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How Anaerobic Storage Affects Quality of Douglas-Fir Pulpwood Chips

Abstract: Douglas-fir wood chips were stored under water or in an atmosphere of 95% nitrogen plus 5% carbon dioxide for periods of up to 26 months to determine the effects of anaerobic storage on pulp yields and quality. Storage time and medium did not significantly reduce the specific gravities of stored wood chips or the yields of kraft pulps from these chips, and the properties of the pulp handsheets remained essentially constant throughout the storage period.

Keywords: Storage · Wood chips · Density · Kraft pulp · • Anaerobic storage* · Decay · Semi-anaerobic*

Until 1967 little or no wood losses were reported from pulpwood stored outdoors on the West Coast in the form of chips (I); severe wood losses in the warmer areas of the piles were noted in the older chip piles. Losses in wood substance during storage were recognized as being more common and serious in these western piles creating a need for some means to control these losses.

Because studies of logs stored in ponds and under water sprays have indicated that wood deterioration is practically nonexistent under anaerobic or micro-aerophilic storage conditions, some method which would exclude oxygen from western storage piles has been seriously considered. However, before this type of control is field tested, it would be well to determine in the laboratory if anaerobic or semi-anaerobic storage of wood in chip form would significantly reduce deterioration of the wood, as well as reduce loss of quality and quantity of kraft pulp made from chips. Concurrently, there is a need to know if anaerobic storage might induce some kind of deterioration.

BACKGROUND

Wood decay fungi and stain fungi have long been known to require oxygen for their development. Realizing this requirement led to controlling degradation in logs by storing them in ponds and under water sprays. Thus, the amount of oxygen in the logs that could support growth of wood-destroying fungi was severely limited. Fungal attack has, for the most part, been controlled in logs stored in this manner (2).

Infection by bacteria, however, has been shown to be widespread in pond-stored pine logs in the West (3, 4). The bacterial attack increases porosity as the contents of ray cells are removed and the ray cells themselves destroyed.

Although this suggests that little degradation should be expected in chips stored under anaerobic conditions, other information indicates greater wood deterioration may occur if the chips are stored under water for lengthy periods. In oak wood submerged in water for many years, soft rot was present (5), and both bacteria and fungi capable of growing anaerobically were isolated from the wood. Recently, studies of various imperfect fungi, isolated from sewage sludge, polluted waters, and soils have shown that these isolates are capable of growth, albeit slowly, under anaerobic or microaerophilic conditions (6).

RESULTS AND CONCLUSIONS

At the end of six storage periods (6–26 months), regardless of whether the chip samples were stored under water or in an atmosphere of nitrogen gas plus carbon dioxide or whether or not they were inoculated with Columbia River water, the chip samples appeared clean and completely unaffected by anaerobic storage. There were obvious differences in the appearance of the water medium in the bottles containing noninoculated and inoculated samples: the water in the non-inoculated samples evidenced few signs of microbiological activity; whereas, in the inoculated, a rich growth of fungi and bacteria appeared on the surface of the water. Appearances of the chips did not differ, however. Bacteria were isolated in large numbers from water-stored chips and in somewhat lesser numbers from gas-stored chips, but no attempt was made to identify isolates because of their apparent lack of effect on wood properties.

Specific gravities determined at the end of the final storage period for both non-inoculated and inoculated samples are given in Table I. Losses in specific gravity were higher in the inoculated than in the non-inoculated chip samples. In both inoculated and non-inoculated samples, losses were higher in water-stored than in gas-stored chips. Because 3% losses occurred in non-inoculated wood subjected in earlier decay tests to leaching, all losses in specific gravity were at levels that would be expected in wood chips stored in sterile water. They were, therefore, considered

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caused by normal leaching of soluble materials stored in the wood cells.

The effect of both types of anaerobic storage on kraft pulping of Douglas-fir wood chips and on the physical properties of the pulps are given in Table 11. Because differences at 6-month intervals were small, the data for the non-inoculated samples at 6 months and 18 months (20 months for the inoculated) were not included in this table. In addition, for brevity, only the handsheet properties at a Canadian Standard Freeness of 600 ml were included. Data not included here are available from the authors. Each value shown in the table is an average of the results from two (duplicate) pulpings. Although small fluctuations in yields of kraft pulps occurred between samplings at different storage periods, the differences are within the range of experimental error; consequently, are insignificant. These findings are consistent with those of McKee and Daniel (7) who found that little change in pulp yield was associated with pine chips stored for periods of 6 months and 12 months in sealed steel drums. Similarly, the properties of the pulp handsheets remained, in the present test, essentially constant regardless of storage time, medium, and whether or not inoculated (Table 11). The only exception was brightness: handsheets tended to decrease in brightness in the non-inoculated sample.

To determine if these results are similar for aspen, wood chips are being subjected to storage conditions and to tests similar to those described here for Douglas-fir chips. Results of the aspen tests will be described in a future paper.

Table I. Losses in Specific Gravity of Anaerobically Stored Douglas-Fir Wood Chips

Storage medium	*Specific gravity*	*Specific gravity loss, %*
Non-Inoculated—Stored for 24 Months		
Control (not stored)	0.422	
Water	0.409	3.1
Nitrogen plus carbon dioxide	0.415	1.7
Inoculated—Stored for 26 Months		
Control (not stored)	0.422	
Water	0.408	3.3
Nitrogen plus carbon dioxide	0.411	2.6

METHODS

Treatment of Wood Chips

In August 1968 Douglas-fir wood chips, predominantly sapwood from slabwood and edgings, were obtained from a sawmill in Washington, and upon arrival were thoroughly mixed. A representative sample was extracted and the average moisture content determined to be 27% (o.d. basis). From similar representative samples, specific gravity of the chips was determined (8), and duplicate kraft pulps were made. These chips (4000 g, wet weight) 'were then placed into each of thirty-two 5-gal glass bottles. Enough distilled water was added to one-half of the bottles to bring the moisture content of the chips to an average of 70%. To create an anaerobic condition in these bottles, a vacuum of 20 in. of mercury was applied for 1 hr, followed by replacing the original air with a mixture of 95% nitrogen and 5% carbon dioxide. Possible buildup of pressure due to evolvement of metabolic gases during storage was prevented by venting a tube into the rubber stopper at the top of the bottle, and by inverting the bottle. Entry of oxygen into the bottle during incubation was circumvented by submerging the exterior end of the tube in water. In the other half of the bottles, water was added in sufficient amounts to completely cover the wood chips contained therein. The water level remained essentially constant during the 26-month storage.

The bottles of chips were stored for 6, 12, 18, or 24 months at 80°F under intermittent artificial light. At the end of each of the storage periods, six bottles, three of water-stored chips and three stored in nitrogen plus carbon dioxide, were removed. The contents of two bottles of each type were removed for pulping tests, whereas the contents of the third bottle were used for determining specific gravity (8).

No attempt was made to inoculate the chips prior to storage; it was thought they would possess microorganisms normally found in Douglas-fir chip piles because of their being chipped and handled at western sawmills and pulpmills. After 1 year of storage, the chips appeared fresh and free of any fungal or bacterial growth. This was possibly due to lack of suitable inoculum because the chips had dried to a low moisture content during shipment. Therefore, a new shipment of Douglas-fir chips with a moisture content of 97%, far in excess of that in the

Table II. Effect of Anaerobic Storage on Kraft Pulping of Douglas-Fir and Physical Properties of the Pulps

		Kraft pulping[a]			*Handsheet properties at 600 ml CSF*[b]					
		Yield[c]								
Storage time, months	*Storage medium*	*Total, %*	*Screenings, %*	*Kappa no*	*Beating time, min*	*Burst factor*	*Tear factor*	*Breaking length, km*	*Density, g/cc*	*Brightness, %*
				Non-Inoculated[d]						
0	...	44.8	1.2	33.3	25	76	203	10.0	0.63	22.5
12	H_2O	43.0	0.3	33.0	25	78	173	10.6	0.63	20.0
12	$N_2 + CO_2$	45.2	0.9	35.4	25	79	175	10.5	0.65	19.6
24	H_2O	42.6	0.1	30.5	25	74	190	10.2	0.65	19.5
24	$N_2 + CO_2$	43.5	0.9	34.8	25	76	173	10.3	0.65	17.9
				Inoculated[d]						
0	...	47.4	0.4	30.1	31	80	190	10.4	0.63	20.7
12	H_2O	47.4	0.1	32.0	27	79	199	11.1	0.63	20.7
12	$N_2 + CO_2$	48.6	0.1	43.1	26	80	175	10.9	0.63	17.2
26	H_2O	47.8	0.1	35.0	28	80	193	11.0	0.63	20.7
26	$N_2 + CO_2$	45.7	0.5	31.1	29	81	202	10.9	0.63	21.8

[a] Constant conditions used were 18.0% active alkali, 25.0% sulfidity, 4:1 liquor-to-wood ratio, 90 min from 100° to 170° C and 90 min at 170° C
[b] Tested according to TAPPI methods.
[c] Based on moisture-free weight of wood before storage.
[d] With Columbia River water and mud.

chips received earlier, was obtained in August 1969. These chips were tested as before; however, to ensure that a suitable inoculum was available in the chips, a small quantity of Columbia River water and mud was poured over them. Samples removed after 6, 12, 20, and 26 months storage were treated as before. In addition, at the end of 20 and 26 months of storage, isolations were attempted from 50 representative chips from one of each of the water-stored and gas-stored bottles.

Pulping

Duplicate kraft pulps were made at each sampling period under the following conditions: 18% active alkali; 25% sulfidity, 4:1 liquor-to-wood ratio; 90 min (100–170°C) and 90 min (170°C). These conditions were based on the original moisture-free weight of wood placed in anaerobic storage. Stainless steel digesters of 0.8-ft^3 capacity with a heat exchanger and a liquor-circulating system were used for this small-scale pulping. After the digester was charged with chips in a perforated basket, air was evacuated from the digester and the cooking liquor drawn in. At the end of cook, the chips were partially washed inside the digester by running hot water (90°C) through them for 20 min. The partially washed chips were then removed and disintegrated with a stirrer in a stainless steel mixing tank containing hot water. After stirring for 10 min, the pulps were drained into a 100-mesh stainless steel screenbox, re-washed with hot water, and screened through a flat screen with 0.012-in. slots. The pulps were then partially dewatered in a 100-mesh stainless steel screenbox and transferred to a canvas bag in which the consistency was raised to about 30% in a hydraulic press. The pulp cakes were shredded, weighed and sampled for consistency and Kappa number determinations.

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