

## Hydrogenated or oxyfunctionalized turpentine: Options for automotive fuel components.

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### Supplementary material

**Table 1S.** Elemental composition from GC-MS and estimated properties of turpentine, hydroturpentine and oxyturpentine

	<b>C</b> (% w/w)	<b>H</b> (% w/w)	<b>O</b> (% w/w)	<b>Mean</b> <b>molecular</b> <b>formula</b>	<b>Molecular</b> <b>weight</b> <b>(kg/kmol)</b>	<b>H/C</b> <b>ratio</b>	<b>Fuel/air</b> <b>stoichiometric</b> <b>ratio</b>
T	88.1	11.8	0.1	C <sub>10.19</sub> H <sub>16.30</sub> O <sub>0.00</sub>	138.85	1.60	1/14.20
HT	87.4	12.2	0.4	C <sub>10.16</sub> H <sub>16.88</sub> O <sub>0.03</sub>	139.64	1.66	1/14.21
OT	84.7	11.5	3.8	C <sub>10.33</sub> H <sub>16.75</sub> O <sub>0.35</sub>	146.55	1.62	1/13.48

**Table 2S.** Measured properties of fuels

<i>Fuel</i>	<i>Density (kg/m<sup>3</sup>)</i>	<i>Kinematic viscosity at 40°C (mm<sup>2</sup>/s)</i>	<i>WSD (µm)</i>	<i>Higher heating value (MJ/kg)</i>	<i>Lower heating value (MJ/kg)</i>	<i>Flash point (°C)</i>	<i>Derived cetane number</i>	<i>SP (mm)</i>	<i>OESI</i>	<i>Cloud point (°C)</i>	<i>Pour point (°C)</i>	<i>COT (°C)</i>
T	864.3 ± 0.9	1.35 ± 0.00	461 ± 11	44.9 ± 0.0	42.3 ± 0.0	37.3 ± 1.2	19.9 ± 0.5	9.0 ± 0.0	53.7 ± 0.0	-104.1 ± 3.4	-101.7 ± 2.9	<-90.0
HT	861.7 ± 0.5	1.47 ± 0.00	360 ± 6	45.1 ± 0.1	42.5 ± 0.1	33.2 ± 0.6	23.1	10.7 ± 0.6	44.4 ± 3.0	n.d.	n.d.	<-90.0
OT	912.6 ± 0.0	3.51 ± 0.01	302 ± 42	42.2 ± 0.1	39.7 ± 0.1	37.0	19.8	33.3 ± 0.6	8.0 ± 0.6	n.d.	-94.8 ± 0.8	<-90.0
D	826.6 ± 0.6	2.59 ± 0.01	429 ± 55	45.8 ± 0.1	43.1 ± 0.1	74.0 ± 0.0	59.9	23.0 ± 0.6	26.0 ± 0.9	-22.7 ± 0.0	-22.0 ± 0.0	-27.0 ± 0.1
B	875.8 ± 1.0	4.53 ± 0.05	174 ± 7	39.7 ± 0.6	37.1 ± 0.6	137.8 ± 1.2	59.3	n.d.	n.d.	7.0 ± 0.0	10.0 ± 0.0	2.0 ± 0.0

n.d. not detected

**Table 3S.** Measured properties of blends of turpentine, hydroturpentine and oxyturpentine with diesel

<i>Blend with diesel (% in v/v)</i>	<i>Density (kg/m<sup>3</sup>)</i>	<i>Kinematic viscosity at 40°C (mm<sup>2</sup>/s)</i>	<i>WSD (µm)</i>	<i>Higher heating value (MJ/kg)</i>	<i>Lower heating value (MJ/kg)</i>	<i>Flash point (°C)</i>	<i>Derived cetane number</i>	<i>SP (mm)</i>	<i>OESI</i>	<i>Cloud point (°C)</i>	<i>Pour point (°C)</i>	<i>COT (°C)</i>
T (1%)	827.0 ± 0.5	2.54 ± 0.01	399 ± 3	45.8 ± 0.0	43.0 ± 0.0	71.8 ± 0.6	59.8	22.6 ± 0.6	26.3 ± 0.9	-25.3 ± 0.6	-22.0 ± 0.0	-27.9 ± 0.0
T (2%)	828.0 ± 0.7	2.58 ± 0.01	390 ± 5	45.8 ± 0.0	43.0 ± 0.0	70.8 ± 1.3	58.6	22.0 ± 0.6	27.2 ± 1.0	-25.4 ± 0.1	-22.0 ± 0.0	-28.3 ± 0.1
T (3%)	828.3 ± 0.4	2.51 ± 0.01	398 ± 17	45.8 ± 0.0	43.0 ± 0.0	68.5 ± 0.0	58.3	21.6 ± 0.6	27.6 ± 1.0	-25.7 ± 0.1	-22.7 ± 0.6	-28.3 ± 0.1
T (5%)	829.0 ± 0.4	2.47 ± 0.01	435 ± 52	45.8 ± 0.0	43.0 ± 0.0	65.2 ± 0.6	57.6	20.6 ± 0.6	29.1 ± 1.1	-25.6 ± 0.0	-23.0 ± 0.0	-28.9 ± 0.0
T (10%)	829.7 ± 0.3	2.42 ± 0.00	441 ± 3	45.7 ± 0.0	43.0 ± 0.0	60.5 ± 0.0	54.4	19.6 ± 0.6	30.3 ± 1.2	-26.0 ± 0.0	-23.7 ± 0.6	-29.7 ± 0.1
T (15%)	831.4 ± 0.7	2.32 ± 0.00	446 ± 75	45.7 ± 0.0	43.0 ± 0.0	55.5 ± 0.1	51.6	18.9 ± 0.6	30.9 ± 1.3	-26.3 ± 0.2	-24.3 ± 1.2	-30.1 ± 0.2
T (20%)	834.3 ± 1.1	2.29 ± 0.01	445 ± 43	45.6 ± 0.0	42.9 ± 0.0	46.5 ± 0.6	49.9	18.6 ± 0.6	30.8 ± 1.2	-26.7 ± 0.1	-25.3 ± 0.6	-31.0 ± 0.0
HT (1%)	831.6 ± 0.3	2.48 ± 0.01	367 ± 24	46.0 ± 0.1	43.2 ± 0.1	73.5 ± 0.0	n.m.	23.0 ± 0.6	25.7 ± 0.9	-28.7 ± 0.3	-28.3 ± 0.6	-37.5 ± 0.1
HT (2%)	831.7 ± 0.8	2.54 ± 0.04	366 ± 57	46.0 ± 0.0	43.2 ± 0.0	74.0 ± 0.0	51.2	22.6 ± 0.6	26.1 ± 0.9	-31.3 ± 2.5	-28.3 ± 0.6	-37.7 ± 0.2
HT (3%)	832.9 ± 0.4	2.63 ± 0.04	352 ± 22	46.0 ± 0.0	43.3 ± 0.0	71.0 ± 0.0	n.m.	22.6 ± 0.6	25.9 ± 0.9	-29.2 ± 0.3	-29.0 ± 0.0	-37.8 ± 0.0
HT (5%)	833.0 ± 0.1	2.47 ± 0.02	363 ± 29	46.0 ± 0.1	43.2 ± 0.1	68.3 ± 0.6	n.m.	22.3 ± 0.0	26.2 ± 0.0	-29.4 ± 0.1	-29.0 ± 0.0	-38.2 ± 0.0
HT (10%)	834.8 ± 0.4	2.40 ± 0.06	440 ± 18	45.9 ± 0.0	43.2 ± 0.0	62.0 ± 0.0	48.6	22.0 ± 0.6	26.0 ± 0.9	-31.3 ± 1.1	-31.0 ± 0.0	-39.1 ± 0.1
HT (15%)	834.9 ± 0.4	2.26 ± 0.01	400 ± 8	46.0 ± 0.0	43.2 ± 0.0	58.0 ± 0.0	49.3	20.3 ± 0.0	28.2 ± 0.0	-31.4 ± 0.6	-34.0 ± 0.0	-40.1 ± 0.1
HT (20%)	836.6 ± 0.2	2.23 ± 0.01	463 ± 7	45.8 ± 0.0	43.1 ± 0.0	55.0 ± 0.0	n.m.	18.6 ± 0.6	30.8 ± 1.2	-32.6 ± 3.5	-36.0 ± 0.0	-41.0 ± 0.0
OT (1%)	830.5 ± 0.8	2.44 ± 0.00	237 ± 0	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	-22.8 ± 0.0	n.m.	-28.4 ± 0.0
OT (2%)	831.4 ± 0.0	2.43 ± 0.00	202 ± 1	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	-22.9 ± 0.1	n.m.	-28.5 ± 0.0
OT (3%)	831.5 ± 0.4	2.46 ± 0.00	260 ± 0	n.m.	n.m.	77.0	n.m.	n.m.	n.m.	-22.9 ± 0.0	n.m.	-28.6 ± 0.0
OT (5%)	834.3 ± 0.1	2.42 ± 0.00	197 ± 16	n.m.	n.m.	74.0	61.8	n.m.	n.m.	-23.2 ± 0.0	-20.4	-28.7 ± 0.0
OT (10%)	838.3 ± 0.8	2.43 ± 0.00	305 ± 27	44.8 ± 0.3	42.1 ± 0.3	69.0	58.1	24.7 ± 0.8	21.7 ± 0.8	-23.9 ± 0.2	-21.2	-29.1 ± 0.0
OT (15%)	843.3 ± 0.3	2.45 ± 0.00	308 ± 15	n.m.	n.m.	65.0	54.4	n.m.	n.m.	-24.5 ± 0.3	-21.9	-29.5 ± 0.0
OT (20%)	846.6 ± 0.5	2.48 ± 0.00	341 ± 35	44.6 ± 0.1	41.9 ± 0.1	63.0	51.7	25.3 ± 0.6	19.8 ± 0.6	-25.2 ± 0.1	-22.2	-29.9 ± 0.0

n.m. not measured

**Table 4S.** Measured properties of blends of turpentine, hydroturpentine and oxyturpentine with biodiesel

<i>Blend with biodiesel (% in v/v)</i>	<i>Density (kg/m<sup>3</sup>)</i>	<i>Kinematic viscosity at 40°C (mm<sup>2</sup>/s)</i>	<i>WSD (µm)</i>	<i>Higher heating value (MJ/kg)</i>	<i>Lower heating value (MJ/kg)</i>	<i>Flash point (°C)</i>	<i>Derived cetane number</i>	<i>SP (mm)</i>	<i>OESI</i>	<i>Cloud point (°C)</i>	<i>Pour point (°C)</i>	<i>COT (°C)</i>
T (1%)	875.7 ± 0.4	4.46 ± 0.01	176 ± 5	39.8 ± 0.0	37.2 ± 0.0	110.3 ± 1.2	59.9	n.d.	n.d.	6.7 ± 0.2	9.0 ± 0.0	1.7 ± 0.1
T (2%)	875.1 ± 0.3	4.35 ± 0.01	173 ± 4	39.9 ± 0.0	37.3 ± 0.0	100.7 ± 1.3	59.4	n.d.	n.d.	6.5 ± 0.1	7.3 ± 0.6	0.9 ± 0.1
T (3%)	875.0 ± 0.4	4.34 ± 0.01	177 ± 8	39.9 ± 0.0	37.3 ± 0.0	91.8 ± 1.0	58.9	n.d.	n.d.	6.6 ± 0.1	7.0 ± 0.0	0.8 ± 0.1
T (5%)	874.4 ± 0.0	4.20 ± 0.01	175 ± 8	40.0 ± 0.1	37.4 ± 0.1	80.3 ± 1.5	58.4	n.d.	n.d.	5.8 ± 0.1	7.0 ± 1.0	0.1 ± 0.1
T (10%)	873.9 ± 0.2	4.03 ± 0.02	177 ± 13	40.2 ± 0.1	37.7 ± 0.1	66.3 ± 0.6	56.7	n.d.	n.d.	5.1 ± 0.2	6.3 ± 0.6	-1.0 ± 0.1
T (15%)	873.4 ± 0.2	3.68 ± 0.01	177 ± 5	40.5 ± 0.1	37.9 ± 0.1	58.7 ± 0.6	55.4	n.d.	n.d.	4.5 ± 0.2	4.3 ± 0.6	-2.2 ± 0.1
T (20%)	873.3 ± 0.2	3.20 ± 0.01	178 ± 0	40.7 ± 0.1	38.1 ± 0.1	55.7 ± 0.6	54.1	n.d.	n.d.	3.3 ± 0.1	4.0 ± 0.0	-3.3 ± 0.1
HT (1%)	873.3 ± 0.7	4.61 ± 0.05	167 ± 5	40.0 ± 0.1	37.5 ± 0.1	117.0	n.m.	n.d.	n.d.	6.8 ± 0.1	9.0 ± 0.0	-0.3 ± 0.0
HT (2%)	872.6 ± 0.1	4.53 ± 0.03	169 ± 8	40.0 ± 0.1	37.5 ± 0.1	108.0	63.8	n.d.	n.d.	6.5 ± 0.2	7.0 ± 0.0	-1.3 ± 0.1
HT (3%)	872.3 ± 0.4	4.46 ± 0.01	160 ± 10	40.3 ± 0.1	37.7 ± 0.1	95.0	n.m.	n.d.	n.d.	6.8 ± 0.0	7.0 ± 0.0	-1.0 ± 0.0
HT (5%)	872.1 ± 0.6	4.37 ± 0.00	159 ± 13	40.1 ± 0.1	37.5 ± 0.1	84.0	n.m.	n.d.	n.d.	6.1 ± 0.1	7.0 ± 0.0	-1.7 ± 0.0
HT (10%)	871.9 ± 0.4	4.08 ± 0.01	160 ± 4	40.3 ± 0.1	37.7 ± 0.1	68.0	64.9	n.d.	n.d.	5.6 ± 0.3	7.0 ± 0.0	-1.8 ± 0.1
HT (15%)	870.6 ± 0.4	4.01 ± 0.04	165 ± 10	40.7 ± 0.1	38.1 ± 0.1	61.0	56.9	n.d.	n.d.	4.4 ± 0.2	6.0 ± 0.0	-3.6 ± 0.1
HT (20%)	869.5 ± 0.4	3.63 ± 0.01	179 ± 11	40.9 ± 0.1	38.3 ± 0.1	56.0	n.m.	n.d.	n.d.	4.2 ± 0.2	4.3 ± 1.5	-5.2 ± 0.0
OT (1%)	878.0 ± 0.3	4.20 ± 0.00	182 ± 18	n.m.	n.m.	n.m.	n.m.	n.d.	n.d.	n.m.	n.m.	1.1 ± 0.0
OT (2%)	877.4 ± 0.1	4.18 ± 0.00	244 ± 26	n.m.	n.m.	n.m.	n.m.	n.d.	n.d.	n.m.	n.m.	0.8 ± 0.2
OT (3%)	877.4 ± 0.2	4.20 ± 0.01	245 ± 29	n.m.	n.m.	100.0	n.m.	n.d.	n.d.	n.m.	n.m.	-0.6 ± 0.2
OT (5%)	878.2 ± 0.1	4.15 ± 0.01	242 ± 0	n.m.	n.m.	92.0	55.6	n.d.	n.d.	5.1	8.1	-1.4 ± 0.1
OT (10%)	880.8 ± 0.4	4.11 ± 0.03	216 ± 20	39.9 ± 0.1	37.3 ± 0.1	80.0	53.4	n.d.	n.d.	4.6	7.6	-2.9 ± 0.0
OT (15%)	883.3 ± 0.1	4.00 ± 0.02	227 ± 0	n.m.	n.m.	69.0	52.1	n.d.	n.d.	3.6	6.6	-4.0 ± 0.1
OT (20%)	884.3 ± 0.1	3.93 ± 0.01	238 ± 4	40.3 ± 0.4	37.8 ± 0.4	65.5	50.5	n.d.	n.d.	3.5	3.5	-5.0 ± 0.0