



Succinate Esters for Renewable Plasticizers

Succinate Esters as Plasticizers

- Produces flexible PVC with mechanical properties similar to those produced by DOA
- Phthalate-free, bio-based plasticizer
- Low temperature flexibility and migration similar to DOA
- DOSX is priced and performance equal to DOA and useful as a secondary plasticizer with DOP



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- Application Areas and Plasticizer Testing
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Application Areas for Plasticizers

Application Area	General Purpose Offset 312 kMT	Flooring 241 kMT	Low Temperature Flexibilization 35 kMT	Food Film 24 kMT
Typical End Use	General purpose applications with low heat resistance requirements	Vinyl flooring, sheet and tile	Secondary plasticizer in blends for low temperature flexibility	Food wrap stretch film
Incumbent Composition	DOP	DOP, Benzoates	Aliphatic esters, DOA	DOA, Citrates
Myriant Tested	Prepared samples of Flexible PVC with multiple levels of DOSX and compared physical properties against DOA and DOP			

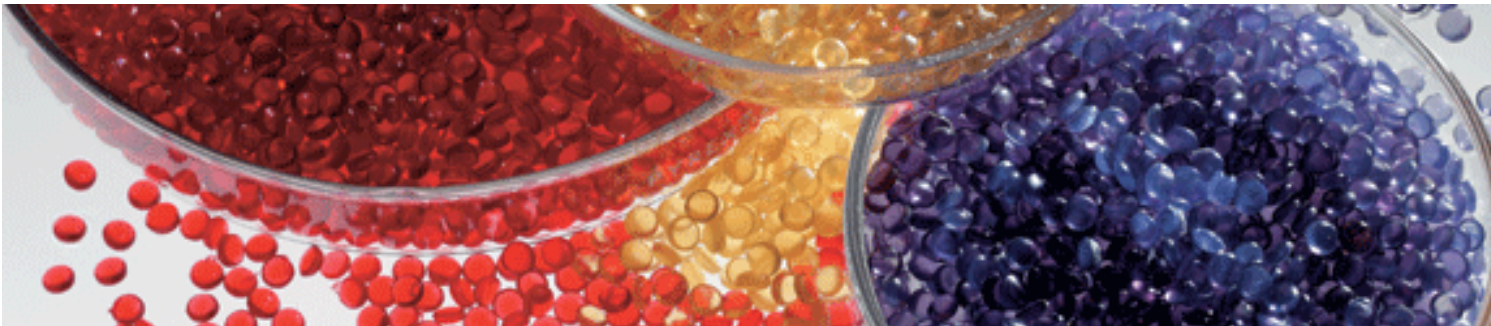
Myriant Development Partnerships



Polymer
Diagnostics Inc.

Contract research laboratory

- Plasticizers and PVC
- Formulation development
- Physical characterization



Plasticizers Key Performance Parameters

- Myriant succinate ester plasticizers evaluated in flexible PVC blends for the following characteristics:
 - Thermal properties
 - Dynamic mechanical analysis
 - Brittleness temperature
 - Mechanical properties
 - Modulus
 - Break stress
 - Break strain
 - Elongation
 - Shore hardness
 - Aging properties
 - Weight loss after aging
 - Mechanical properties after aging

Test Protocols and Materials

Flexible PVC compositions used for basic property screening

- Base resin- OxyVinyls 226F
 - K value 67, relative viscosity 0.95, 80-200 mesh powder
- Stabilizer- Halstab 2165, powdered Ca Zn stabilizer at 2.5 phr
- Plasticizers compounded at 40, 50, and 60 phr and compression molded into test specimens
- Di-octyl succinate (DOSX) compared to dioctyl adipate (DOA) and dioctyl phthalate (DOP)
- Compound prepared in small scale high intensity mixer

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Tensile Properties

DOSX produces good mechanical properties compared to DOA

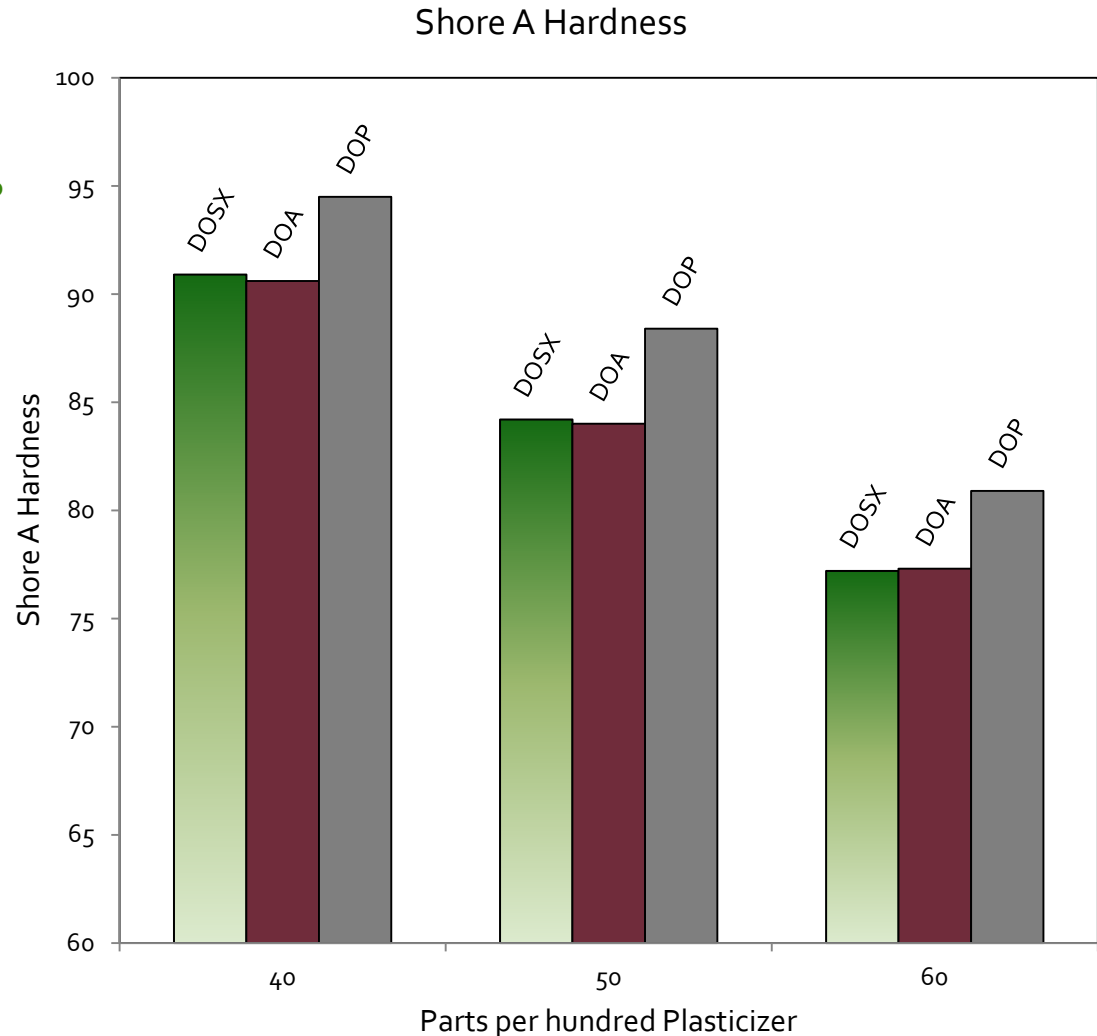
Break Stress (SD), (MPa)	40 phr	50 phr	60 phr
DOSX	19.8 (0.8)	16.8 (0.5)	13.7 (0.7)
DOA	18.7 (0.5)	15.5 (0.5)	13.1 (0.2)
DOP	20.9 (0.9)	19.2 (0.5)	16.9 (0.7)
Break Strain (SD), (%)	40 phr	50 phr	60 phr
DOSX	346 (10)	373 (23)	380 (25)
DOA	327 (26)	343 (24)	385 (8)
DOP	328 (28)	364 (13)	385 (16)
Tensile Modulus (SD), (MPa)	40 phr	50 phr	60 phr
DOSX	23.5 (1.2)	12.6 (0.2)	8 (0.1)
DOA	19.8 (1.6)	11.0 (0.3)	7.3 (0.2)
DOP	55.8 (5.5)	17.9 (0.3)	11.2 (0.3)

Shore A Durometer Hardness- Plasticizer Efficiency



DOSX is as efficient at plasticizing PVC as DOA, slightly better than DOP

Shore A	40 phr	50 phr	60 phr
DOSX	91	84	77
DOA	91	84	77
DOP	95	88	81

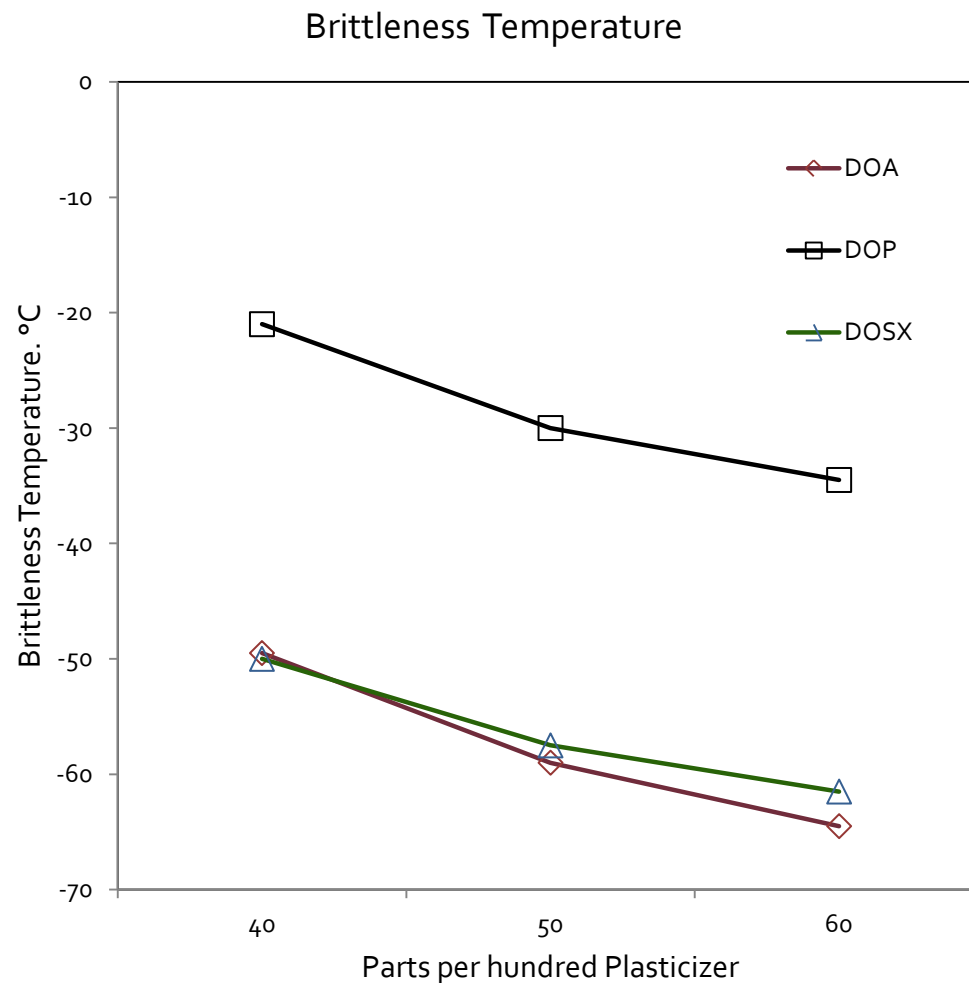


Brittleness Temperature- Low Temperature Flexibility

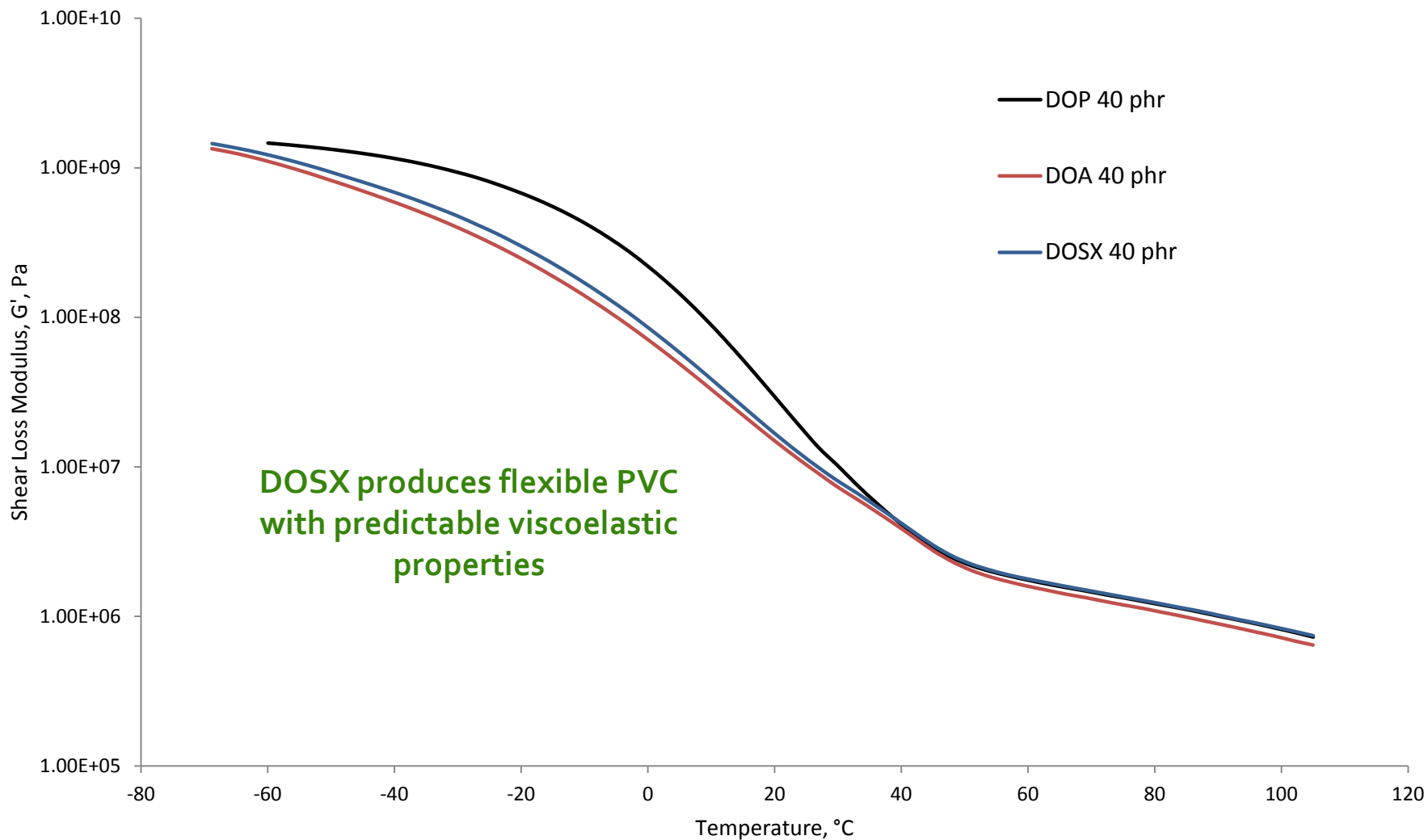


DOSX is as efficient at flexibilizing PVC as DOA

T_b (°C)	40 phr	50 phr	60 phr
DOP	-21	-30	-35
DOA	-50	-59	-64
DOSX	-50	-58	-62



Dynamic Mechanical Analysis of 40 phr Compounds



Tested on compression molded specimens at 1 rad/s shear rate

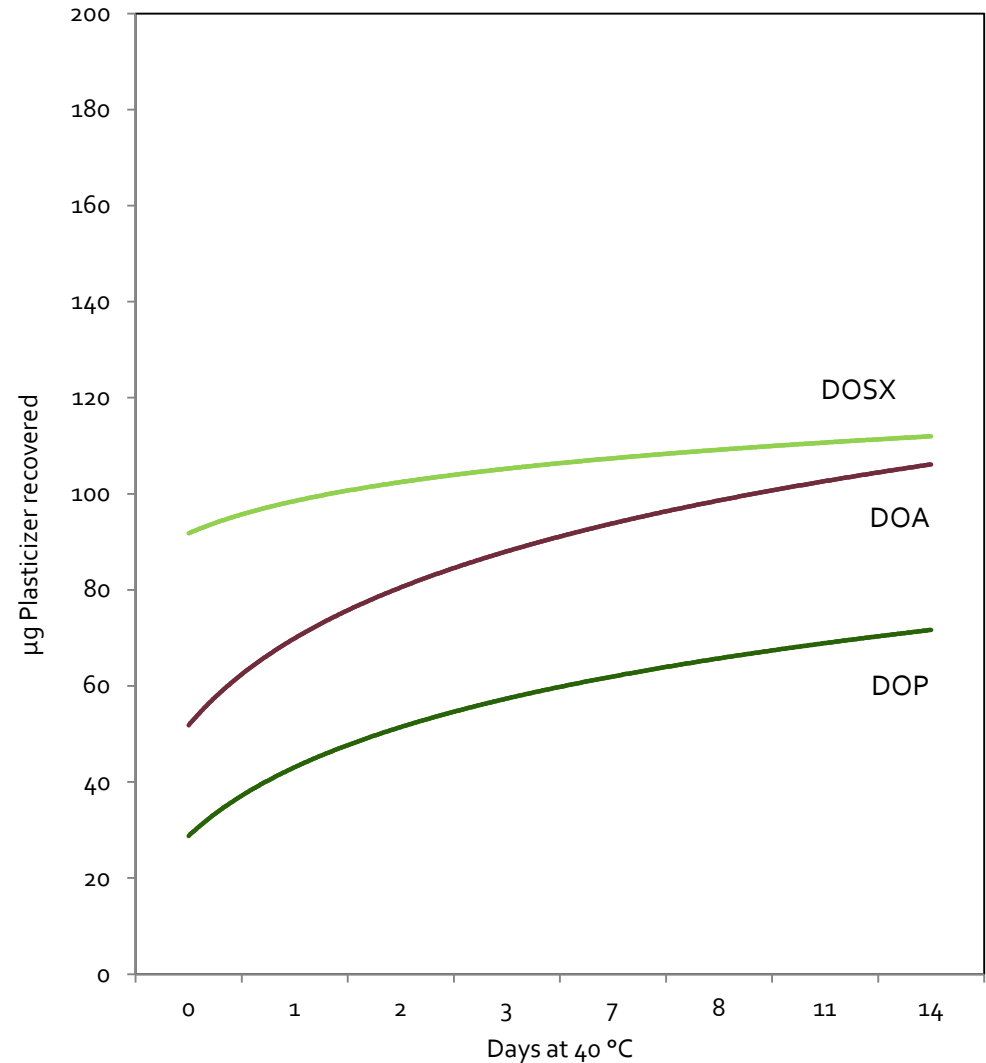
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Plasticizer Migration in 50 phr Compounds

Migration of DOSX is comparable to that of DOA after 14 days

- Measured on compression molded plaques at 50 phr plasticizer
- Weighted plate with absorbent paper on top of plaques at 40 °C
- Plasticizer measured by GC analysis



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DOSX/DOP Head-to Head

- DOSX is most comparable to aliphatic esters like DOA
- Can get properties close to those with DOP in a flexible PVC
 - Except for low temperature flex (better)
 - Volatility (worse)
- DOSX at 40 phr gives properties close to DOP at 50 phr
- May be suitable for applications that do not require high temperature performance as a direct phthalate replacement

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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