Myriant

Chemistry Refined...Naturally

Polyurethanes: The Case for Renewable Succinic Acid Based Polyester Polyols

Succinic Acid Polyols

- Renewable content up to 100% based on choice of diol
- Comparable performance to adipic polyols
- Price competitive with adipic polyols
- Long term stability of raw material pricing
- Smaller carbon footprint

Application Areas for Polyester Polyol Testing

Application Area	Cast Elastomers 251 kMT SAC	Coatings and Adhesives 115 kMT resin	TPU 95 kMT SAC	Specialty Flexible Foams 27 kMT SAC
Typical End Use	Shoe soles, belts, hoses	Industrial and Consumer Paints and adhesives, Polyurethane dispersions, 2K coatings	Belts, hoses, wheels, medical, shoes, electronics	Reticulated foam, laminated foams
Incumbent Composition	Adipic/EG, Adipic/DEG, Adipic/BDO, Adipic/HDO f~ 2.0 OH # 110			Adipic/DEG f ~2.4-2.7 OH # 56
Myriant Tested	SAC/EG, SAC/DEG, SAC/BDO, SAC/HDO f ~ 2.0 OH # 110			SAC/DEG f ~ 2.4-2.7 OH # 56

Myriant Development Partnerships

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PIEDMONT CHEMICAL INDUSTRIES I,LLC

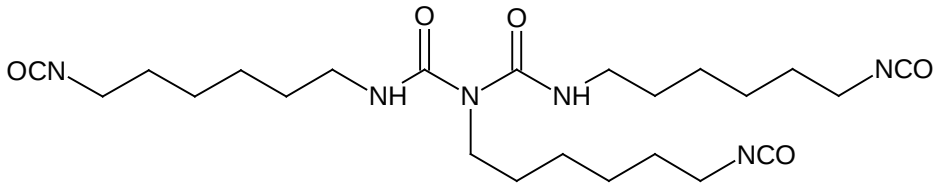
Polymer manufacturing
- Lab scale
- Pilot scale
- Commercial scale
- Polyester polyols
- Specialty additives

1ST SOURCE RESEARCH

Contract research laboratory
- Polyurethanes, coatings, polymers
- Formulation development
- Polymer and product design
- Performance characterization

Polyurethane Synthesis

- Basic laboratory formulation to highlight performance differences between succinic and adipic based polyester polyols
- Desmodur N3200
  - Liquid aliphatic isocyanate



  - 23.0 % NCO, Viscosity 2500 cPs, f ~3.2
- Components (polyol + catalyst and isocyanate) preheated to 70 °C
- 1 minute mixing time, overnight cure at 85 °C

Properties of Polyester Polyols

	Foams				Coatings, Adhesives, Elastomers, TPU's					
Acid	**Succinic**	Adipic	**Succinic**	Adipic	**Succinic**	Adipic	**Succinic**	Adipic	**Succinic**	Adipic
Code Number	**DGTA-56**	AGTA Control	**DGTB-56**	AGTB Control	**EG-110**	AEG Control	**DG-110**	ADEG Control	**HD-110**	AHD Control
Diol	DEG (90)/ PEG (10)/ TMP	DEG/TMP	DEG (90)/ PEG 10)/ TMP	DEG/TMP	EG	EG	DEG	DEG	HDO	HDO
Functionality	Branched (f ~ 2.4)		Branched (f ~ 2.7)		Linear		Linear		Linear	
OH Number	61	76	64	60	107	90	113	116	108	95
Viscosity, (60 °C, cPs)	3150	440	4000	1340	400 (80°C)	415	440	250	450	450
Bio-based Carbon Content	47%	0%	47%	0%	66%	0%	50%	0%	40%	0%

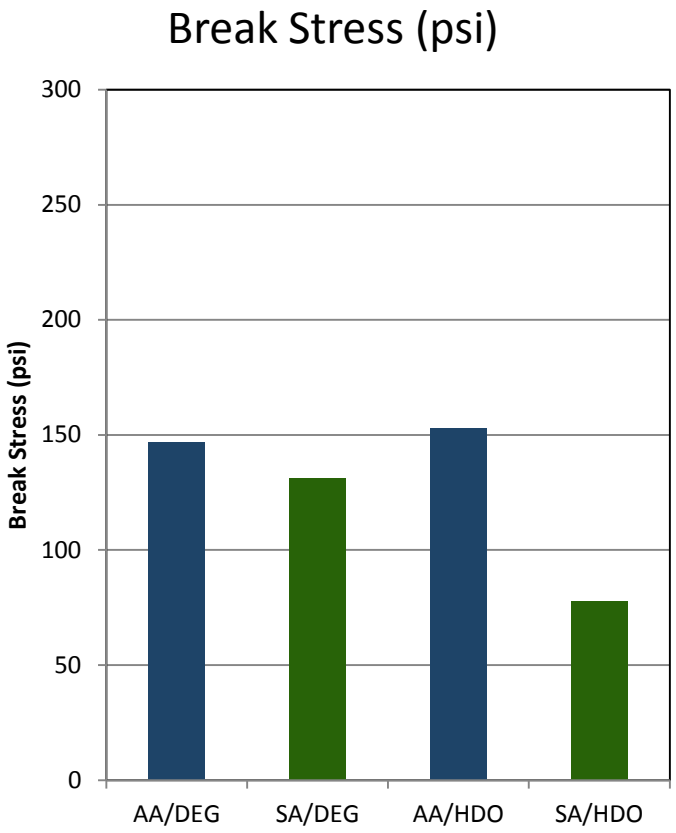
Properties of Polyester Polyols

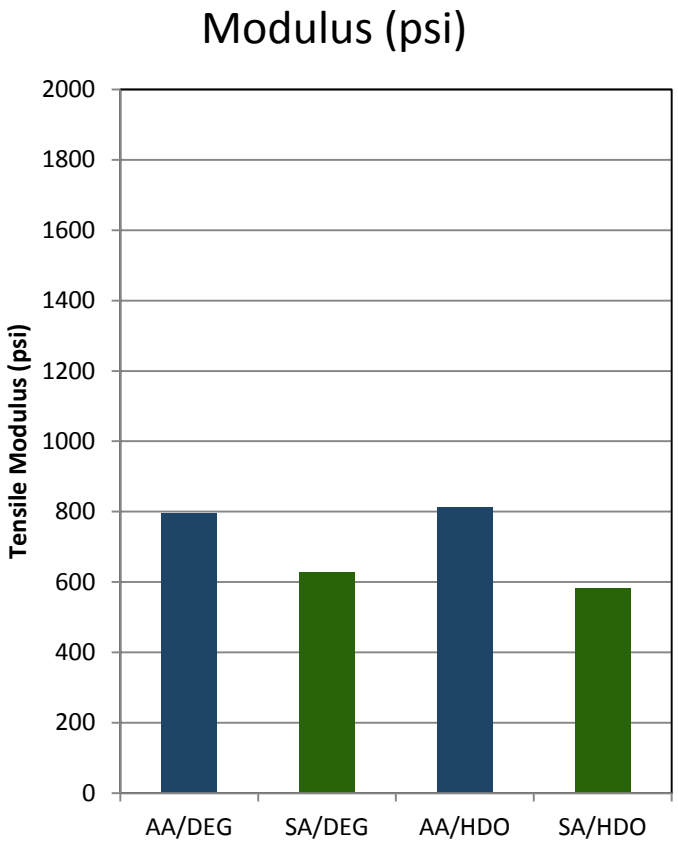
Higher T_g for succinic acid based polyurethanes

Diol	Succinic	Adipic
EG	-6 °C	-30 °C
DEG	-12 °C	-29 °C
BDO	-16 °C	-38 °C
HDO	-33 °C	-44 °C

T_g for test polyurethanes made from polyester polyol indicated. Second scan at 10 °C/min.

Properties of Polyester Polyols





Comparable Tensile Properties across all compositions

Properties of Polyester Polyols

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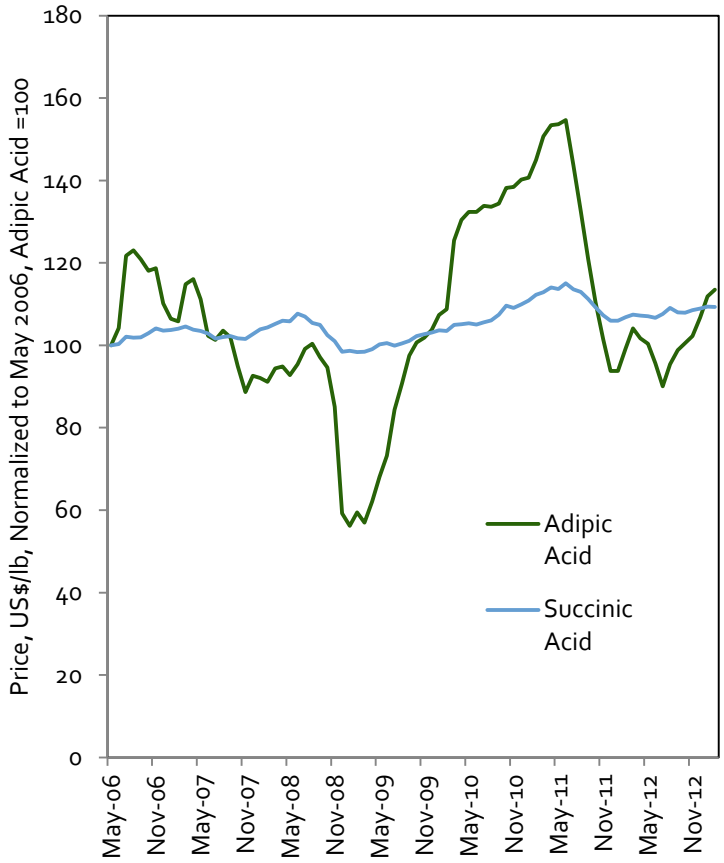
Comparable Shore D hardness for polyurethanes

Diol	Succinic	Adipic
DEG/TMP	16	17
BDO	28	21
DEG	20	20
HDO	16	25

Physical Property Comparison - Conclusions

- Succinic polyurethanes have higher T_g's than adipic polyurethanes, but will still perform well at a broad range of temperatures
- Mechanical properties are comparable
  - Shore A and D hardness, Tensile properties, Tabor abrasion
- Succinic polyester polyols have slightly higher viscosities, but still processable
- Succinic acid polyurethanes are better than Adipic acid for:
  - Chemical resistance
  - Abrasion resistance

Bio Succinic versus Adipic Acid Market Price



Green line: Historical adipic acid prices from PCI Nylon report

Blue line: Example of corn-based succinic acid

Adipic acid market price:

Highly volatile, with generally increasing trend since 2006

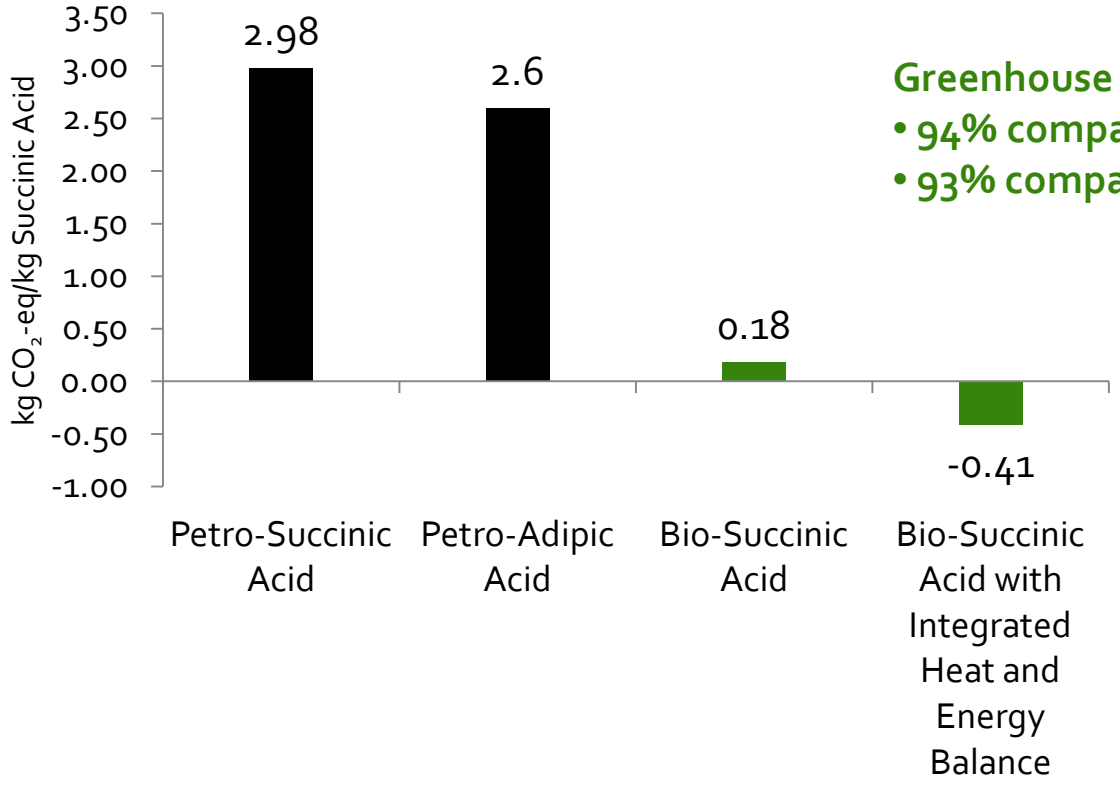
Succinic acid formula price:

Lower volatility than adipic market price and roughly equal average price over the period.

Corn-based formula pricing offers comparable average price and more stability than historic adipic acid market pricing

Life Cycle Analysis: Myriant Bio Succinic Acid Production

Reduced Carbon Footprint



Greenhouse gas reduction:

- **94% compared to Petro-based Succinic Acid**
- **93% compared to Petro-based Adipic Acid**

* Life Cycle Analysis of Bio-Succinic Acid production using the IPCC 2007 (GWP) method

Succinic Acid Polyols

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Not All Chemicals Are Created Equal™

LOWER CARBON FOOTPRINT

- Bio-Succinic Acid Process Has Low Greenhouse Gas Emissions
  - ✓94% Less Than Petrochemical Succinic Acid*
  - ✓93% Less Than Petrochemical Adipic Acid*

NO GREEN PRICE PREMIUM

- Renewable Feedstocks Are Less Expensive And Less Volatile Than Petroleum
- Efficient Fermentation And Downstream Processes Optimize Production Costs

NON-FOOD BASED

- Feedstock Can Be Sorghum (Non-Food) Based Or Corn Based

HIGH PERFORMANCE

- Drop-In Replacement Anywhere Succinic Acid Is Currently Being Used
- Replaces Petroleum Based Chemicals In Urethane, Plasticizer, Coatings And Polymer Applications

* Life Cycle Analysis of Bio-Succinic Acid production using the IPCC 2007 (GWP) method