Development of Bio-based Phenol Formaldehyde (BPF) Foams for Various Applications

Western Engineering

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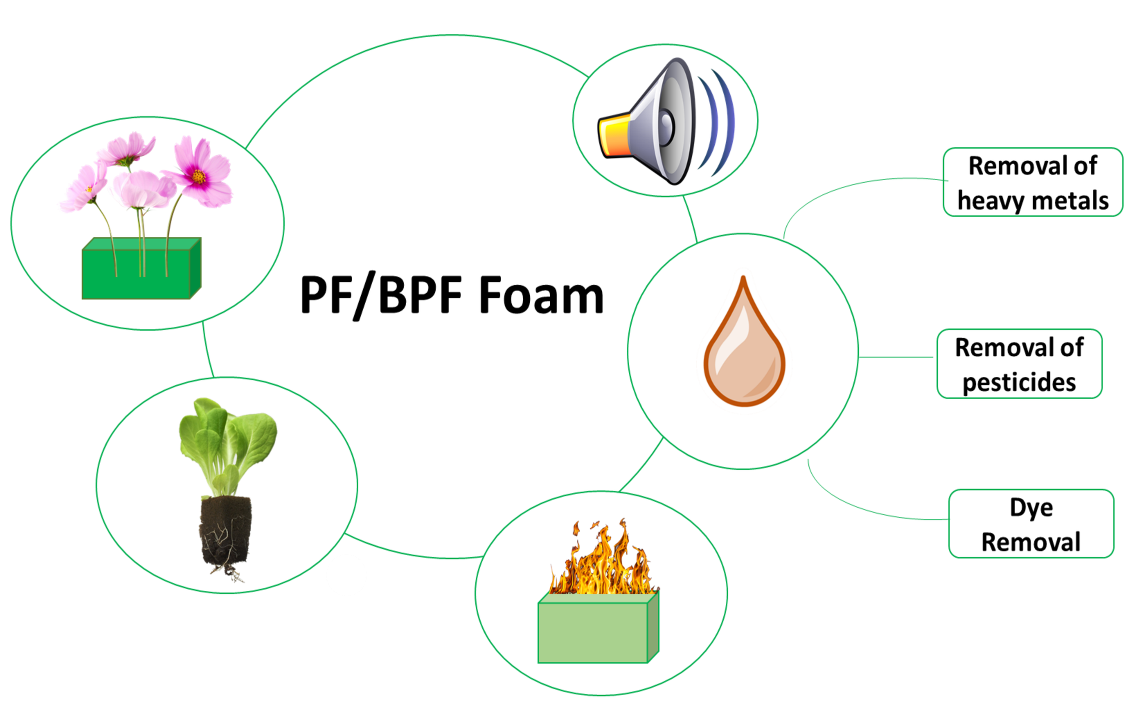
Chemical and Biochemical Engineering

Introduction

- Phenolic foams are widely used in the insulation, construction, floral, and transportation industries.
- Phenol and formaldehyde, required for the production of PF foams, are predominantly derived from fossil resources.
- Phenol is conventionally produced from petroleum crude oil through the cumene route, constrained by greenhouse gas emissions and increasing prices of crude oil.
- Consequently, there has been a keen interest in replacing petroleum-based phenol with alternative renewable resources.
- Lignocellulosic biomass has been one such alternative used for the production of bio-based chemicals such as phenols, alcohols and organic acids.
- A lignin-based polymeric foam with desirable properties can be obtained by foaming a BPF resole resin with curing catalysts, surfactants, and blowing agents.
- Applications of phenol formaldehyde (PF) foams are dependent on their cell structure: while closed-cell foams are used predominantly in the insulation sector, open-celled foams are used for floral, soundproofing and hydroponic applications

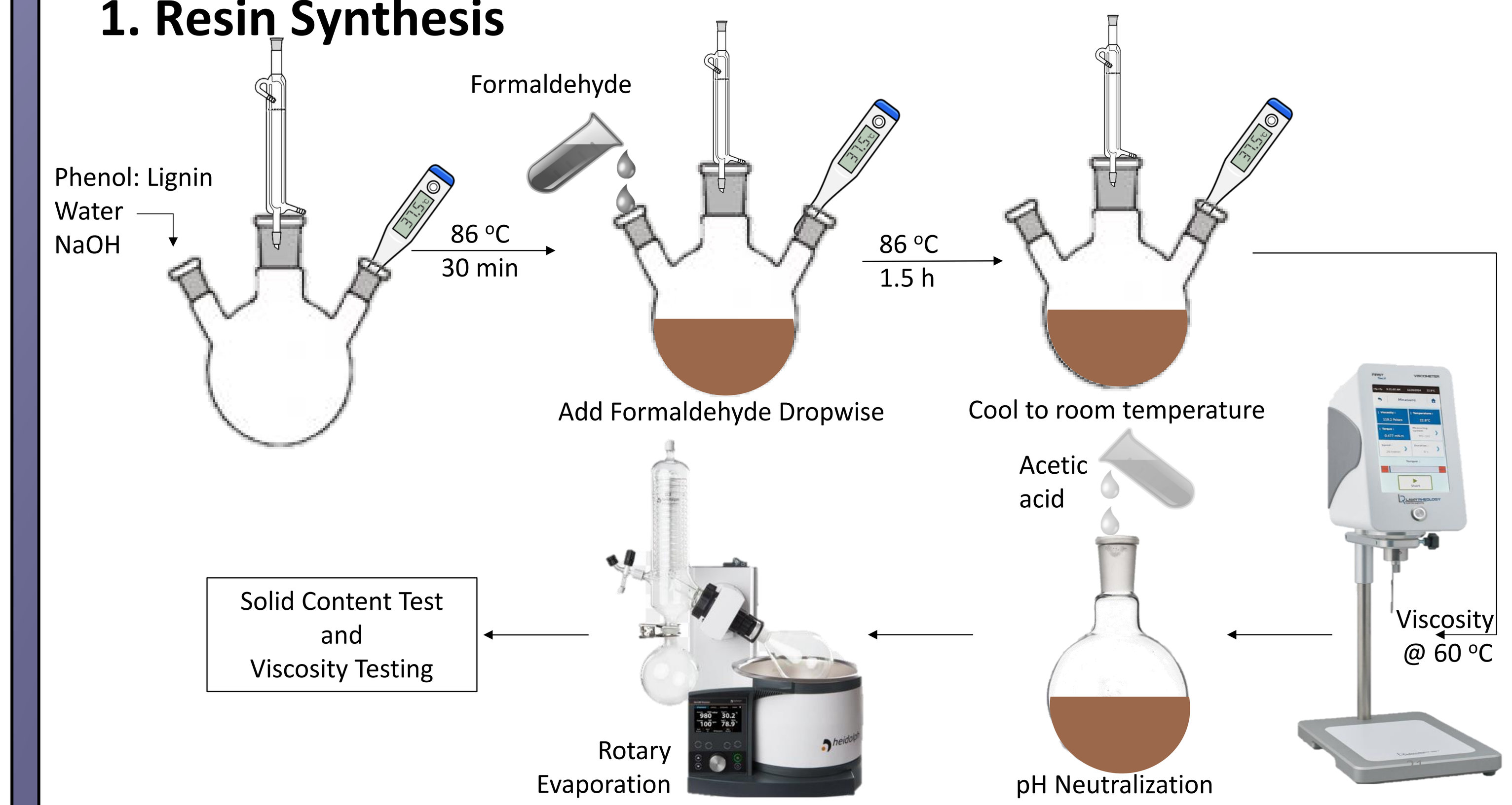


Objectives

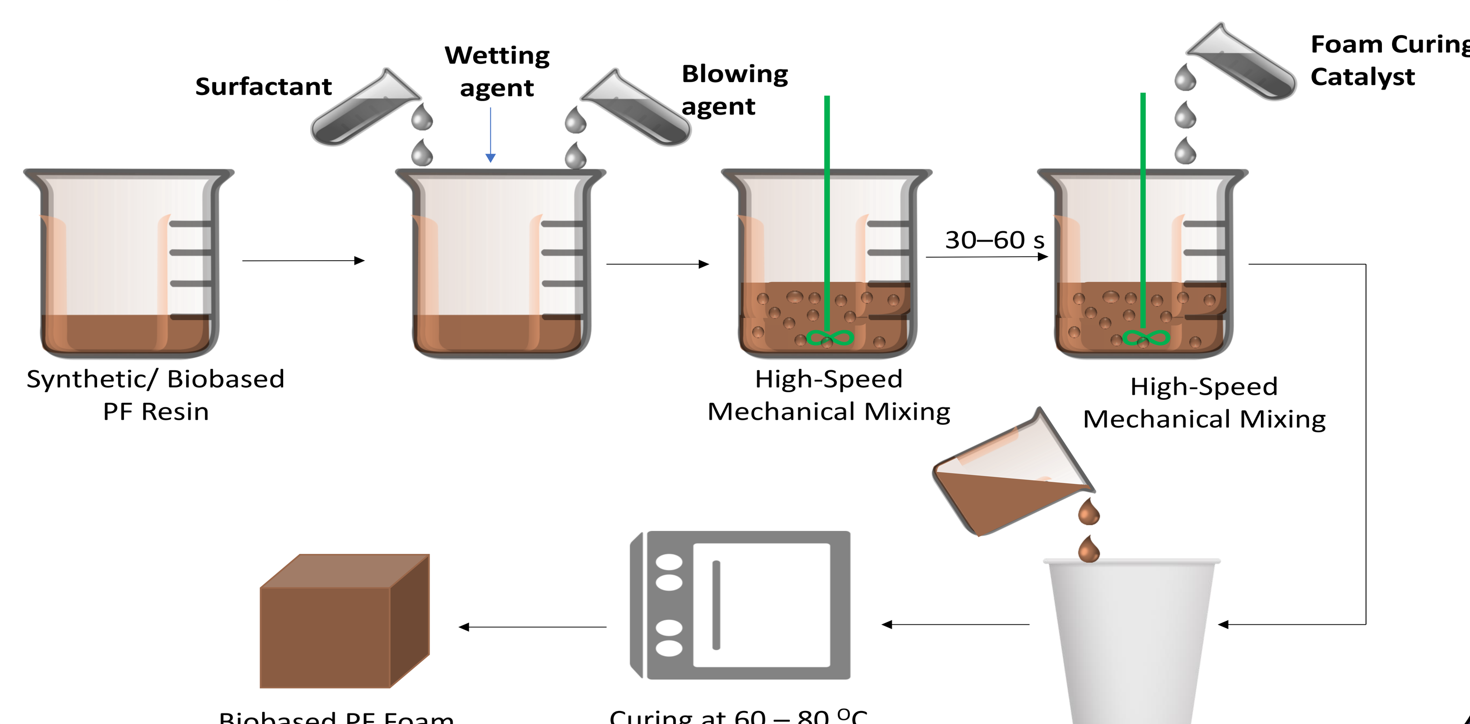
1. Establish the synthesis methods of foamable neat PF resole resins
2. Synthesize foamable biobased resole resins by replacing phenol with bio-phenols (kraft lignin, lignosulfonate or de-polymerized lignin) at a high substitution ratio (30-100 wt%), followed by foaming, to obtain desired characteristics of BPF foams
3. Demonstrate applications of the prepared BPF foams as floral foams, for hydroponic seed germination in a greenhouse, and for environmental remediations

Research Procedure

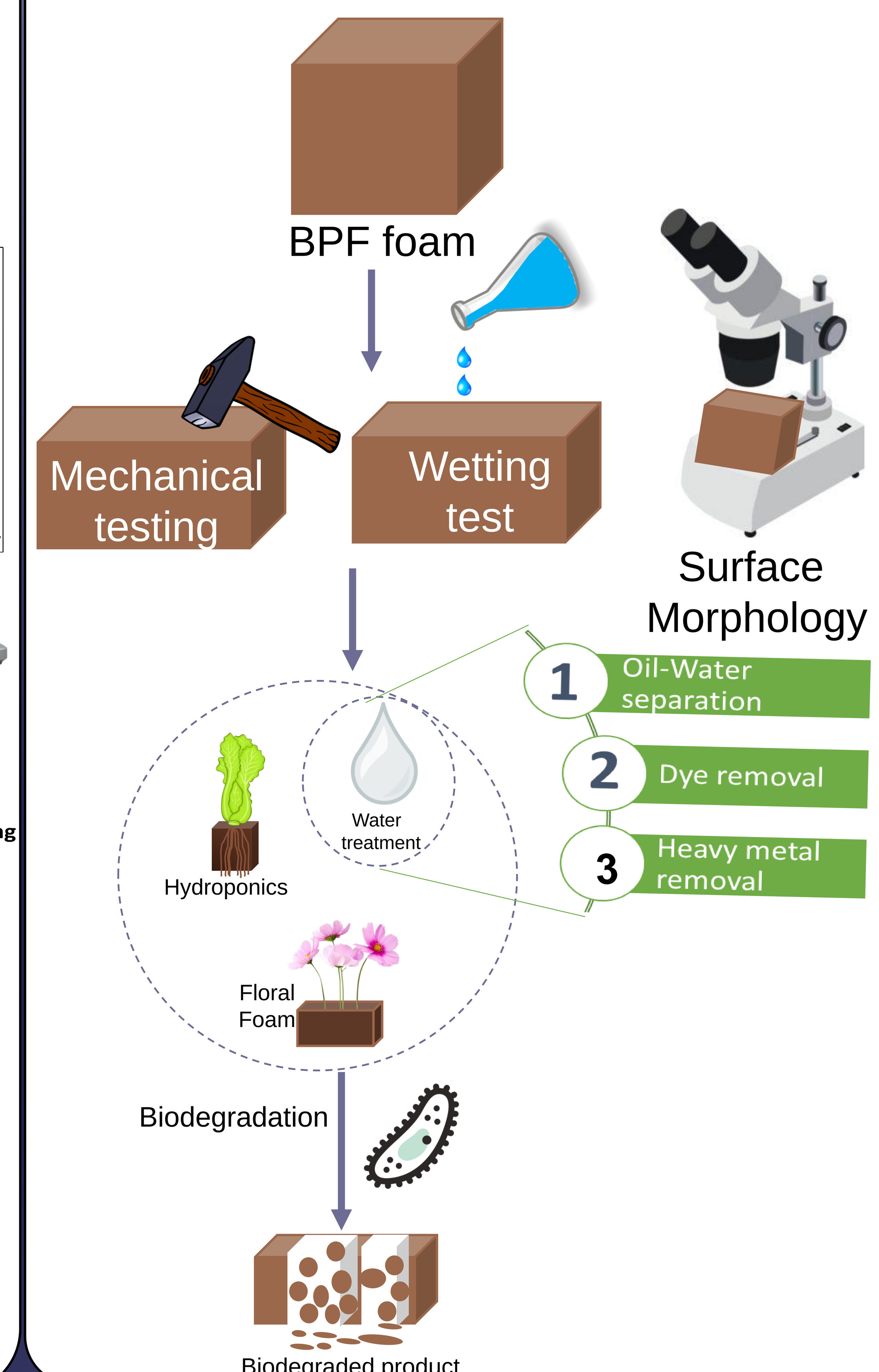
1. Resin Synthesis



2. Foaming Procedure



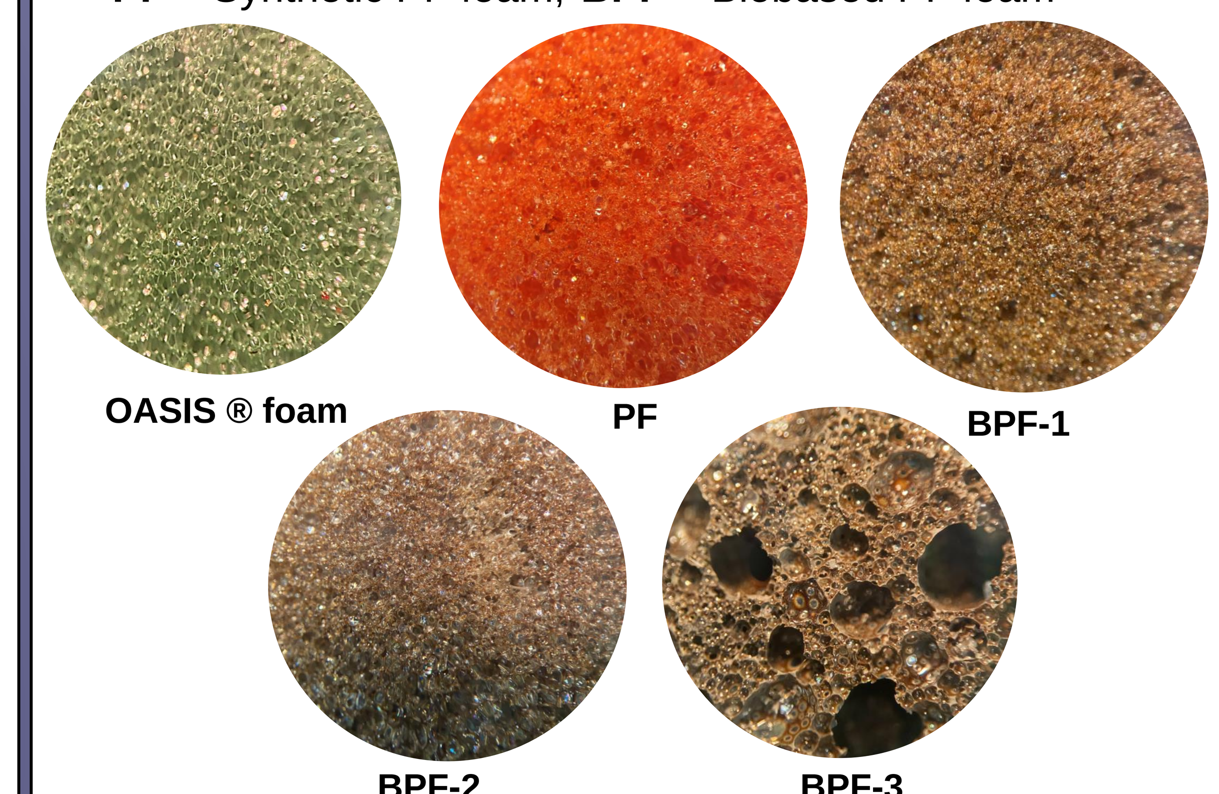
Tests and Foam Characterization

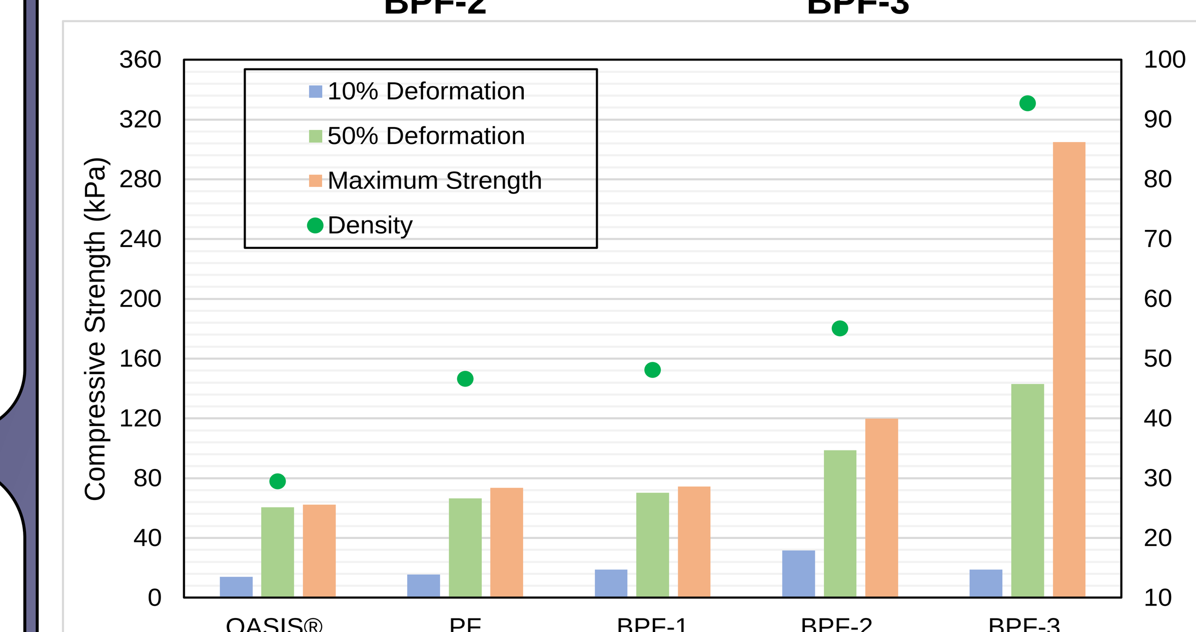


2. Effect of lignin substitution on foam characteristics

Foams	Lignin substitution (%)	Apparent density (kg/m³)	Open cell content (%)	Water absorption capacity (%)
OASIS®	0	29.92	98.60	2300
PF	0	46.62	56.69	1209
BPF-1	20	48.15	56.22	1064
BPF-2	30	55.08	60.25	891
BPF-3	50	92.75	86.87	882

#PF – Synthetic PF foam; **BPF** – Biobased PF foam



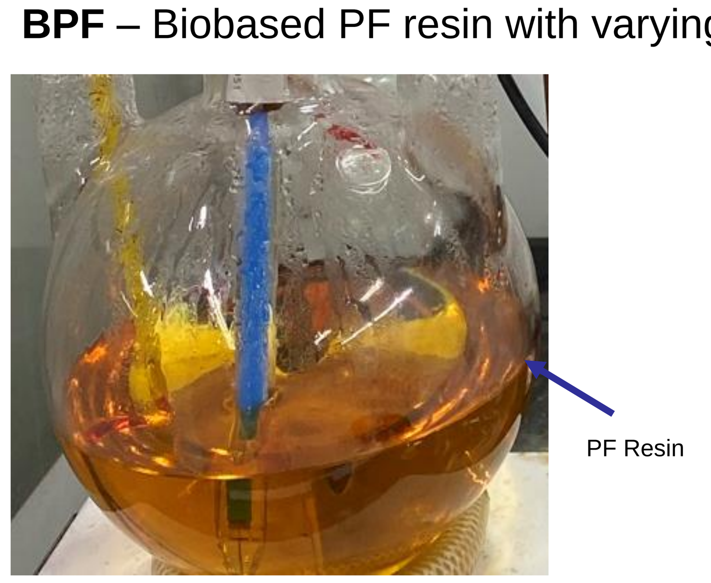


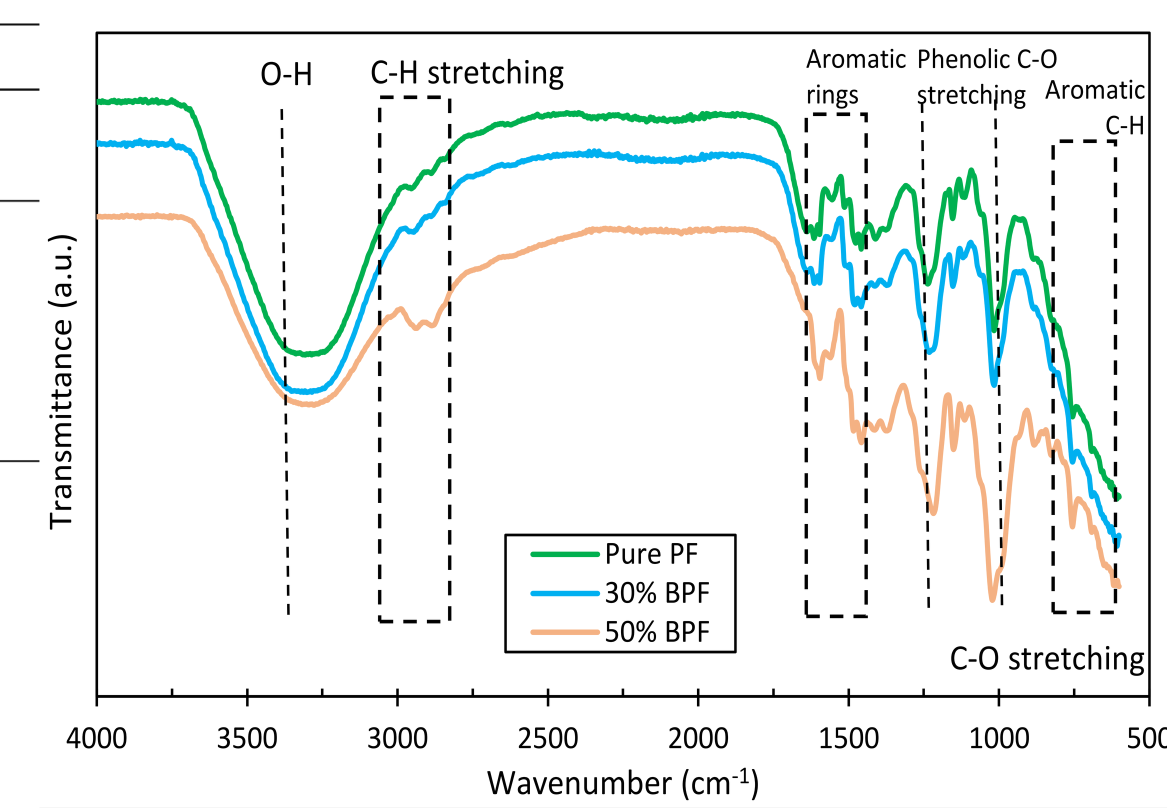
Key Results

1. Physical and Chemical properties of foamable PF and BPF Resins

Resin	pH		Viscosity at 60 °C	Solid content (%)	
	Before neutralization	After neutralization	(cP)	Initial	Final
PFR	9.40	6.29	302	45.85	75.52
BPF-20	9.31	6.20	1193	51.92	74.10
BPF-30	9.75	6.36	1209	50.02	77.45
BPF-50	9.40	6.36	4321	47.19	78.10

BPF – Biobased PF resin with varying lignin substitution ratio





Conclusions:

- With increasing lignin content, open cell content increased and the water absorption capacity steadily decreased
- The apparent density and the compressive strength increased with the increase in kraft lignin substitution
- The maximum compressive strength increased from 74.39 to 302 kPa when the lignin substitution increases from 20 to 50%

Acknowledgements

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