FUNGI ON FUEL WOOD CHIPS IN A HOME

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ABSTRACT

Softwood tops and branch fuel chips with high moisture contents were subject to biological heating in storage. This was due primarily to infestations of mesophilic (ca. 5×10^4 propagules/g dry weight wood) and thermophilic (ca. 1.6×10^6 propagules/g dry weight wood) fungi. Loading chips into a home fuel-chip furnace resulted in the distribution of fungal propagules throughout the basement and upper floors. Many of the species isolated are human allergens and pathogens.

The results suggest that dry storage of chips (that is, environmental conditions which do not allow fungal growth) is important to avoid propagation of allergenic and pathogenic fungi. They also suggest that chips which have been subject to biological heating should not be transported into a home without precautions. Individuals handling chips should wear dust masks, and take other measures to avoid prolonged contact and contamination of living quarters.

Keywords: Wood chips, chip storage, fuel chips, pathogens, allergenic fungi.

INTRODUCTION

Wood chips used for fuel in domestic and other furnaces can be manufactured from logging residue. Chip production can create another marketable product from the forest, and the use of this product has convenience, safety, and economic advantages (Beijbom and Nilson 1979; Schneider and Short 1981).

Fungal biodeterioration of pulp chips has been of interest to the pulp and paper industry because poor storage can result in degradation with subsequent loss of yield and also poorer pulp quality (Shields and Unligil 1968). Some of the fungi involved in this biodeterioration can, under certain circumstances, be allergenic or pathogenic (Emmons et al. 1970). Pathogenic fungi on chips used in buildings where people spend much of their time, such as homes, are of greater concern than those on pulp chips (Thornqvist and Lundstrom 1980).

This study reports on the fungi associated with wood chips used in an experimental wood-chip furnace in a private home and the dissemination of these fungi through the house after loading the furnace, as well as a consideration of the potential health hazards.

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MATERIALS AND METHODS

Site and description of fuel chips

Sampling was done at a private two-storey (with basement), hot-air-heated home near Fredericton, New Brunswick. Details of the heating installation were reported by Schneider and Short (1981).

Fuel chips were from logging residue consisting of non-merchantable tops and branches from a softwood (*Abies balsamea, Picea* spp., *Pinus strobus,* and *Pinus resinosa*) clearcut. Harvesting of the merchantable wood occurred in the fall, winter, and spring of 1978–79. The residue remained on the ground until April 1980, when it was piled in windrows and chipped within a few days. The fuel chips (approximately 0.5 cm long) were blown directly into trailers and transported to a barn near the house under study and stored in two bins. The larger bin contained approximately 60 m^3 of chips (12 tons at 45% MC) and was loaded to a depth of 2.4 m. The smaller bin contained 24 m^3 of chips (4.5 tons at 45% MC) and was loaded to a depth of 1.1 m. The bins had plastic liners to prevent wetting from below. Rain before and during the chipping operation resulted in initial chip moisture contents averaging 45% with a range of 20% to 70%.

During the heating season, chips from the storage bins were loaded by hand into polymer bags holding 16 kg of chips. Each day some bags containing chips were weighed and the contents dumped into the stoker hopper in the house basement from which an auger fed them into the furnace.

Temperature monitoring

Temperature of the chips in the storage bins was checked periodically (twice weekly during the summer, infrequently during the winter) with a grain thermometer. When heating above ambient was observed, a grain drier was inserted into the pile until temperatures returned to ambient.

Mycological testing

In November 1980, seven months after the chips were put into storage bins, two types of tests were used to determine fungi associated with the wood chips and their distribution throughout the house.

1) Fungi on chips: Duplicate samples (ca. 40 g each) were taken in sterile plastic bags from four areas of the pile in the large bin as detailed in Table 1 for the first four samples. Individual chips from each sample were plated on each of 12 plates of Sabouraud Dextrose Agar (SDA), Malt Extract Agar (MA), and Cellulose Agar (Cel) (Park 1973), and incubated for 1 week at 23 C. Chips were also plated as described above on YpSs Agar (Cooney and Emerson 1964) and incubated for 24 h at 42 C. Fungal colonies that developed on the various media were transferred for identification.

   Approximately 1 g of chips was placed aseptically in 1 litre sterile distilled water in an Erlenmeyer flask, which was stoppered and vigorously agitated for 1 min. One-ml aliquots were plated on each of 6 plates of MA using the spread plate method and incubated for 1 week at 23 C. Additional 1-ml aliquots were plated as above on YpSs and incubated for 12 to 18 h at 42 C. Colonies were counted, recorded, and transferred for identification. Wood chips were

TABLE 1. *Numbers of fungal propagules on wood chips in storage.*

Sample	Moisture content %[1]	Counts[2]/g dry wt wood YpSs/42°C	MA/23°C	Comments
1	17.8	25.4	12.8	Top of pile
2	26.1	139.8	32.5	0.7 m down
3	54.8	207.3	56.4	0.7 m down
4	22.6	266.6	95.6	0.5 m down, heating noted
5	13.3	0	7.0	Hardwood chips from different location

[1] Oven-dry basis.
[2] ×1,000.

filtered on Whatman #1 filter paper and dried at 100 C. Numbers of fungal colonies per g dry weight wood were calculated.

The latter procedure was also applied for 5 samples of chips made from dried hardwood. These were obtained from another wood-chip furnace installation near Fredericton (Schneider and Short 1981). These chips had been produced from yard-dried and stored hardwood roundwood.

2) Sedimentation: Studies were made of the air spora in the areas where the chips were handled and stored as well as in the house. Plates of MA and YpSs were exposed in various locations as detailed in Table 2.

RESULTS

Temperature monitoring

Chip heating in the larger bin occurred within hours of filling. A temperature of 60 C occurred at a depth of 0.7 m at any location except the edges. Temperatures decreased below and above this depth. The grain drier reduced the temperature to 50 C in 4 h and to ambient (20 C) in 24 h in an area of 2-m radius around the drier. Heating (47 C) occurred again after 4 months. Heating (54 C)

TABLE 2. *Sedimentation of fungal propagules on media in different locations.*

Location	Sampling conditions	$\bar{x}$ count/30 s[3] YpSs/42°C	MA/23°C	Dominant fungi
1. Over large storage bin[1]	After stirring (4)[2]	1,420.0	510.0	*A. fumigatus*, *T. viride*
2.	24 h after stirring (4)	153.2	58.0	
3. Over small bin[1]	After stirring (4)	1,105.0	437.6	
4.	24 h after stirring (4)	83.3	16.6	
5. Basement furnace room	After loading chips (3)	125.3	85.0	*A. fumigatus*, *T. viride*, *P.* sp.
6.	20 min after loading (3)	30.3	46.3	
7.	1.5 h after loading (3)	28.1	40.0	
8.	24 h after loading (3)	23.6	27.0	
9. First floor	20 min after loading (3)	26.7	7.6	
10.	1.5 h after loading (3)	5.7	5.0	
11.	24 h after loading (3)	1.7	2.7	
12. Second floor	20 min after loading (3)	16.7	7.0	
13.	1.5 h after loading (3)	5.3	7.7	
14.	24 h after loading (3)	2.0	0.7	

[1] Plates exposed for 15 s, values doubled.
[2] Number of plates exposed for each medium.
[3] Sampling for YpSs and MA done on different days.

TABLE 3. *Fungi isolated by all methods.*

Species	Isolated from		Media/incubation Temperature (°C)			
	air	chips	YpSs/42	MA/23	Cel/23	SDA/2
1. *Aspergillus fumigatus* Fresenius	X	X	X			X
2. *A. niger* Van Tieghem		X		X		
3. *Aureobasidium pullulans* (DeBary) Arnaud		X		X		
4. *Cladosporium cladosporioides* (Fresen.) de Vries	X	X		X		
5. *Mucor pusillus* Lindt	X	X	X	X	X	X
6. *Penicillium cyclopium* Westling	X			X		
7. *P. purpurrescens* (Sopp.) Raper and Thom	X	X		X		
8. *P. raistrickii* Smith	X	X		X		
9. *Trichoderma viride* Pers.	X	X		X	X	X

at a depth of 0.7 m was also observed in the smaller bin after filling. It was cooled with the grain drier, but 5 days later heating (47 C) was again observed. Heating (32 C) was also observed after 4 months. Slight temperature increases above ambient were noted at various times between filling and after 4 months. No heating was observed after that time to the present sampling period (November 1980).

Mycological

The numbers of fungi on the wood chips are reported in Table 1. Counts from the samples at the top of the pile were significantly ($P = 0.001$) lower than those from where heating had previously been noted. Numbers of thermophilic fungi were significantly ($P = 0.001$) higher than mesophilic fungi. Counts from the hardwood chips obtained at the other location showed no thermophilic fungi and counts of mesophilic fungi similar to those from the chips at the top of the pile (sample 1).

Results of the sedimentation studies are reported in Table 2. Air spora increased dramatically over the storage bins when the chips were stirred (to simulate loading of the bags for transfer to the house). Twenty-four h after loading chips into the furnace from the basement, air spora in the basement were significantly ($P = 0.001$) higher than those in the upper floors of the house.

After loading the chips, air spora in the basement increased significantly ($P = 0.001$), as did the air spora in the two upper floors. There was a gradual return to the basal levels after loading in all locations. Dominant species from the air spora were identical to those isolated from wood chips.

Species of fungi found by all methods are listed in Table 3. Most were isolated in the air as well as directly from the chips.

DISCUSSION

Previous studies on piles of pulp wood chips had reported heating caused by fungi, which led to combustion (Shields and Unligil 1968; Scheffer 1969). The present study suggests that heating in wet softwood fuel chips poses an additional problem, the buildup of fungi on the chips. Wood that contains sufficient moisture will be colonized by fungi. Under normal summer conditions, the fungi found on wood would be growing at temperatures between 10 and 25 C, and hence would be mesophilic in character. Under the conditions found in a pile of wood chips,

the heat of respiration of this mesophilic mycoflora is conserved to some extent and consequently the temperature of the substrate increases. The mesophilic mycoflora is then unable to compete, allowing the dominance of thermophilic and facultative thermophilic saprophytic fungi. Many of these organisms are mammalian pathogens (either primary or more commonly, secondary) at least partially because of their ability to grow at 37 C.

The majority of the fungi isolated in this study are molds known to be pathogenic to humans (Emmons et al. 1970). Virtually all strains of these molds are pathogenic when the spores are in sufficient concentration in the presence of a susceptible individual. *Aspergillus fumigatus* may invade numerous organs in the body, and along with *A. niger* may cause "fungus balls to form in the bronchial tubes" (Emmons et al. 1970). Danger exists for anyone exposed to large quantities of spores, but more so if the person is already suffering from something else such as diabetes, pulmonary disease, or using corticosteroid medication. Although some of the fungi found in this study are found in the air under all circumstances, the number of propagules is generally very low.

Fungi, particularly *A. fumigatus,* may cause allergic reactions in sensitized persons. The second author of this paper has had allergic reactions after working with the fuel. This has been controlled by using a dust mask and washing exposed skin right after handling chips. Coveralls that are removed before entering the house are also used.

Fungi similar to those reported in this study were found in home-heating fuel chips in Sweden (Thornqvist and Lundstrom 1980), and this suggests the possible ubiquitousness of these dangerous human pathogens in wood chips used as fuel.

The numbers of fungal propagules in the air in this study were much higher than those reported by Thornqvist and Lundstrom (1980). Their method included the use of malic acid-MA, which is used for the selective isolation of Basidiomycetes (Booth 1971). Consequently, the resulting numbers and diversity of mold fungi would be lower than on MA. The use of YpSs medium has been reported as selective of thermophilic fungi (Cooney and Emerson 1964) and would also yield higher numbers of fungi than malic acid-MA. Numbers of fungi in the air in the upper floors and basement of the house in the present study (24 h after loading) were higher than those found in the Swedish study in houses with oil or roundwood furnaces. However, it is difficult to compare these results directly because of the problems with their methods noted above.

The data show that moisture content of the wood chips at the time of sampling does not necessarily relate to the number of propagules in the chips. The data reported for samples 1 to 4 in Table 1 show that no direct relationship existed in these cases with respect to moisture content and numbers of fungal propagules. The storage history is more important. For example, sample 4 (where heating had been noted) had significantly ($P = 0.001$) higher numbers of fungal propagules (both mesophiles and thermophiles) than sample 2, although the moisture content of sample 4 was somewhat lower. High moisture content of the chips at any time in storage would allow fungal development.

The data also illustrate the importance of determining the fungi on the wood chips by some washing method. Propagules released from the chips into the air upon handling may be inversely related to chip moisture content. The air over wet chips in storage may show low spore counts. When these chips are dried,

proportionately more spores may be released into the air. Hence sedimentation studies alone may not accurately assess the potential hazard.

Trichoderma viride was a significant member of the mesophilic mycoflora. This fungus is capable of degrading cellulose. *Aureobasidium pullulans* is a noted staining fungus. The presence of these fungi have implications for the construction of storage containers of these chips.

This study provides little data on the mycoflora of different types of wood chips and of wood chips under different storage regimes. This requires further study now underway in this laboratory. However, the data obtained from the hardwood chips illustrate that wood chips prepared from dried roundwood and stored under dry conditions had a much lower infestation of fungi than the wet softwood chips, and no detectable thermophiles. Thus the presence of these thermophiles cannot be said to be normal. In addition, Thornqvist and Lundstrom (1980) (see Izlar 1981) reported that hardwood chips were more likely to be subject to fungal infestations of the type noted in this paper as opposed to softwood chips. The results of this study demonstrate that this is erroneous. The data also call attention to the need to take precautions such as wearing a suitable mask (mold spores are ca. 4 μm diameter) when handling fuel chips as well as the other sanitary recommendations of Thornqvist and Lundstrom (1980).

REFERENCES

BEIJBOM, L., AND N. NILSON. 1979. Chip heating on farms and single family homes. Silvconsult Ltd. 230 50 Bjarred, Sweden. (Swedish, edited English translation by Joakim Hermelin and M. H Schneider, University of New Brunswick, Fredericton, N.B. E3B 5A3.)

BOOTH, C. 1971. Fungal culture media. *In* C. Booth, ed. Methods in microbiology, v. 4. Academic Press, New York.

COONEY, D. G., AND R. EMERSON. 1964. Thermophilic fungi. W. H. Freeman, San Francisco.

EMMONS, C. W., C. H. BINFORD, AND J. P. UTZ. 1970. Medical mycology, 2nd ed. Lea and Febiger, Philadelphia.

IZLAR, B. 1981. Factors affecting the occurrence of fungi in fuel chips for domestic consumption. American Pulpwood Association, Technical Paper 81-P-9.

PARK, D. 1973. A modified medium for isolation and enumeration of cellulose-decomposing fungi. Trans. Br. Mycol. Soc. 60:148.

SCHEFFER, T. C. 1969. Protecting stored logs and pulpwood in North America. Mater. Org. 4(3):169–199.

SCHNEIDER, M. H., AND C. A. SHORT. 1981. Small-scale wood-chip heating project in New Brunswick. Wood Fiber (in press).

SHIELDS, J. K., AND H. H. UNLIGIL. 1968. Deterioration of softwood chips owing to outside storage in New Brunswick. Pulp Pap. Mag. Can. Nov.:62–67.

THORNQVIST, T., AND H. LUNDSTROM. 1980. Factors affecting the occurrence of fungi in fuel chips for domestic consumption. Skogsenergi Project Report No. 18. Garpenberg, Sweden. (Swedish, English summary. English translation available from Institute of Man and Resources, Charlottetown, Prince Edward Island.)