Recent advances in enzymatic pitch control

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Use of an enzymatic pitch control system has demonstrated a dramatic reduction in pitch problems as well as several other unexpected advantages.

A group of triglycerides (TG) in wood extractives has been identified as one of the troublesome components that cause pitch problems in a papermaking process where mechanical pulp is used as the main furnish. These TG are decomposed during storage in the woodyard ("seasoning"), a technique which has been useful in reducing pitch problems in papermaking.

The authors have developed a unique pitch control system—enzymatic pitch control—which attempts to reduce TG content in a mechanical pulp slurry by enzymatic hydrolysis. The system's successful mill trial results were first introduced at the TAPPI 1990 Papermakers Conference.[1] Since that trial, the system has been used routinely at two paper mills of the Jujo Paper Co.: the Ishinomaki mill (since May 1990) and the Yatsushiro mill (since May 1991).

The mill use of the system has demonstrated a dramatic reduction in pitch problems as well as several other unexpected advantages, which are introduced in this paper.

Screening of powerful enzymes for this purpose is also going on; one candidate—thermostable lipase—was tried in a mill and looks very promising.

Experience at the Yatsushiro mill

Utilization of unseasoned wood

At the Yatsushiro mill, located in southern Japan at Kyushu, newsprint, wood-containing, and wood-free paper are produced. Newsprint consists of 15–35% groundwood pulp (GP), which is produced from Japanese red pine (*Pinus densiflora*). These logs were normally seasoned in the millyard for at least three months after cutting and collecting. The treatment reduces TG content in wood and prevents severe pitch problems in the newsprint papermaking process. However, pitch often deposits on the center roll of the paper machine press, especially in winter, and in those cases the center roll must be cleaned frequently.

The frequency of cleaning at the center roll was 0.10–0.68 times per day before December, when the logs collected before September were used. However, the frequency increased drastically, to 3.4 times per day in January and 9.3 times per day in February. This was 5–15 times more than before December. We know that wood in the forest starts to accumulate pitch and TG, a major component of pitch, in October, and cold winter weather decelerates the seasoning effect during storage. Therefore, we had higher TG levels in our wood, resulting in severe pitch problems on the paper machine.

The mill trial was designed to demonstrate the effect of the enzymatic treatment against pitch problems in a case where unseasoned wood logs were added to the wood supply line.

Operating conditions

The mill trial was conducted under the following conditions:

Groundwood pulp line. Production capacity was 160 tons/day.

Raw materials. We used 100% seasoned red pine for more than three months preceding the trial. During the trial, we used 0–50% unseasoned red pine with the seasoned wood.

Machine condition. Our Bel-Baie II paper machine produced newsprint from pulp consisting of 15–35% groundwood, kraft pulp, thermomechanical pulp, and deinked pulp (DIP) at a production rate of 200 tons/day.

Enzyme addition. We introduced the following enzymes into the system during the trial: Resinase A (liquid) genetically engineered from *Aspergillus*, Lipase AYL (liquid) produced from *Candida rugosa*, and Lipase OF (powder) produced from *Candida cylindracea*. Liquid-type enzyme dosages were 500–1000 mL/ton of groundwood pulp; powder-type enzyme dosage was 80–120 g/ton of groundwood pulp.

The first trial was conducted in the groundwood pulp fiber line (**Fig. 1**) from March to July 1991.

The ratio of unseasoned wood was 20% at first and was increased gradually to 50% maximum.

Prevention of pitch deposition on the center roll

The test operation with enzymatic pitch control took place during March and April. From March 1 to March 12, we ran

[1]Irie, Y., Matsukura, M., Usui, M., and Hata, K., TAPPI 1990 Papermakers Conference Proceedings, TAPPI PRESS, Atlanta, p. 1.

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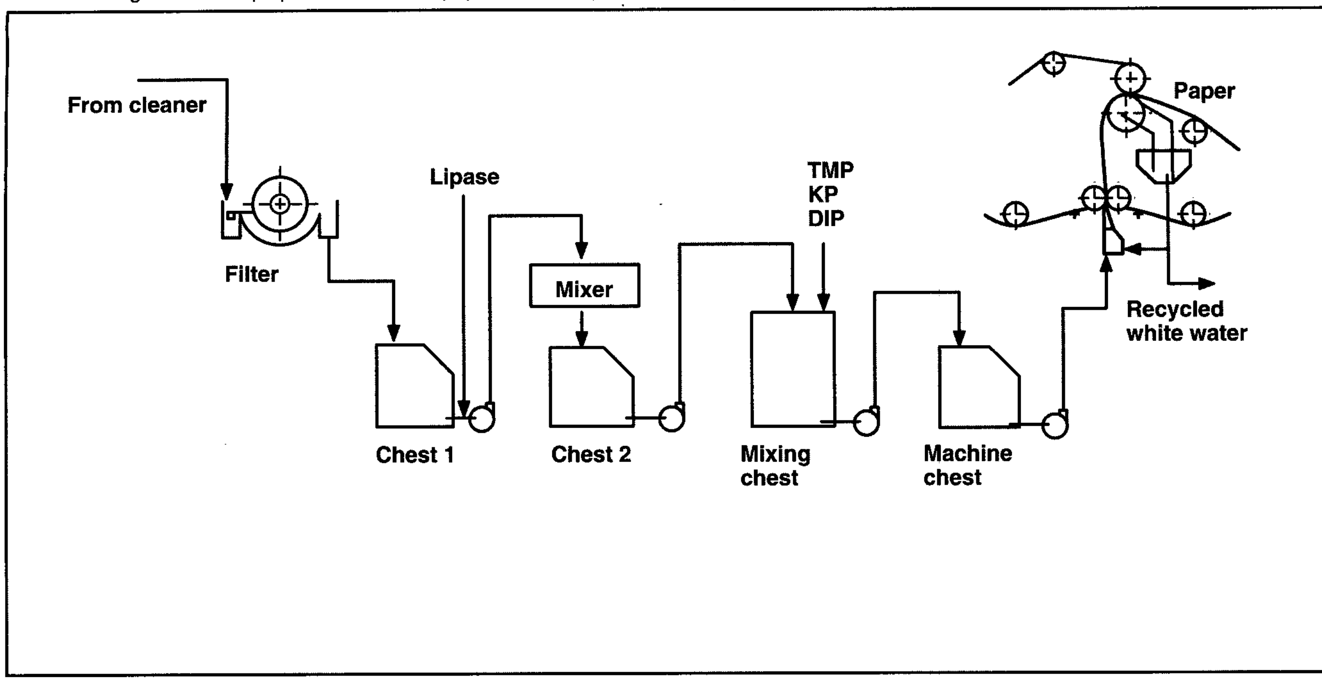
1. Outline of groundwood pulp fiber line to the paper machine (Yatsushiro mill)



I. Amount of pitch and TG in the lipase treatment operation

Date	Content of unseasoned wood, %	GP chest		Mixing chest		Stock inlet		Unseasoned wood to GP	
		Pitch[a]	TG[b]	Pitch	TG	Pitch	TG	Pitch	TG
5/5	0	2.18	6.9	1.50	0.8	1.70	Trace	...	...
5/6	0	1.48	8.5	1.79	0.8	1.85	Trace	...	...
5/10	20	1.94	13.5	2.07	Trace	2.18	Trace	...	...
5/21	20	2.37	11.4	2.45	1.2	1.41	Trace	2.67	21.3
5/26	30	2.09	15.7	1.96	1.3	2.01	Trace	...	...
5/30	30	2.02	19.2	2.38	2.0	1.61	Trace	2.76	17.6
6/10	40	1.86	16.2	2.49	5.9	1.76	4.6	...	...
6/18	40	2.02	17.3	2.53	5.1	1.64	5.8	2.84	20.1
6/20	50	1.94	16.1	2.53	2.7	2.01	2.9	...	...
6/21	50	1.87	19.0	2.34	4.4	1.87	2.2	2.57	24.7

[a]All measurements in percent based on oven-dry wood.
[b]All measurements in percent based on pitch.

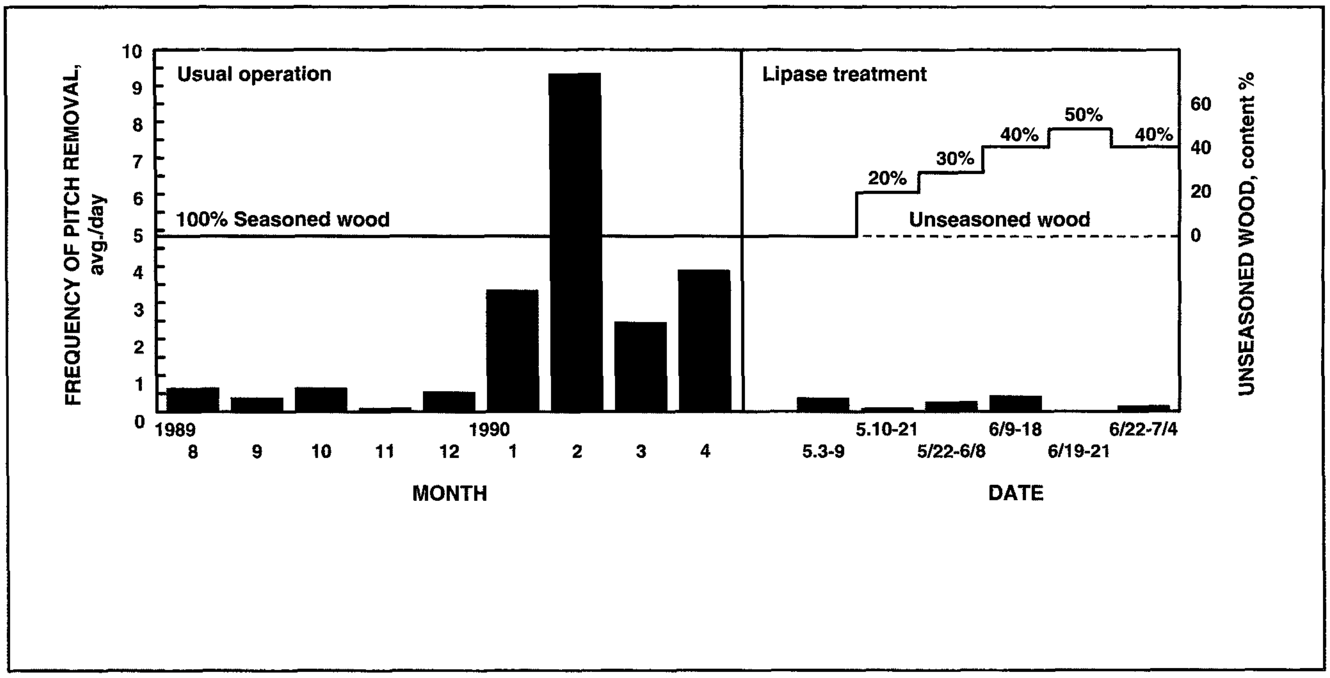
II. Frequency of deposits removal on the center roll

Date	Wood/(seasoned/unseasoned	Frequency of removal, avg./day
5/3–9	100/0	0.29
5/10–21	80/20	0.08
5/22–6/8	70/30	0.22
6/9–18	60/40	0.30
6/19–21	50/50	0.00
6/22–7/4	60–80/20–40	0.15

the system under its usual conditions, and the frequency of pitch removal at the center roll was 2.5 times per day. Cleaning frequency dropped to 0.21 times per day during the test period (March 13–31). In this preliminary trial, 10–30% of unseasoned wood was mixed with the groundwood pulp supply. From April 1 to April 15, we again ran the system under its usual conditions, with a corresponding increase in cleaning frequency to 3.37 times per day. Clearly, the enzyme addition eliminated the troubles with pitch that would have occurred without the enzymatic treatment.

Details from the next trial are shown in **Table I. Table II** and **Fig. 2** show the frequency of pitch removal. The contents of the surface pitch[1] in groundwood pulp produced from unseasoned wood were 2.6–2.8% compared with 1.5–2.2% in

2. Effect of lipase treatment in frequency of deposits removal on the center roll



groundwood produced from seasoned wood. TG content in the surface pitch of the seasoned wood was 7–9%. On the other hand, they were 18–25% in unseasoned wood, which was 2.5 times higher. **Table I** shows that the enzymatic treatment reduced TG content at the inlet of the mixing chest to less than 6% while 50% unseasoned was used. During the entire trial period, the removal frequency was kept at less than 0.3 times per day by the enzymatic treatment. So, the enzyme addition guaranteed a normal and stable operation at the paper machine with a relatively high unseasoned wood mixture. Finally, we concluded that the enzymatic treatment would reduce woodyard space required for seasoning.

Improvement of groundwood pulp brightness

The brightness of groundwood pulp produced from unseasoned wood in March was 3.5 points higher than that produced from seasoned wood. It would be possible to reduce the amount of bleaching chemicals used to some extent by increasing the unseasoned wood content.

Enzymatic pitch control and unseasoned wood have been continually used at the Yatsushiro mill since this trial. The mill has reduced the cost of seasoning and of bleaching chemicals.

Progress at the Ishinomaki mill

Enzymatic pitch control has been used on the No. 3 (referred to as No. 9 paper machine in our previous report) and No. 5 paper machines. The operational condition of these paper machines and the enzyme addition are listed below. The groundwood pulp fiber line and a papermaking process flow chart are shown in **Fig. 3.**

Operating conditions

The mill trial was conducted under the following conditions:

Groundwood pulp line. Production capacity was 300 tons/day.

Raw materials. For about six months, we used 50% seasoned wood plus 50% unseasoned wood.

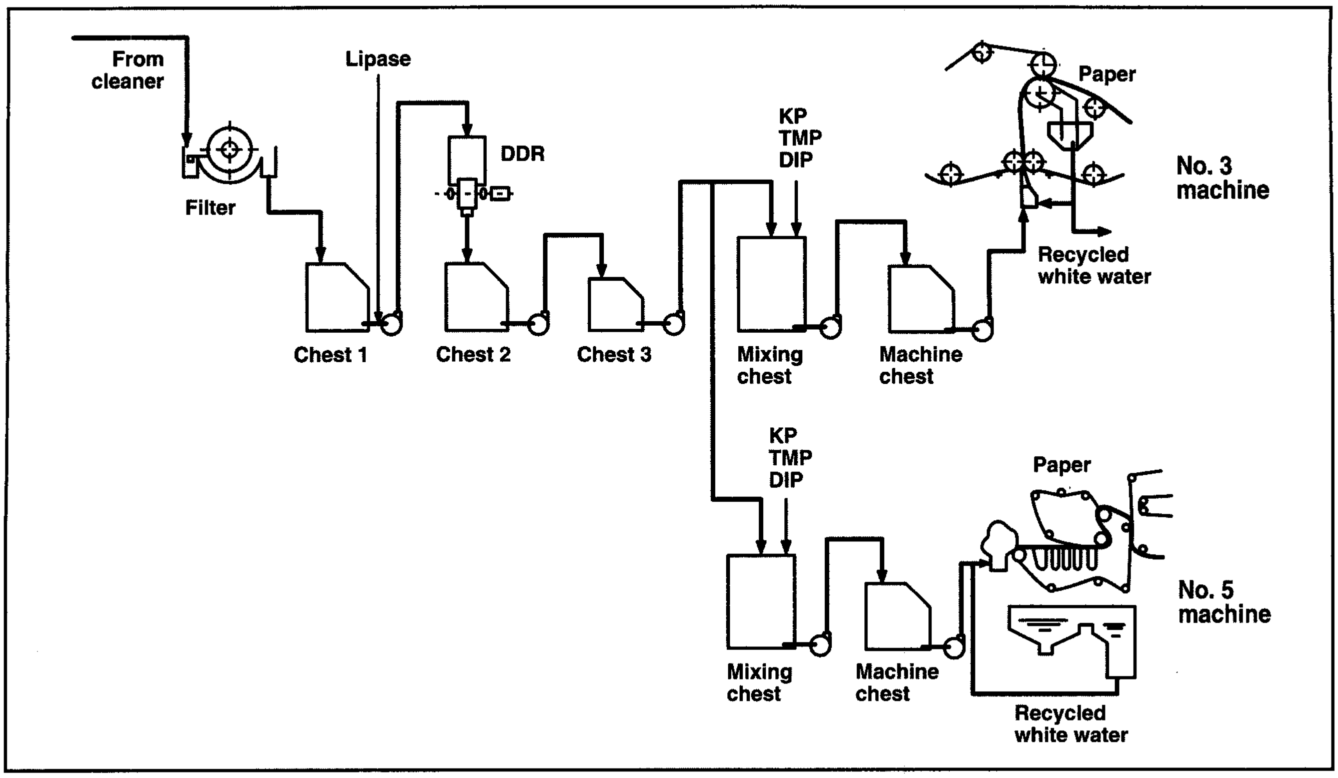
Machine condition. Paper machine No. 3 is a 5850-mm-wide Bel-Baie II which produces newsprint and lightweight papers from pulp consisting of 15–35% groundwood, kraft pulp, thermomechanical pulp, and DIP at a production rate of 200 tons/day. Paper machine No. 5 is a 7500-mm-wide Duoformer which produces newsprint and slightly coated papers from pulp consisting of 10–40% groundwood, kraft pulp, thermomechanical pulp, and DIP at a production rate of 400 tons/day.

Enzyme addition. We introduced Resinase A (liquid) into the system at a dosage of 500–750 mL/ton of groundwood pulp.

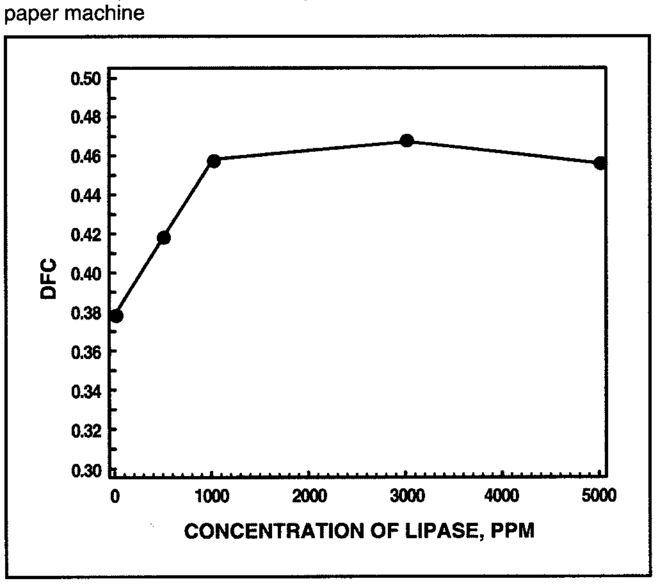
Improvement of product quality

We reported in our previous paper that the groundwood pulp fiber line and No. 3 paper machine occasionally had serious problems because up to 50% of its wood supply was unseasoned logs. And, in the winter, the mill had to reduce the unseasoned wood ratio to avoid uncontrollable, severe pitch problems. But the introduction of enzymatic pitch control has made the operation smooth and stable without serious pitch troubles. Long-term data recorded by a spot detector showed that the number of defects, which mean bigger holes and spots more than 1.5 mm large, was reduced to less than 21 from an average of 61 by the addition of enzyme. Clearly, the product quality was more stable and reliable with the enzyme addition. Finally, the mill has been using 50% unseasoned logs in its wood supply even in winter.

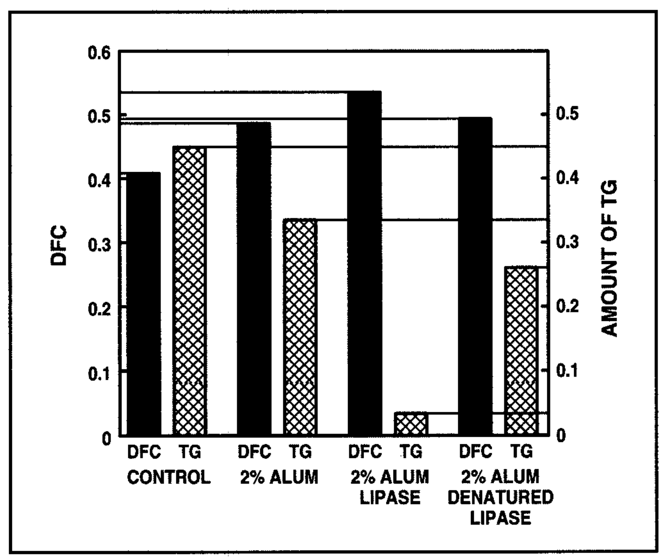
3. Outline of groundwood pulp fiber line to the No. 3 and No. 5 machines and addition of lipase (Ishinomaki mill)



4. Effect of lipase treatment on dynamic friction coefficient in the No. 3 paper machine



5. Effect of lipase treatment on DFC and TG in the sheet

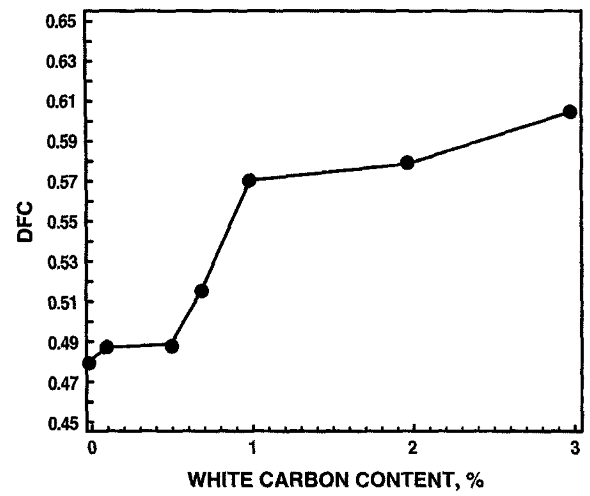


Increasing dynamic friction coefficient of paper

When a paper roll is printed on a web offset press, it is very important to prevent runnability problems such as snaking and wrinkling. This runnability performance is especially a concern in newsprint rolls. The dynamic friction of paper is thought to be related to these problems and is regarded as a quality control parameter at some Japanese paper companies. When dynamic friction coefficient (DFC) is low, a web tends to snake on the printing press. Therefore, when DFC of paper goes to a low level, white carbon (amorphous silicagel SiO_2 x H_2O) is usually added to the pulp furnish to increase DFC.

As we incorporated enzymatic treatment into the production process, we noticed that newsprint DFC increased and that white carbon additions were reduced. Although about 2% white carbon was added to maintain a certain DFC level while making newsprint on the No. 3 and No. 5 paper machines, the

6. Effect of white carbon on DFC

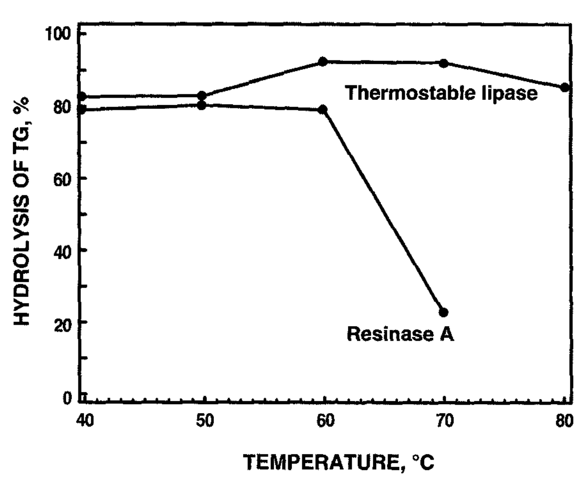


III. Effect of white carbon on dynamic friction coefficient

White carbon, %	*DFC*	*Extractives, %*	*TG, %*
0.0	0.481	2.4	0.29
0.1	0.489	2.4	0.28
0.5	0.490	2.3	0.25
0.7	0.518	2.3	0.26
1.0	0.573	2.4	0.29
2.0	0.581	2.3	0.27
3.0	0.607	2.4	0.26

Percentages based on oven-dry sheet.

7. Temperature profiles of Resinase A and thermostable lipase in pulp slurry



enzymatic treatment of groundwood pulp could decrease white carbon dosage to 1%. **Figure** 4 shows the relation between the addition of enzyme and DFC of paper. DFC increased with enzyme addition, but its effect leveled off with additions of more than 1000 ppm. DFC of paper can be affected by extractives, pigments, and fillers. We suppose that TG is one of the key compounds for decreasing DFC since the enzyme hydrolyses only TG in pitch, and the other compounds may remain unchanged.

Effect of enzymatic treatment and white carbon addition on dynamic friction coefficient

Laboratory experiments for comparing the effect of enzyme addition on DFC with that of white carbon addition were conducted to make sure of the cost savings found in the mill operation.

Procedure

Enzymatic treatment. The raw materials were groundwood pulp in a 4% slurry produced at the Ishinomaki mill. Treatments were made at 40°C and pH 7 for two hours at a dosage of 100 mL/ton of groundwood pulp.

Measurement of DFC. Groundwood pulp was treated with several enzyme dosage levels. White carbon was added to the untreated pulp to evaluate its effect separately. Handsheets of 100 g/m^2 were prepared from each sample, adding alum during sheet forming. DFC was measured according to a Japan TAPPI method[2].

Analysis of TG. Each handsheet was extracted with hot methanol in a soxhlet extractor, and then the extractives were analyzed with a TLC-FID detector to measure the amount of TG.

Effect of enzymatic treatment

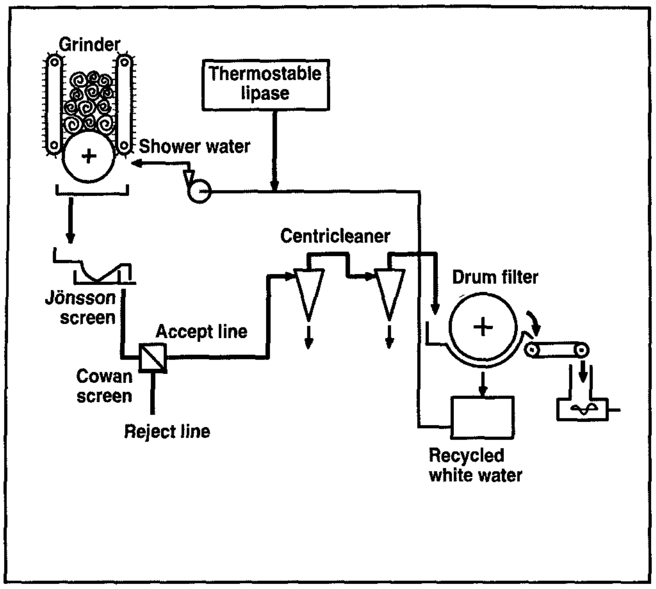
As shown in **Fig. 5**, the addition of alum to groundwood pulp increased DFC by 0.08. Moreover, the enzymatic treatment increased it further by 0.05, and TG in the sheet was hydrolyzed completely in this case. However, the addition of the denatured enzyme could not hydrolyze TG, and therefore did not change it at all. We concluded that the decomposition of TG made DFC increase and that DFC does not increase after TG is completely hydrolyzed.

Effect of white carbon addition

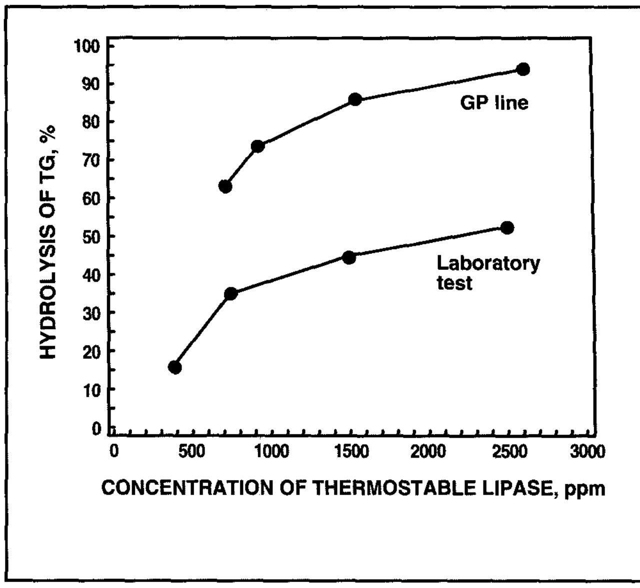
As shown in **Table III** and **Fig. 6**, DFC increased from 0.48 to 0.57 with 1% white carbon addition. However, beyond 1%, its effect was lower. Comparing this result with that of the enzymatic treatment, we concluded that the enzymatic treatment is equivalent to about 1% white carbon addition. The quantities of the extractives and TG were not decreased by white carbon addition. The effect of white carbon seems to be dependent on a different mechanism from that of the enzymatic treatment. Although maximum groundwood pulp content of newsprint was 35%, the result on the paper machine—the reduction of white carbon from 2% to 1%—was

[2]Japan TAPPI Method No. 30-79, Japan TAPPI, Tokyo, 1979.

8. Outline of groundwood pulp fiber line



9. Effect of thermostable lipase concentration on TG hydrolysis in pulp slurry



better than expected from the data in these laboratory experiments. However, there may be some other factors affecting the favorable changes in mill operation.

Development of thermostable lipase

Pitch components are liberated from wood during a grinding stage. If TG is decomposed at this site, it would be most effective and would not influence the papermaking process thereafter. However the temperature of shower water at a grinder is 70-80°C, and the temperature of the grinder surface is near 100°C. Therefore, the present lipase becomes inactive and cannot hydrolyze TG at such a high temperature. We have succeeded in creating a thermostable lipase from a certain fungus that is effective enough even at 80°C. Other lipases rapidly become inactive above 70°C (**Fig.** 7).

To evaluate the activity of this new lipase, a mill trial was carried out. Its flow diagram is shown in **Fig.** 8. The thermostable lipase was mixed in the shower water and then added to the grinder section. The temperature of the shower water was 67-75°C and that of the pulp slurry just after the grinder was estimated to be 75-80°C. It took 30 minutes to flow from the grinder to the cowan screen. The pulp sample at the cowan screen was analyzed for its TG content. The results are shown in **Fig.** 9. The hydrolysis rate in the mill trial was 75% with 1000-ppm addition and was better than the result in the laboratory experiment (45%) with the same lipase dosage. The reasons for this phenomenon would be:

1. Fresh pitch liberated from wood would be more reactive to an enzyme action.
2. A grinder would have a more effective mixing ability than laboratory equipment.

Following this mill trial, a long-term mill trial was conducted, and both cost and pitch control effects were evaluated.

Conclusion

As the first successful application of biotechnology into a papermaking process, this technology has been introduced to four paper machines in two mills since May 1990. Since then, a liquid-type enzyme was developed which has been easy to handle.

Enzymatic pitch control has been helping to solve pitch problems as expected. At the same time, it has demonstrated several other meaningful cost advantages such as a reduction in bleaching chemicals consumption and space and cost savings in a mill woodyard by using unseasoned logs. Moreover, white carbon dosage has been reduced because the enzymatic treatment hydrolyses TG and then increases the dynamic friction coefficient of paper.

Development of the thermostable lipase is proceeding to make it work more effectively. □

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