Plant Based Resins for Fibre Composites

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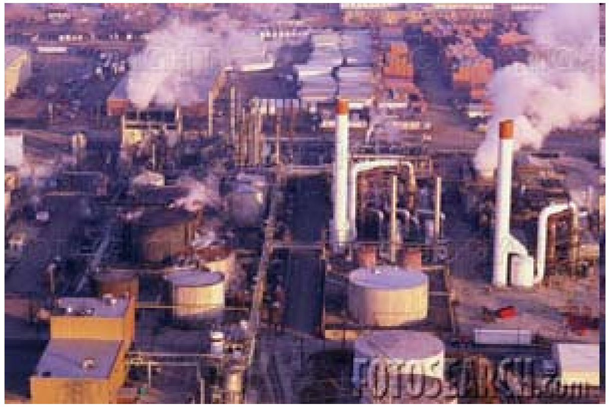
Aims of vegetable oil resin work at CEEFC

- Explore options for sustainable production of several classes of thermosetting resin
- Save resin costs while providing value-adding opportunities for Australian farmers
- ***Short term***: Provide viable technology for immediate partial resin replacement:
  - 30% in structural applications
  - 50% in semi-structural applications
- ***Long term***: Explore development of 100% sustainably sourced composites, combining wholly-vegetable oil resins with natural fibre reinforcements

Vegetable Oil Resins – Background

- ***Cost.*** Resins used in highly-filled civil engineering composites constitute approx. 80% of total cost
- ***Price increases.*** Resin costs have increased steadily over the last 2-3 years in proportion to increase in crude oil price.
- ***Uncertainty of supply.*** Crude oil supplies are finite and unsustainable over the long term. Viable alternatives to crude oil based resins will need to be found to ensure the sustainability of thermosetting resin supply.
- ***"Green Factor".*** Environmentally sustainable technologies increasingly command price premiums. In excess of US $600 million of biopolymers are expected to be sold in 2006.

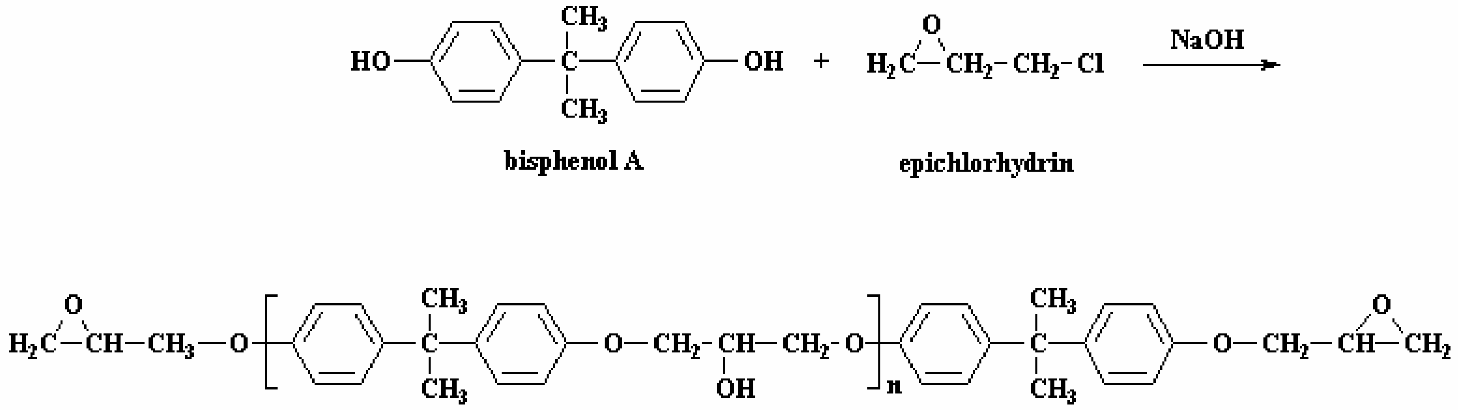
Petrochemical Route for Resin Synthesis

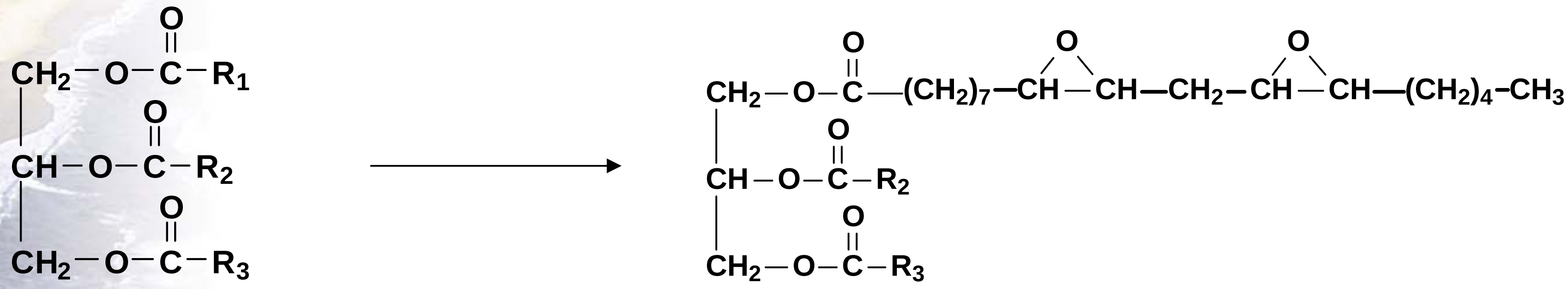


Renewable Route to Resin Synthesis

- local supply, transport savings
- simpler refining
- sustainable resin supply

Synthesis of Epoxides from Nonrenewable & Renewable resources



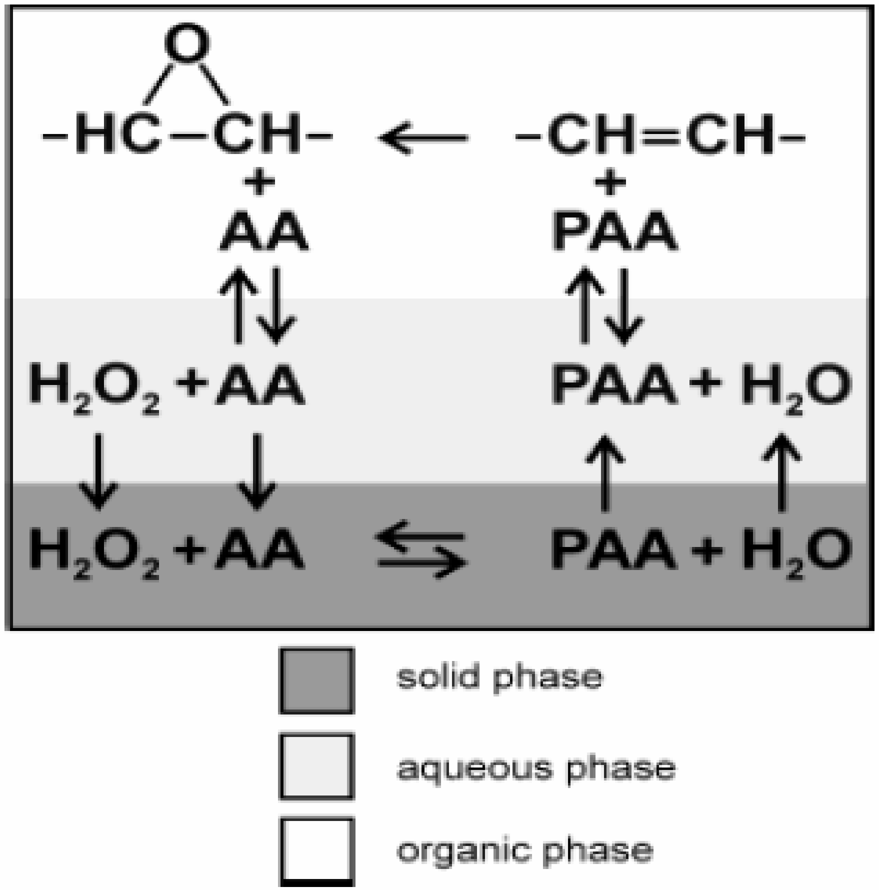


Epoxidation of Double Bond

with in-situ generated peracetic acid

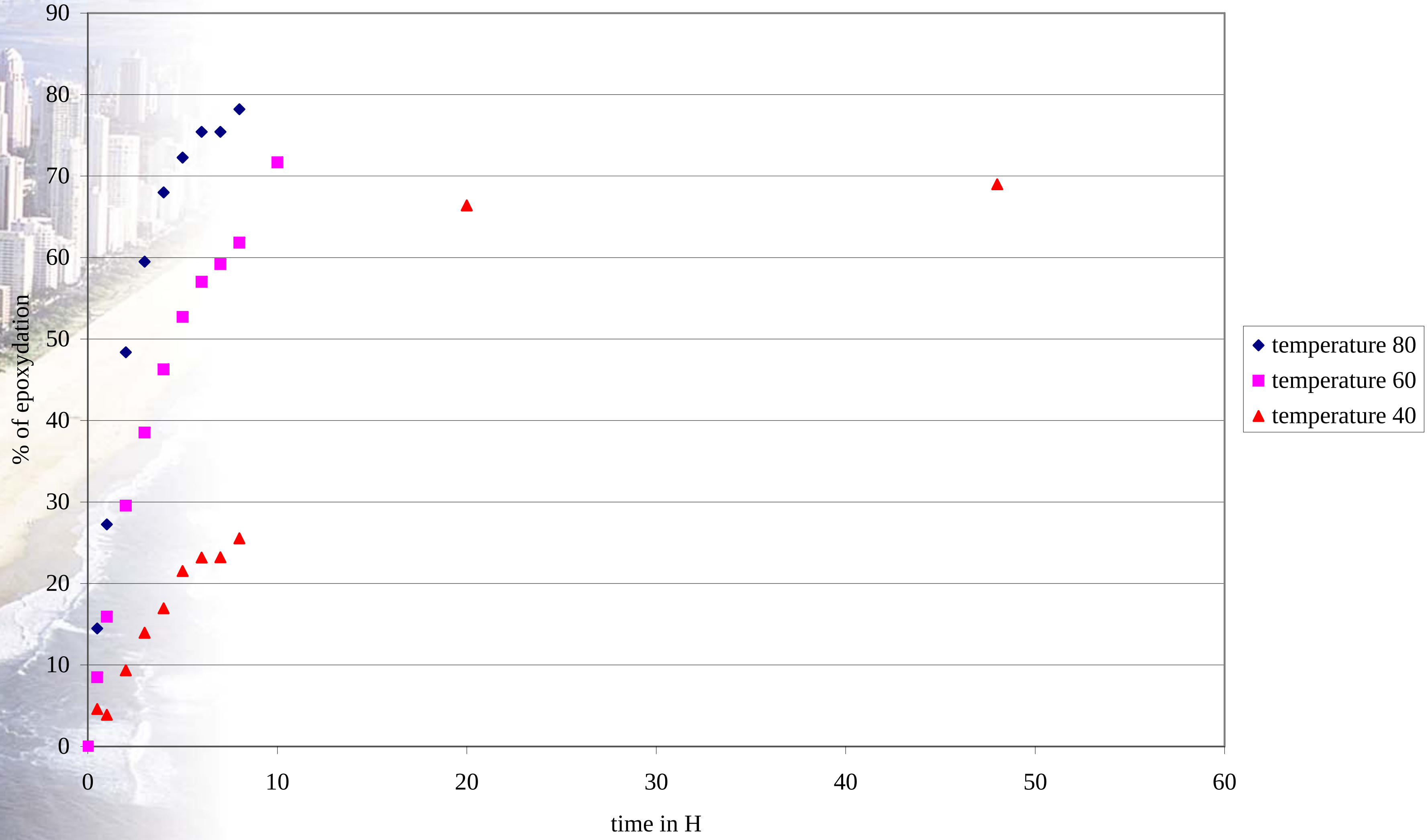
$$H_2O_2 + CH_3COOH \longrightarrow \text{CH3COOOH} + H_2O$$

Two Phase Model of Epoxidation with Ion Exchange Resin



Reactor for Epoxidation

Epoxidation of Canola as Function of Temperature and Time



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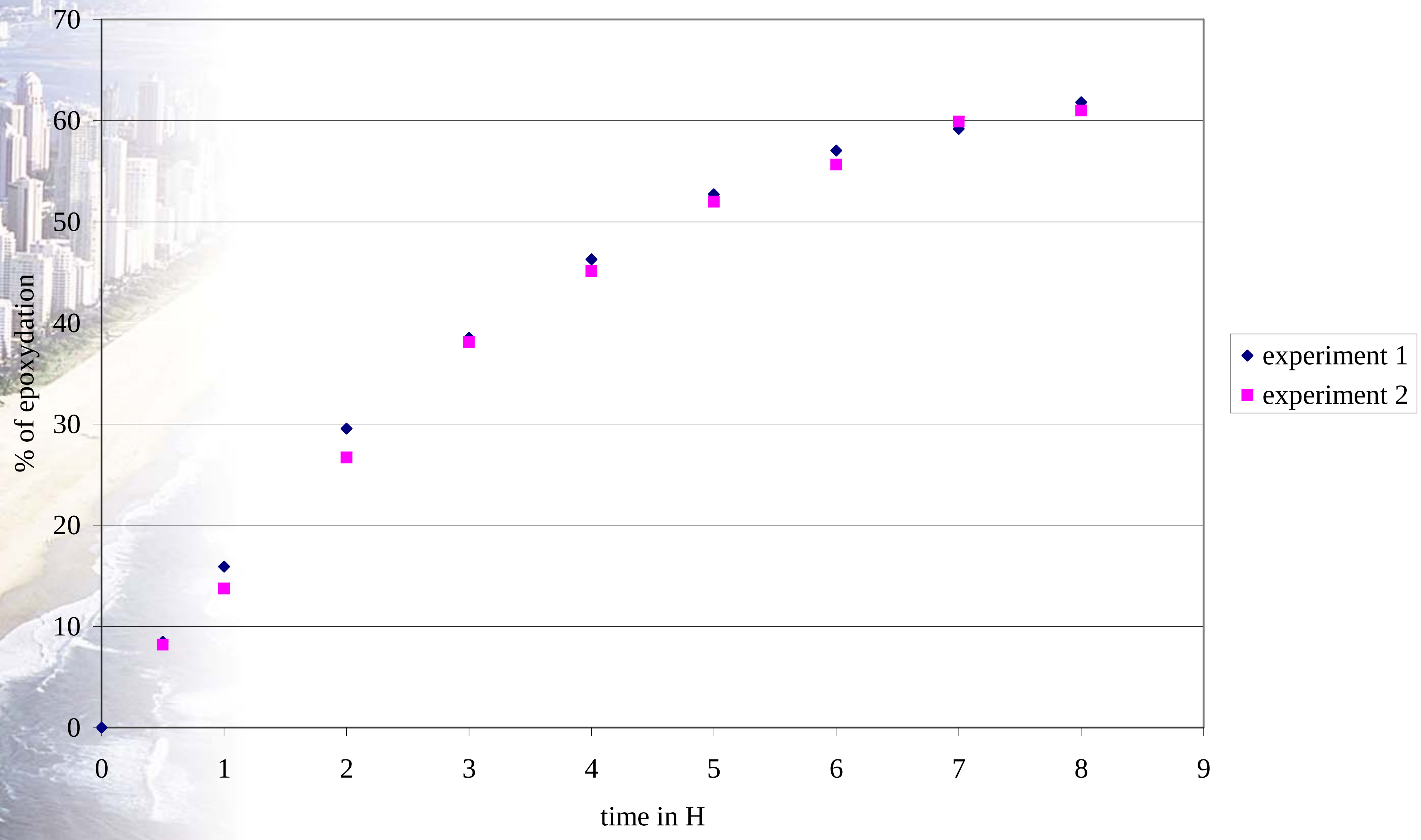
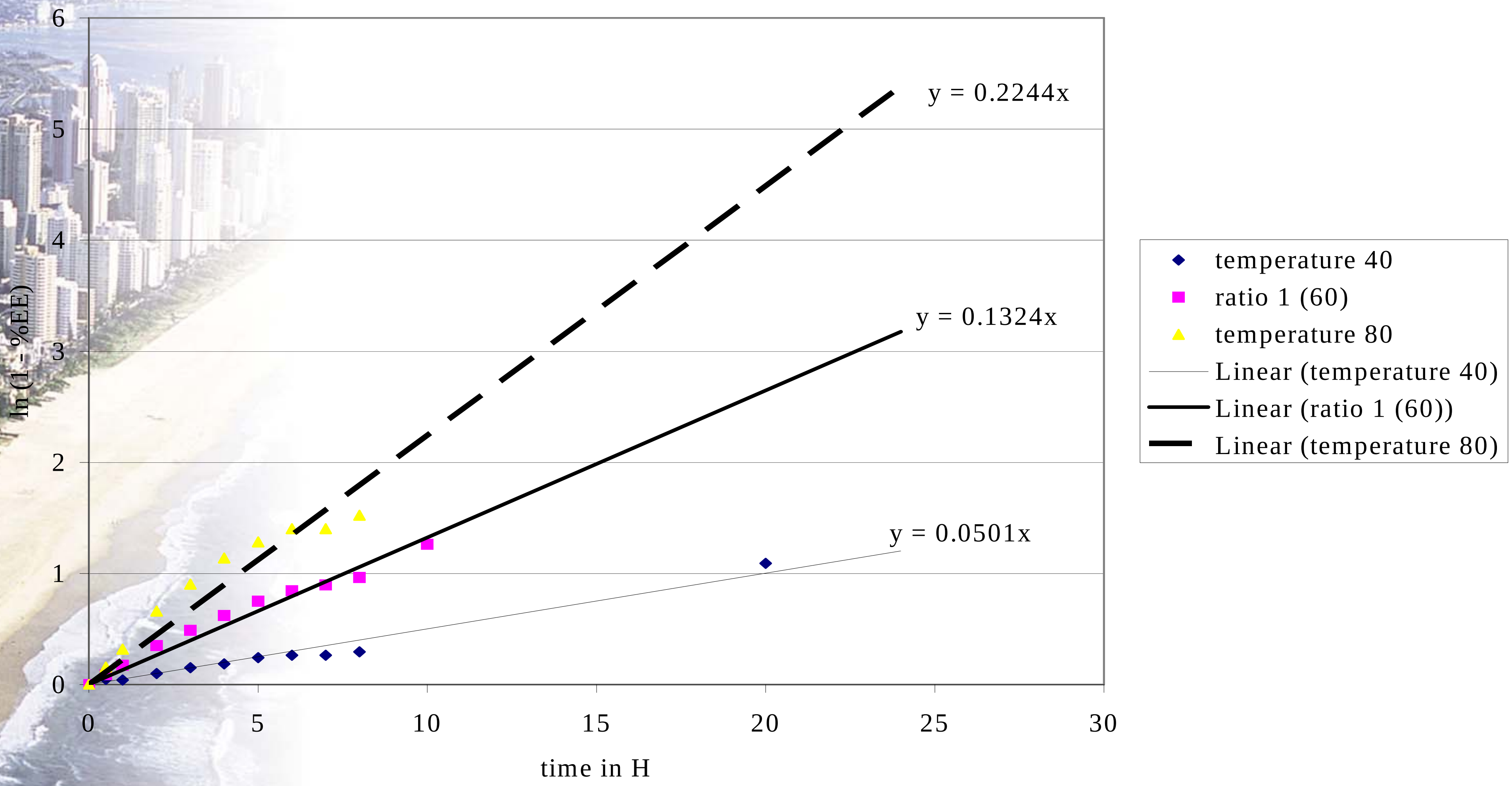
Repeatability of Canola Epoxidation at 60° C



Canola Epoxidation at three Temperatures



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Epoxy Equivalents of the Epoxidized Oils

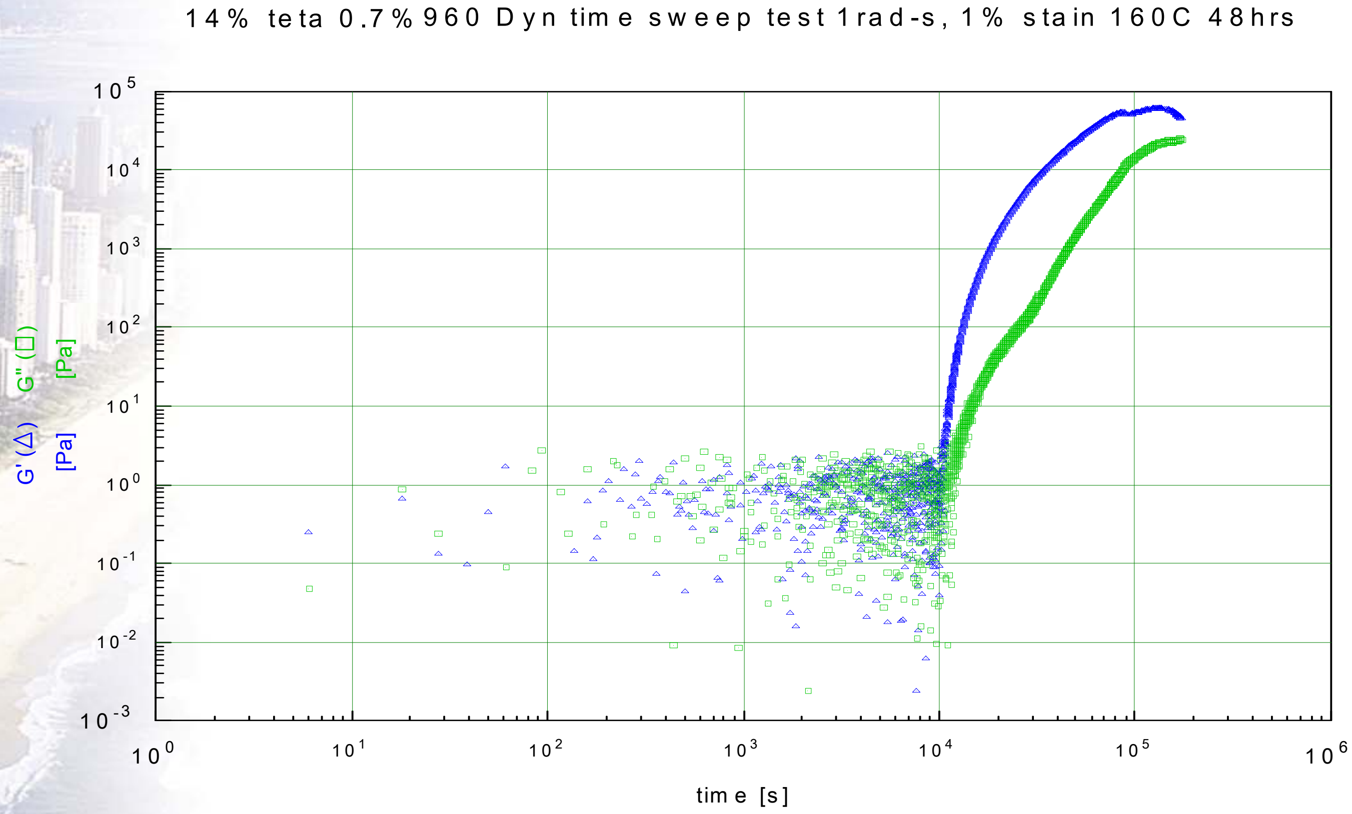
oil	molecular weight (D)			iodine value (IV)			calc. max. EE (g/oxiran oxygen)
	literature	found	difference %	literature	found	difference %	based on found IV value
linseed	873.2	872	0.1	185	177	4.3	137
canola	878.9	934	-6.3	120	118	1.7	212
new hemp	874.4	1018	-16.4	162	159	1.9	160
old hemp	874.4	1022	-16.9	162	162	0.0	157

Comparison of some selected epoxidized materials

No.	Name	EE [g/oxir. oxyg.]	% of the maximum epoxidation achievable	Note
1	Araldite GY 260 IN	181	n/a	petrochemical
2	CTBN, Epon 58042	339	n/a	petrochemical
3	Lakroflex E2307	234	79	estimated, ESBO
4	Epox. Canola -CEEFC	297	71	ECO; 60 ° C, 10 h
5	Epox. Linseed-CEEFC	222	62	ELO; 60 ° C, 10 h

Note: No. 4 and 5 - reaction with: oil/HOAc/H2O2 = 1/1/2

Curing of low epoxidized LSO upto Gel Point



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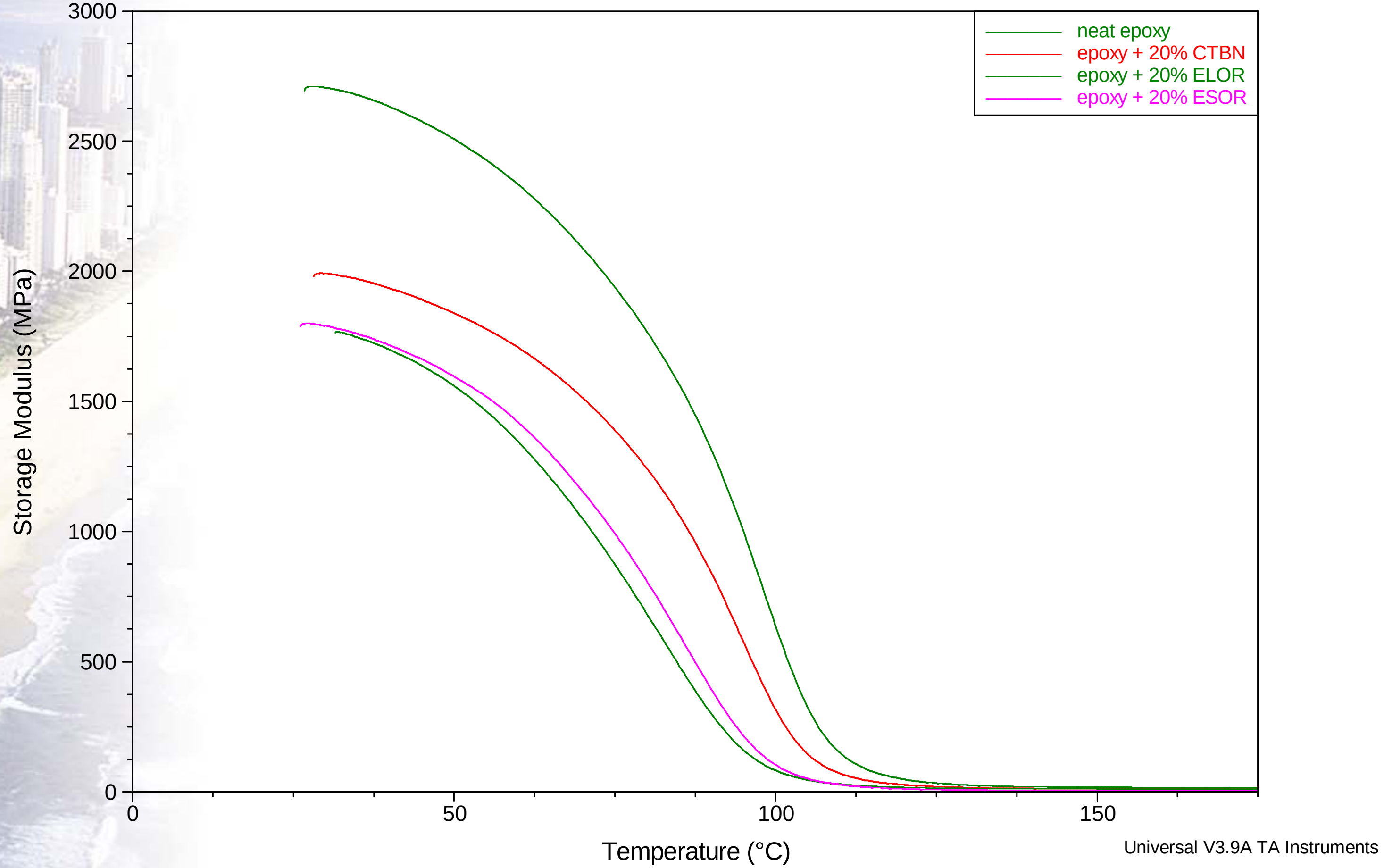
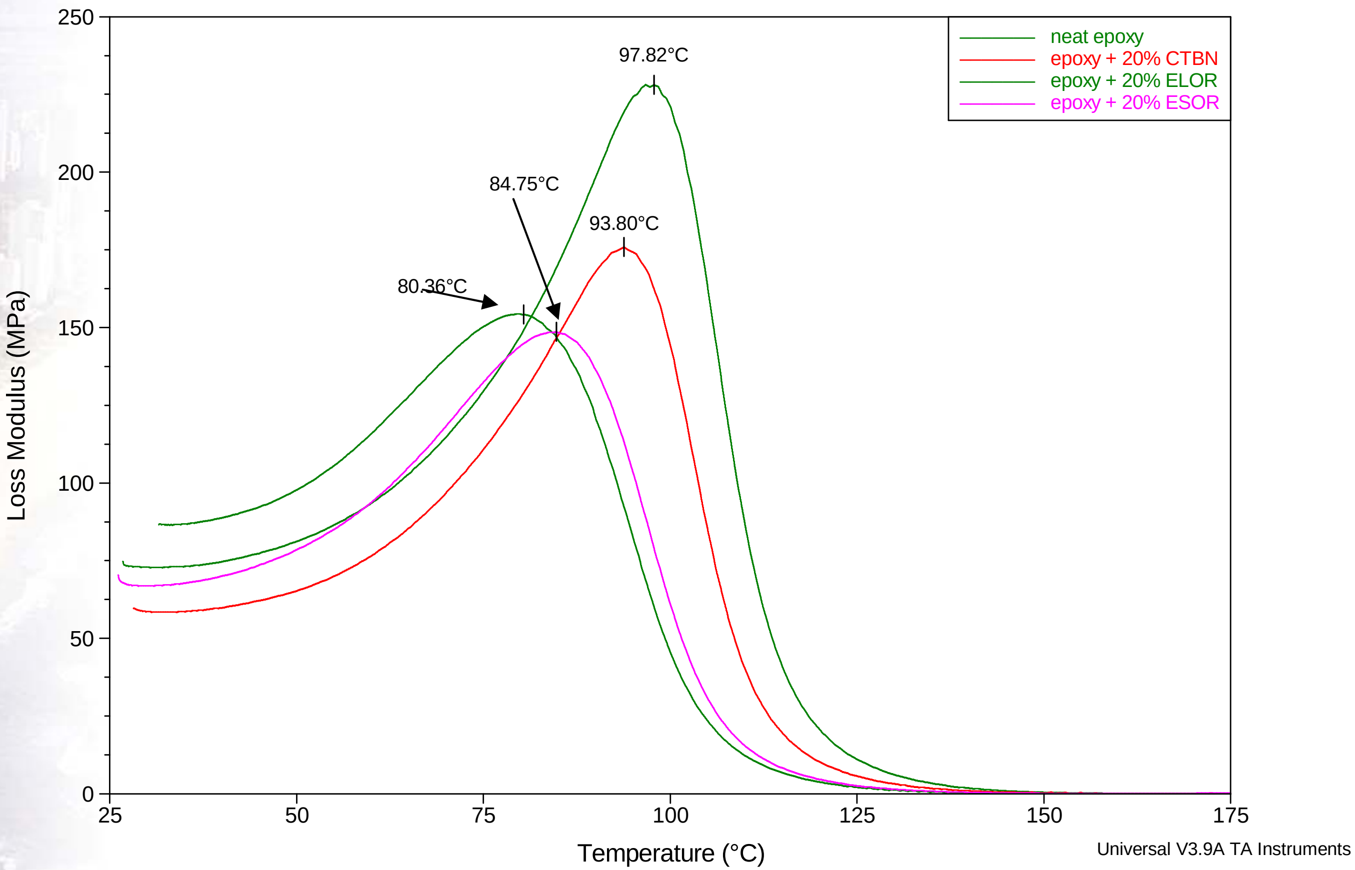
Flexural Properties with Addition of Epoxidized oils

System	Flexural Strength (MPa)	Flexural Modulus (GPa)
Neat epoxy	116	3.2
Epoxy + 5% Epox. Soy Rubber	117	3.2
Epoxy + 10% Epox. Soy Rubber	115	3.1
Epoxy + 20% Epox. Soy Rubber	100	2.9
Epoxy + 30% Epox. Soy Rubber	75	1.9
Epoxy + 40% Epox. Soy Rubber	52	1.3
Epoxy + 5% Epox. Linseed Rubber	118	3.3
Epoxy + 10% Epox. Linseed Rubber	116	3.1
Epoxy + 20% Epox. Linseed Rubber	102	2.9
Epoxy + 30% Epox. Linseed Rubber	77	2.0
Epoxy + 40% Epox. Linseed Rubber	53	1.4

Toughening of Epoxy Resins I

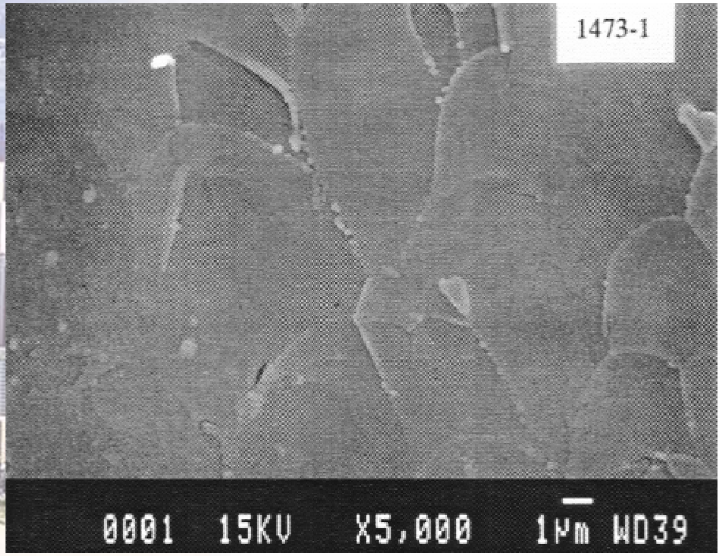


Toughening of Epoxy Resins II

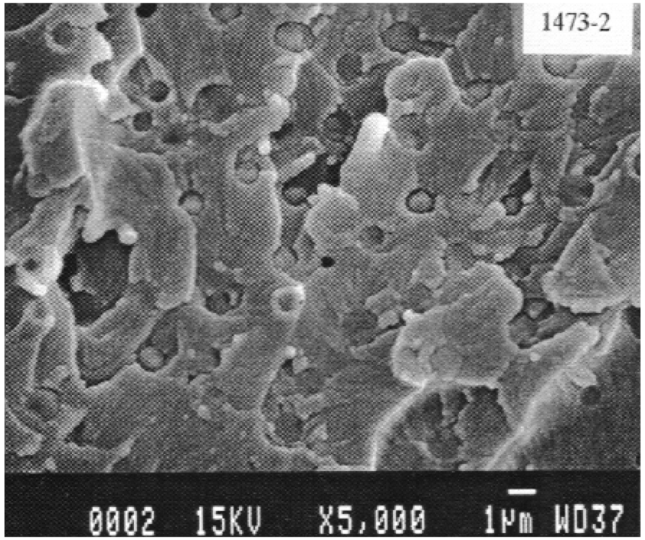


- **Vegetable Oil based tougheners behave similarly to CTBN tougheners**
- **Cost of CTBN tougheners: $40-200/kg; Vegetable Oil Based: $4-10/kg**

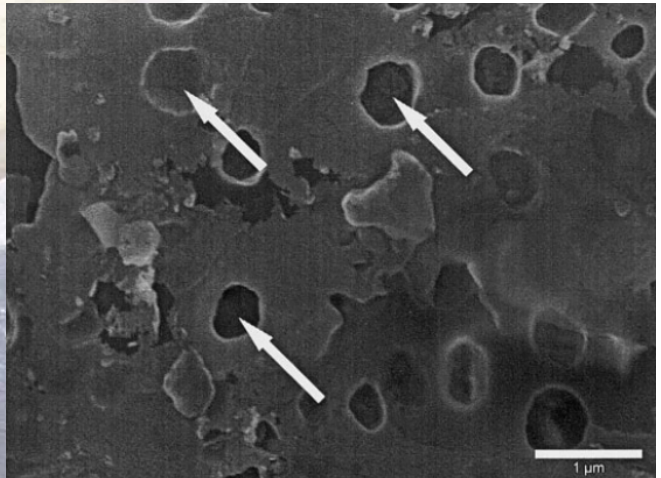
Toughening of Epoxy Resins with Additives



Unmodified epoxy resin



CTBN toughened



Epoxidized vegetable oil toughened resin

Conclusion

We have developed a general procedure for epoxidation of vegetable oils, giving ~70% epoxidation. The 80% epoxidation seems to be a limit of this method

Epoxidised oils as such cannot replace the room-temperature curing epoxies

Pre-curing of the epoxidised oils with suitable amines is necessary. The resulting product can be used to replace conventional rubber tougheners

Epoxidised oils can be used as plasticizers in certain thermosetting resins. Phase separation seem to limit the scope of use

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