

Integrated Forest Products Refinery (IFPR)

PI: *Adriaan van Heiningen, U of Maine*

Co-PI: *Douglas Gardner, U of Maine*

Industry Partner: *Gopal Goyal, International Paper*

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Energy Costs in Pulp Mill

Fuel	Heating Value (GJ/MT)	Fuel Cost (US\$/MT)	Energy Cost (US\$/GJ)
Oil	43.5	512 (US\$60/barrel)	11.8
Biomass (20% moisture)	15	55	3.7
Black Liquor (20% moisture)	12.6	56 (org/inorg = 3/1)	4.4
Lignin	26.9	75	2.8
Carbohydrates	13.6	75	5.5

- Do not use oil
- Obtain energy from biomass
- Minimize use of carbohydrates for energy purposes

Hemicellulose Pre-Extraction Rational

Hemicelluloses: - have low fuel value
 - are valuable in pulp
 - degrade during pulping

→ **extract before pulping and adsorb after pulping to increase pulp yield**

→ **Use rest of extract for production of biofuels and bioproducts**

→ **Additional benefits of hemicellulose production:**

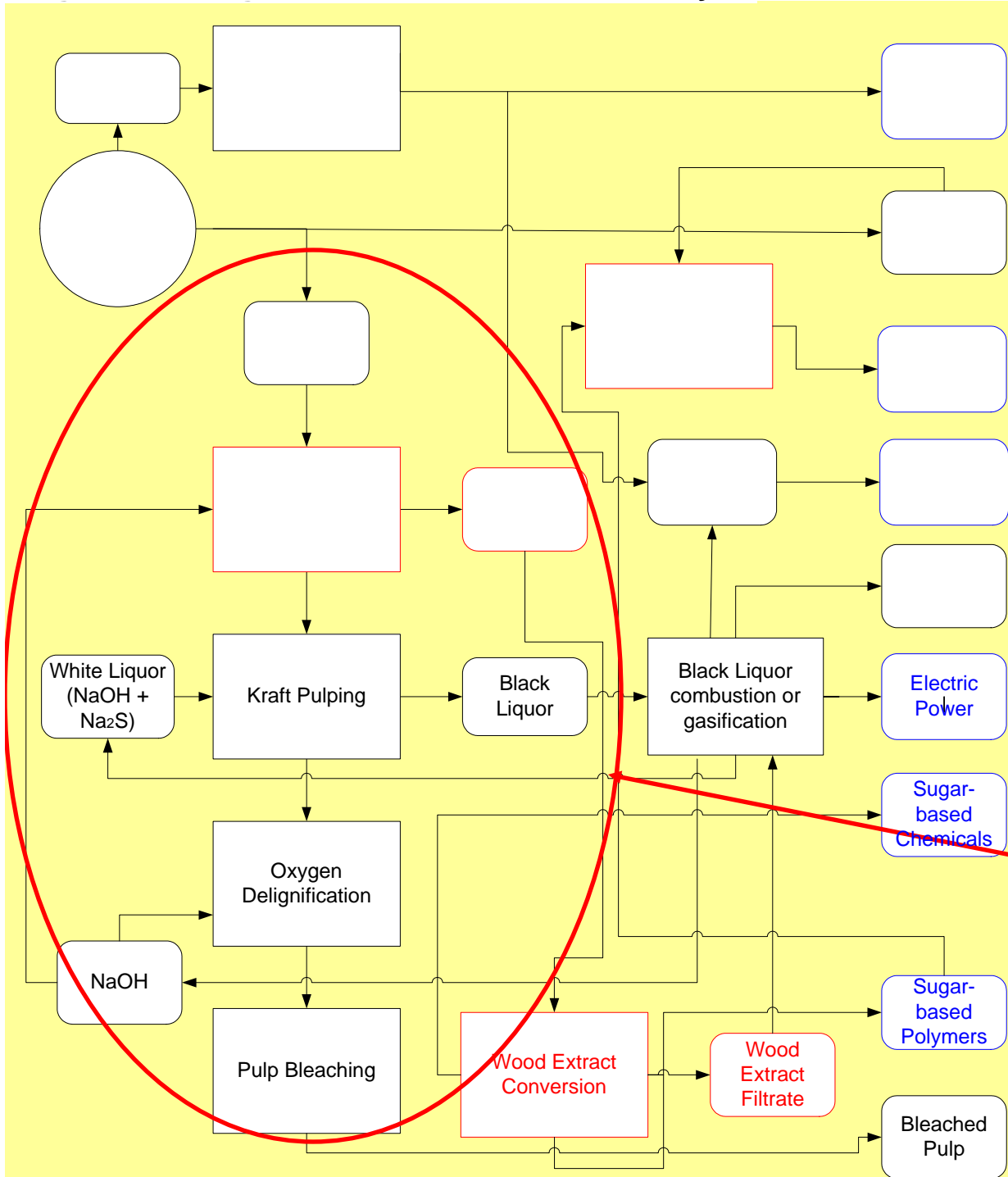
- Decreased alkali consumption
- Reduced organic + inorganic load to recovery
- Increased delignification rate

Increasing Value

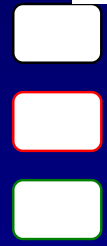
Product	Price	Wood Yield (%)	Conversion Yield (%)	Value (US\$/ODMT wood)
Alkaline Pulp	US\$500/ODMT	47	100	235
Ethanol from hemicellulose	US\$840/MT US\$2.50/Gallon	8	43	29
Extra Biomass Fuel	US\$55/ODMT	136/15 = 9	100	-5
Total		100		259
Alkaline Pulp	US\$500/ODMT	45	100	225
Value Added				259-225=34

- Pulp yield increases value by \$10/ODMT wood or \$22/ODMT pulp
- Ethanol increases value by \$24/ODMT wood or \$53/ODMT pulp

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IFBR



= New Products

Focus of the present work

Project Goal

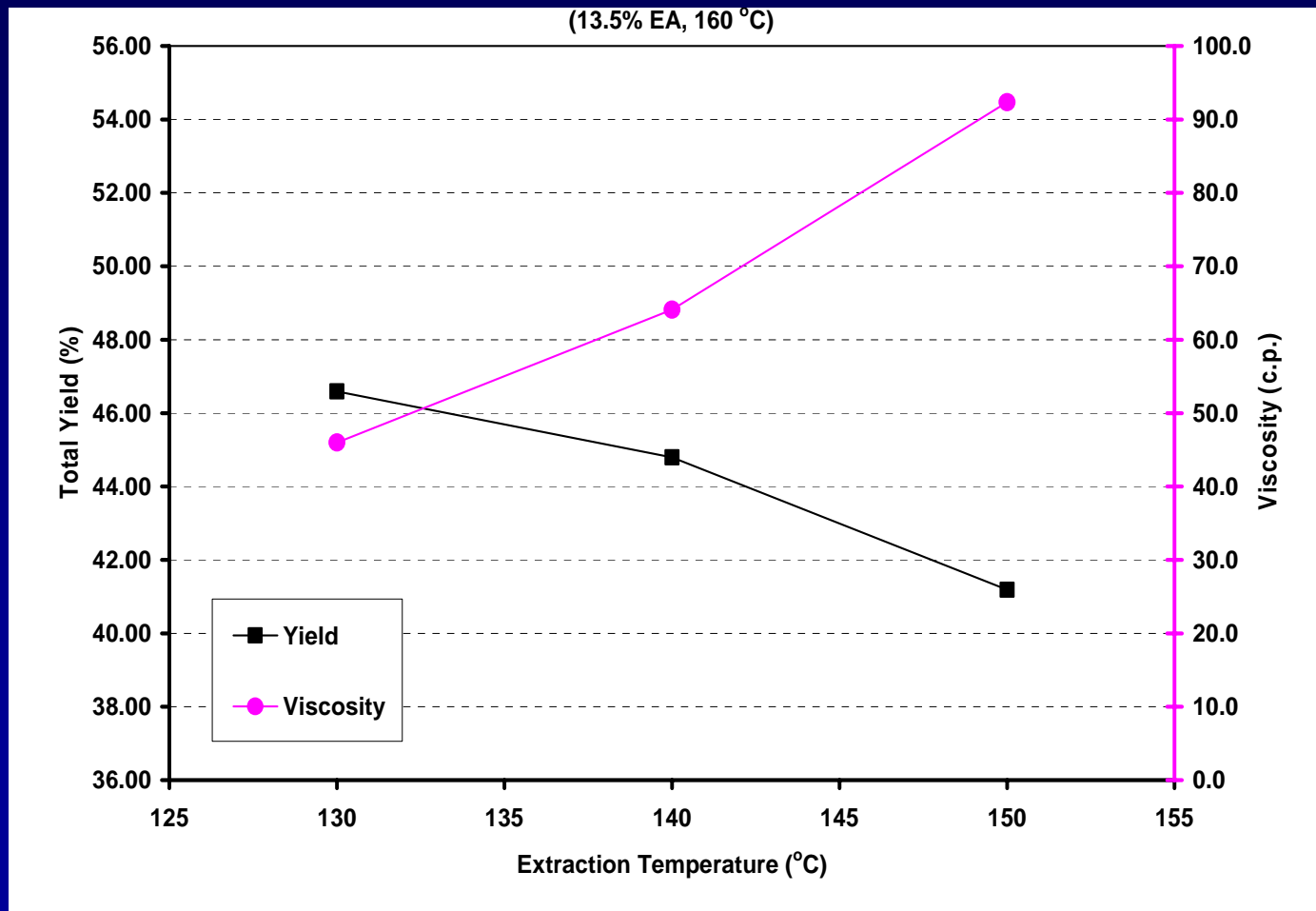
To develop processes for extracting hemicelluloses from wood chips before pulping, redeposit the oligomers on pulp to improve yield without loss in pulp properties

Tasks

**For 1. Southern Mixed Hardwood Chips
2. Loblolly Pine Chips**

- Extraction of wood chips
- Modified kraft cooking of extracted chips
- Redeposition of hemis onto kraft pulp
- O₂ delignification of hemi-deposited pulp
- Bleaching of pulp

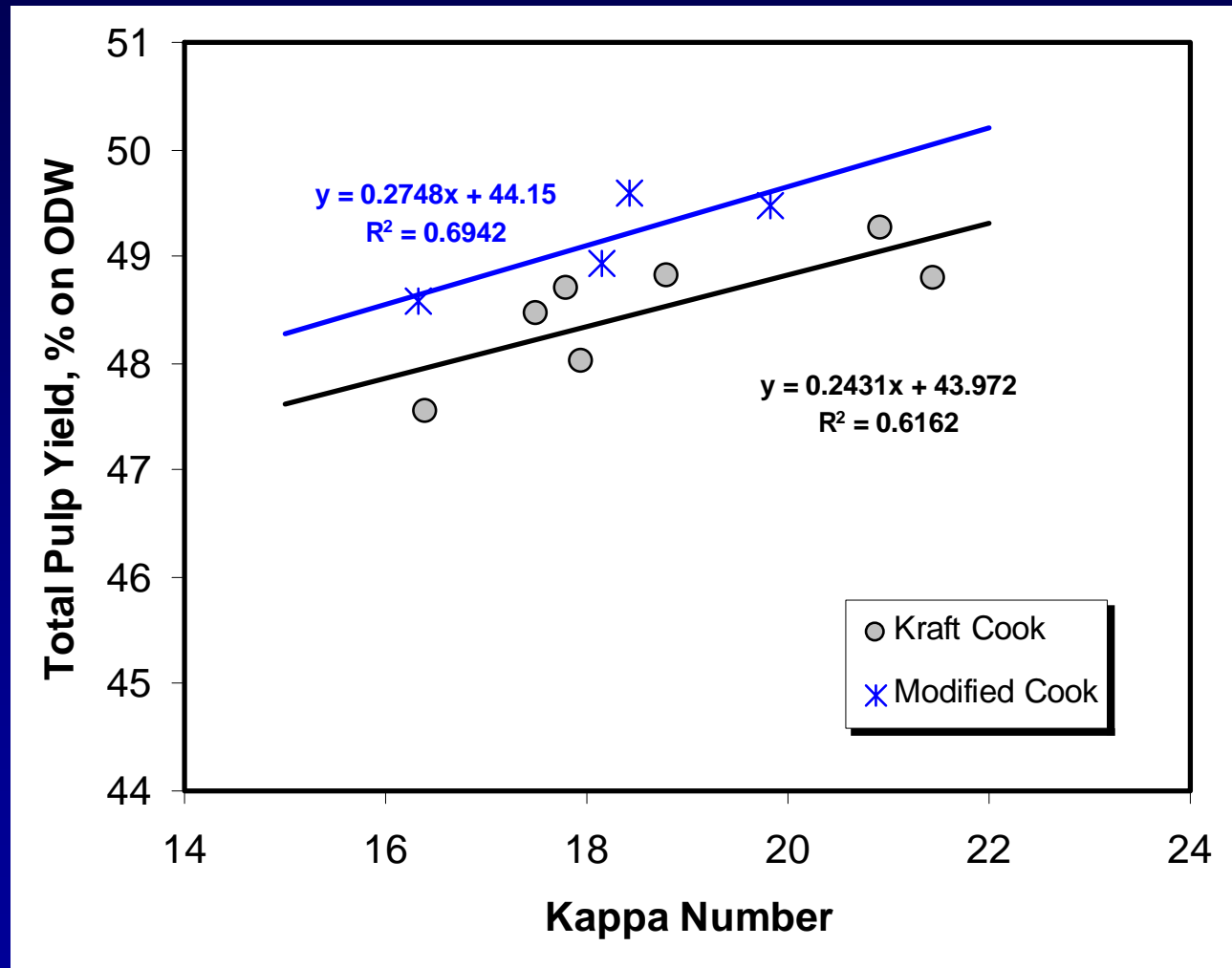
Water Extraction/Kraft Cooking of Southern Mixed Hardwood Chips



Summary of Pure Water Extraction

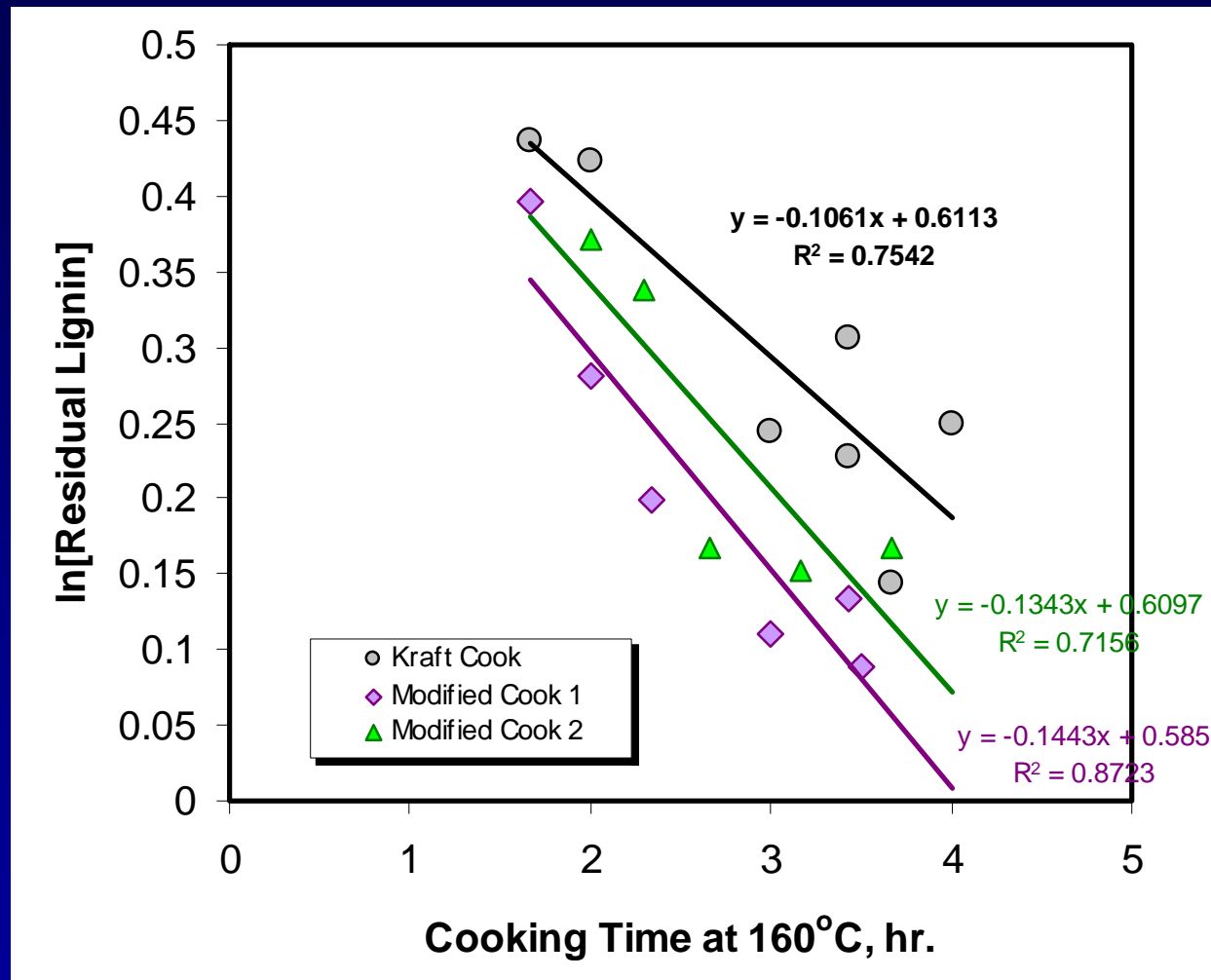
- At 140 °C or higher, the wood substance removal increases strongly due to xylan loss.
 - Total kraft pulp yield (on original od wood) is 2, 5.5 and 8% lower than control at extraction temperature of 140, 150 and 160 °C resp.
 - The viscosities of the pulps obtained with water extraction are much higher than the control.
- ⇒ Extraction of significant amount of xylan with water leads to permanent kraft pulp yield loss.**

Pulp Yield for Modified Extraction and Cooking of Mixed Southern Hardwood



About 1% yield increase (on original wood) relative to kraft

Delignification for Modified Extraction and Cooking of Mixed Southern Hardwood



30 – 40 % higher delignification rate than kraft control

Modified Extraction and Cooking of Southern Mixed Hardwood

We have identified a pre-extraction/pulping procedure for Southern mixed hardwood which:

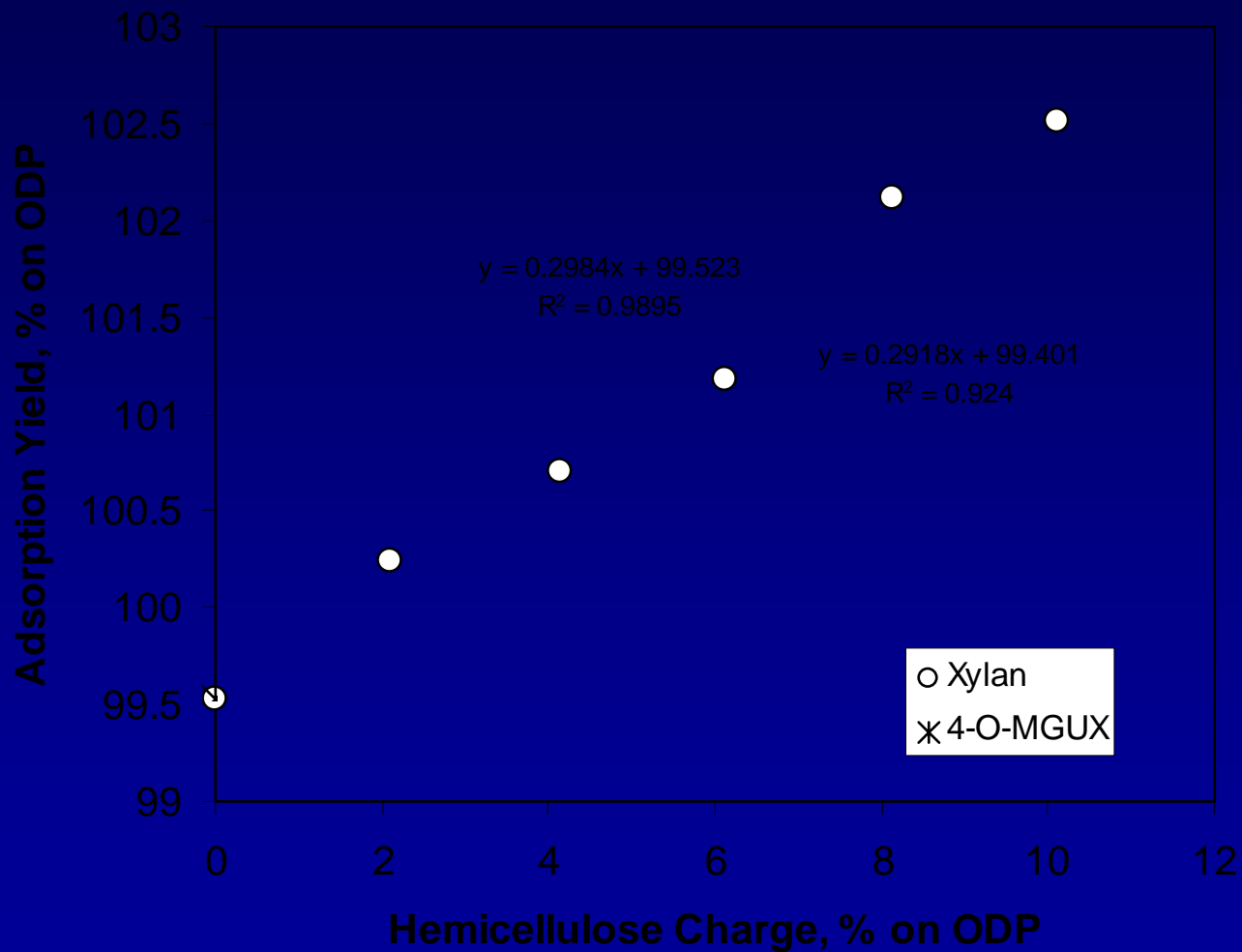
- Increases the pulp yield up to 1%
- Increases the delignification rate by up to 40%
- Decreases the organic load to the recovery boiler by up to 8% based on od wood

Mixed Hardwood Extract Adsorption

Treatment	Yield (%)	Kappa	Lignin (%)	Lignin-free Yield (%)
Water	99.5	14.9	2.20	97.3
Extract 1	100.5	17.1	2.54	98.0
Extract 2	100.8	16.8	2.50	98.3
Extract 3	100.8	17.5	2.61	98.2
Average	100.7	17.1	2.55	98.2
Increase	1.2	2.3	0.35	0.9

1% lignin-free yield increase and 2.3 Kappa unit increase

Adsorption of Xylan on Mixed Hardwood Kraft Pulp



About 30% adsorption of xylan on pulp

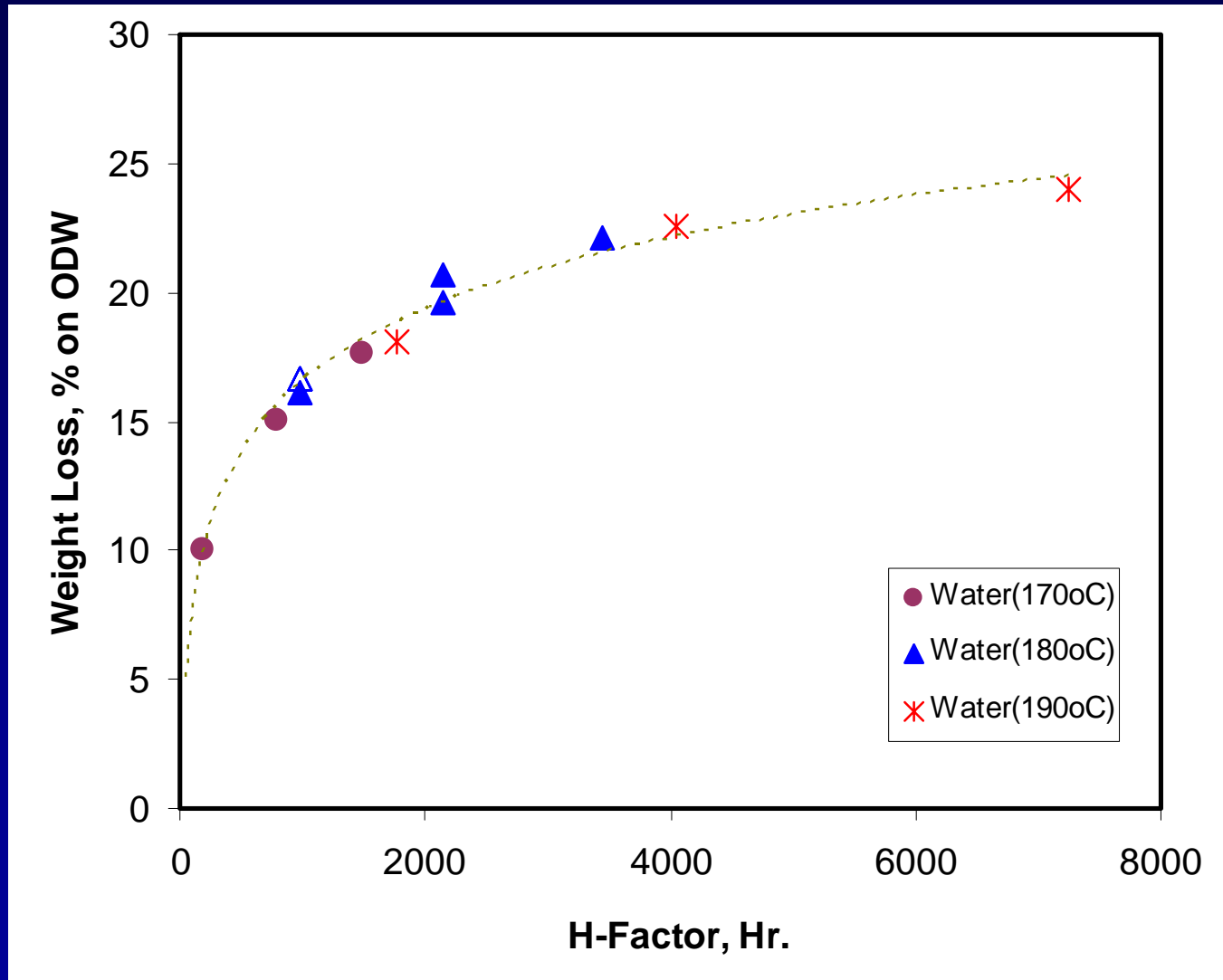
Bleaching of Hardwood Pulp

Test	Kraft 1	Modified 1	Kraft 2	Modified 2
Kappa	18.0	18.0	18.0	17.5
Original Brightness (%)	27.7	28.0	27.7	27.2
ClO ₂ (%)	2.19	2.19	2.87	2.80
NaOH (%)	1.23	1.23	1.68	1.64
Brightness(%)	81.8	81.5	86.8	87.3

Bleaching sequence: D₀EpD₁

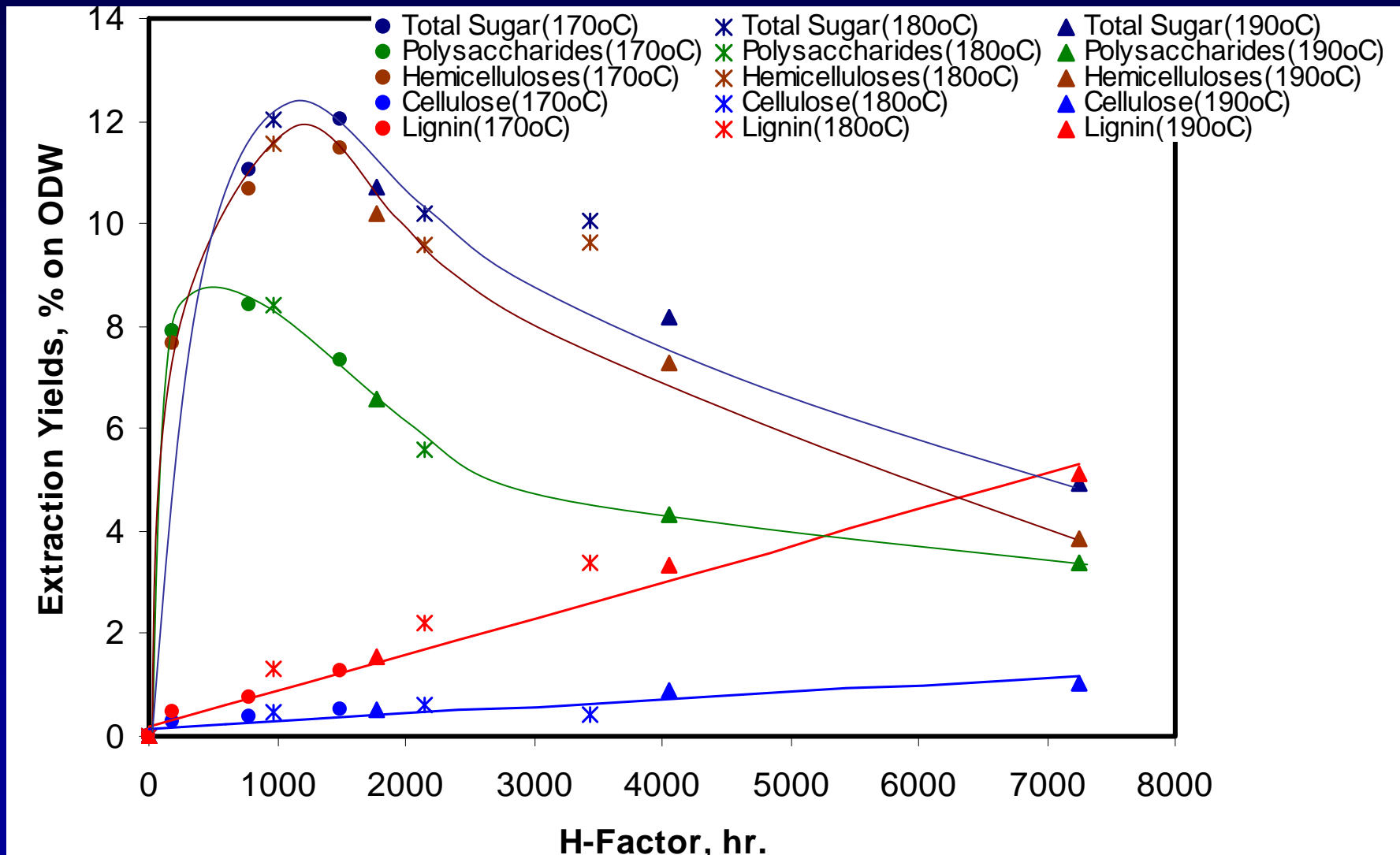
Bleaching response of modified pulp similar to kraft pulp

Water Extraction of Loblolly Pine



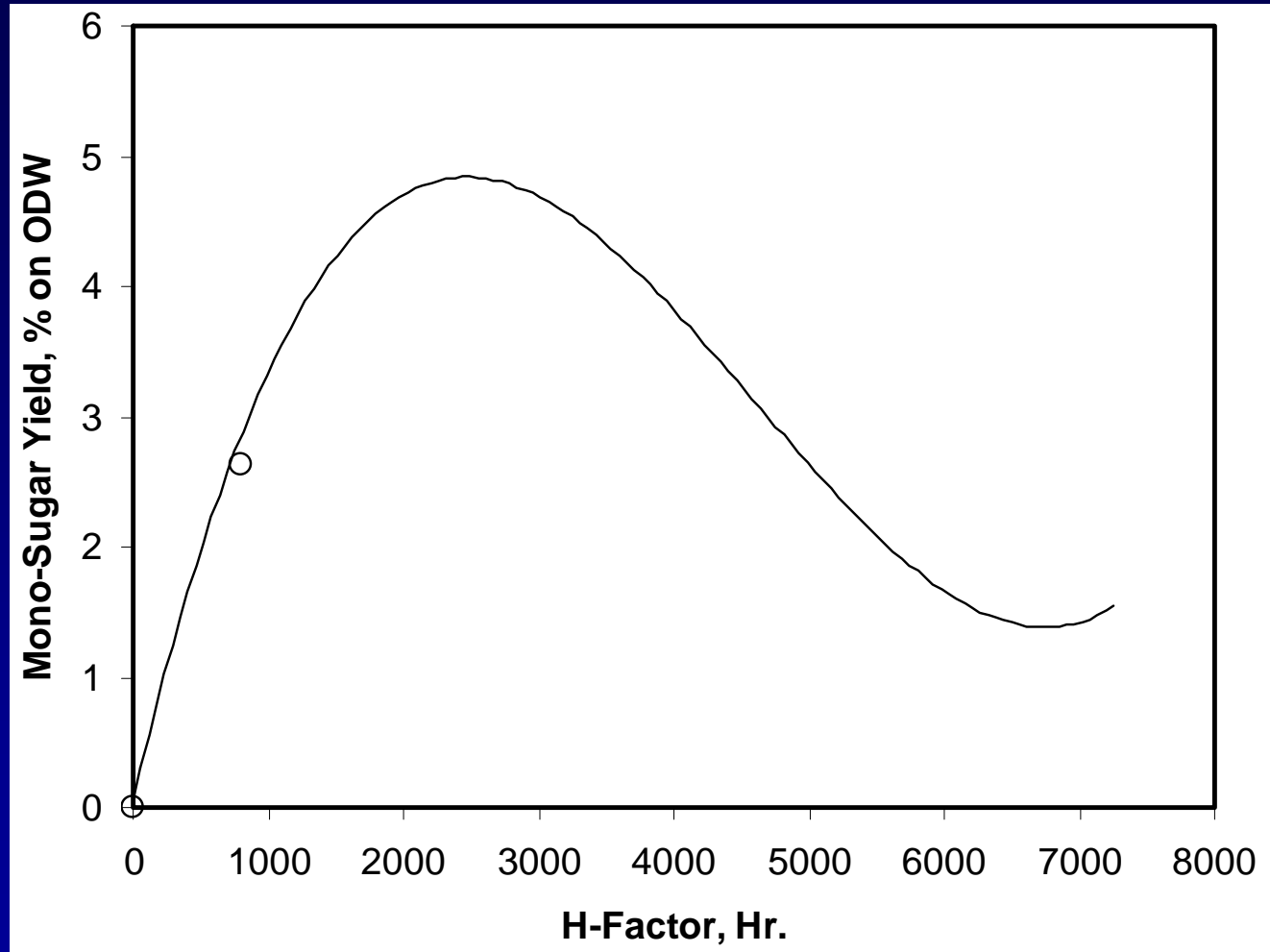
H-factor approach works for water extraction of loblolly pine

Water Extraction of Loblolly Pine



Total sugars and polysaccharides max at H of 1000 and 500

Water Extraction of Loblolly Pine



Mono sugars formed by hydrolysis of polymeric sugars; then further degradation to furfural, hydroxymethylfurfural, etc

Summary Loblolly Pine Water Extraction

- Extracted component are satisfactorily described by H-factor variable.
- Maximum polymeric sugar yield of ~8 % (on wood) at H-factor of ~ 500 hrs. The lignin content at then ~ 0.5 %. Monomeric sugar content below 1 %.
- This condition is reached after ~ 60 or 25 min. at 160 and 170 °C respectively.

Milestones

ID #	Milestone Description	Plan	Actual
1.1h	Hardwood extraction in Dionex ASE 100	3/31/05	10/31/05
1.2h	Hrdwd extraction/cooking in profiling digester	8/31/05	7/31/05
1.3h	Hrdwd hemicellulose deposition on pulp	8/31/05	8/31/05
1.4h	Oxygen delignification hemi + hrdwd pulp	8/31/05	8/31/06
1.1s	Softwood extraction in rocking digester	12/31/05	12/31/05
1.2s	Sftwd extraction/cooking in rocking digester	8/31/06	
1.3s	Sftwd hemicellulose deposition on pulp	8/31/06	
1.4s	Oxygen delignification hemi + sftwd pulp	8/31/06	

Milestones (cont.)

ID #	Milestone Description	Plan	Actual
1.5	Bleaching of hemi + hardwood and hemi + softwood pulp	8/31/06	
1.6	Techno-economic modeling	5/31/07	
1.7	Go/No Go decision of feasibility study of hemi extraction technology at IP mill site	8/31/06	
1.8	Verification of optimized integrated technology of hemi extraction for hardwood and softwood	5/31/07	
1.9	Final report	8/31/07	

Commercialization

- Initial implementation at International Paper mill using conventional and new technology after successful laboratory demonstration of the technology.

Conclusions

- **Extraction of southern mixed hardwood with water leads to permanent kraft pulp yield loss**
- **Identified a modified extraction/ cooking procedure for southern hardwood giving 1% yield gain, increased delignification rate and 8% lower organic load to recovery.**
- **Extraction of Loblolly Pine with water is promising at H-factor of about 500 hrs.**