungi. Typical blue stain fungus on wood surface is *Aureobasidium pullulans*, which also causes graying of wood in exterior conditions. The growth of mould fungi was evaluated using the mould index (Table 1)

Table 1. Mould growth index in asseements and modelling

Index	Growth rate	
0	No growth	Spores not activated
1	Some growth detected only with microscopy	Initial stages of hyphae growth
2	Moderate growth detected with microscopy	Coverage more than 10 %
3	Some growth detected visually	New spores produced
4	Clear visually detected growth	Coverage more than 10 %
5	Plenty of visually detected growth	Coverage more than 50 %
6	Very heavy and tight growth	Coverage around 100 %

Ambient relative humidity (RH) above 75 - 80 **%** is a critical limit for the development of mould fungi on the surface of wood and other wood based building materials (Adan 1994, Grant et. al 1953, Viitanen 1997). The temperature range required for mould growth is mostly between 0 and +50 °C. The mould fungi grow rapidly at higher humidity (RH > 95 % at temperatures between 20 and 40 °C). At low temperatures (below 5 °C), the growth of mould fungi is slower even at high RH. Some fungi species can grow at low temperatures, around 0 and - 5 °C (Land et al 1985) and some species prefer high temperatures, around 45 - 50 °C (Henningsson 1980). In Figure 1, an overview diagram on the critical temperature and humidity limits for risk of mould growth on wood is shown (Hukka and Viitanen 1999).

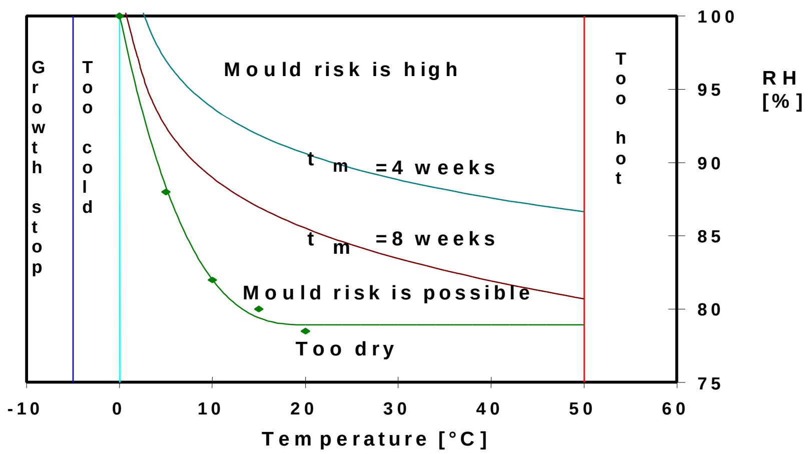

Figure 1. An overview model on the critical temperature and humidity limits for the risk of mould growth (Hukka and Viitanen 1999).

3. MODELLING THE GROWTH OF MOULD FUNGI

A mathematical model for simulation of mould growth on wood material presented by Hukka and Viitanen (1999) and Viitanen et al (2000) was based on previous regression models (Viitanen 1997). The model is based on the mould index used in the experiments. The model consists of differential equations describing mould growth in different conditions including the effect of exposure time, temperature, relative humidity and dry periods. Development of mould growth on wood exposed to arbitrary constant or fluctuating temperature and humidity conditions including dry periods can be calculated by means of the model (Figures 2 and 3).

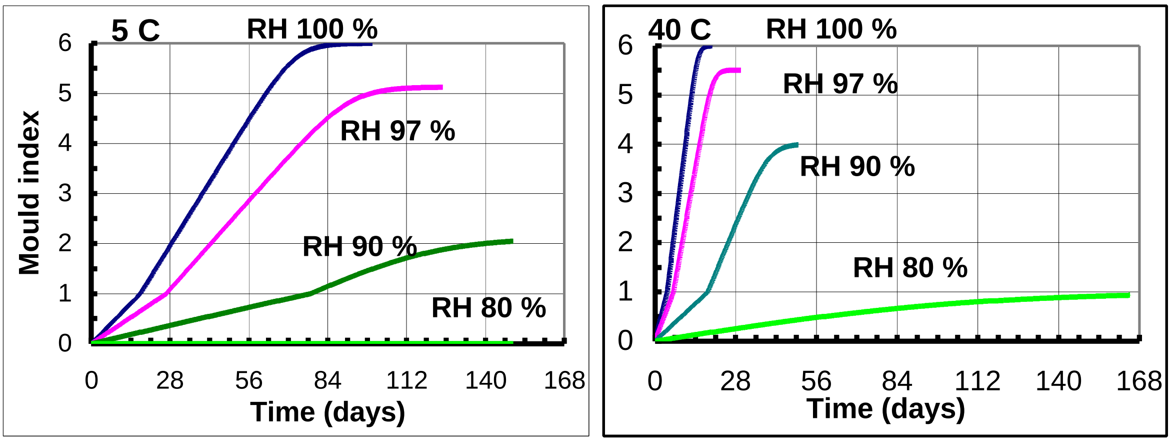

Figure 2. Prediction of mould development on pine sapwood (resawn surface) at prevalent ambient temperatures (5 and 40 °C) and prevalent ambient relative humidity as a function of exposure time using the mould index (Viitanen et al 2000).

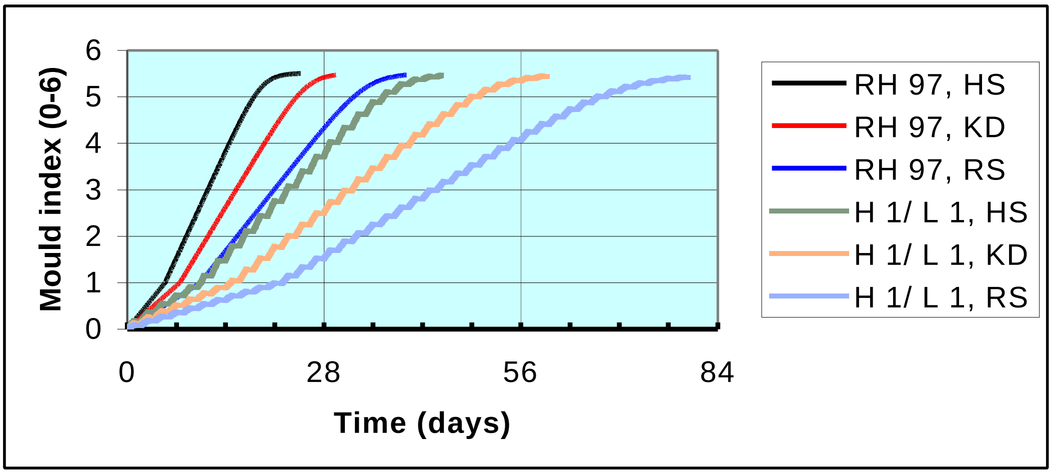

Figure 3. Prediction of mould development on pine sapwood at constant RH 97 % and at fluctuated conditions. The fluctuating conditions are: RH 97 % (high humidity H) 1 day and RH 65 % (low himidity L) 1 day at 20 °C. Different wood type were used: HS is a wood, where mould growth is very active (high nutrient content), KD is a kiln dried surface and RS is a resawn surface. The graph is based on the model presented by Viitanen et al (2000).

At fluctuating humidity conditions, the mould growth is retarded. The retardation depends on the humidity and exposure periods of high and low humidity (Figure 3), and moreover, nutrient content affects mould growth.

4. THE EFFECT OF WOOD DRYING ON THE MOULD GROWTH

The ambient air humidity, moisture content of wood, temperature and exposure time are the primary factors for mould growth. The mould growth intensity, however, varies depending on quality of material. According to Block (1953), the materials that are very hygroscopic and have sufficient nutrients are the most susceptible to mould. However, nutrient content level has no significant effect on the ultimate humidity limit for mould growth.

In wood materials, different factors are involved: amount and quality of sapwood and heartwood, surface quality of wood, nutrient content, permeability of the wood and surface treatments (Terziev 1996, Theander et al 1993, Terziev and Boutelje 1998, Viitanen 1996, Viitanen and Ahola 1999, Bjurman et al 1991) It has been shown that especially the nutrient content of wood surface affect the mould growth.

According to the analyses of soluble sugars or low molecular weight sugars (Mohammod and Alén 1994, in Viitanen 1996), the sugar content of kiln-dried surfaces in pine and spruce sapwood was higher than that of resawn surface (Table 2). The difference on nutrient content reflected in the mould growth (Figure 3). Terziev et al (1996) and Terziev and Boultelje 1998) have found relation between mould growth and sugar content due to drying method (Figures 4 and 5). The low molecular weight (LMW) sugar and nitrogen content of wood has a great impact on the susceptibility of wood to fungal attack.

Table 2. Content of soluble sugars (LMW sugars), expressed in percentages of wood dry weight, on original kiln dried surface and resawn surface (7 mm inside) of pine and spruce sapwood (Mohammod and Alén 1994, inViitanen 1996).

LMW sugar content (% of dry weight)	Pine	Spruce
Original kiln dried surface	0.12 ... 0.21	0.14 ... 0.16
Resawn surface (7 mm)	0.03 ... 0.06	0.04 ... 0.07

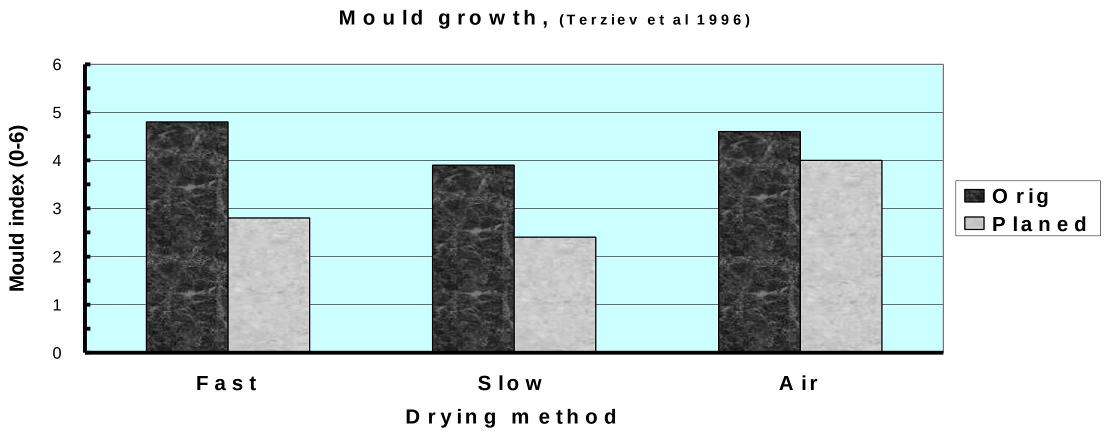

Figure 4. Mould growth on the pine sapwood after drying on original and planed surface (After Terziev et al 1996).

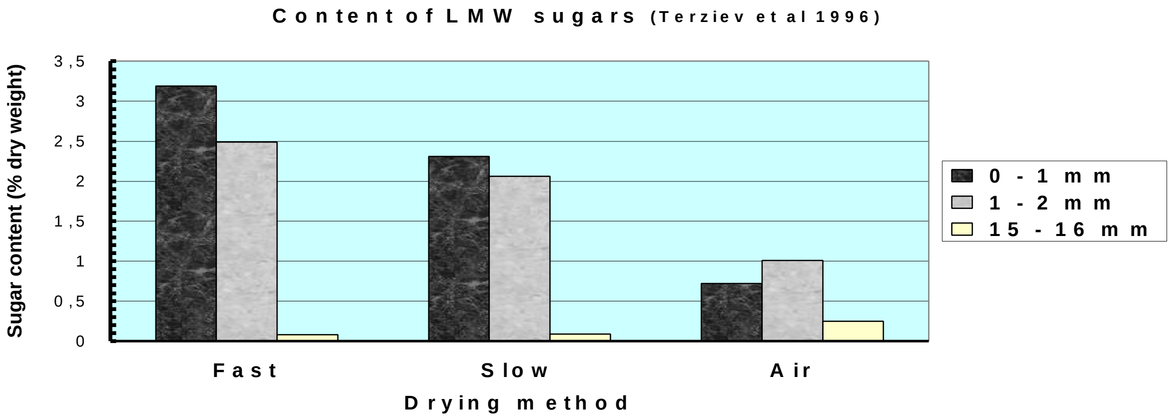

Figure 5. LMW -sugars on the pine sapwood after the drying methods on top surface, in the depth of 1 - 2 mm and inside wood (15 - 16 mm) (After Terziev et al 1996).

The soluble sugar content of living trees varies, the sugar content of the outer sapwood is higher during autumn and winter than in spring and summer, and the composition of sugar may be different (Terziev 1996, Saranpää and Höll 1989). The seasonal fluctuations are more significant to the sugar content than the effect of the growth conditions.

The effect of kiln dried scedule on mould growth on dried wood at humidity exposure was analysed at VTT. The faster kiln drying programs with elevated temperature seemed to produce more sensitive material to mould growth than the slower scedules or kiln drying at high temperature above 100 °C (Figure 6). The mould growth on original surface of dried wood was faster than that on the surface sawn from 10 mm inside from the original kiln dried surface. The nutrient content of wood affects also the time required for the initial stages of mould growth at different humidities and temperatures. On the surface of wood, which were under stickers during kiln drying, very slow and low mould growth was found.

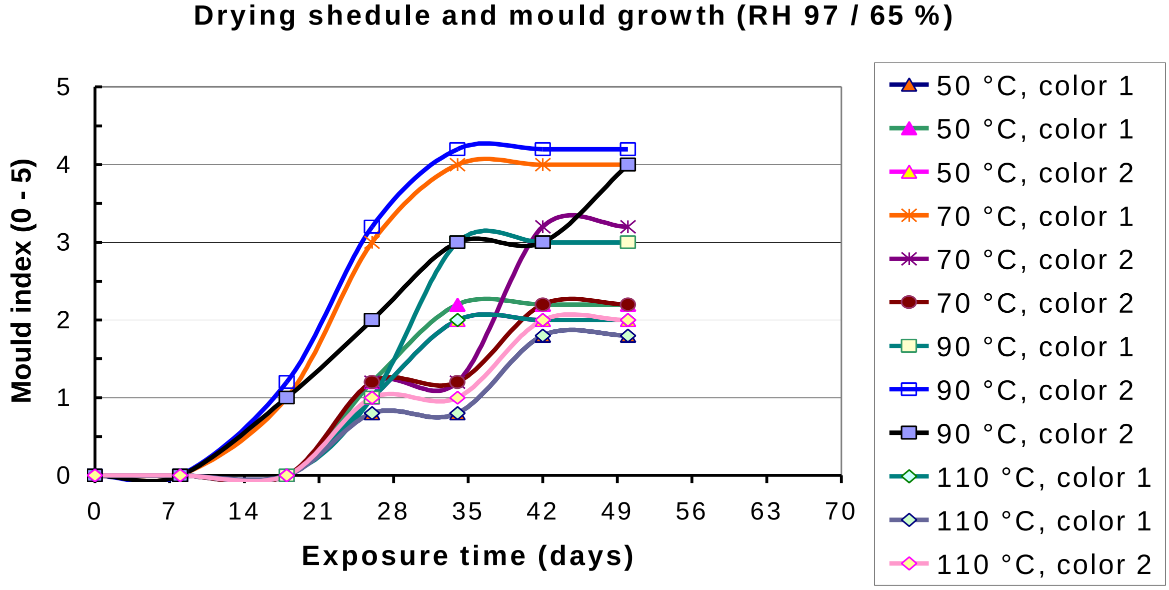

Figure 6. Effect of drying scedule (temperature) and color change on the mould growth on kiln dried wood under fluctuating exposure at RH 97 % (1 day) and RH 65 % (1 day) (Viitanen and Tarvainen 2001). The material is from discoloration research by Repola et al. (2001).

The effect of surface treatments on the mould growth of several wood materials was studied by Viitanen and Ahola (1999).Wood substrate and the location of a fungicide in the treatment system affected mould growth on the topcoat (Figure 7). Mould growth was most vigorous in the samples from the original surfaces of pine sapwood. Also the original spruce surface was more susceptible to mould growth than the resawn samples taken at 10 mm below the original surface.

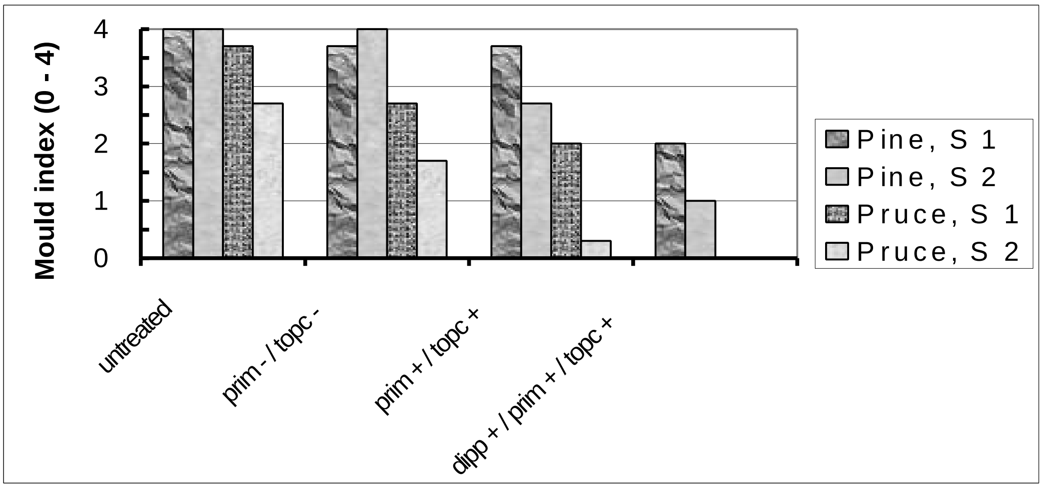

Figure 7. Mould growth on pine and spruce sapwood after 26 weeks incubation at RH 100 % and 20 °C. S1 is original kiln dried surface, S2 resawn surface (sawn 10 mm from the original kiln dried surface). Several treatments were studied: untreated control, acrylate primer and topcoat without fungicides (Prim-/topc-), acrylate primer and topcoat with fungicides (prim + / topc +) and treatment with dipping in preservative, primer and topcoat with fungicide (Viitanen and Ahola 1999). Mould index: 1 is slight visual growth, 4 is very heavy growth (different mould index is used).

The variation of wood quality and properties affect mould growth in service (Figure 8). The difference between sapwood and heartwood and also between parts which were under stickers and open during kiln drying can be seen.

Figure 8. Mould and bluestain on wooden facade. Mould attack is varied on the surface.

REFERENCES

Bjurman, J., Jönssön, S. Herder, C and Sjöblom, E. 1991: Misfärgande svampars angrepp på målade ytor. Färg och lack Scandinavia 9, 185-190.

Block, S.S. 1953. Humidity requirements for mould growth. Applied Microbiology 1(6):287--293.

Fengel, D. and Wegener, G. 1989. Wood chemistry, ultrastructure, reactions. Walter de Gruyter. Berlin, New York. 613 p.

Grant, C., Hunter,C.A., Flannigan, B and Bravery, A.F. 1989. The moisture requirements of moulds isolated from domestic dwellings. Internat. Biodet. 25:259-284.

Henningsson, B. 1980. Thermotolerant moulds on timber during kiln drying. Uppsala. Swed. Univ. Agric. Sci., Dep. For. Prod.. Res. Note No 96.

Hukka, A. and Viitanen, H. 1999. A mathematical model of mould growth on wooden material. Wood Science and Technology 33(6)475-485.

King, B, Oxley, T. and Long, K.D. 1976. Some biological effects of redistribution of soluble nutrients during drying of wood. Mat und Org. 3: 263-276.

Land, C.J., Banhidi, Z.G. and Albertsson, A-C. 1985. Surface discolouring and blue staining by cold-tolerant filamentous fungi on outdoor softwood in Sweden. Mat. und Org. 20(2): 133-156.

Mohammod, A. & Alén, R. 1994. Wood analysis report. Part 1. University of Jyväskylä. Department of Chemistry. Unpublished. (In Viitanen 1996)

Repola, J. Saranpää, P. and Tarvainen, V. 2001. Discoloration of spruce and pine timber during drying. Finnish Forest Research Institute, Research Notes 804 (in Finnish).

Ritschkoff, A. and Viitanen, H. 2000. The response of building materials to the mould exposure at different humidity and temperature conditions. In: HB 2000. SIY, Indoor Air Information Oy, Finland. Vol 3, 335-340.

Saranpää, P. and Höll, W. 1989. Soluble carbohydrates of *Pinus silvestris* L. sapwood and heartwood. Trees 3: 138-143.

Saranpää, P., Laakso, T., and Voipio, R. 1995. Changes in the amount and composition of sapwood extractives *Pinus silvestris* L. During wet storage. In: Abstracts of the XX IUFRO World Congress, Tampere. IAWA J 16:16.

Terziev. N. 1996. Low-Molecular Weight Sugars and Nitrogenous Compounds in Scots Pine. Acta Universitatis Agriculturae Sueciae, Silvestria 6. SLU, Uppsala, Doctoral Thesis. p 7-32.

Terziev, N, Bjurman, J. and Boutelje, J. 1996. Effect of planing on mould susceptibility of kiln- and air-dried Scots pine (*Pinus silvestris* L.) lumber. Mat. und Org. 30 (2): 95-103.

Terziev, N. and Boultelje, J. 1998. Effect of felling time and kiln-drying on color and susceptibility of wood to mould and fungal stain during an above-ground filed test. Wood Science and Technology 30(4) pp 360-367.

Theander, O., Bjurman, J. and Boutelje, J. 1993. Increase in the content of low-molecular carbohydrates at lumber surfaces during drying and correlation with nitrogen content, yellowing and mould growth. Wood Sci. and Technol. 27:381-389.

Viitanen, H. & Bjurman, J. 1995. Mould growth on wood under fluctuating humidity conditions. Mat. und Org. 29(1): 27-46.

Viitanen, H. 1996. Factors affecting the development of mould and brown rot decay in wooden material and wooden structures. Effect of humidity, temperature and exposure time. Disseratation. Uppsala. The Swedish University of Agricultural Sciences, Department of Forest Products. Thesis. 58 p.

Viitanen, H. 1997. Modelling the time factor in the development of mould fungi in wood - the effect of critical humidity and temperature conditions. Holzforschung 51 (1): 6-14.

Viitanen, H. and Ahola, P. 1999. La formazione della muffa su pitture a basso VOC. Mould growth on Low VOC Paints. Pitture e Vernici Europe - *Coatings*. 75. 33 - 42.

Viitanen, H, Hanhijärvi, A, Hukka A and Koskela, K. 2000. Modelling mould growth and decay damages. In: HB 2000. SIY, Indoor Air Information Oy, Finland. Vol 3, 341-346.

Viitanen, H. & Ritschkoff, A. 1991. Mould growth in pine and spruce sapwood in relation to air humidity and temperature. Uppsala. The Swedish University of Agricultural Scienses, Department of Forest Products. Report no 221. 40 p + app 9 p.

Viitanen, H. and Tarvainen, V. 2001. The effect of drying scedule on the mould growth on kiln-dried wood (manuscript).

Wang, Q. 1992. Wood-based boards - Response to attack by mould and stain fungi. Dissertation. Swed. Univ. Agric. Sci., Dep. For. Prod., Uppsala. 25 p.