Building Leadership Excellence

Environmentally friendly wet-end paper reinforcement agents

Asif Hasan, Chen Gong, Biljana Bujanovic*, Tom Amidon
Department of Paper and Bioprocess Engineering
SUNY ESF, Syracuse, New York-13210

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RETHINK PAPER:
Lean and Green

SMART, ENVIRONMENTALLY FRIENDLY PAPER

- Today's motto " more for less"

Increase in profit margin by

-Reduction of basis weight

-Replacement of fiber by cheaper materials such as fillers

- Industry of future needs to design its paper without compromising

-strength

- bulk

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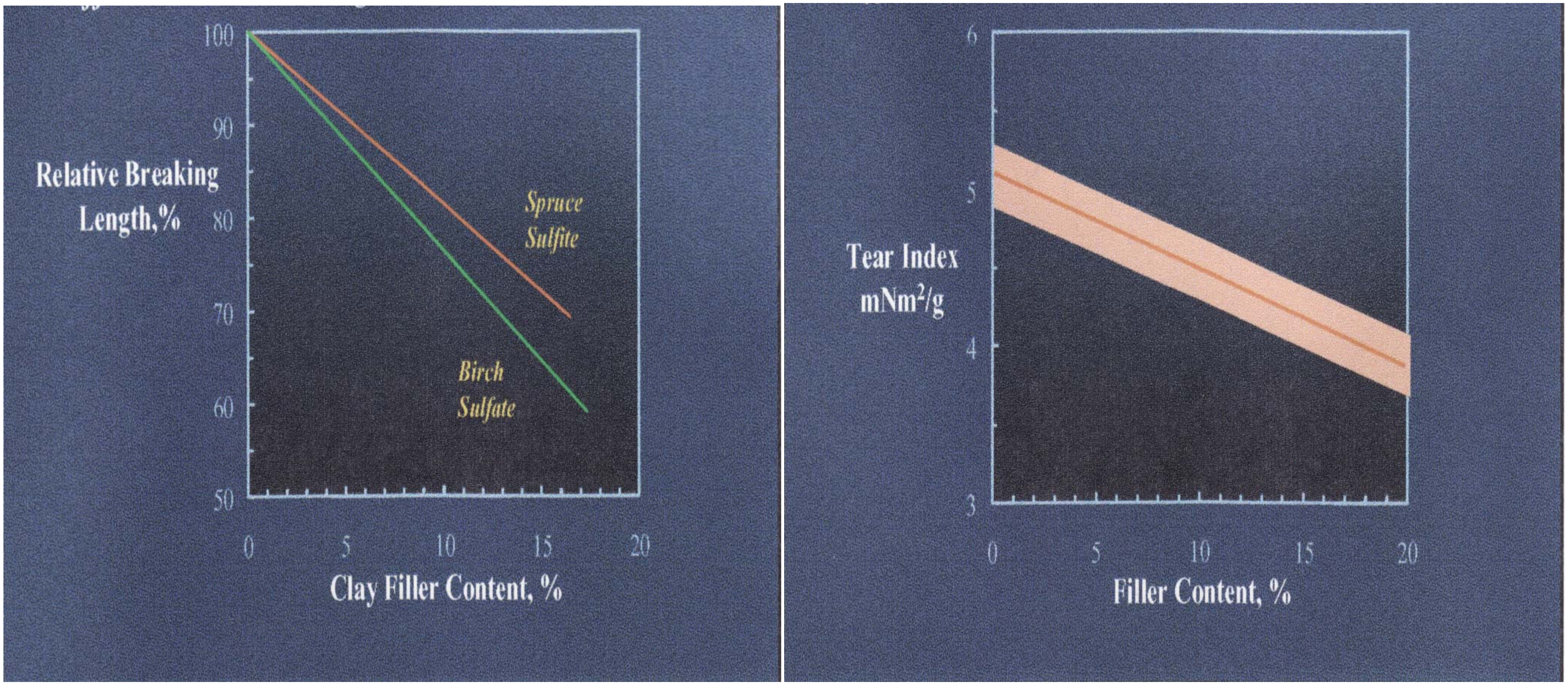
REPLACE FIBER?

- Disadvantage of adding fillers



- How to compensate for the strength loss?

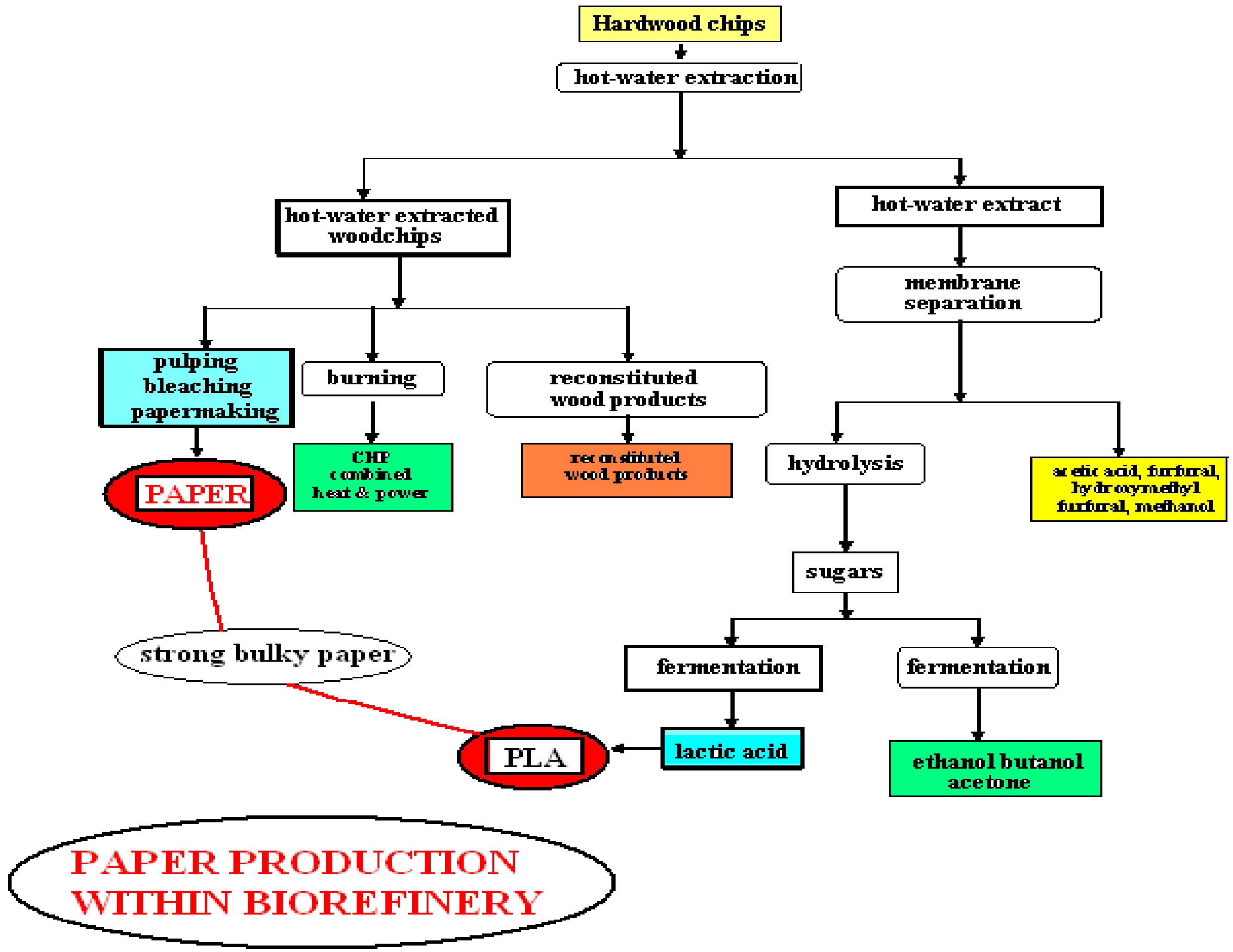
-Additives?

- Society and Government are looking for an industry :

  1. **More sustainable**
  2. **Based on renewables**
  3. **Environmentally benign**
  4. **Produces net positive energy**
  5. **Green**

  Consistent with that is the concept of Biorefinery….

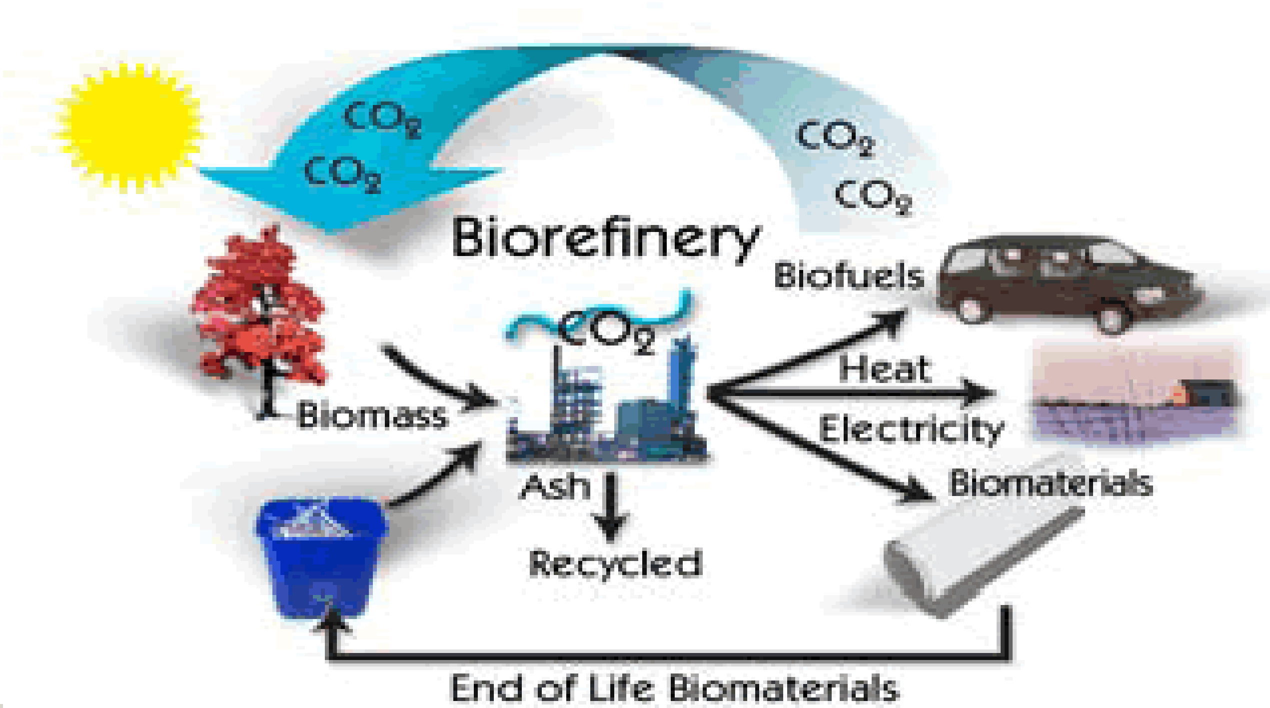
Pulping within biorefinery: hot water extraction (HWE) of chips before pulping, ESPRI SUNY ESF process



➢Hot water Extraction (HWE) is Performed to produce fermentable feedstock by dissolution of hemicelluloses

➢Hemicelluloses are worth 3 to 4.5 times as Ethanol than energy in kraft pulping (Restina, Pykannen, 2007)

HW Extracted chips for pulp/paper production



BENEFICIAL EFFECTS OF EXTRACTION

- **Hemicelluloses as fermentable feedstock**
- **Lower H-factor** requirement to make the same kappa number of pulp as with un-extracted wood
  - Open substrate structure, penetration of chemicals and diffusion of degraded products become easier
- **Lower alkali consumption**
  - Due to lower hemicellulose content (lower acetyl content)
- **Higher bulk**
  - Resulting in high porosity, high scattering coefficient / good opacity, greater caliper , high stiffness
- **Higher refining energy**
  - Due to higher fiber rigidity, lower response to beating

- **Lower tensile strength**

-There is a need to strengthen paper based on pulp from extracted woodchips to retain the bulk advantage and have compatible strength to unextracted pulp

Conventional Additives	Environmentally Friendly Additives
❑**PAE(Polyamide – Epichlorohydrin) resins** •Compatible with alkaline pulps, •Gives wet strength •produce chlorine compounds	❑**Starch:** •Compatible with any pulping system •Gives only dry strength - hydrophillic •Biodegradable •Renewable
❑**Urea-formaldehyde resins** ❑**Melamine-fpormaldehyde resins** •Used in acid conditions, in the presence of Alum •Gives wet strength • Both linked to respiratory problem and poor air quality	❑**Polylactic Acid (polylactide):** •Compatible with any pulp system •Gives wet strength •Helps dry strength •Compostable •Product of Renewable feedstock
❑**Glyoxalated Polyacrylamide:** •Gives dry and wet strength •potentially Carcinogenic in monomeric form	❑Polyhydroxy alkanoates (PHA): •Product of Renewable feedstock •Potential for dry and wet strength

In our earlier work

- We demonstrated on Kraft pulp made from Sugar Maple (Acer saccharum) chips that **PLA** applied on surface improved :

- **Tensile Index (35-100%)**
- **% Stretch (20-40%)**
- **Tear Index (10-100%)**
- **Wet Tensile Index(50-250%)**

- **Hot water extracted, unbleached Kraft pulp** which is hemicellulose depleted and lignin rich, responded the most favorably to PLA treatment in strength parameters while being able to retain its bulk. (Change in the chemical composition has a positive effect on interaction between PLA and fiber).

[Hasan, A. Bujanovic, B. and Amidon, T.(2009): " Strength properties of Kraft pulp produced from hot-water extracted woodchips within the **biorefinery**" **Journal of Biobased Materials and Bioenergy**, V.4. 1-7]

Figure 1: SEM micrograph of paper made from biorefinery pulp

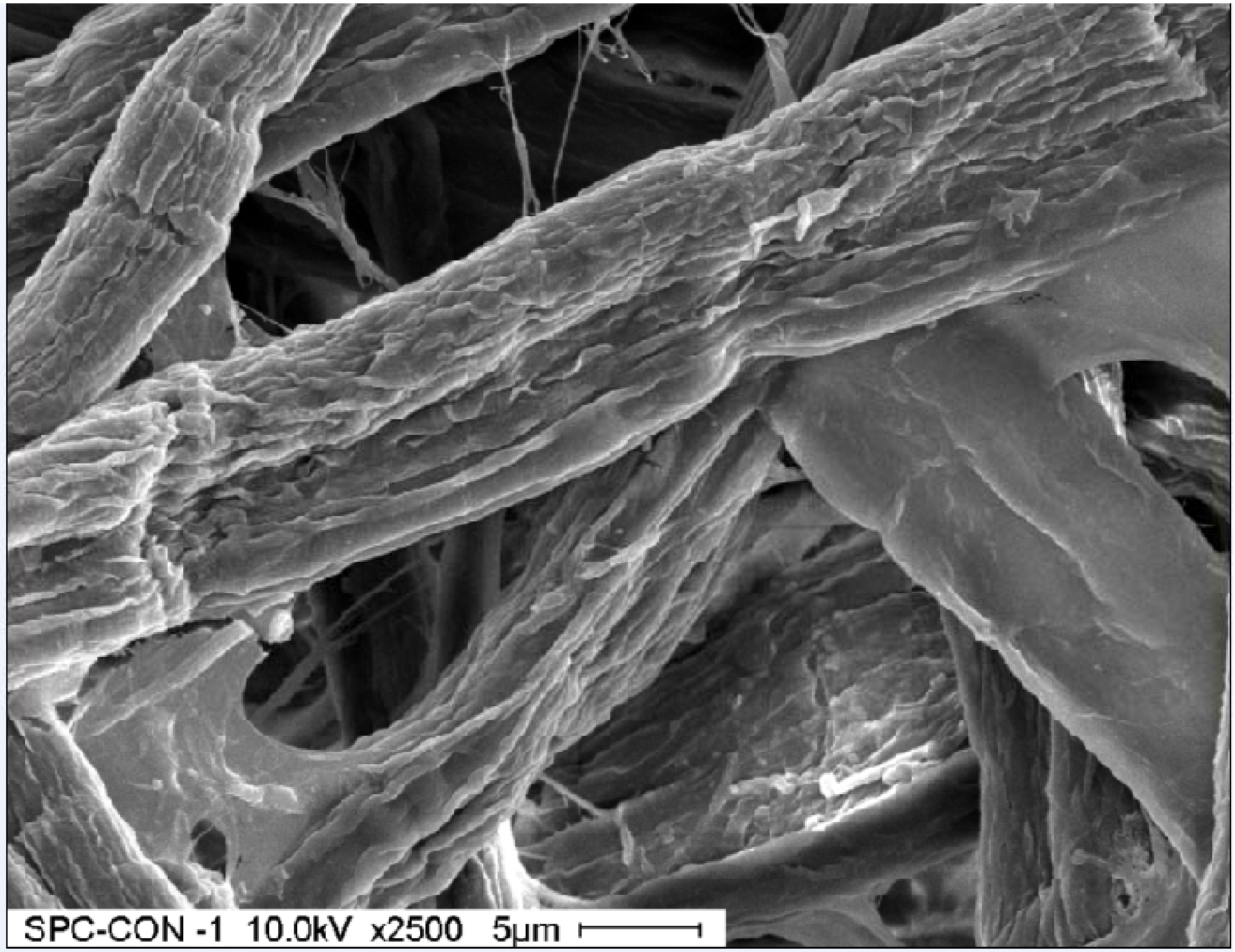
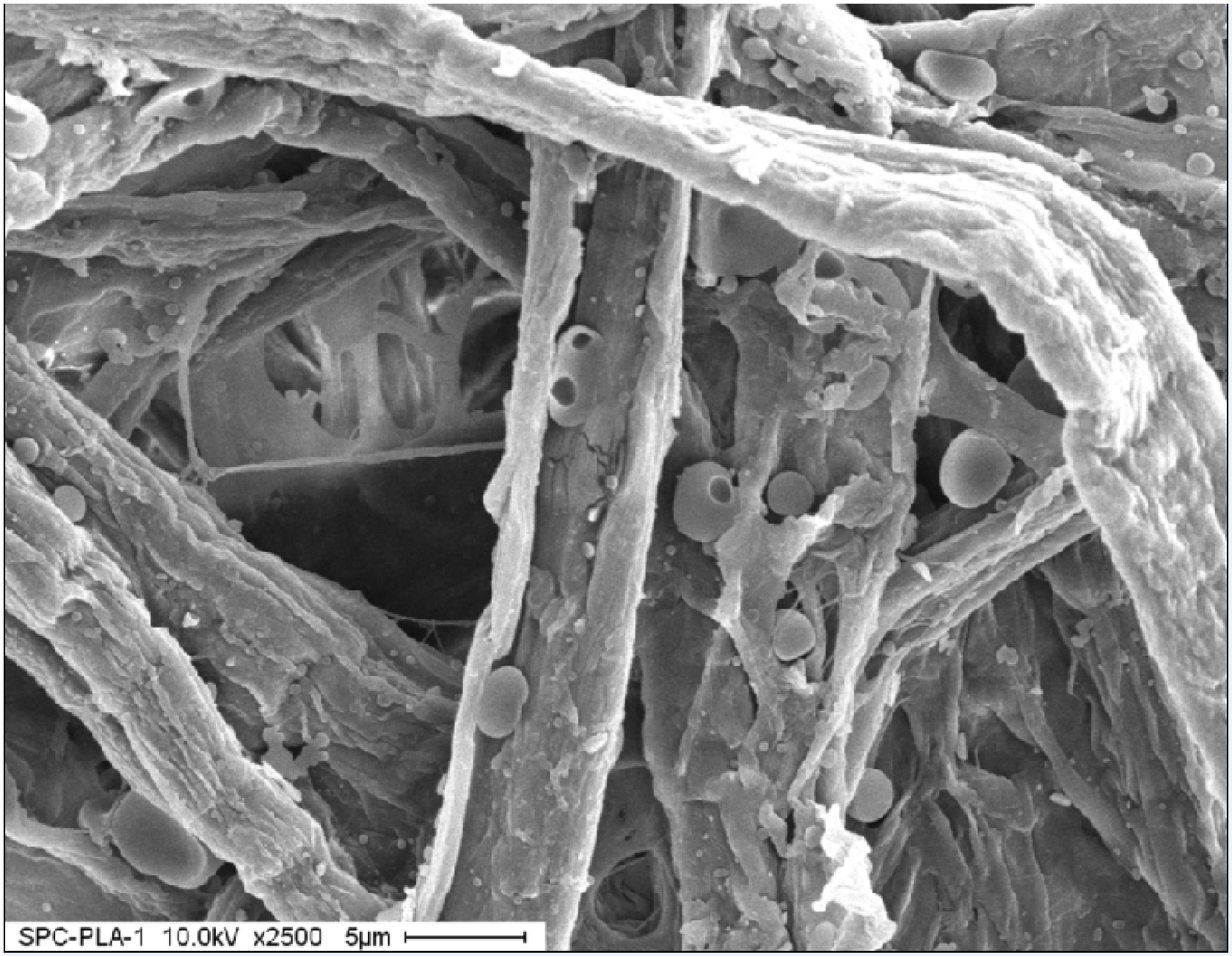


Figure 2: SEM micrograph of paper made from biorefinery pulp and treated in the surface with PLA (2% based on OD fibers)



- **Unbleached Kraft** pulp from **Hotwater extracted** chips in the Biorefinery is the natural step forward in exploring potential for PLA treatment.
- However the SEM images revealed that the PLA was not uniformly distributed.
- If PLA could be uniformly distributed by application in the **WET END,** it can further improve its prospects.
- PLA by itself is not soluble in water, so if combined with Cationic starch it could be stabilized in papermachine white water stock.

MATERIALS AND METHODS:
HOT WATER EXTRACTION

- Wood

-Sugar maple

(*Acer saccharum*)

Hot water extraction conditions

- **Performed in an M/K digester**
- **OD chips - 500 g**
- **Water to wood ratio - 4:1.**
- **Temperature profile - 45 minutes to 160 °C and 120 minutes at 160°C.**

At the end of the extraction the liquor was drained, Chips were washed and collected, and kept in plastic bags for pulping

Yield 81.4% OD wood

MATERIALS AND METHODS:
KRAFT PULPING

- **Pulping Conditions**

Temperature profile

- 60 minutes to 165° C ,

-5 minutes at 165° C , H-factor 132 (HW extracted kraft)

-45 minutes at 165° C , H-factor 536 (Regular kraft)

Active Alkali -16% on OD Chips

Sulfidity – 25%

Liquor to Wood - 4:1

- **H-factor was adjusted based on the results of preliminary experiments to produce pulp of kappa number ~40**

MATERIALS AND METHODS: PULP CHARACTERIZATION

- Kappa number (Tappi T 236 cm-85)
- PFI beating of pulp (T 248 sp-08) 5000 rev.
- CSF(T227 om-4)
- Hand sheet preparation (T205 sp-06)

** Strength properties tested

-Internal tearing resistance (Elmendorf type method, T 414 om-04)

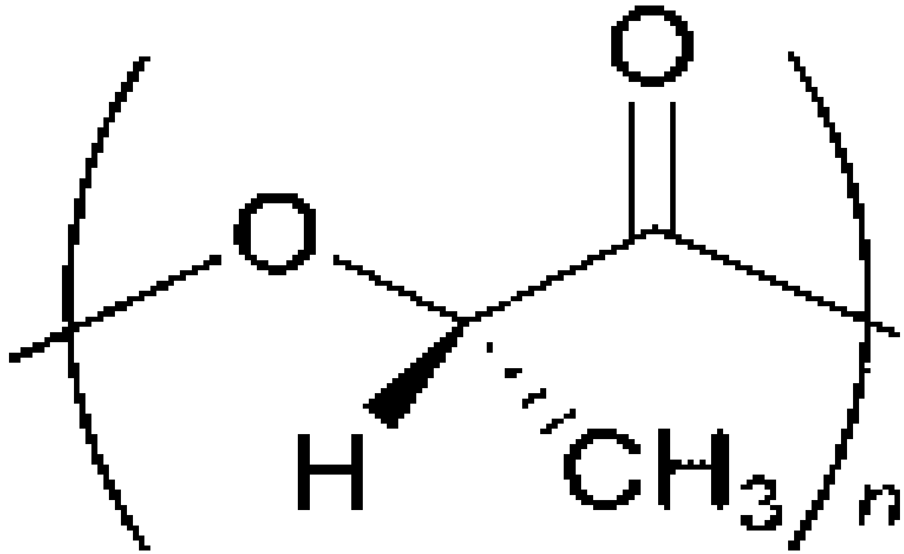
-Tensile strength (constant rate elongation apparatus, T494 om-06)

- Wet strength

MATERIALS AND METHODS: PLA AS A REINFORCING AGENT

- **PLA poly (dl-lactic acid)**

PLA	Poly (dl-lactic acid)	Supplier
MW	20K-30K	Polysciences, Inc.
Tg	54 C	Cat.#165



- **PLA solution in acetone, 0.8-1 g/L concentration**
- **Experiments were performed at PLA level:**

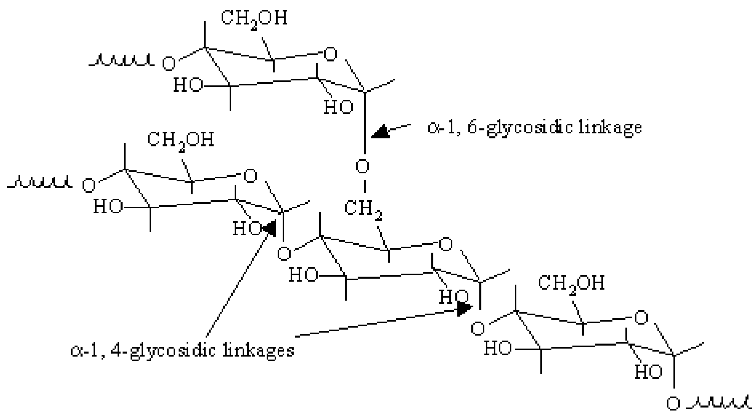
On surface based on OD fiber w/w

- **2%**

In Stock based on OD fiber w/w

- **0.9% (max)**
- **0.5% (min)**

MATERIALS AND METHODS: Starch AS A REINFORCING AGENT



AMYLOPECTIN	N2 CONTENT (%)	Supplier
Starch A	0.43	Tate & Lyle,
Starch B	0.3	Decatur IL 62525

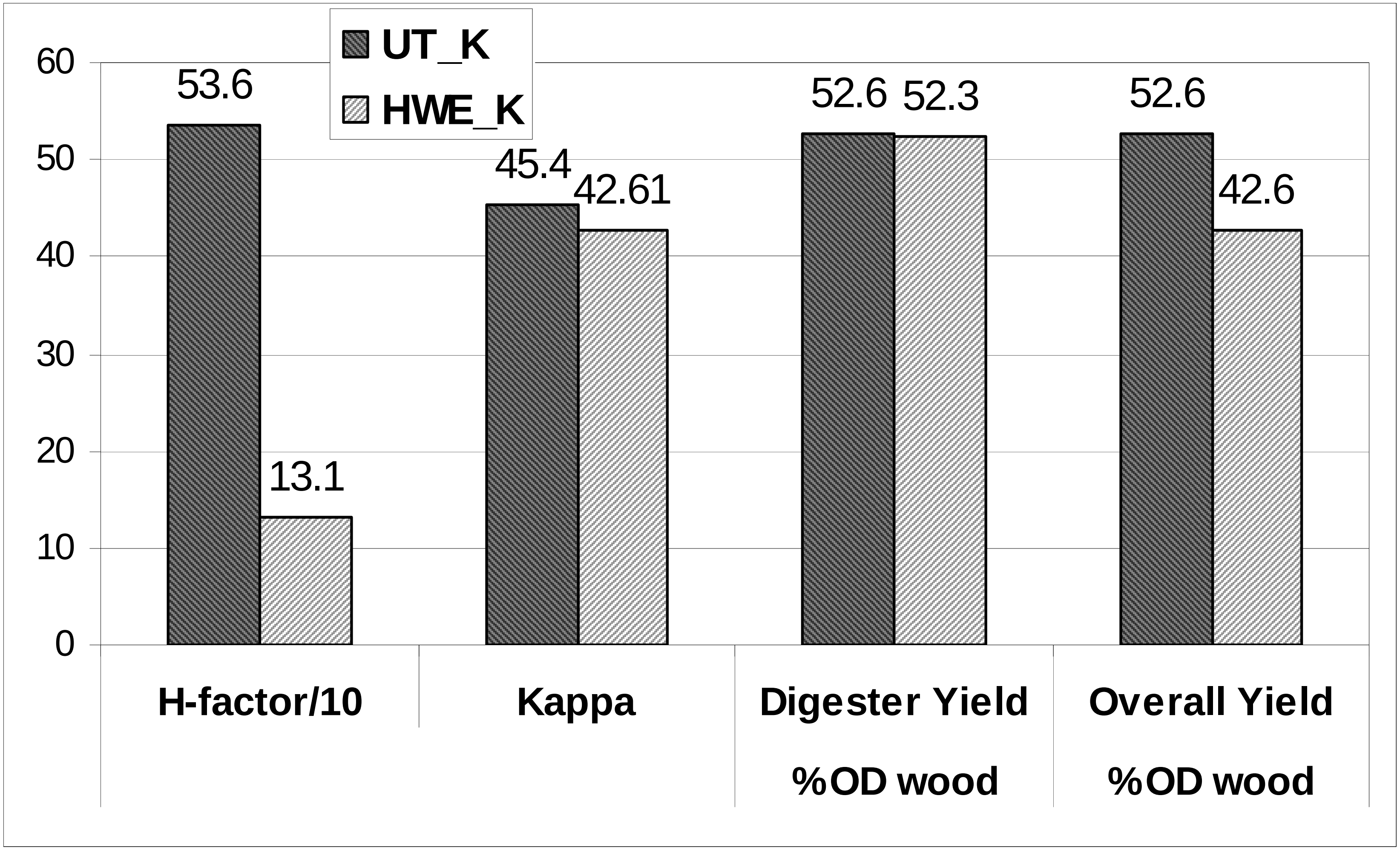
- Starch was first slurried by mixing dry powder with water
- cooked at 0.3% solids at 95-97^{0}C for an hour under constant stirring
- It formed a clear aqueous starch paste ready to be applied in stock.
- PLA-Starch mix: Since PLA is not soluble in water, PLA in acetone was mixed with the aqueous starch paste and together they formed a clear stable solution.

MATERIALS AND METHODS: ADDITIVE DOSAGE

Test sheets	Description	Reinforcement method		
		Surface	Wet-end	
		PLA % OD fiber	PLA % OD fiber	Starch % OD fiber
CP	Control Unextracted	-	-	-
BP	Biorefinery Hot Water Extracted	-	-	-
BPPLA2	BP with 2% PLA sprayed	2	-	-
BPSA1	BP with 1% starch A in wet end	-	-	1
BPSB1	BP with 1% starch B in wet end	-	-	1
BPPLA0.5SA0.5	BP with PLA 0.5% and Starch A 0.5%	-	0.5	0.5
BPPLA0.5SB0.5	BP with PLA 0.5% and Starch B 0.5%	-	0.5	0.5
BPPLA0.9SA0.1	BP with PLA 0.9% and Starch A 0.1%	-	0.9	0.1
BPPLA0.9SB0.1	BP with PLA 0.9% and Starch B 0.1%	-	0.9	0.1

PULPING RESULTS

Kraft pulp from HW extracted chips vs. un-extracted chips



SHEET PROPERTIES of HWE vs. control pulp
(without any use of Additives)

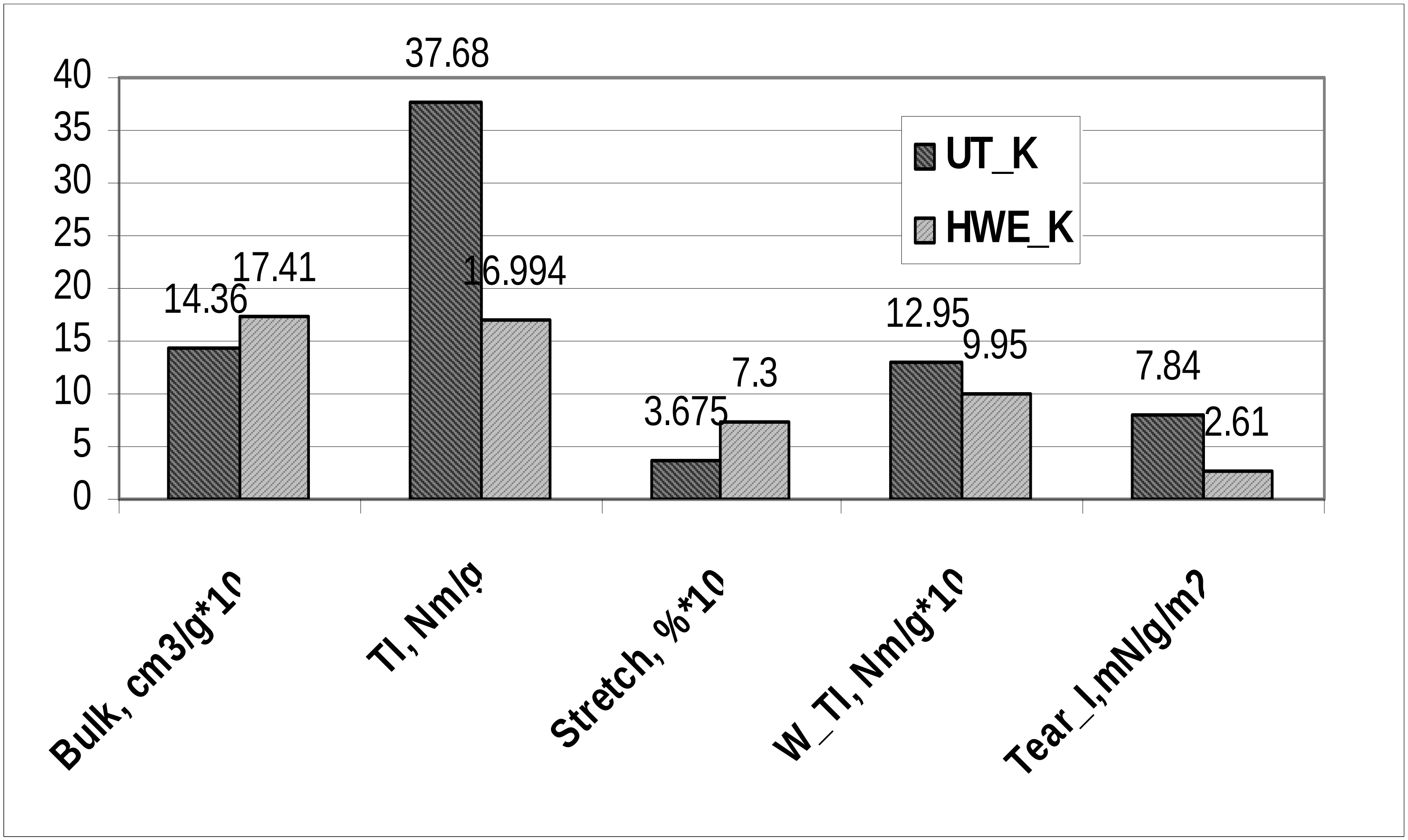


Figure : Effect of increasing amount of PLA in the PLA-starch B blend at the constant amount of starch B at 0.5% based on OD fiber **on the bulk** of HWE biorefinery pulp (BPPLA_SB0.5)

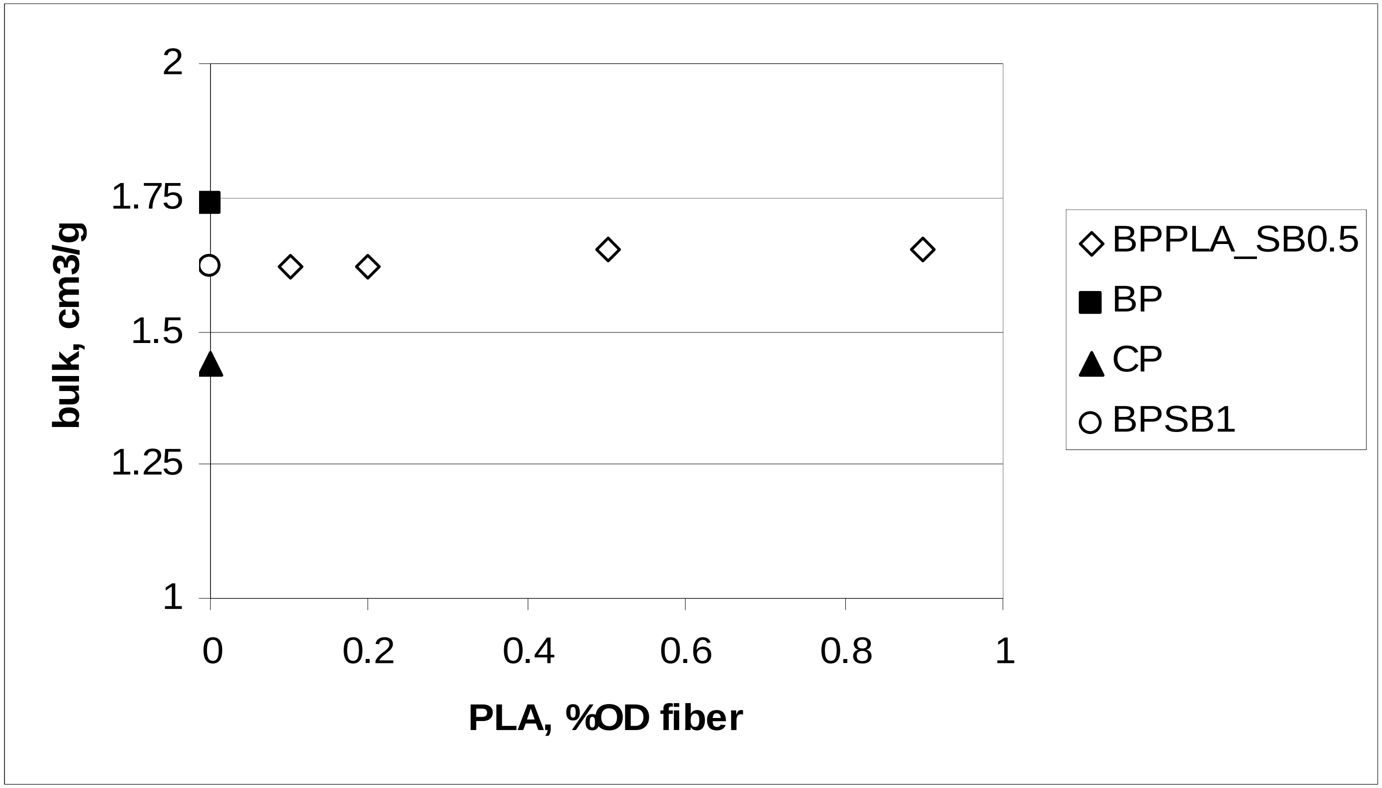


Figure : Effect of increasing amount of PLA on the **Tensile index** of HWE biorefinery pulp (BPPLA_SB0.5) using the PLA-starch B blend for starch B dosage at 0.5% based on OD fiber

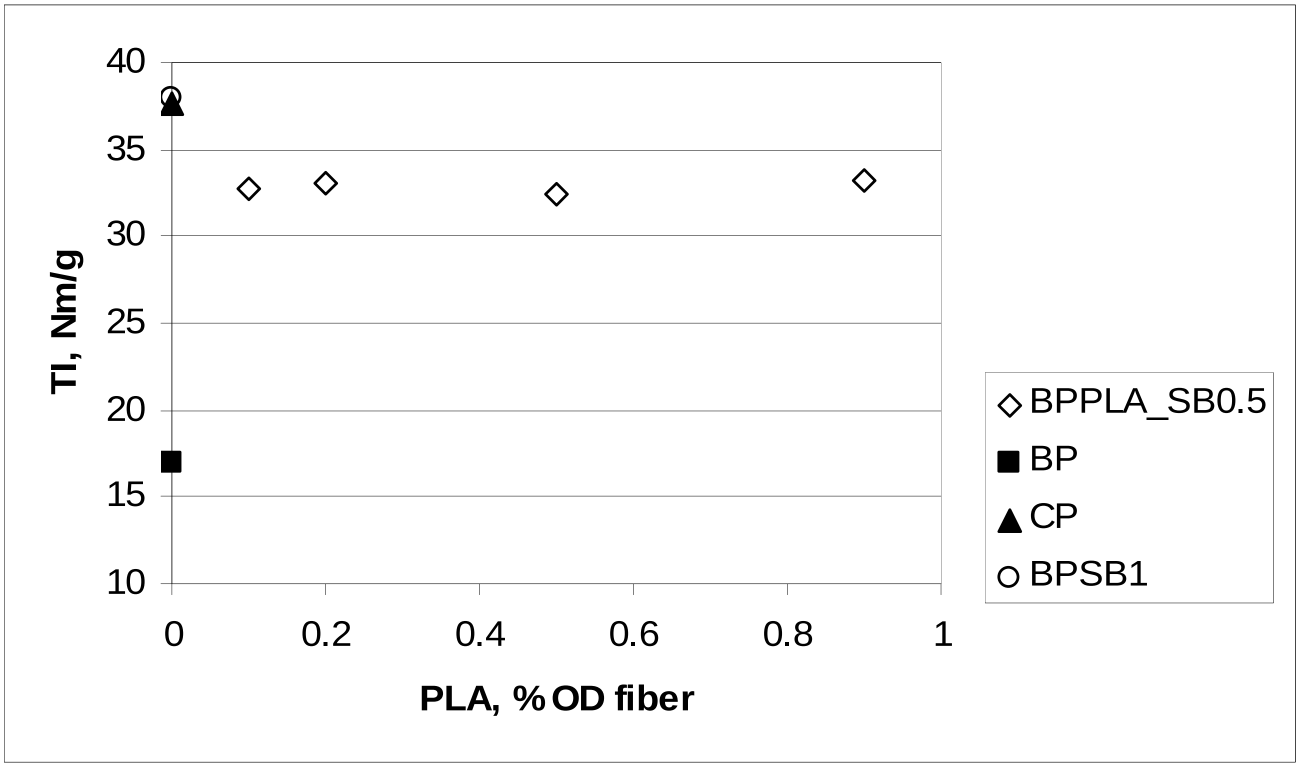


Figure : Increasing amount of PLA in the PLA-starch B blend at the constant amount of starch B at 0.5% and the **Tear index** of HWE biorefinery pulp (BPPLA_SB0.5)

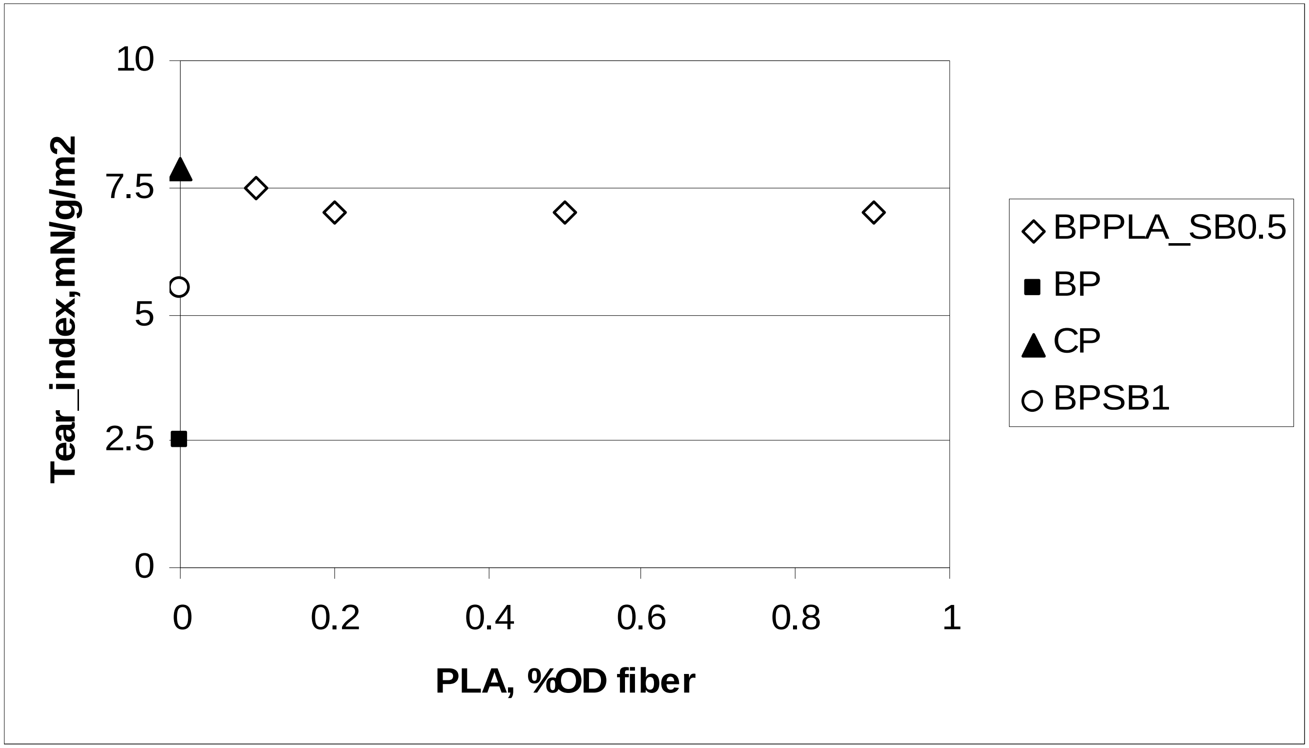
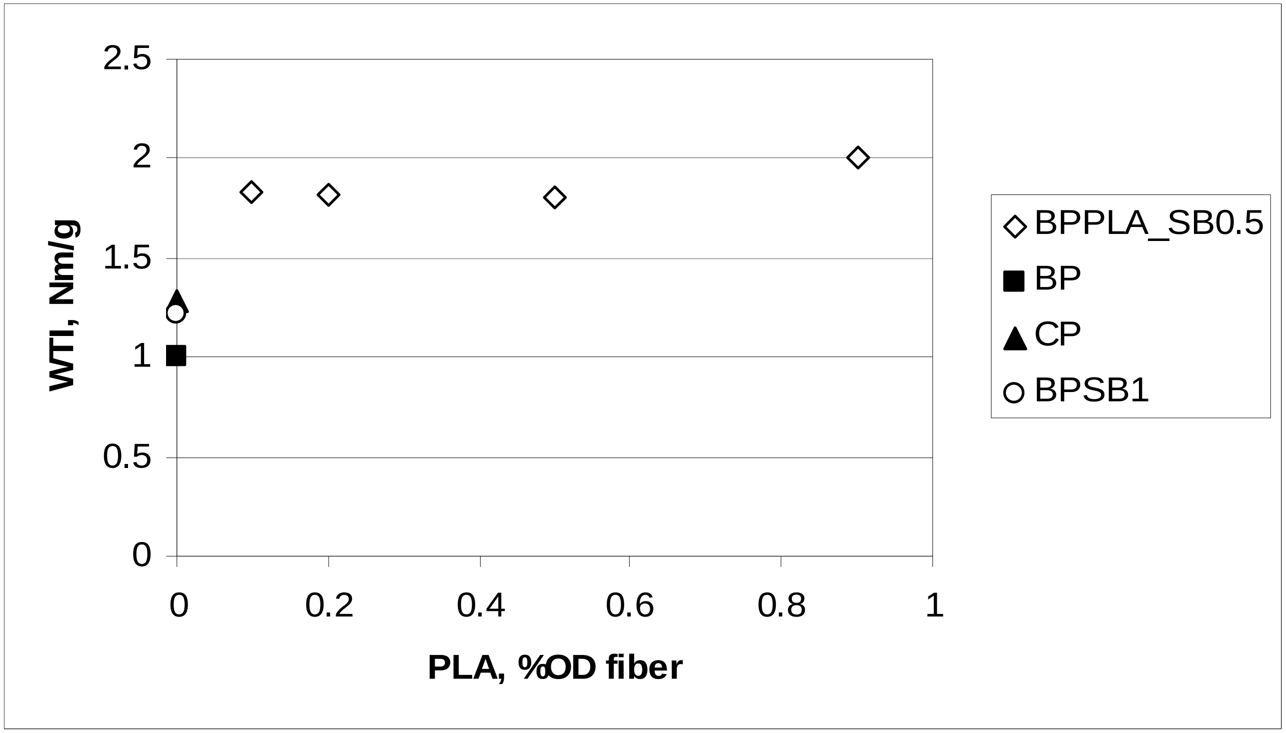


Figure : Effect of increasing amount of PLA in the PLA-starch B blend at the constant amount of starch B at 0.5% based on OD fiber on the **Wet Tensile index** biorefinery pulp (BPPLA_SB0.5)



Conclusion

- Reinforcement of sheets was achieved by adding the PLA-cationic starch blend in the wet end.

-This is important as it is convenient to add PLA-starch emulsion in the wet end stock

- In addition, these experiments demonstrated that five parts of the cationic starch applied as a dry strength agent may be successfully replaced with one part of PLA with minimal loss of Tensile strength and improvement in Tear and Wet tensile strength.
- The PLA/starch combination enhances both wet and dry strength of the biorefinery pulp

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