Estolides, new bio-based fluids for high performance environmentally friendly lubricants

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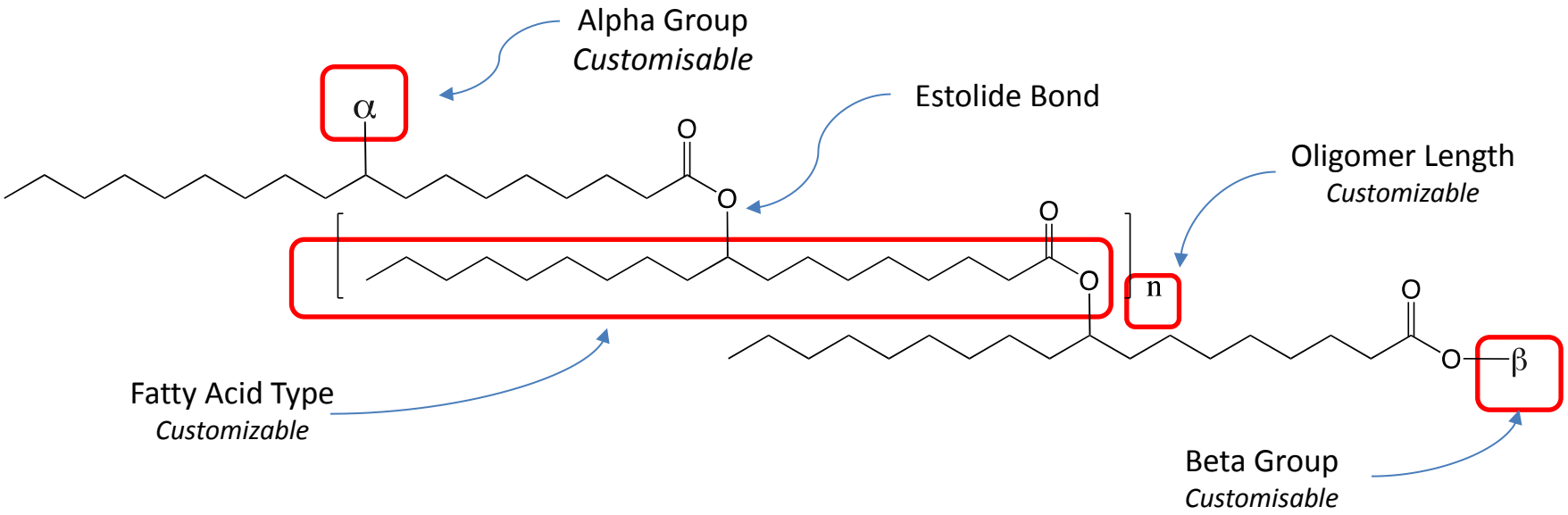
Estolides: What are they?

- Estolides are a class of ester, based on vegetable oils that form when the carboxylic acid functionality of one fatty acid reacts at the site of unsaturation of another fatty acid to form an ester linkage.
- These linkages are used to help characterize the structure of the estolide since the estolide number (EN) is defined as the average number of fatty acids added to a base fatty acid.
- The secondary ester linkages of the estolide are more resistant to hydrolysis than those of triglycerides, and the unique structure of the estolide results in materials that have far superior physical properties for certain applications.
- As a result, Estolides are a chemical platform and can be designed to support a wide range of industries or applications.

Estolides are highly customisable molecules



Synthetic Variations

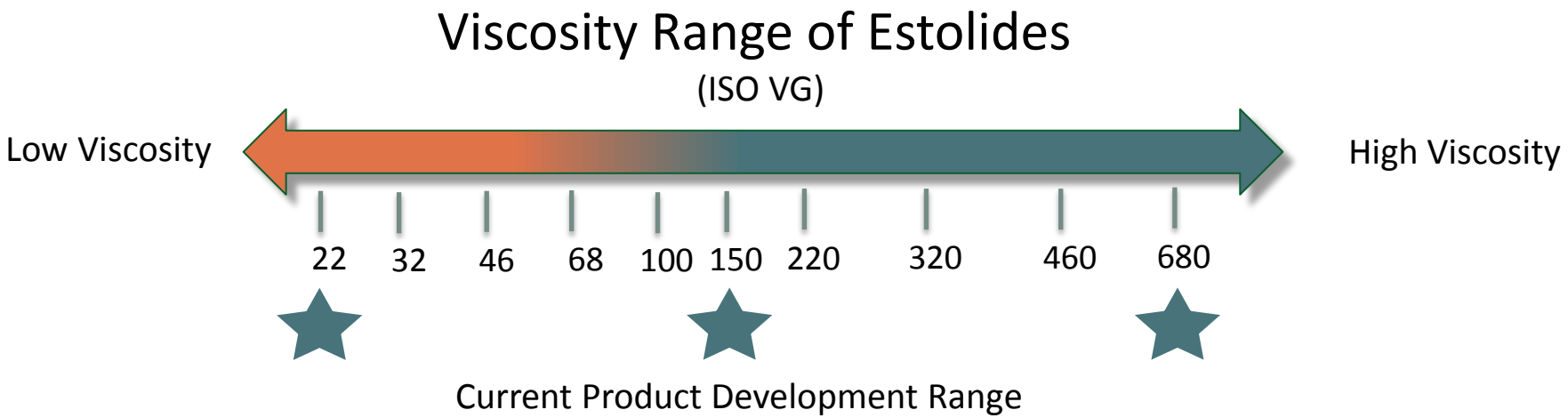
- Use of different fatty acid feedstocks
- Oligomerization (n)
- Unique functional groups (a, b)

Performance Focus

- Variable viscosity
- Improved cold temperature properties
- Increased or decreased polarity
- Improved oxidative stability

Estolides: Current position

- Biosynthetic® Technologies has patented and developed a new class of **Estolide** compounds that are derived from various bio-derived oils.
- **Estolides** are now available in a range of viscosities from ISO 22 to ISO 680.



- These oils exhibit a range of superior qualities that make them ideal for the use in high performance finished lubricants.

Estolides: Sustainability

The production of the Biosynthetic Technologies' Estolides has been assessed by **ISO 14040**:2006, which describes the principles and framework for life cycle assessment (LCA).

Hence, they have assessed environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, product manufacture and distribution. This has included inputs of the use of water, energy, raw materials and environmental releases into air, land, and water.

This analysis has established that the production of the Estolides has a negative carbon footprint.

Estolides: Features & Performance Benefits

The outstanding features of these Estolides include

- **For Ecolabel**
  - High bio-based content of ~90%
  - Excellent level of biodegradability of >75%
  - Non-Bioaccumulative
  - Low toxicity (EC50 > 1000 ppm)
- **For high performance**
  - High Oxidative Stability
  - Excellent low friction and wear performance
  - High Viscosity Index
  - Low volatility
  - Exceptional hydrolytic stability

Estolides: Environmental Properties

	ISO VG 22	ISO VG 150	ISO VG 680
Biodegradability OECD 301	88%	79%	76%
Bio Content ASTM D6866	68%	86%	94%
Toxicity			
OECD 201 Alga Toxicity	EC50 > 1000 mg/L	EC50 > 1000 mg/L	EC50 > 1000 mg/L
OECD 202 Daphnia Toxicity	EC50 > 1000 mg/L	EC50 > 1000 mg/L	EC50 > 1000 mg/L
OECD 203 Fish Toxicity	LC50 > 1000 mg/L	LC50 > 1000 mg/L	LC50 > 1000 mg/L
OECD 209 Bacteria Toxicity	EC50 > 1000 mg/L	EC50 > 1000 mg/L	EC50 > 1000 mg/L

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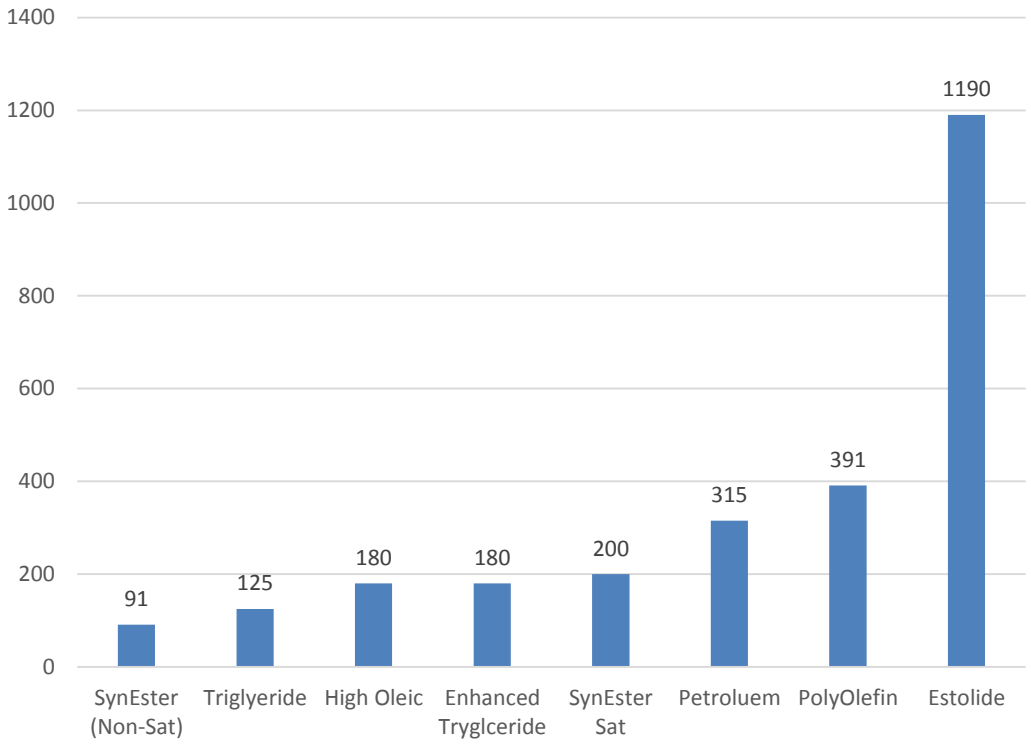
Superior oxidation performance

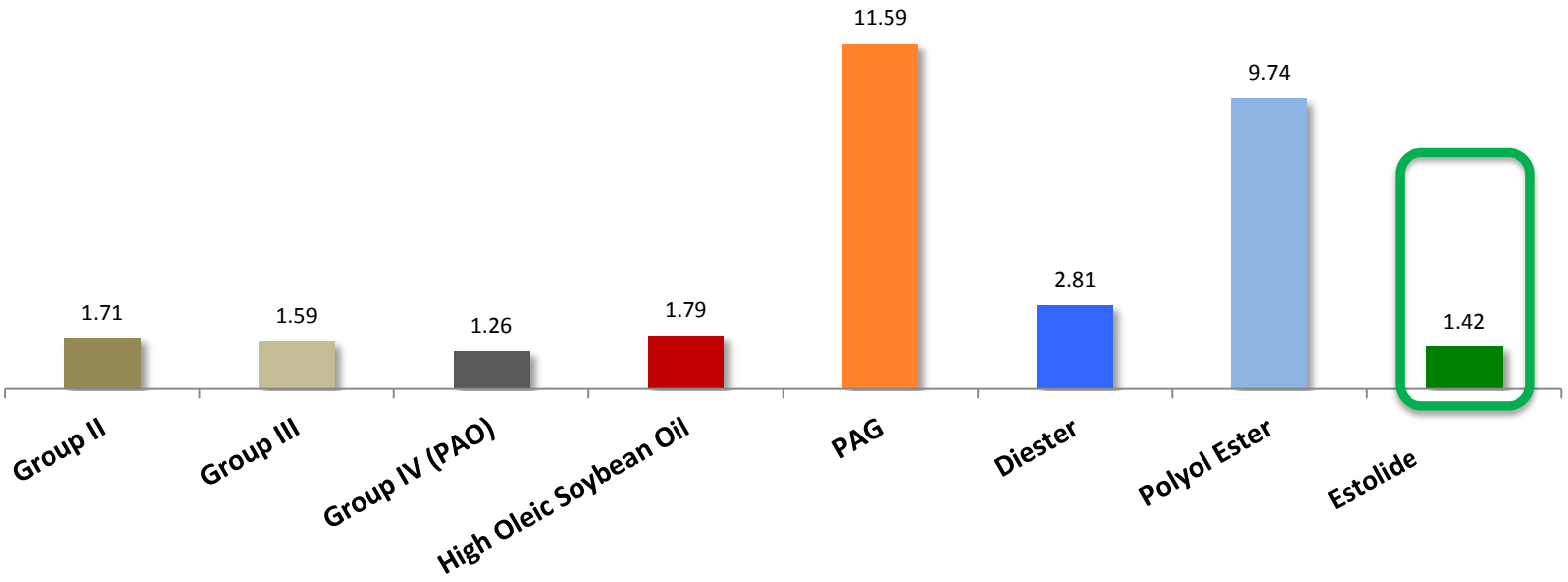
ASTM D2272 - Rotary Pressure Vessel Oxidation Test



Hydrolytic Stability Performance

Comparison Base Oils with Similar Low Viscosities

Modified ASTM D2619, Water Acidity Increase at 144 Hours (mg KOH/g)



Notes: Base oil samples are unadditized.

Estolide applications

- With their exceptional oxidative and hydrolytic stability, BT 4 and BT22 can be blended to establish high quality ISO 32 to 68 hydraulic oils.
- The highly renewability and biodegradable BT 22 & BT 75 oils can be used to establish grades from ISO 150 to ISO 680, which can be used to formulate highly sustainable premium performance industrial gear oils & greases.
- BT4 is ideal for manufacturing neat metal working fluids that are both sustainable and reduce health risks in the work place.
- BT 4 has also been used to formulated a highly renewable SAE 0W20 resource conserving engine oil, to meet the requirements of ILSAC GL-6.

Conclusions

- Estolides are new class of environmentally friendly base fluids, manufactured from vegetable oils.
- Their unique stable structure of fatty acid oligomers makes them more resistant to hydrolysis and oxidation than traditional esters.
- They have high levels of Biodegradability & Renewability.
- As a result of this, Estolides are ideal base fluids for a wide range of sustainable environmentally friendly lubricant applications.
- Estolides are customisable to meet the needs of final formulations