NORA Lab Studies on Biofuels

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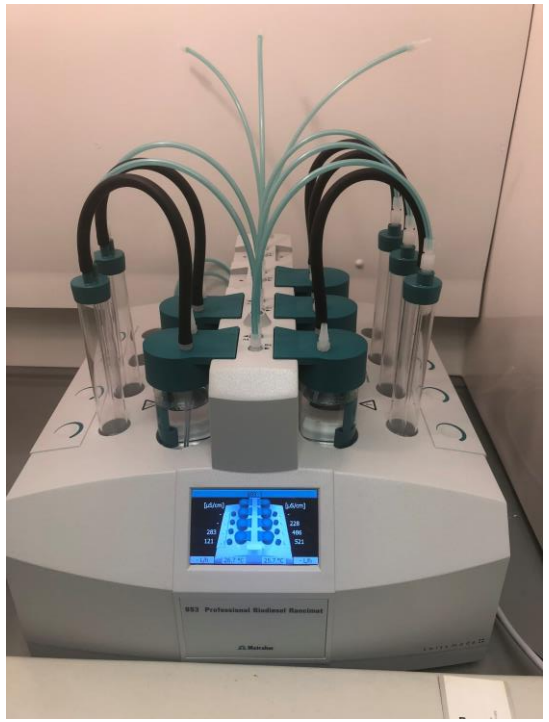
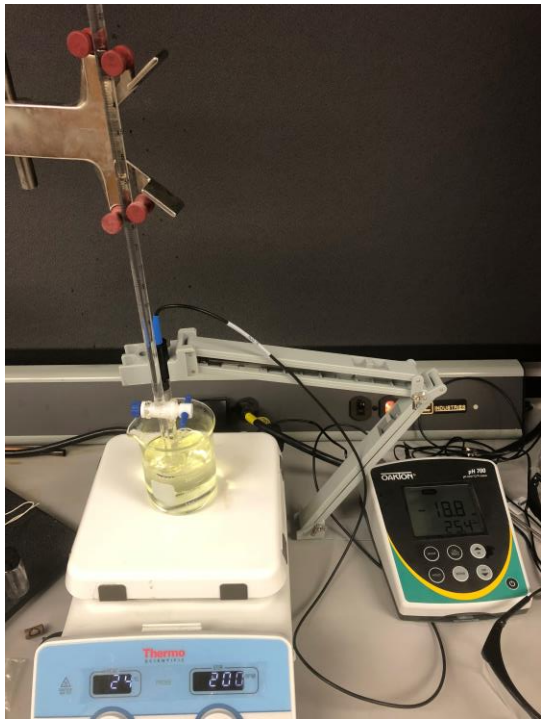
NORA Test Methods



Rancimat – EN15751

- Heated to 230°F
- Air pumped in
- Conductivity of water measured



Acid Number – ASTM D664

- Swirl sample and add small amounts of KOH
- Measure voltage, note inflection point

Swell Test

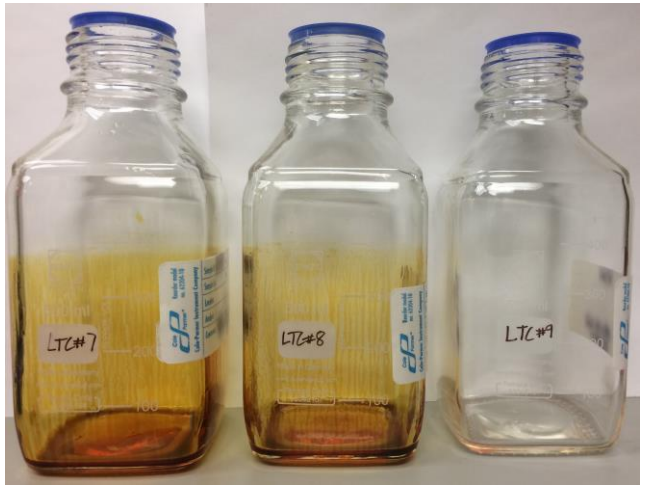
- O-rings immersed in fuel
- Dimensions measured before and after 3 days

NORA Test Methods

Long Term Stability Test – ASTM D4625

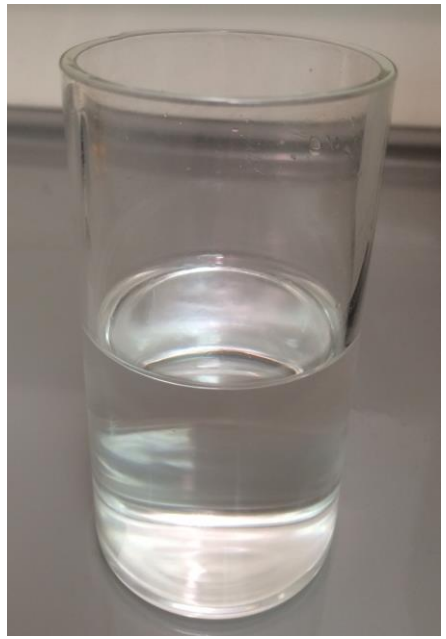
- Samples heated to 104°F
- Left in incubator for 9 weeks
- 1 week in incubator equal about 1 month at room temperature
- Filterable and adherent insolubles collected

Vacuum Filtration (filterable insolubles)



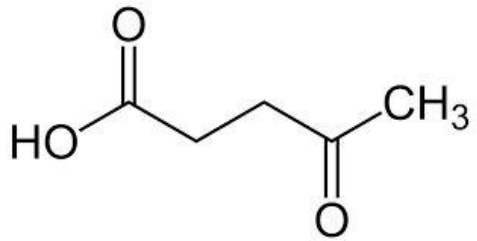
Adherent Insolubles

Ethyl Levulinate (EL)

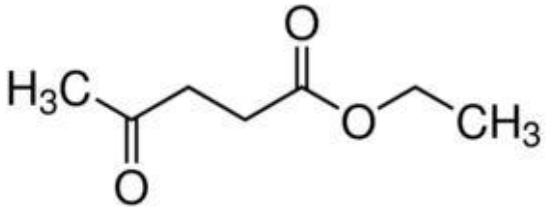


- Renewable biofuel derived from biomass (ex: wood waste)
- Biomass is converted to levulinic acid
- Levulinic acid is esterified with ethanol to produce ethyl levulinate

Wood Residue



Levulinic Acid



Ethyl Levulinate

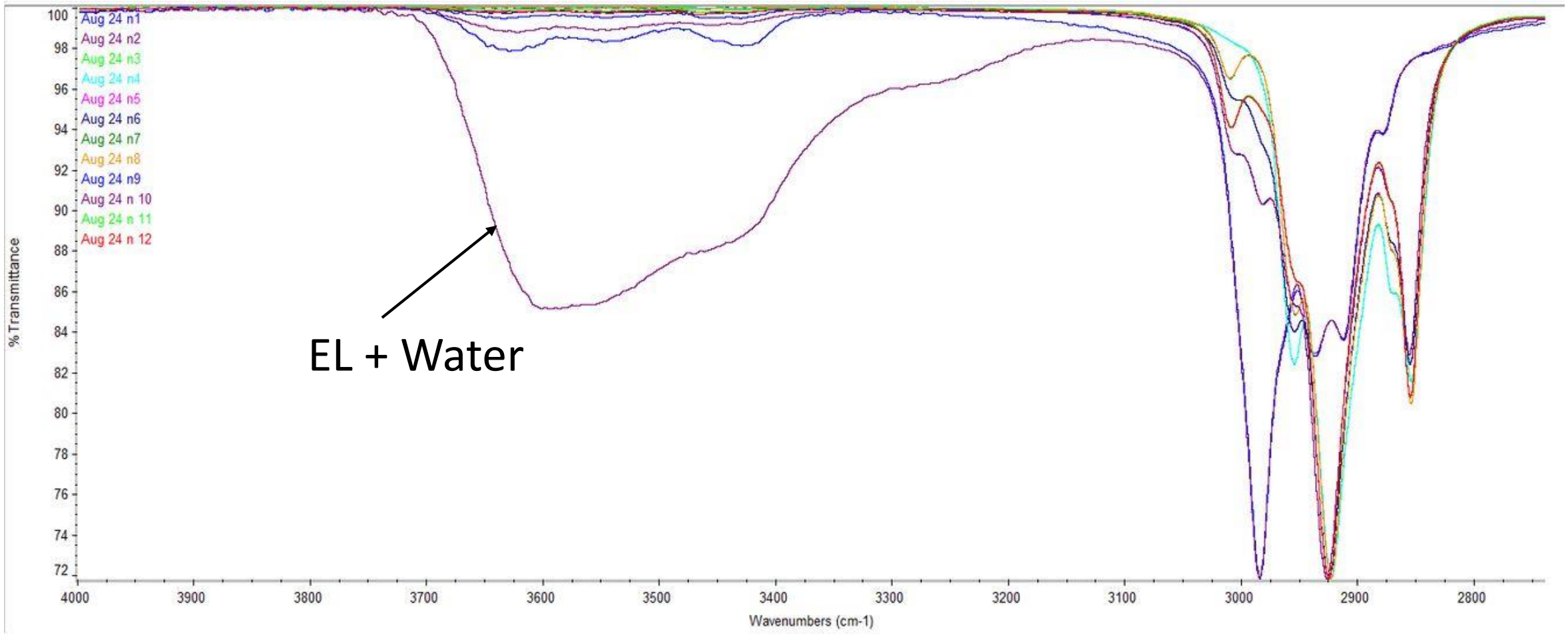
EL Proprieties

- LHV = 88,715 Btu/gallon (31% less than No. 2 oil)
- Good lubricity: 430 µm
- Good viscosity: 1.50 cSt
- Cloud Point: <-58°F (-50 °C)
- Density: 1.016 g/cm^3
- Very water miscible

Tests from NORA Lab:

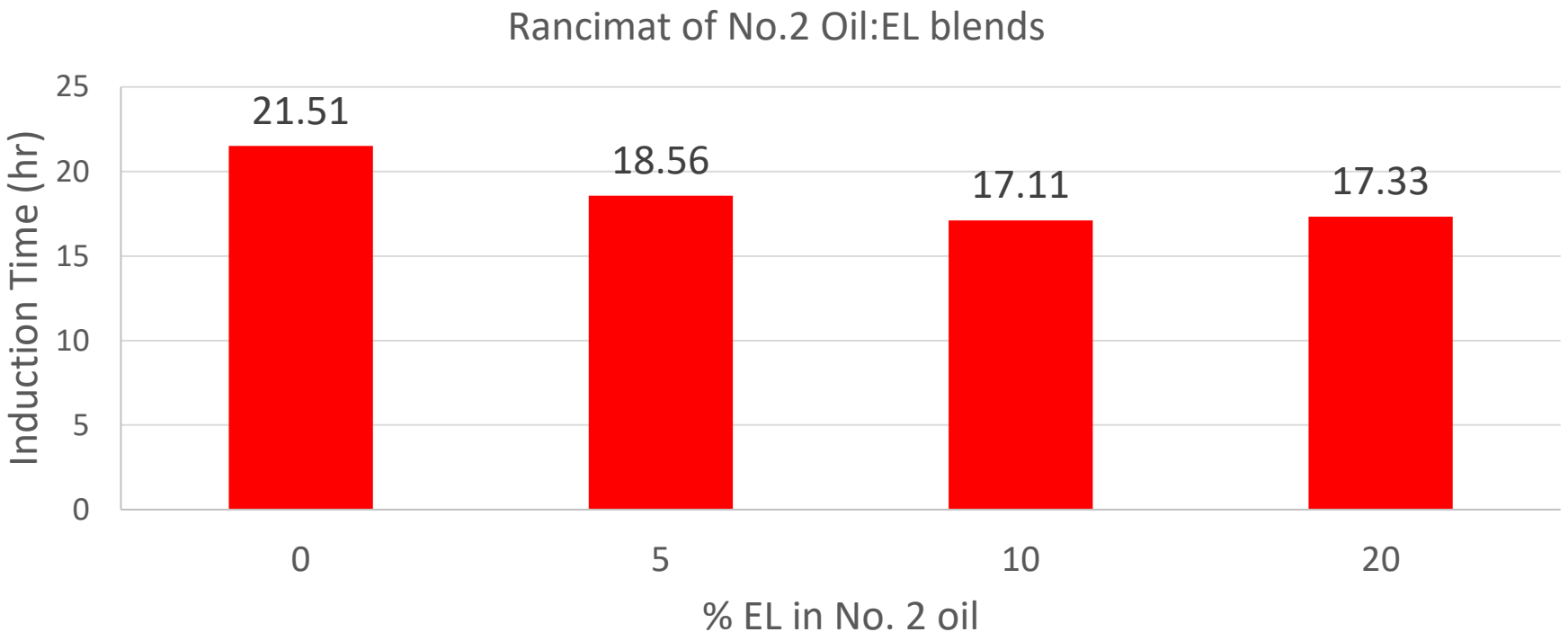
- High Rancimat induction time: >50 hr
- Low Acid Number: 0.06 mg KOH/g

EL and Water



FTIR analysis of EL done at Stony Brook University

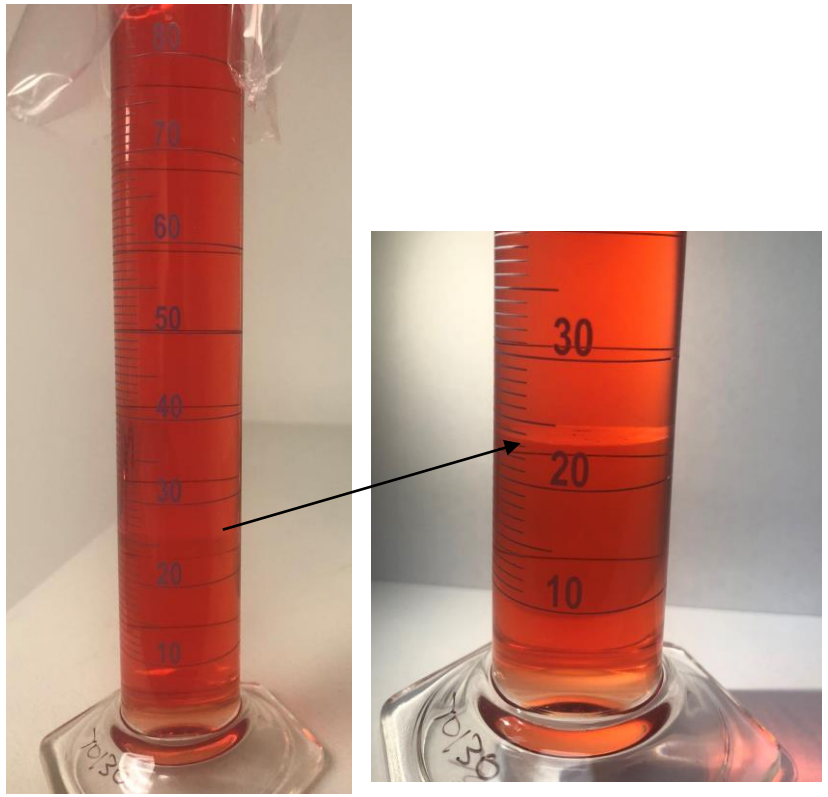
EL Blended with No. 2 oil



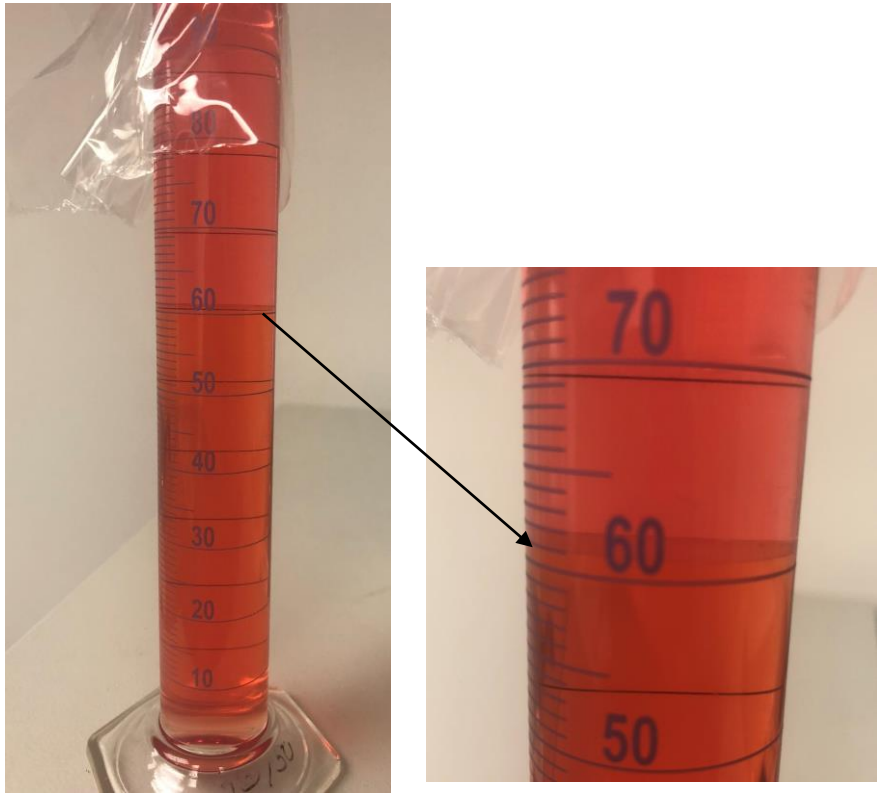
Slight decrease in induction time with addition of EL

No.2 Oil:EL Separation Issue at Room Temp

80/20 No. 2 Oil:EL,
No separation



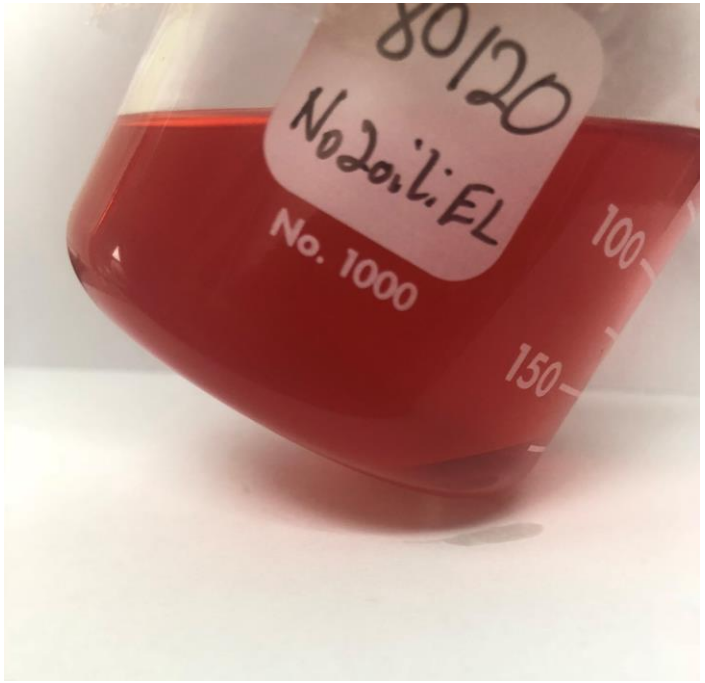
70/30 No. 2 Oil:EL,
Separation



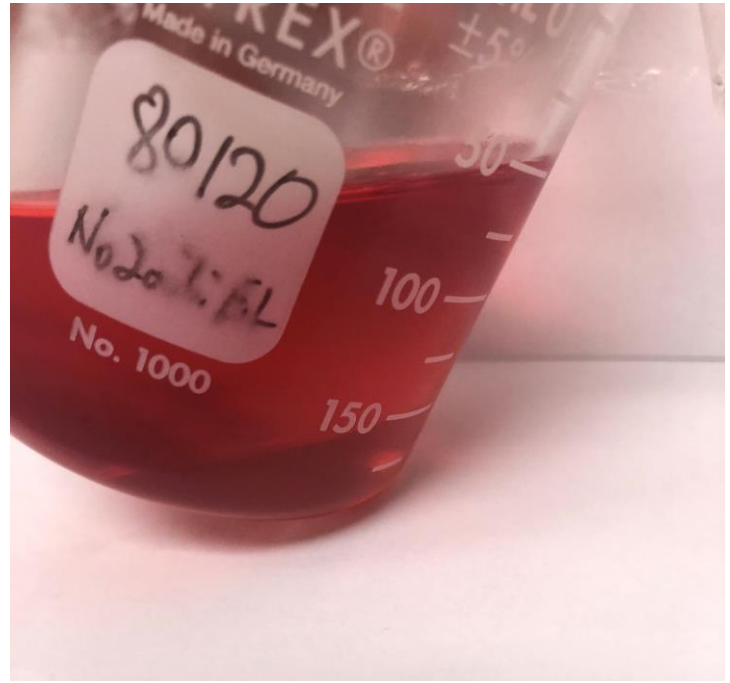
50/50 No. 2 Oil:EL,
Separation

No.2 Oil:EL Cold Temperature Issue

80/20 No. 2 oil:EL
Before freezer



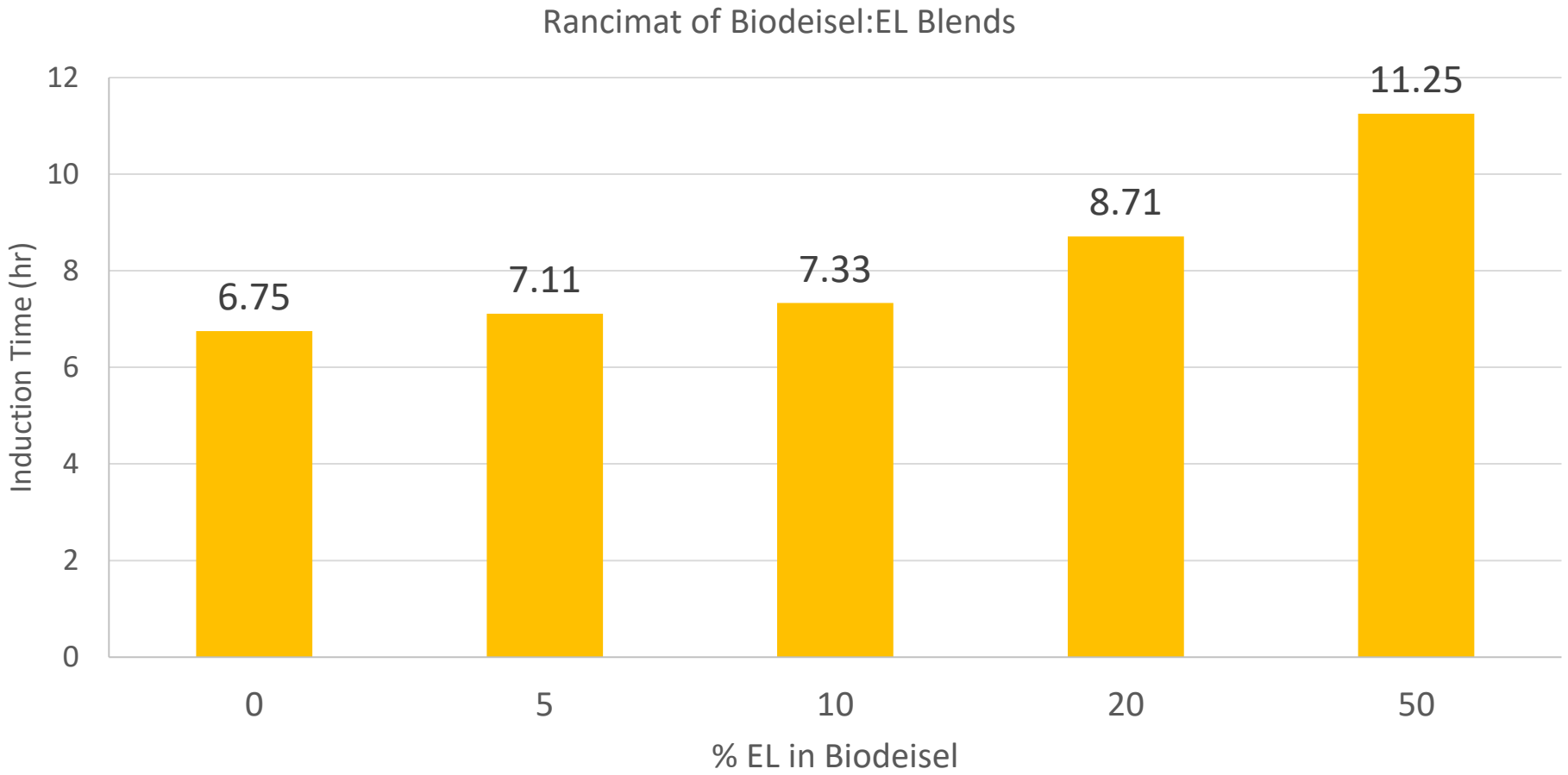
80/20 No. 2 oil:EL
After 30 min in
freezer



80/20 No. 2 oil:EL
After 1 day in
freezer

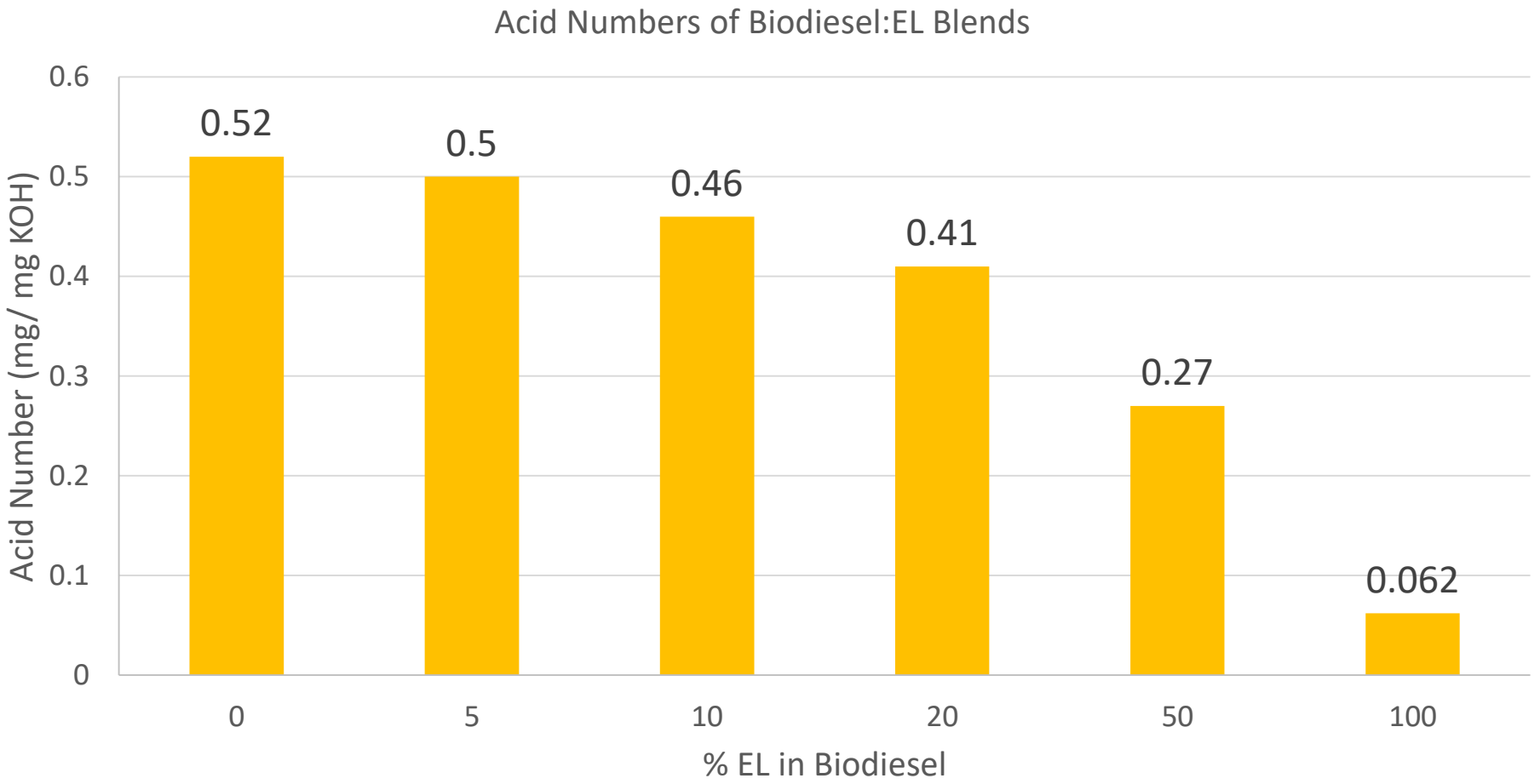
Freezer set to 55°F

EL Blended with Biodiesel



Induction time increased with the addition of EL

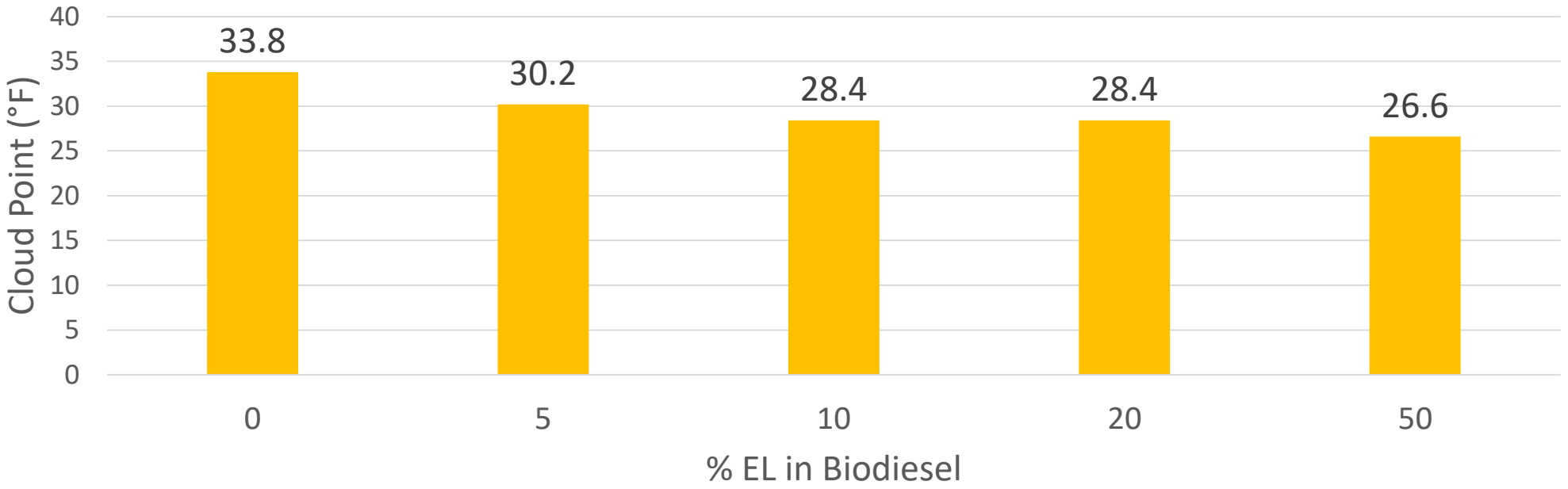
EL Blended with Biodiesel



Acid number was improved with more EL

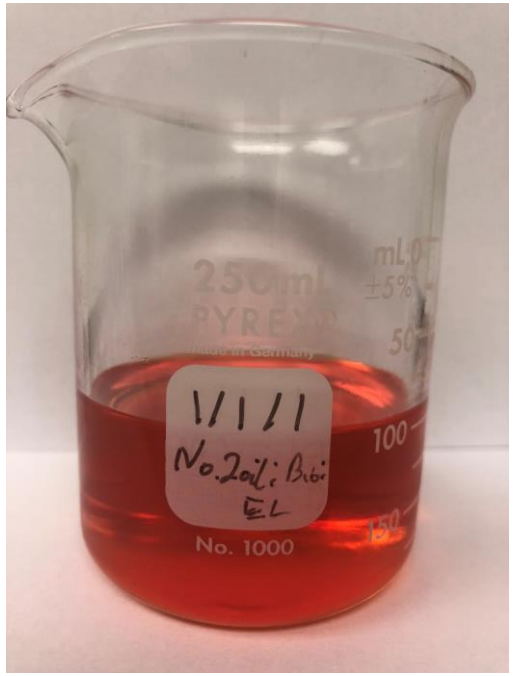
Biodiesel:EL Cold Temperature Properties

- Does not separate at low temperatures
- Adding EL to biodiesel decreases the cloud point



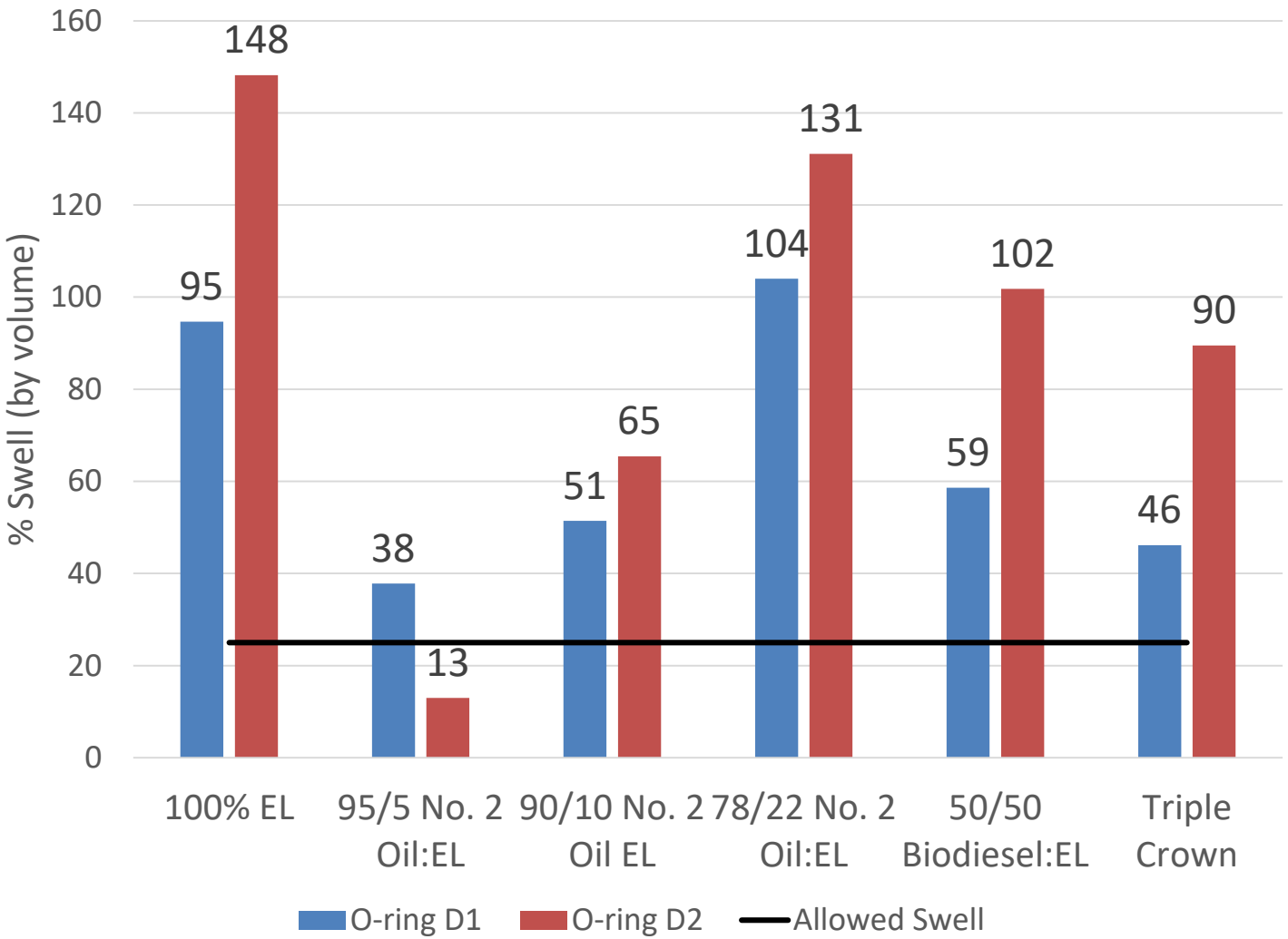
Triple Crown

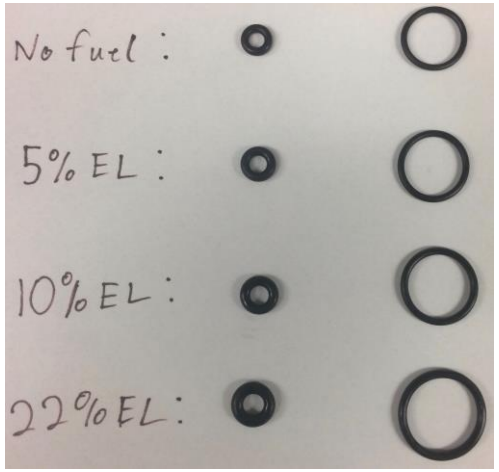
- 1/1/1 blend of No. 2 oil, Biodiesel, EL
- Induction Time: 9.19 hr
- Acid Number: 0.20 mg KOH/g
- Cloud Point: 23°F (-5°C)
- Cloud Point of No. 2 oil used: 12.2°F (-11°C)



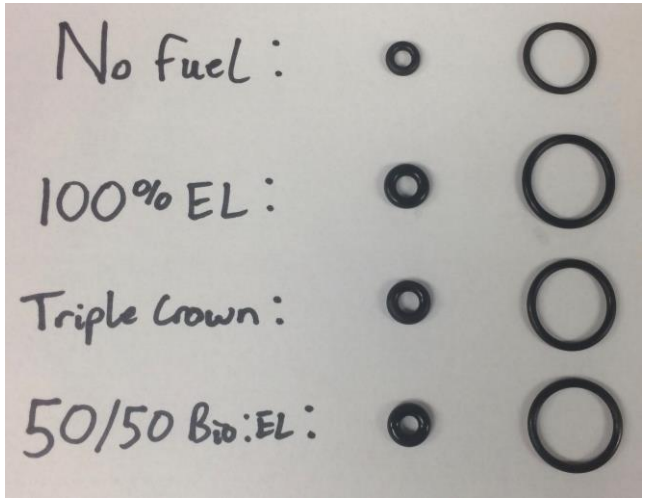
Triple Crown

Elastomer Swell: Nitrile



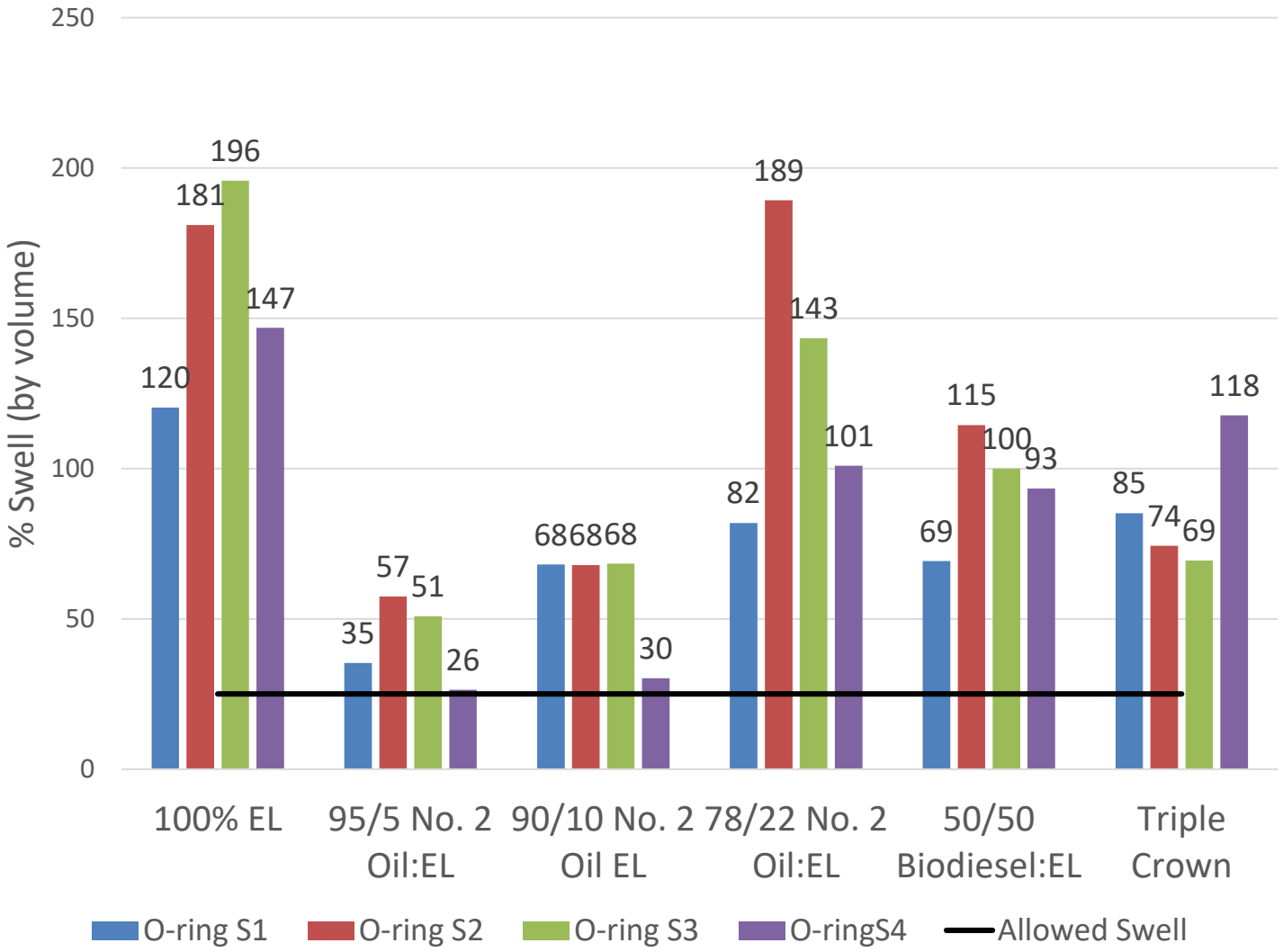


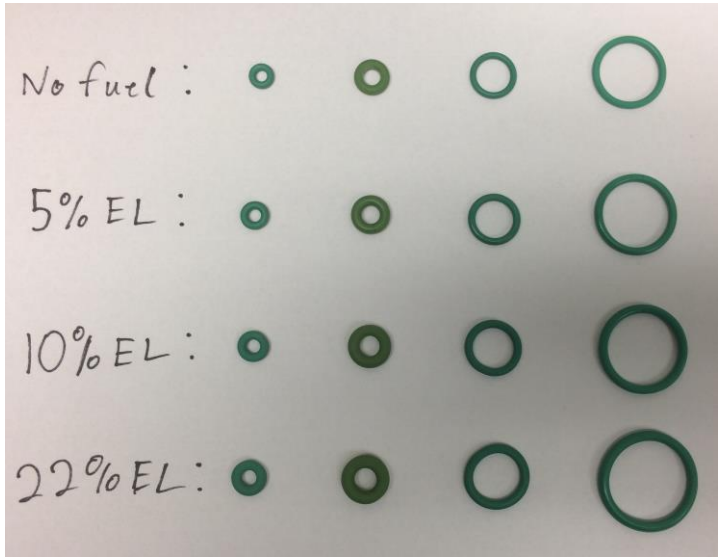
Nitrile O-ring 1 and 2 Swell in No. 2 Oil:EL Blends



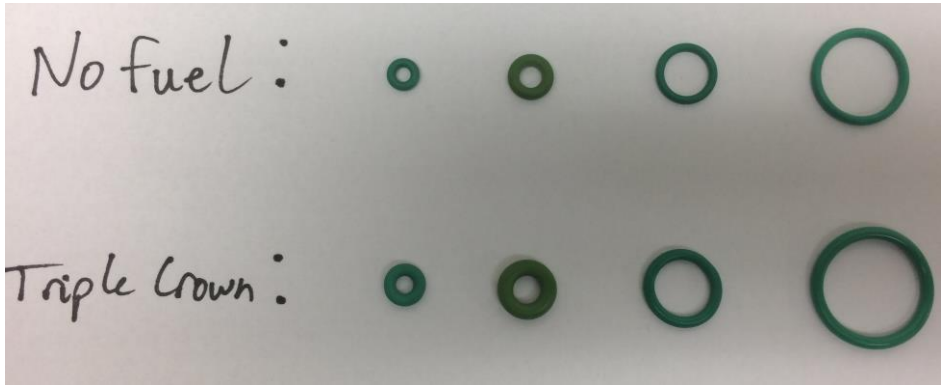
Nitrile O-ring 1 and 2 Swell in 100% EL, 50/50 Bio:EL, and Triple Crown

Elastomer Swell: Viton



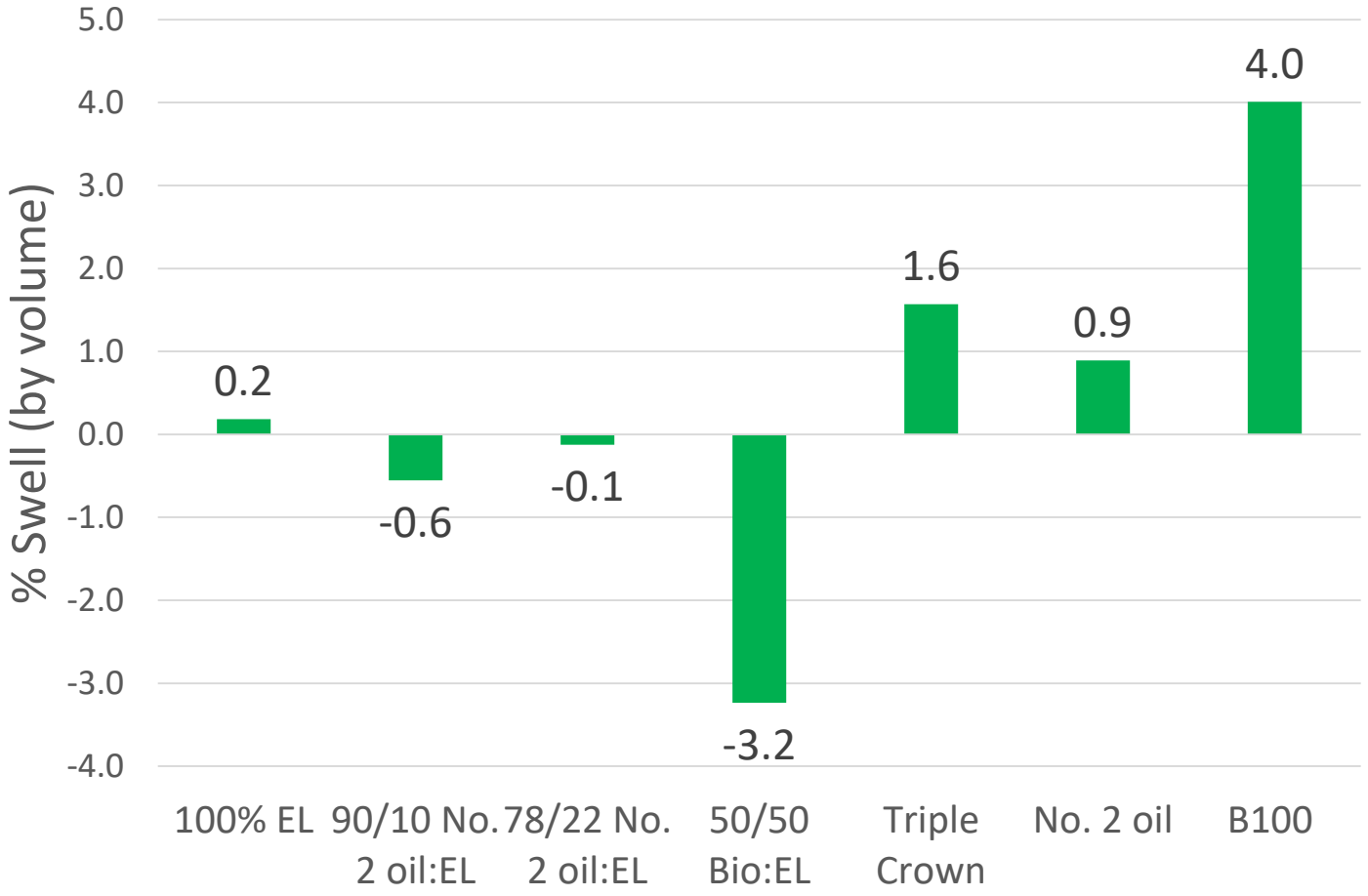


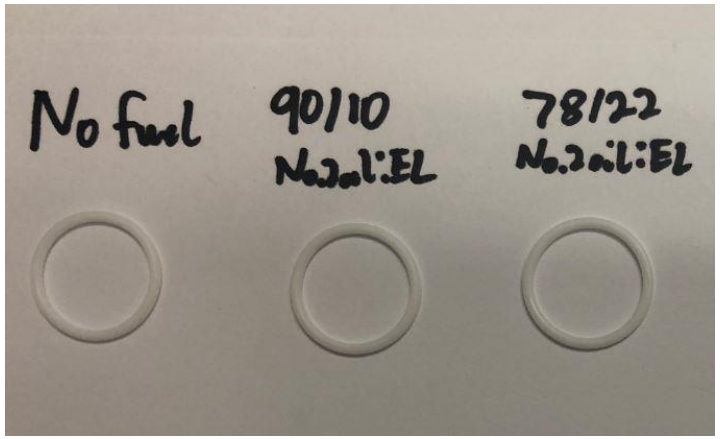
O-ring 1 – 4 Swell in No.2 oil:EL blends

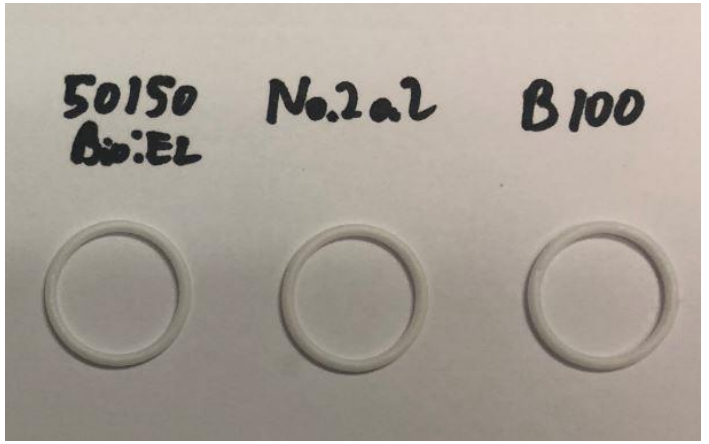


O-ring 1 – 4 Swell in Triple Crown blend

Elastomer Swell: Teflon

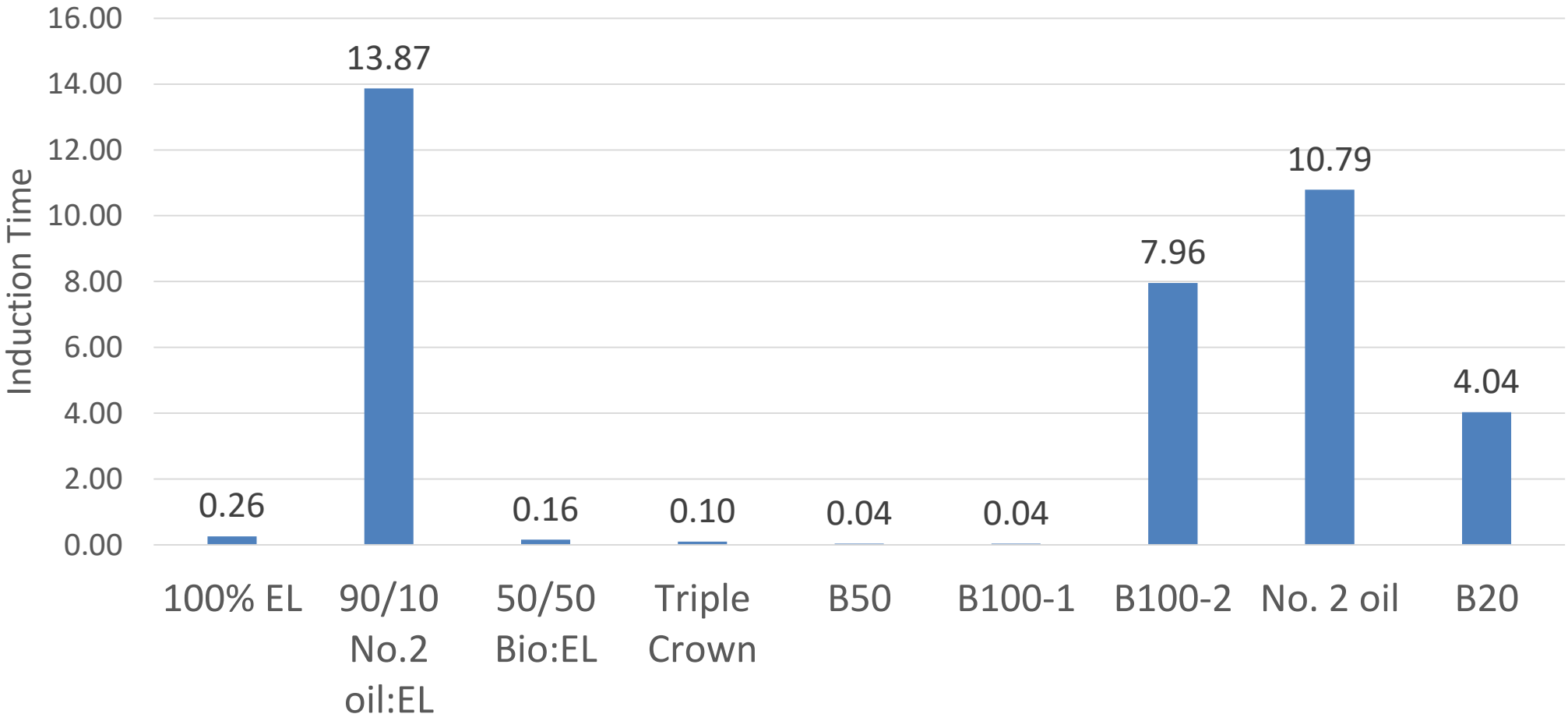






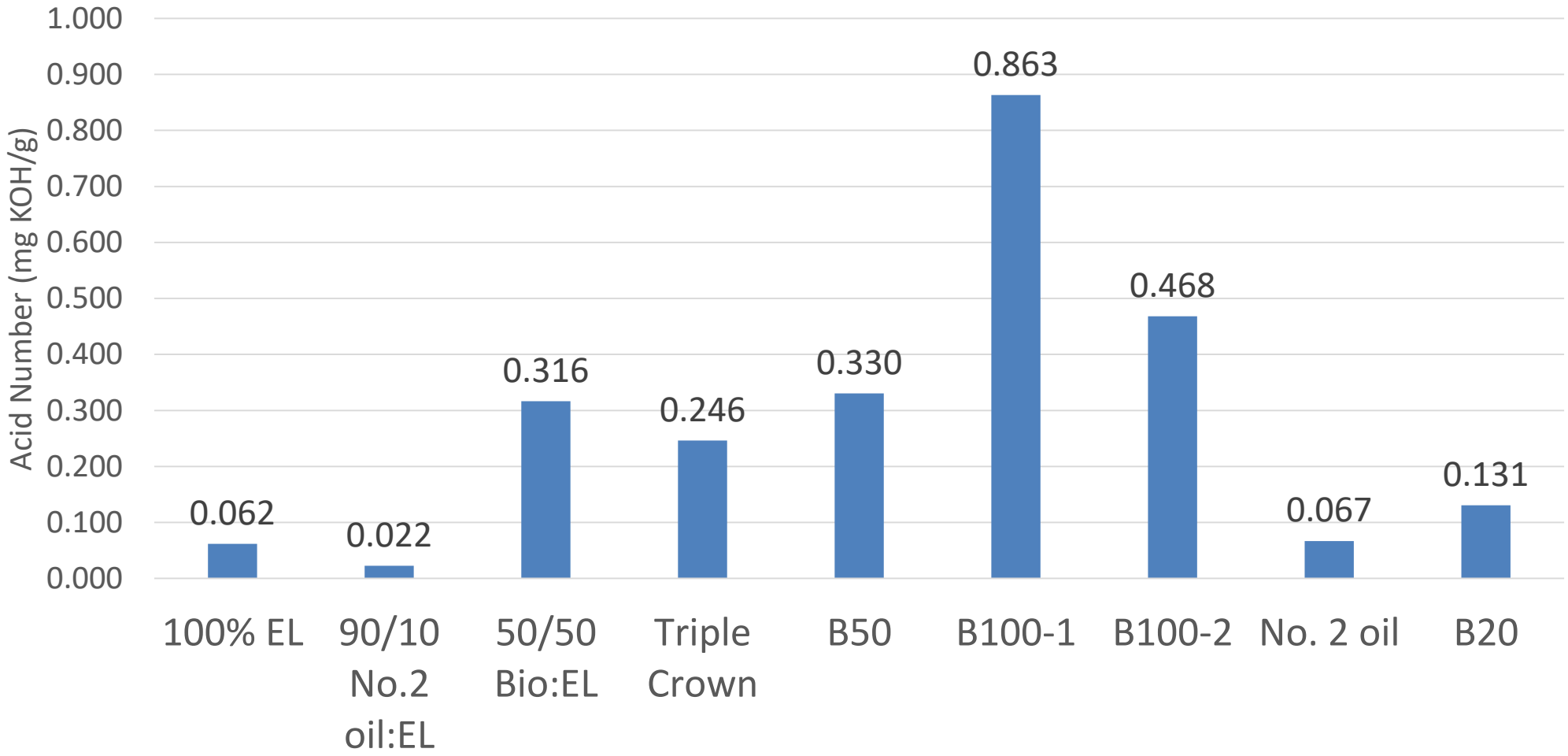
Teflon O-ring Swell

EL Long Term Stability Test: Rancimat



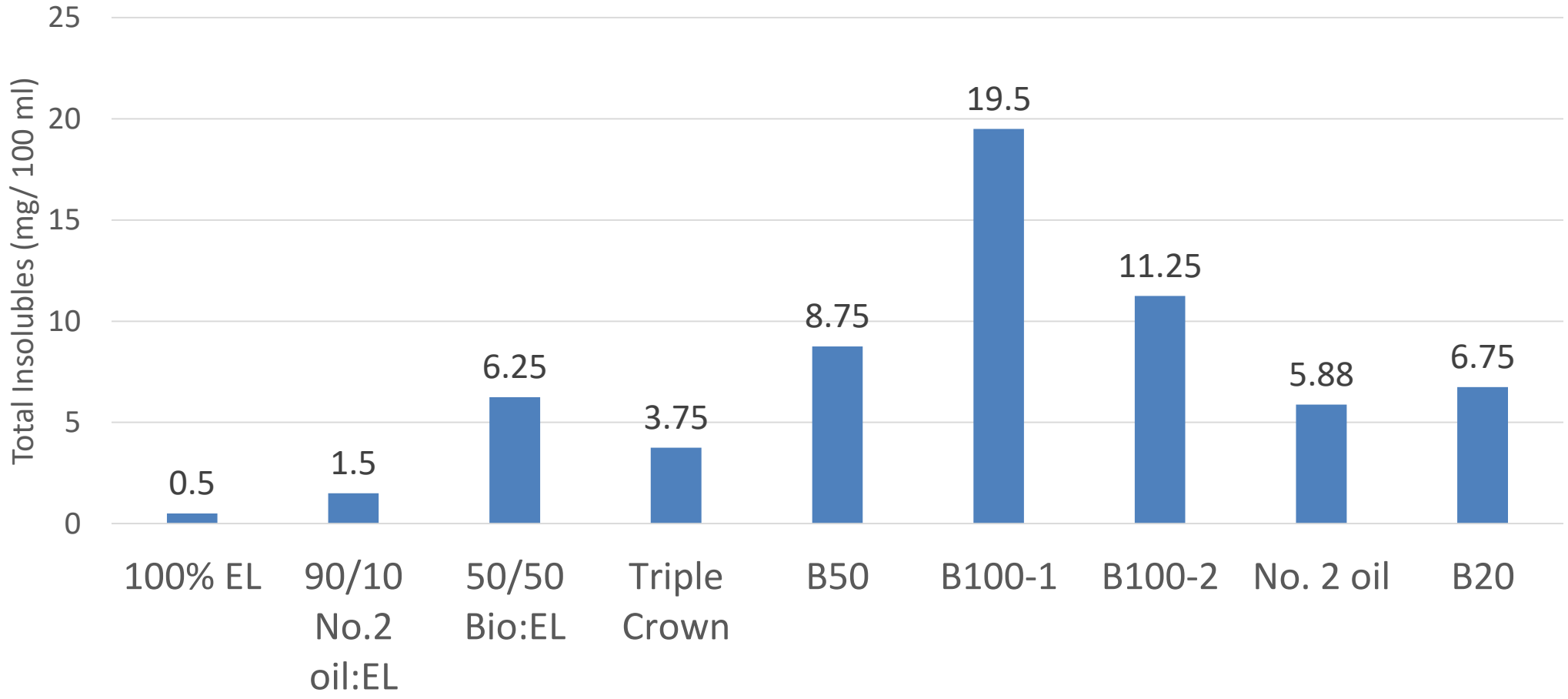
EL induction time fell dramatically after 9 weeks in incubator

EL Long Term Stability Test: Acid Number



EL acid number still very good after 9 weeks in incubator

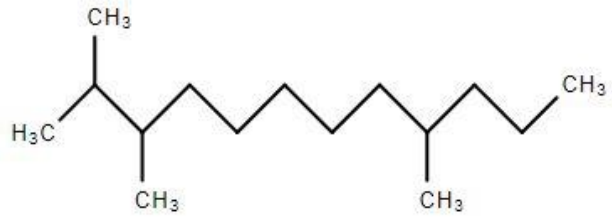
EL Long Term Stability Test: Total Insolubles



Total insoluble was very low for EL, and blends with EL produced less insolubles.

Renewable Diesel

- Also known as hydrogenated vegetable oil (HVO)
- Made up of a mixture of straight chain and branched paraffins
- Very similar properties to No. 2 oil
- Unlike No. 2 oil, renewable diesel has very low aromatic content
- Not the same as biodiesel

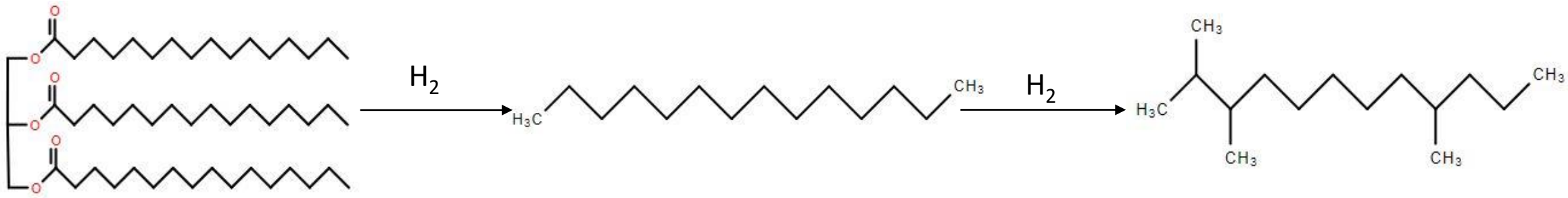


Renewable Diesel

Biodiesel

Renewable Diesel Production

- All types of fats and oils can be used, but vegetable oil and waste oil are main feedstocks.
- Process used is called hydrogenation or hydrotreating. Hydrogen is added to the feed stock to remove the oxygen from the feedstock.
- Isomerization is then used to convert fuel into a branched chain, to improve cold temperature properties.



Hydrogenation

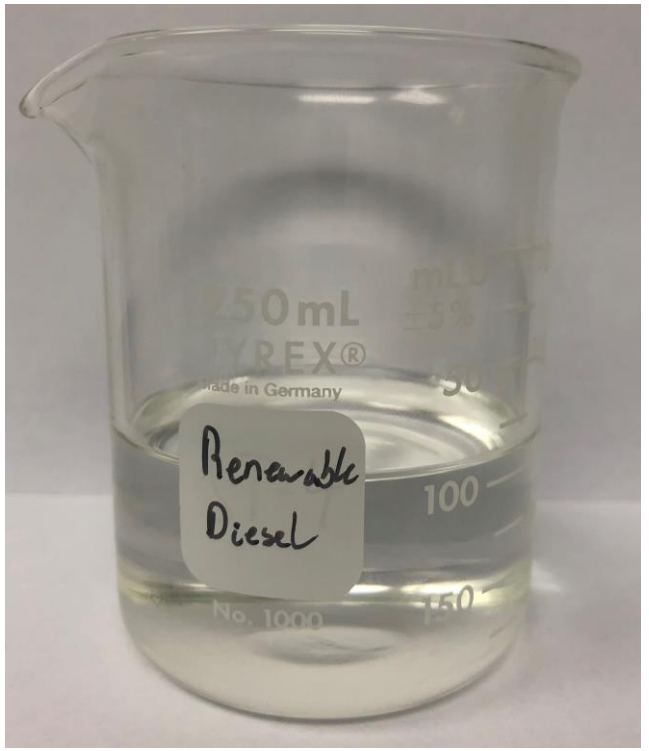
Isomerization

Renewable Diesel Properties

- High cetane number: >70
- Lower Density: 0.78 g/cm^3
- Slightly less Heating Value: about 4% lower than No. 2 oil (by volume)
- Cloud point: similar to No. 2 oil, can go as low as -40°F
- Viscosity, Lubricity, and Distillation curve are all similar to No. 2 oil

NORA Tests on Renewable Diesel

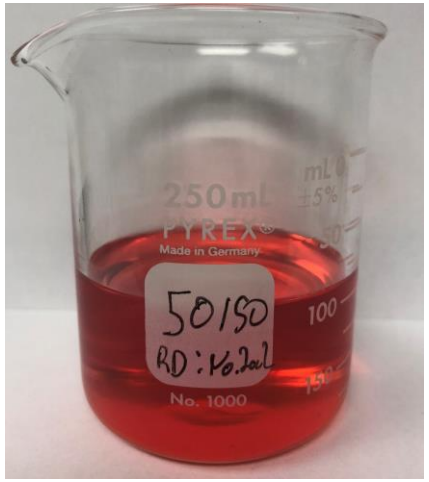
- Induction Time: 41.98 hr
- Acid Number: 0.042 mg KOH/g



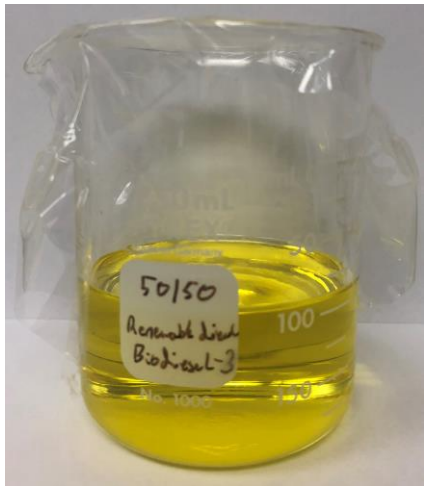
Renewable Diesel

Renewable Diesel Blending

- No issues mixing with No. 2 oil at any amount
- We found no issues mixing with biodiesel
- Because of RD low aromatic content, No. 1-B biodiesel may be preferred
- In blends of renewable diesel and biodiesel, one RD supplier has indicated minor components in biodiesel could precipitate out.



50/50 Renewable Diesel:No. 2 oil



50/50 Renewable Diesel:Biodiesel

Long Term Storage Test

- Induction Time: 27.39 hrs
- Acid Number: 0.036 mg KOH/g
- Total Insolubles: 7 mg/100 ml

Conclusions

- EL
  - Very good induction time and acid number
  - Separation issues with No. 2 oil
  - Blending with biodiesel helps improve cloud point
  - Swells nitrile and viton materials
  - Has the potential for very good long term stability
- Renewable Diesel
  - Very good induction time and acid number
  - Similar properties to No. 2 oil
  - Very good cold temperature properties
  - Blends with No. 2 oil at any amount; might need added controls for biodiesel
  - Good long term storage properties