SUPLEMENTARY INFORMATION

Reduction of CO_2 captured in basic solutions with biomass as reducing agent and metallic catalysts

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1. FORMIC ACID
1.1 Formic acid yields for different catalysts and biomass
Conditions: 0.5 M Sodium bicarbonate, 0.1 g biomass, 300 ºC, 4.5 ml of liquid solution, 0.1 g of respective catalyst

First set of experiments

Catalyst	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
No catalyst	7%	6%	2%	0%	11%	5%	0%
C powder	1%	5%	2%	3%	11%	5%	6%
Pd/C 5%	9%	6%	2%	9%	17%	4%	9%
Ru/C 5%	7%	6%	3%	4%	3%	4%	4%
C granular	1%	6%	2%	8%	11%	5%	6%
Pd/C 10%	8%	6%	2%	6%	15%	7%	10%

Second set of experiments

Catalyst	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
No catalyst	8%	6%	2%	7%	10%	5%	8%
C powder	3%	5%	2%	5%	9%	5%	6%
Pd/C 5%	8%	9%	1%	9%	18%	6%	13%
Ru/C 5%	5%	6%	3%	5%	3%	5%	4%
C granular	7%	5%	3%	7%	10%	5%	4%
Pd/C 10%	8%	7%	2%	13%	17%	2%	10%

Average yields of formic acid

Catalyst		Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
No catalyst	Average	8%	6%	2%	3%	10%	5%	4%
	Standard deviation	1%	0%	0%	5%	1%	0%	2%
C powder	Average	2%	5%	2%	4%	10%	5%	6%
	Standard deviation	1%	0%	0%	1%	1%	0%	0%
Pd/C 5%	Average	9%	7%	2%	9%	18%	5%	11%
	Standard deviation	1%	2%	0%	0%	1%	2%	3%
Ru/C 5%	Average	6%	6%	3%	5%	3%	4%	4%
	Standard deviation	1%	0%	0%	0%	0%	0%	0%
C granular	Average	4%	6%	2%	7%	11%	5%	5%
	Standard deviation	4%	0%	0%	1%	1%	0%	1%
Pd/C 10%	Average	8%	6%	2%	9%	16%	5%	10%
	Standard deviation	0%	0%	0%	5%	1%	3%	0%

1.2 Variation of formic acid yields with amount of biomass

Conditions: 0.5 M Sodium bicarbonate, 0.1 g Pd/C 5%, 300 ºC, 4.5 ml of liquid solution

0.025 g

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	5%	3%	4%	6%	7%	2%	7%
2	5%	5%	4%	8%	7%	4%	7%
Average	5%	4%	4%	7%	7%	3%	7%
Standard deviation	1%	1%	0%	1%	0%	1%	0%

0.05 g

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	10%	6%	1%	10%	13%	3%	9%
2	8%	6%	1%	10%	13%	4%	9%
Average	9%	6%	1%	10%	13%	4%	9%
Standard deviation	1%	0%	0%	0%	0%	1%	0%

0.1 g

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	9%	6%	2%	9%	17%	4%	9%
2	8%	9%	1%	9%	18%	6%	13%
Average	9%	7%	2%	9%	18%	5%	11%
Standard deviation	1%	2%	0%	0%	1%	2%	3%

1.3 Variation of formic acid yields with temperature

Conditions: 0.5 M Sodium bicarbonate, 0.1 g biomass, 4.5 ml of liquid solution, 0.1 g Pd/C 5%

200ºC

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	2%	0.2%	1%	1%	3%	0.3%	1.2%
2	2%	1%	0.2%	3%	3%	0.3%	1%
Average	2%	0%	0%	2%	3%	0%	1%
Standard deviation	0%	0%	0%	2%	0%	0%	0%

250ºC

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	7%	3%	1%	8%	13%	5%	8%
2	6%	3%	1%	6%	12%	4%	5%
3	5%	3%	1%	6%	12%	4%	10%
Average	6%	3%	1%	7%	12%	5%	8%
Standard deviation	1%	0%	0%	1%	0%	1%	2%

300ºC

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	8%	9%	1%	9%	18%	6%	13%
2	9%	6%	2%	9%	17%	5%	9%
Average	9%	7%	2%	9%	18%	6%	11%
Standard deviation	1%	2%	0%	0%	1%	1%	3%

2. ACETIC ACID

2.1 Acetic acid yields for different catalysts and biomass type

Conditions: 0.5 M Sodium bicarbonate, 0.1 g biomass, 300 ºC, 4.5 ml of liquid solution

First set of experiments

Catalyst	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
No catalyst	3%	2%	1%	3%	2%	3%	3%
C powder	2%	4%	2%	4%	2%	2%	3%
Pd/C 5%	6%	5%	3%	7%	3%	3%	2%
Ru/C 5%	4%	3%	2%	5%	2%	2%	3%
C granular	5%	4%	2%	5%	2%	3%	2%
Pd/C 10%	5%	3%	2%	5%	2%	2%	3%

Second set of experiments

Catalyst	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
No catalyst	4%	4%	2%	5%	2%	3%	3%
C powder	2%	5%	1%	6%	2%	3%	3%
Pd/C 5%	4%	3%	1%	5%	1%	2%	2%
Ru/C 5%	4%	3%	2%	5%	2%	2%	2%
C granular	1%	4%	2%	5%	2%	3%	2%
Pd/C 10%	4%	3%	1%	5%	2%	3%	3%

Average yields of acetic acid

Catalyst		Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
No catalyst	Average	4%	3%	2%	4%	2%	3%	3%
	Standard deviation	1%	1%	1%	1%	0%	0%	0%
C powder	Average	2%	4%	2%	5%	2%	3%	3%
	Standard deviation	0%	1%	1%	1%	0%	1%	0%
Pd/C 5%	Average	5%	4%	2%	6%	2%	3%	2%
	Standard deviation	1%	1%	1%	1%	1%	1%	0%
Ru/C 5%	Average	4%	3%	2%	5%	2%	2%	3%
	Standard deviation	0%	0%	0%	0%	0%	0%	1%
C granular	Average	3%	4%	2%	5%	2%	3%	2%
	Standard deviation	3%	0%	0%	0%	0%	0%	0%
Pd/C 10%	Average	5%	3%	2%	5%	2%	3%	3%
	Standard deviation	1%	0%	1%	0%	0%	1%	0%

2.2 Variation of acetic acid yields with amount of biomass

Conditions: 0.5 M Sodium bicarbonate, 0.1 g Pd/C 5%, 300 ºC, 4.5 ml of liquid solution

0.025 g

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	1%	1%	0%	0%	0%	1%	1%
2	1%	1%	0%	2%	0%	1%	1%
Average	1%	1%	0%	1%	0%	1%	1%
Standard deviation	0%	0%	0%	1%	0%	0%	0%

0.05 g

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	2%	0%	1%	2%	1%	0%	1%
2	2%	2%	1%	2%	1%	0%	1%
Average	2%	1%	1%	2%	1%	0%	1%
Standard deviation	0%	1%	0%	0%	0%	0%	0%

0.1 g

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	4%	3%	1%	5%	1%	2%	2%
2	6%	5%	3%	7%	3%	3%	2%
Average	5%	4%	2%	6%	2%	3%	2%
Standard deviation	1%	1%	1%	1%	1%	1%	0%

2.3 Variation of acetic acid yields with temperature

Conditions: 0.5 M Sodium bicarbonate, 0.1 g biomass, 4.5 ml of liquid solution, 0.1 g Pd/C 5%

200ºC

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	3%	1%	3%	3%	1%	2%	1%
2	4%	2%	0%	3%	0%	2%	2%
Average	3%	1%	2%	3%	0%	2%	1%
Standard deviation	0%	1%	2%	0%	0%	0%	0%

250ºC

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	4%	2%	1%	4%	1%	2%	1%
2	3%	2%	1%	4%	1%	2%	2%
Average	4%	2%	1%	4%	1%	2%	2%
Standard deviation	0%	0%	0%	0%	0%	0%	1%

300ºC

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	6%	5%	3%	7%	3%	3%	2%
2	4%	3%	1%	5%	1%	2%	2%
Average	5%	4%	2%	6%	2%	3%	2%
Standard deviation	1%	1%	1%	1%	1%	1%	0%

3. LACTIC ACID
3.1 Lactic acid for different catalysts and biomass
Conditions: 0.5 M Sodium bicarbonate, 0.1 g biomass, 300 ºC, 4.5 ml of liquid solution

First set of experiments

Catalyst	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
No catalyst	10%	5%	1%	9%	10%	6%	14%
C powder	2%	6%	1%	4%	12%	5%	9%
Pd/C 5%	10%	5%	2%	9%	4%	3%	5%
Ru/C 5%	9%	6%	2%	6%	2%	3%	4%
C granular	16%	7%	2%	16%	13%	6%	12
Pd/C 10%	14%	6%	2%	13%	5%	3%	6%

Second set of experiments

Catalyst	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
No catalyst	17%	9%	2%	9%	13%	6%	8%
C powder	2%	7%	2%	4%	13%	6%	14%
Pd/C 5%	3%	13%	1%	6%	4%	2%	3%
Ru/C 5%	5%	6%	2%	8%	1%	3%	4%
C granular	16%	8%	2%	14%	12%	6%	12%
Pd/C 10%	10%	6%	1%	9%	5%	3%	6%

Average yields of lactic acid

Catalyst		Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
No catalyst	Average	14%	7%	2%	9%	12%	6%	11%
	Standard deviation	5%	3%	1%	0%	2%	0%	4%
C powder	Average	2%	7%	2%	4%	13%	6%	12%
	Standard deviation	0%	1%	1%	0%	1%	1%	4%
Pd/C 5%	Average	7%	9%	2%	8%	4%	3%	4%
	Standard deviation	5%	6%	1%	2%	0%	1%	1%
Ru/C 5%	Average	7%	6%	2%	7%	2%	3%	4%
	Standard deviation	3%	0%	0%	1%	1%	0%	0%
C granular	Average	16%	8%	2%	15%	13%	6%	12%
	Standard deviation	0%	1%	0%	1%	1%	0%	0%
Pd/C 10%	Average	12%	6%	2%	11%	5%	3%	6%
	Standard deviation	3%	0%	1%	3%	0%	0%	0%

3.2 Variation of lactic acid yields with amount of biomass

Conditions: 0.5 M Sodium bicarbonate, 0.1 g Pd/C 5%, 300 ºC, 4.5 ml of liquid solution

0.025 g

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	1%	0%	0%	0%	0%	0%	1%
2	1%	0%	0%	2%	0%	0%	1%
Average	1%	0%	0%	1%	0%	0%	1%
Standard deviation	0%	0%	0%	1%	0%	0%	0%

0.05 g

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	4%	1%	1%	2%	2%	0%	2%
2	4%	3%	1%	4%	2%	0%	2%
Average	4%	2%	1%	3%	2%	0%	2%
Standard deviation	0%	1%	0%	1%	0%	0%	0%

0.1 g

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	3%	13%	1%	6%	4%	2%	3%
2	10%	6%	1%	9%	5%	3%	6%
Average	12%	6%	2%	11%	5%	3%	6%
Standard deviation	3%	0%	1%	3%	0%	0%	0%

3.3 Variation of lactic acid yields with temperature

Conditions: 0.5 M Sodium bicarbonate, 0.1 g biomass, 4.5 ml of liquid solution, 0.1 g Pd/C 5%

200ºC

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	4%	2%	0%	1%	2%	1%	1%
2	3%	2%	1%	1%	1%	5%	1%
Average	4%	2%	0%	1%	2%	3%	1%
Standard deviation	1%	0%	0%	0%	1%	3%	0%

250ºC

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	10%	6%	1%	7%	3%	1%	5%
2	8%	5%	1%	6%	3%	2%	3.0%
Average	9%	6%	1%	7%	3%	2%	4%
Standard deviation	1%	1%	0%	1%	0%	1%	1%

300ºC

Repetition	Sugar beet	Pine needles	Vermi-compost	Sugarcane bagasse	Cellulose	Cork	Softwood
1	10%	5%	2%	9%	4%	3%	5%
2	3%	13%	1%	6%	4%	2%	3%
Average	7%	9%	2%	8%	4%	3%	4%
Standard deviation	5%	6%	1%	2%	0%	1%	1%

4. NMR DIAGRAMS

Conditions: 13C-NaHCO$_3$ 0.5M, 0.1 g of biomass, 200ºC and 300ºC, 4.5 ml of liquid solution.

1st EXPERIMENTS AT 300ºC

Sugarbeet, Pd/C 5%, 300ºC, carbon spectra

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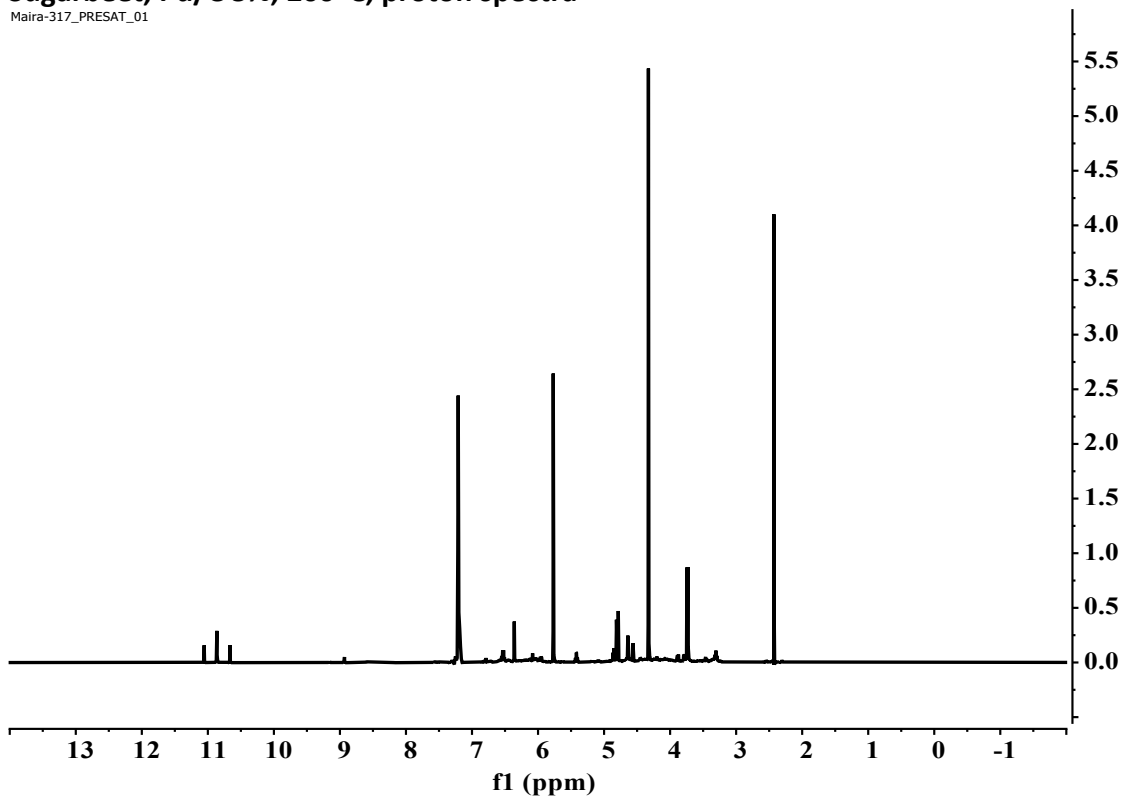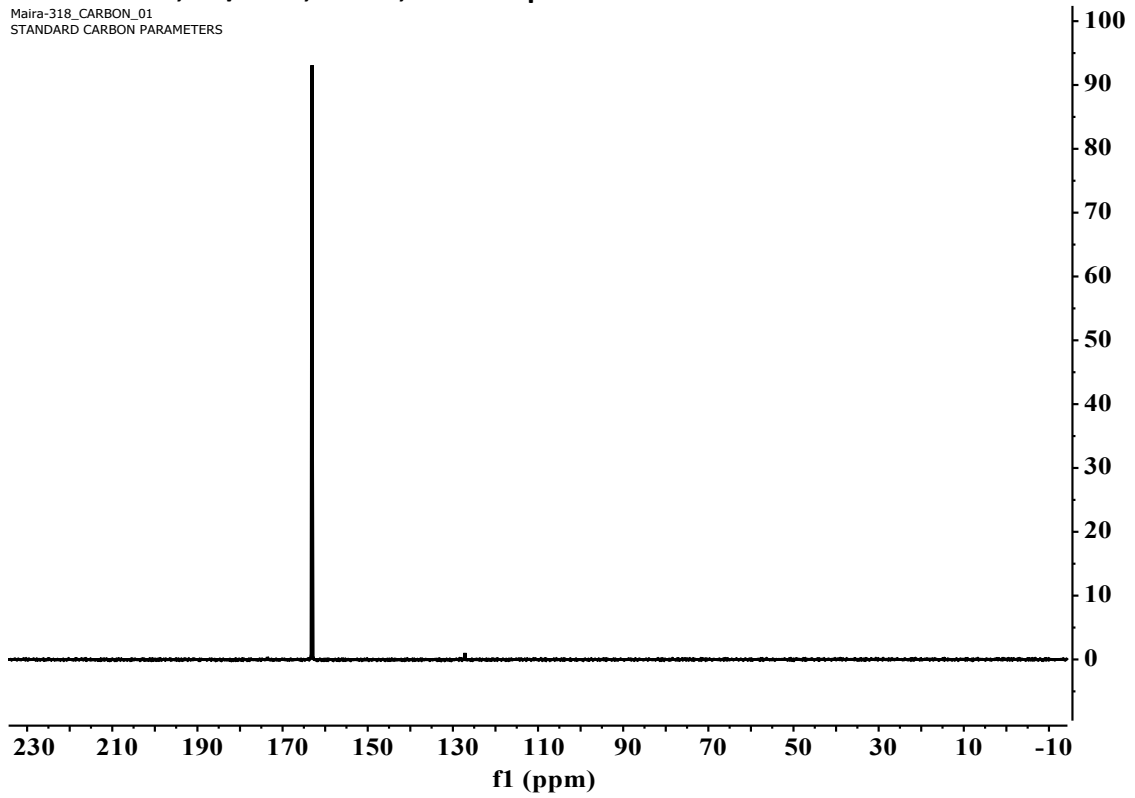STANDARD CARBON PARAMETERS
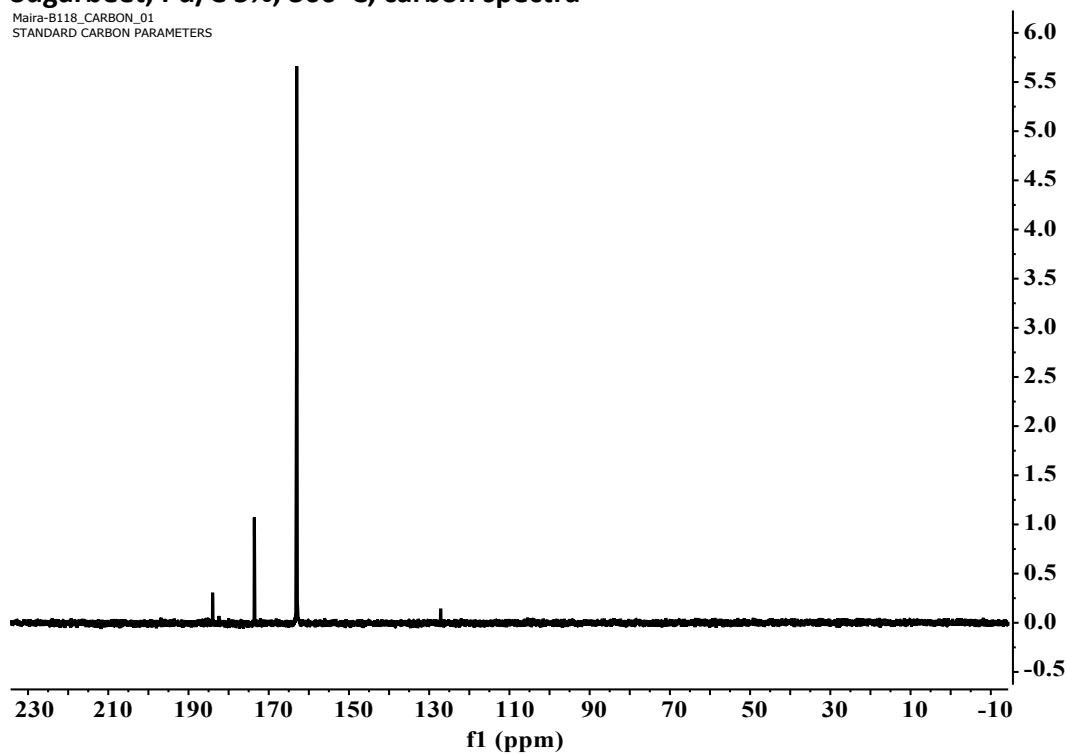
**Sugarbeet, Pd/C 5%, 300ºC, proton spectra**

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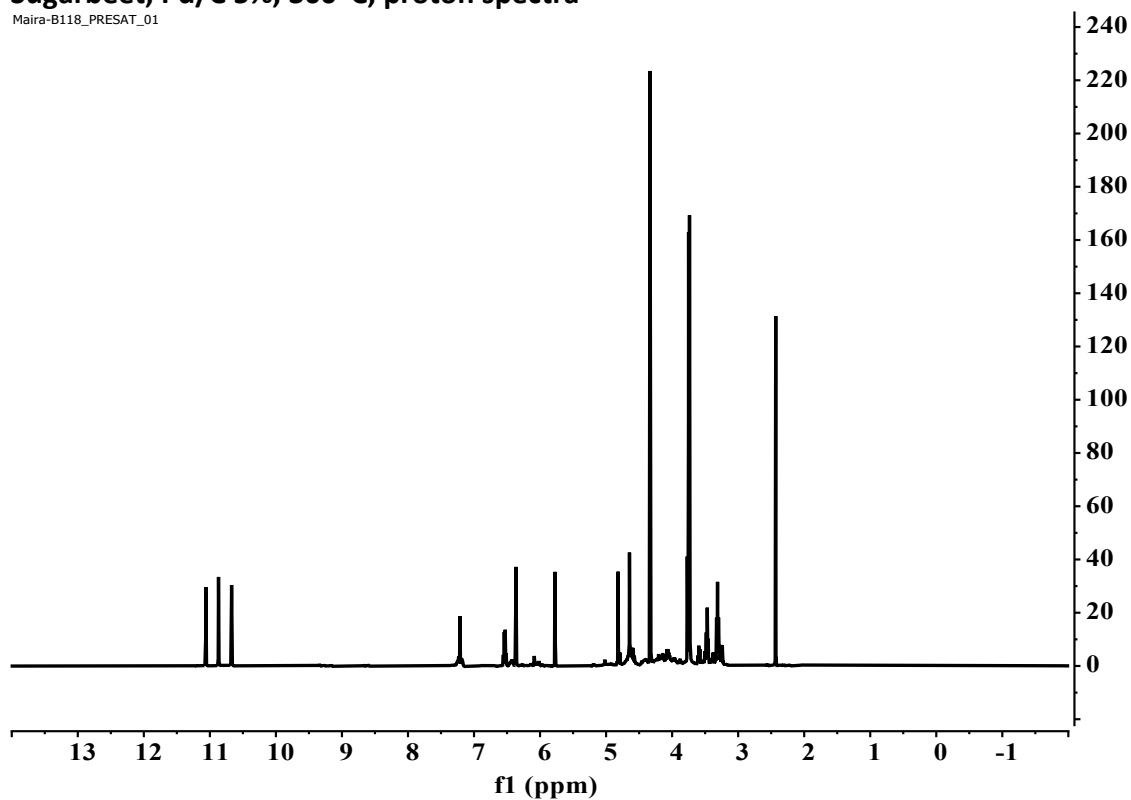
Pine needles, Pd/C 5%, 300ºC, carbon spectra

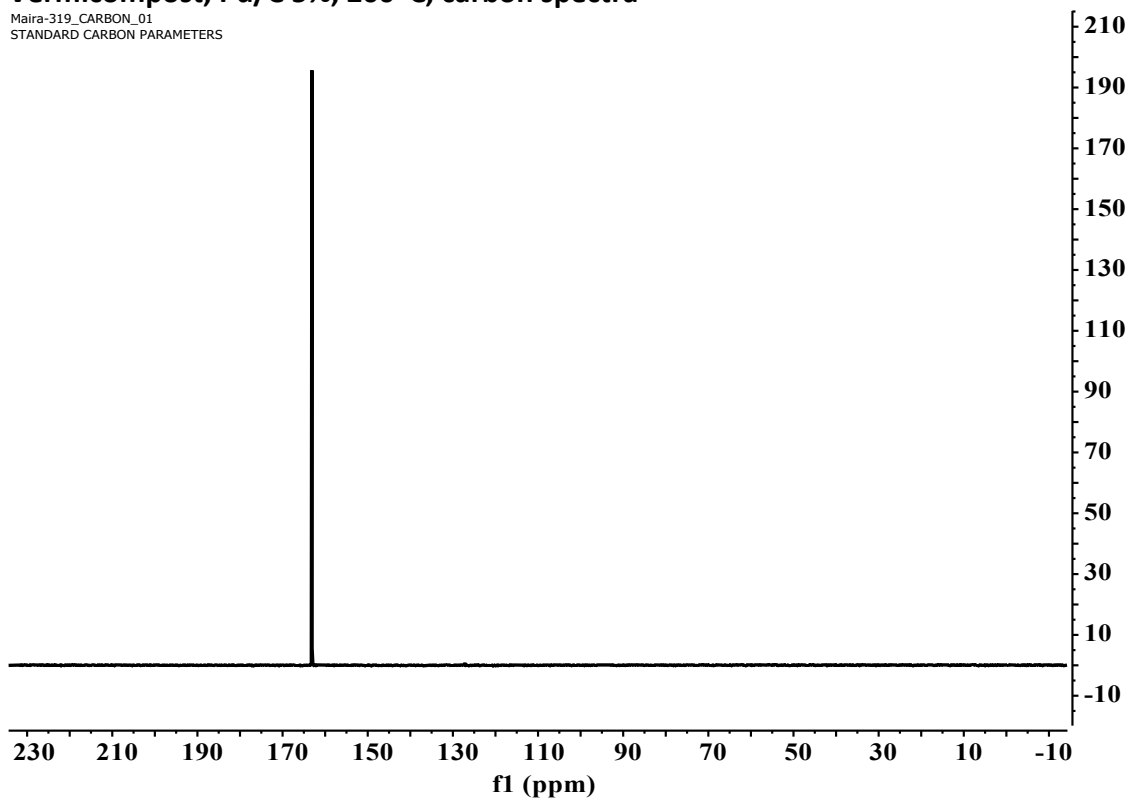Maira-B119_CARBON_01
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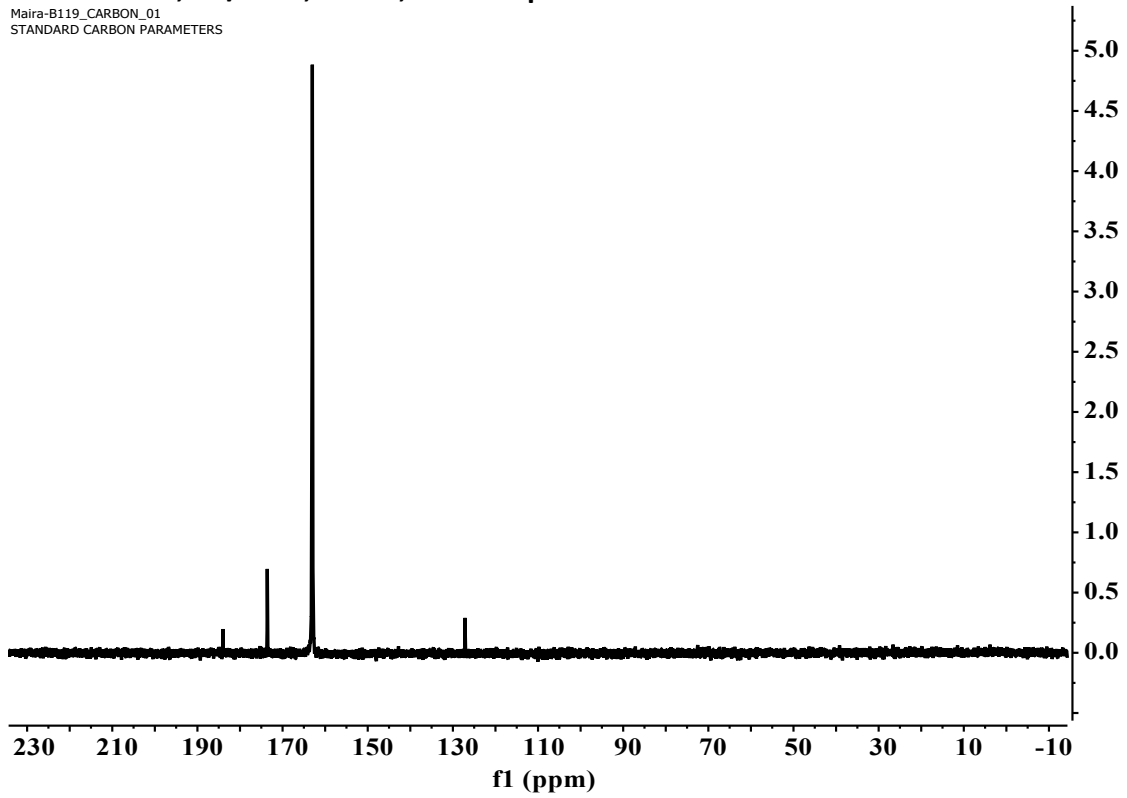
Pine needles, Pd/C 5%, 300ºC, proton spectra

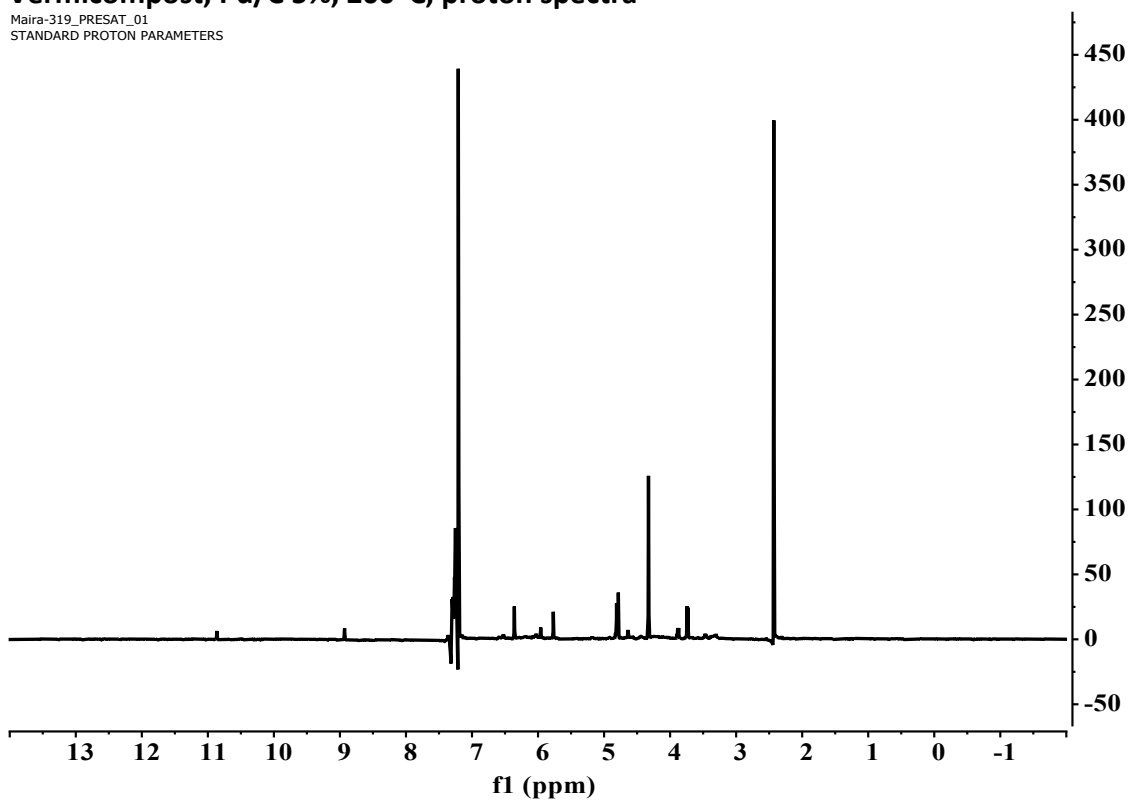Maira-B119_PRESAT_01
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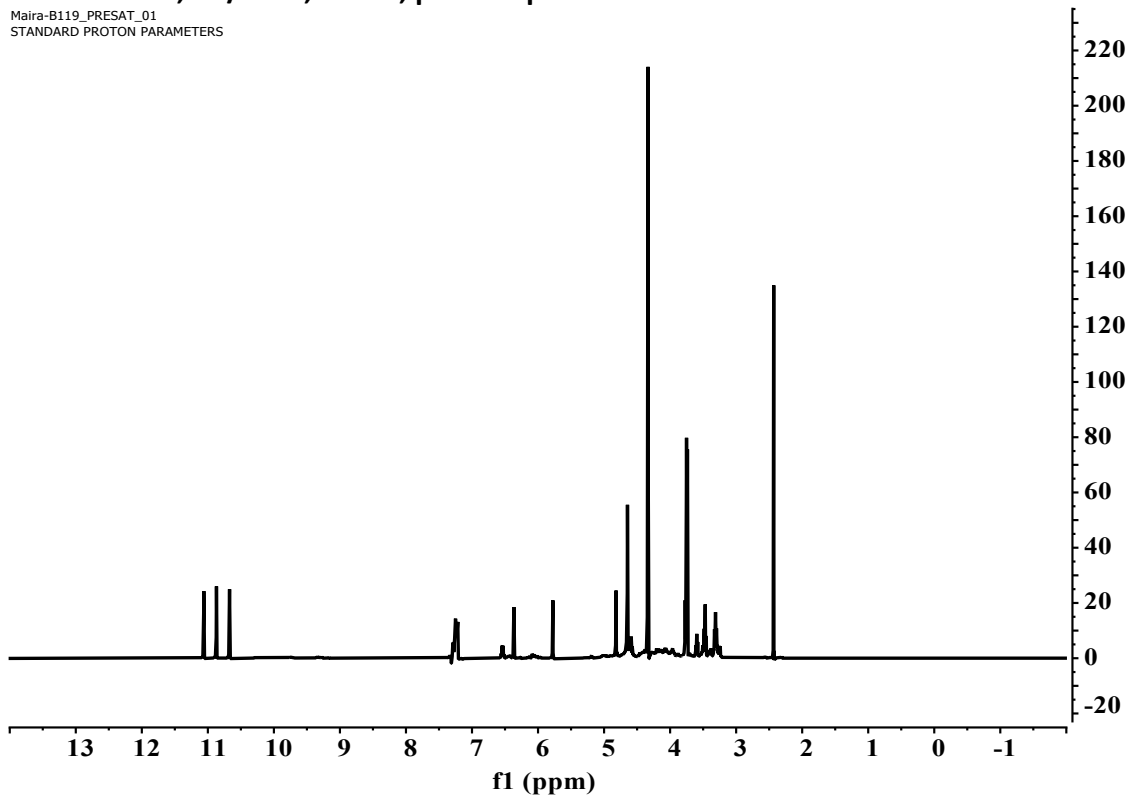
Vermicompost, Pd/C 5%, 300ºC, carbon spectra

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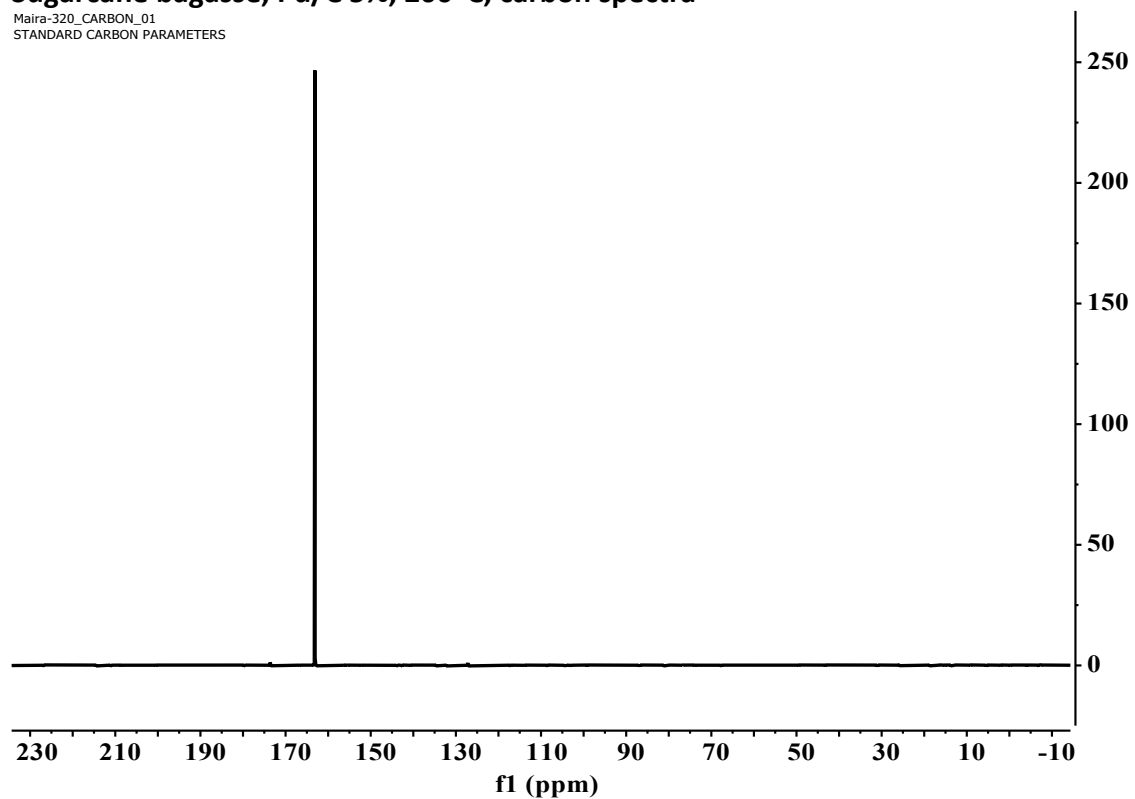STANDARD CARBON PARAMETERS
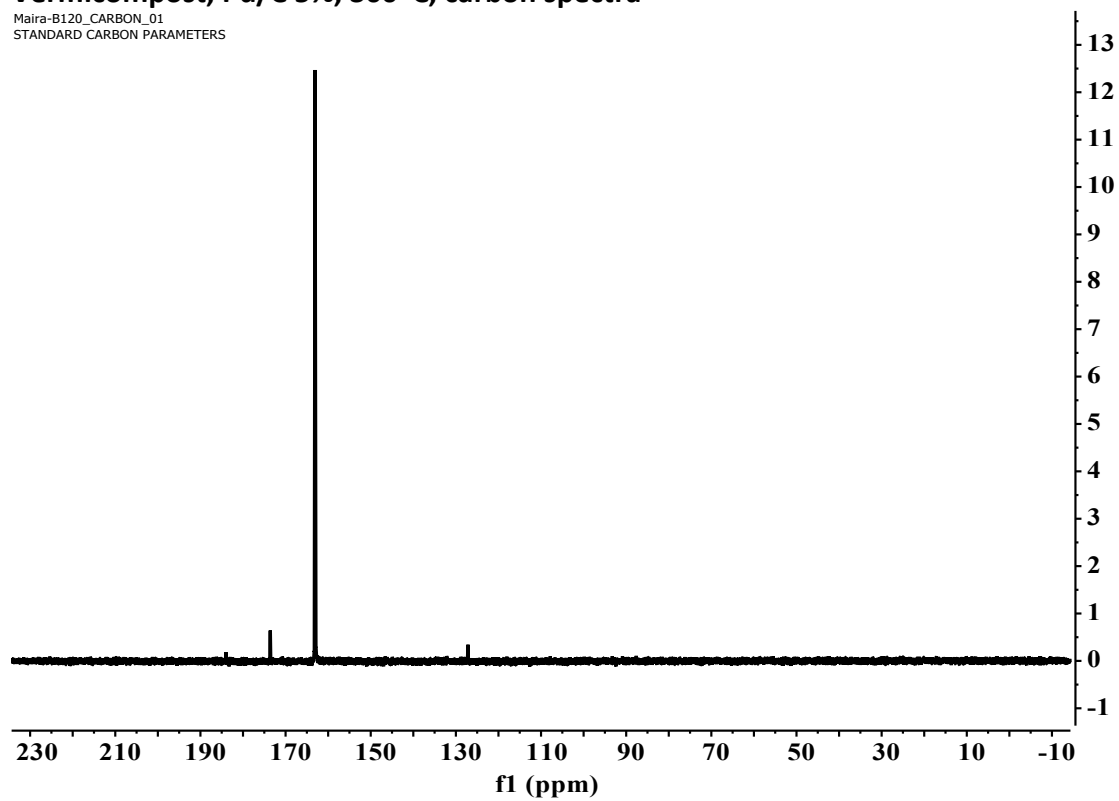
Vermicompost, Pd/C 5%, 300ºC, proton spectra

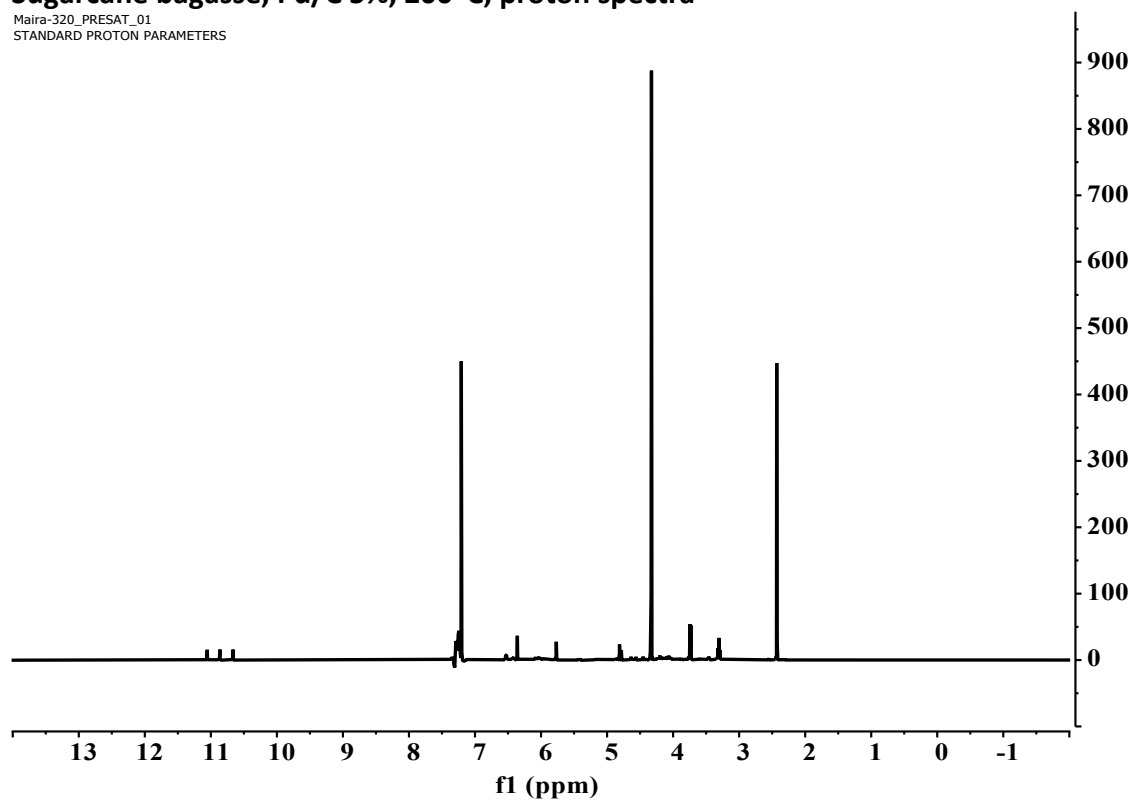Maira-B120_PRESAT_01
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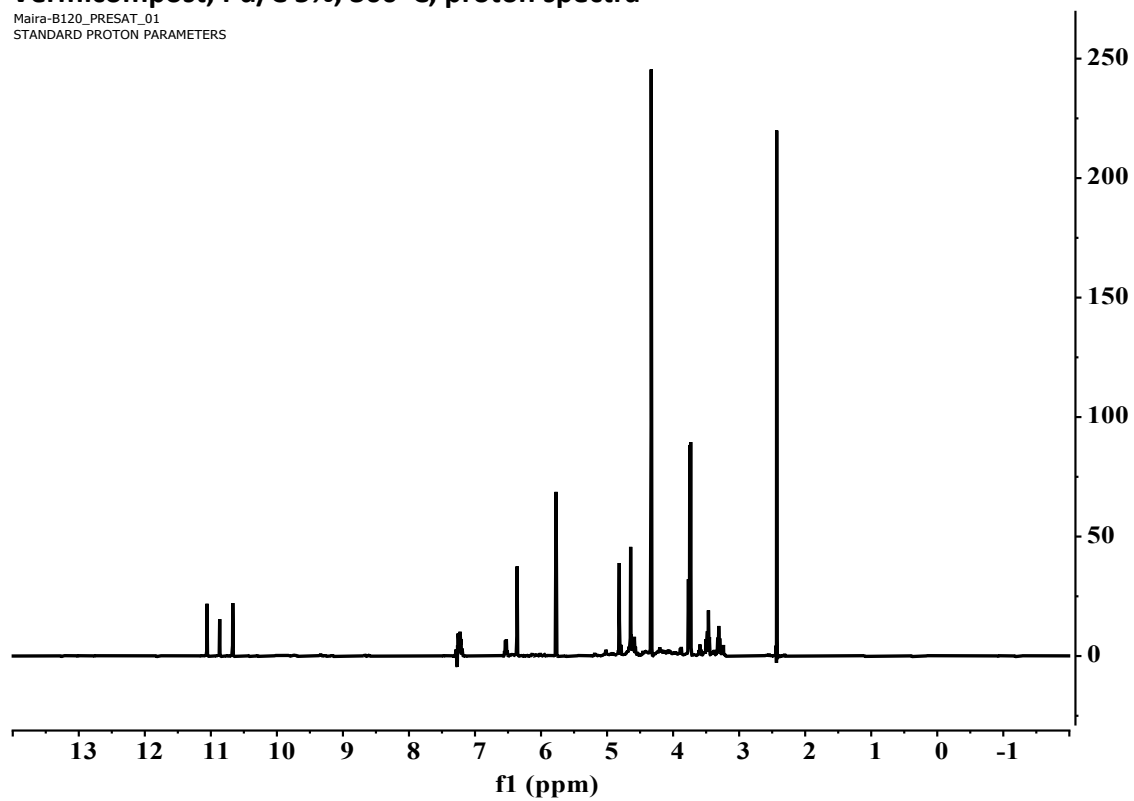
Sugarcane bagasse, Pd/C 5%, 300ºC, carbon spectra

Maira-B121_CARBON_01
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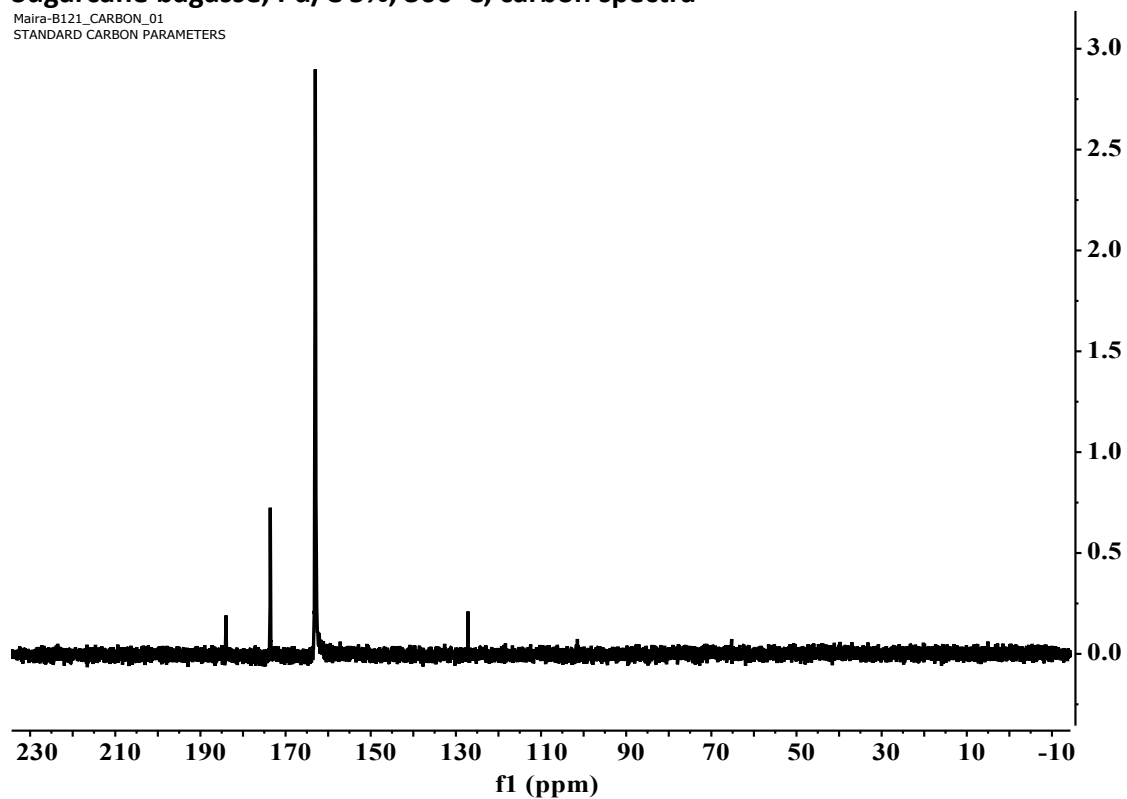
Sugarcane bagasse, Pd/C 5%, 300ºC, proton spectra

Maira-B121_PRESAT_01
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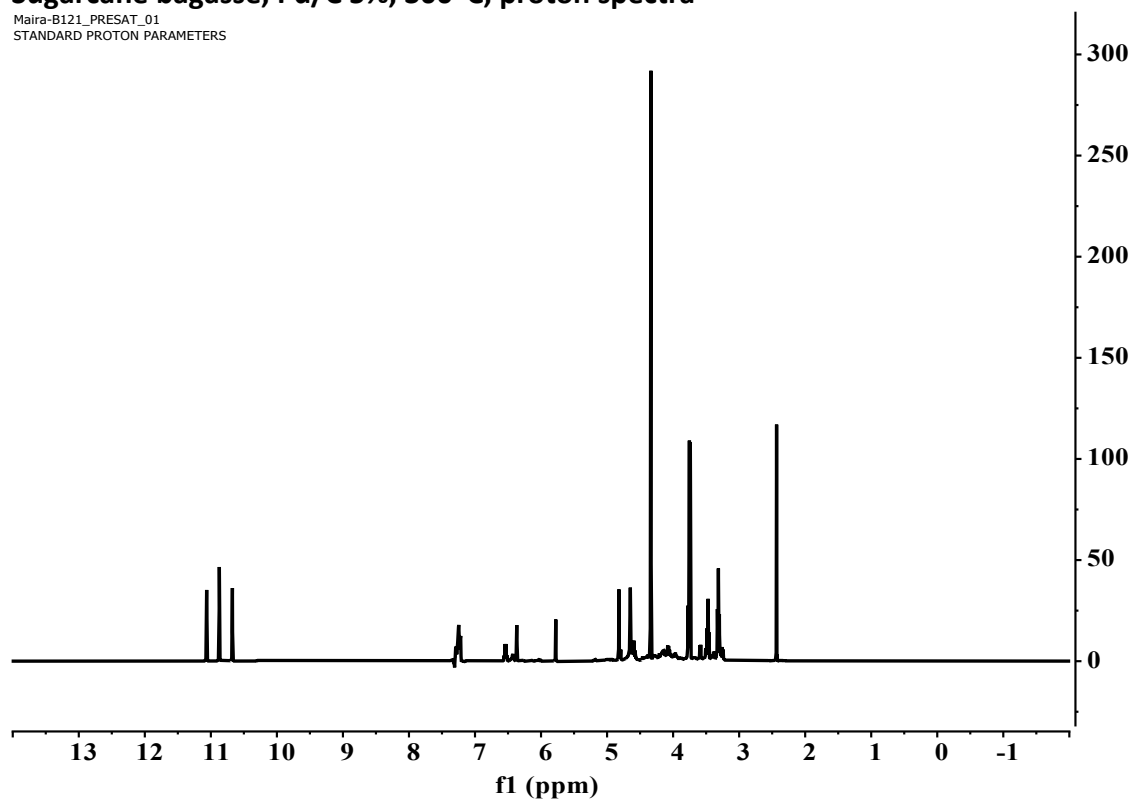
Cellulose, Pd/C 5%, 300ºC, carbon spectra

Maira-B122_CARBON_01
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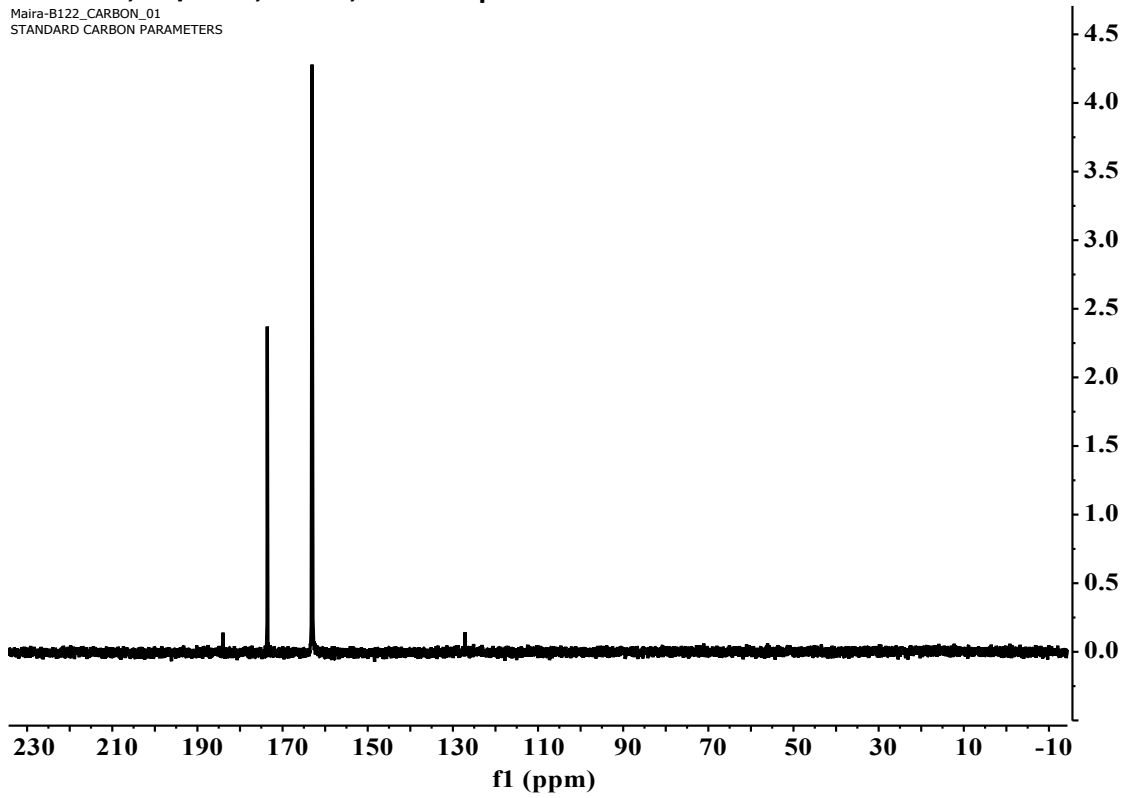
Cellulose, Pd/C 5%, 300ºC, proton spectra

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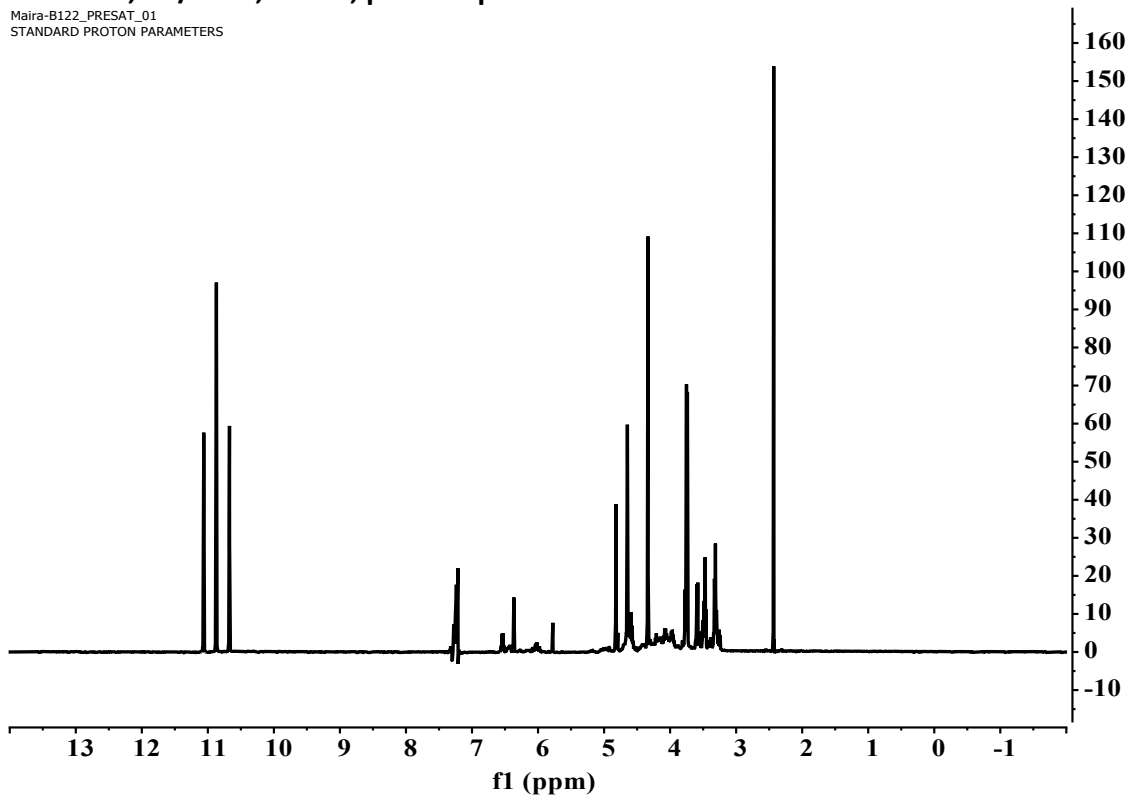
Cork, Pd/C 5%, 300ºC, carbon spectra

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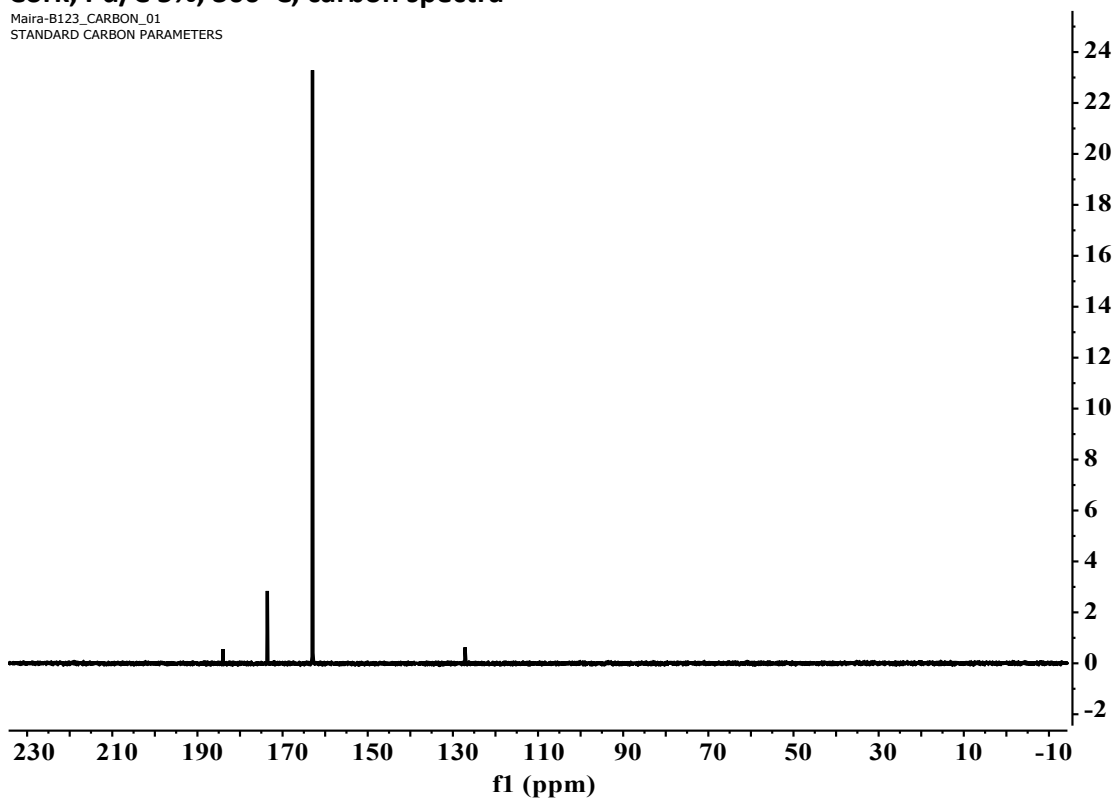
Cork, Pd/C 5%, 300ºC, proton spectra

Maira-B123_PRESAT_01
STANDARD PROTON PARAMETERS

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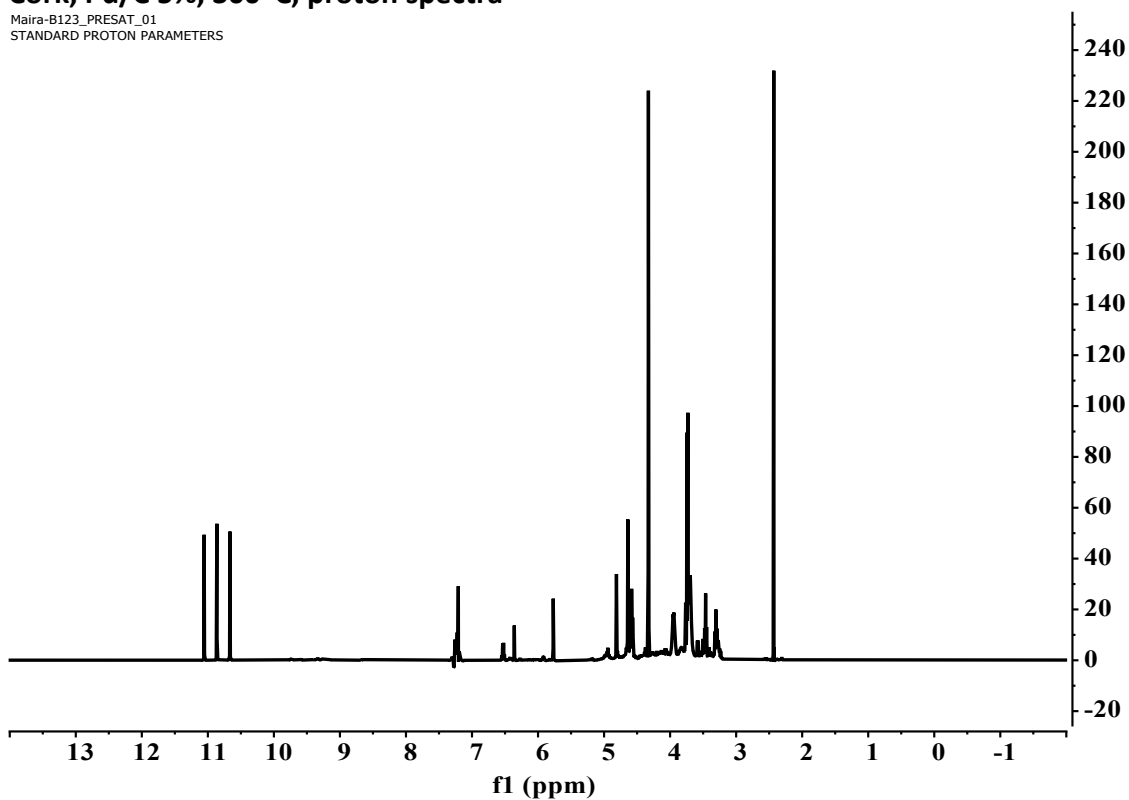
2nd EXPERIMENTS AT 300ºC

Sugarbeet, Pd/C 5%, 300ºC, carbon spectra

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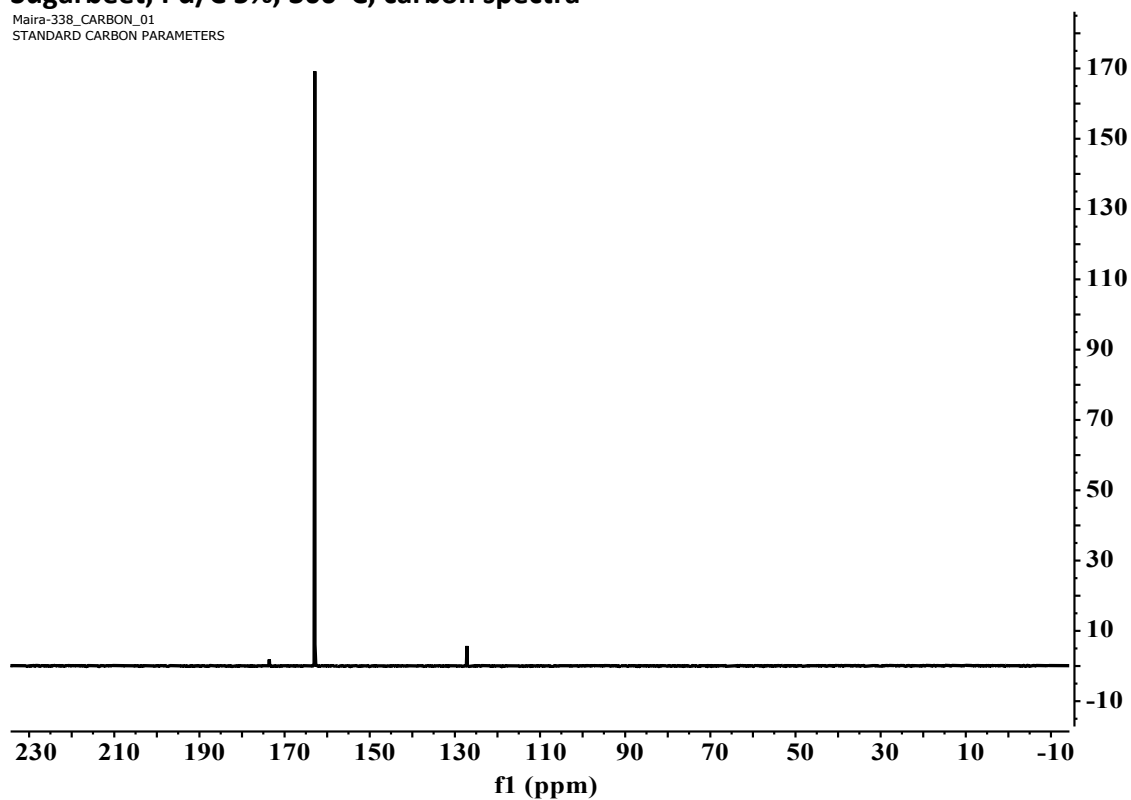
Sugarbeet, Pd/C 5%, 300ºC, proton spectra

Maira-338_PRESAT_02
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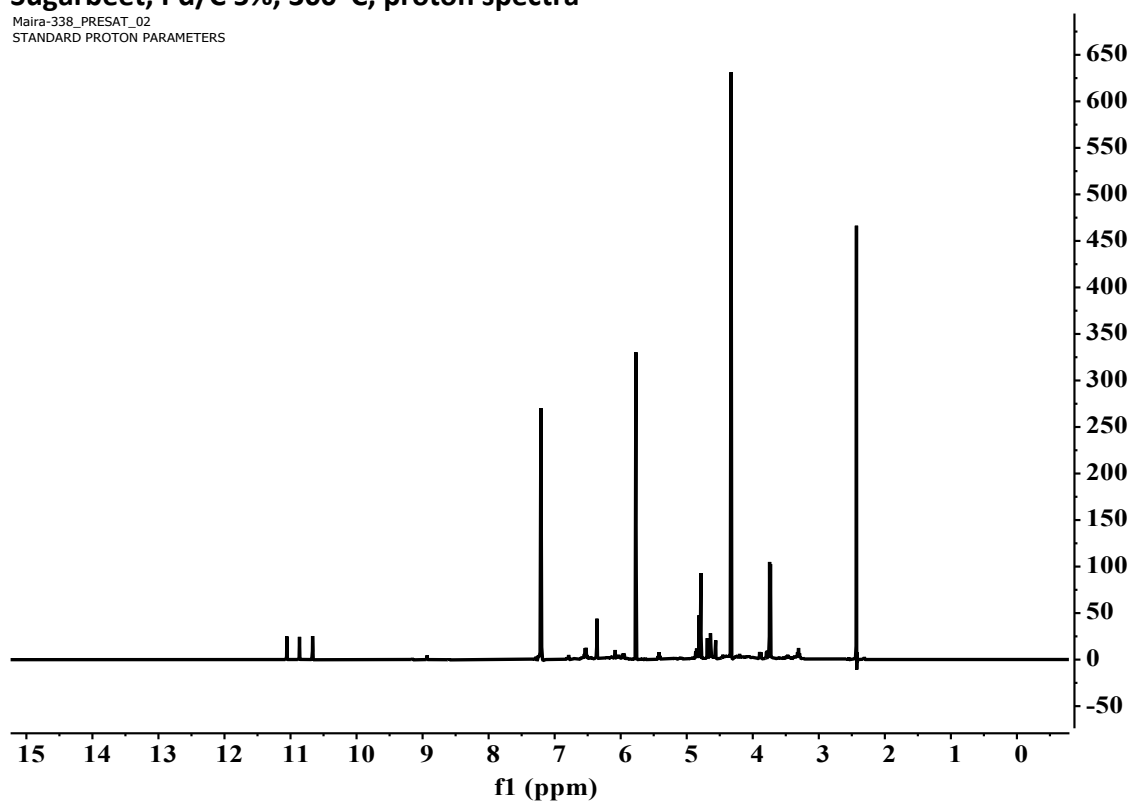
Pine needles, Pd/C 5%, 300ºC, carbon spectra
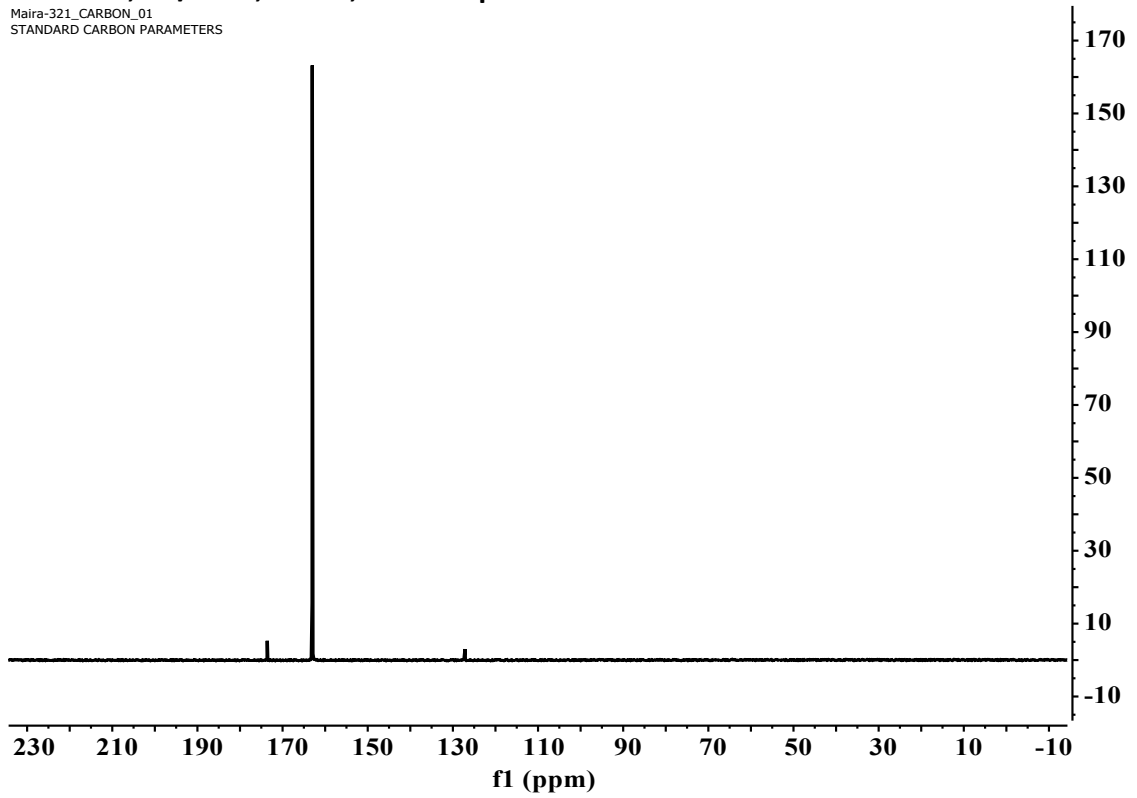
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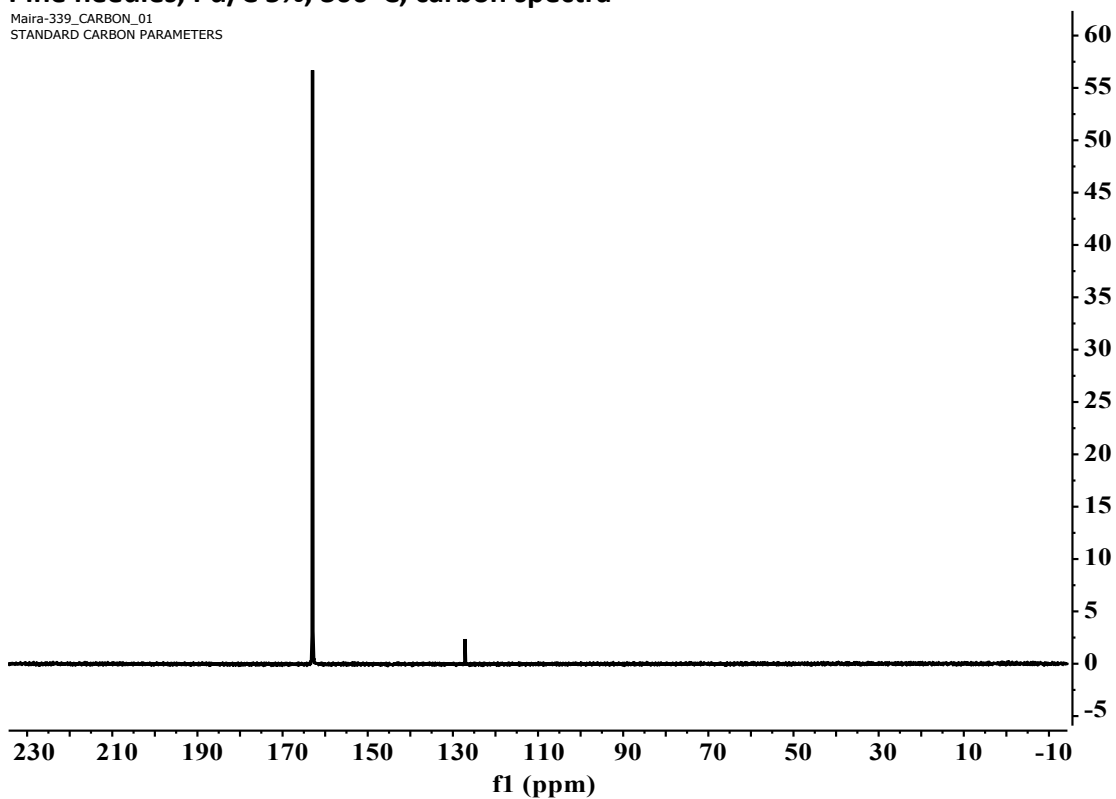
Pine needles, Pd/C 5%, 300ºC, proton spectra

Maira-339_PRESAT_01
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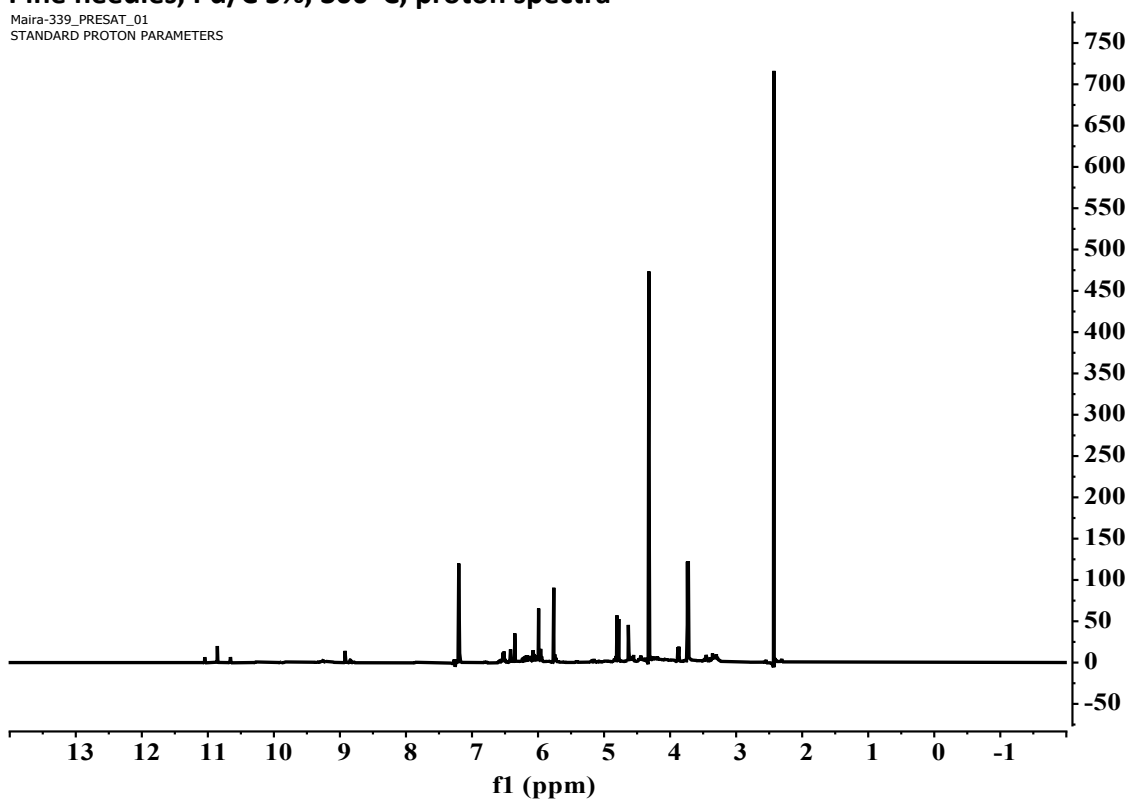
Vermicompost, Pd/C 5%, 300ºC, carbon spectra

Maira-340_PRESAT_01
STANDARD PROTON PARAMETERS
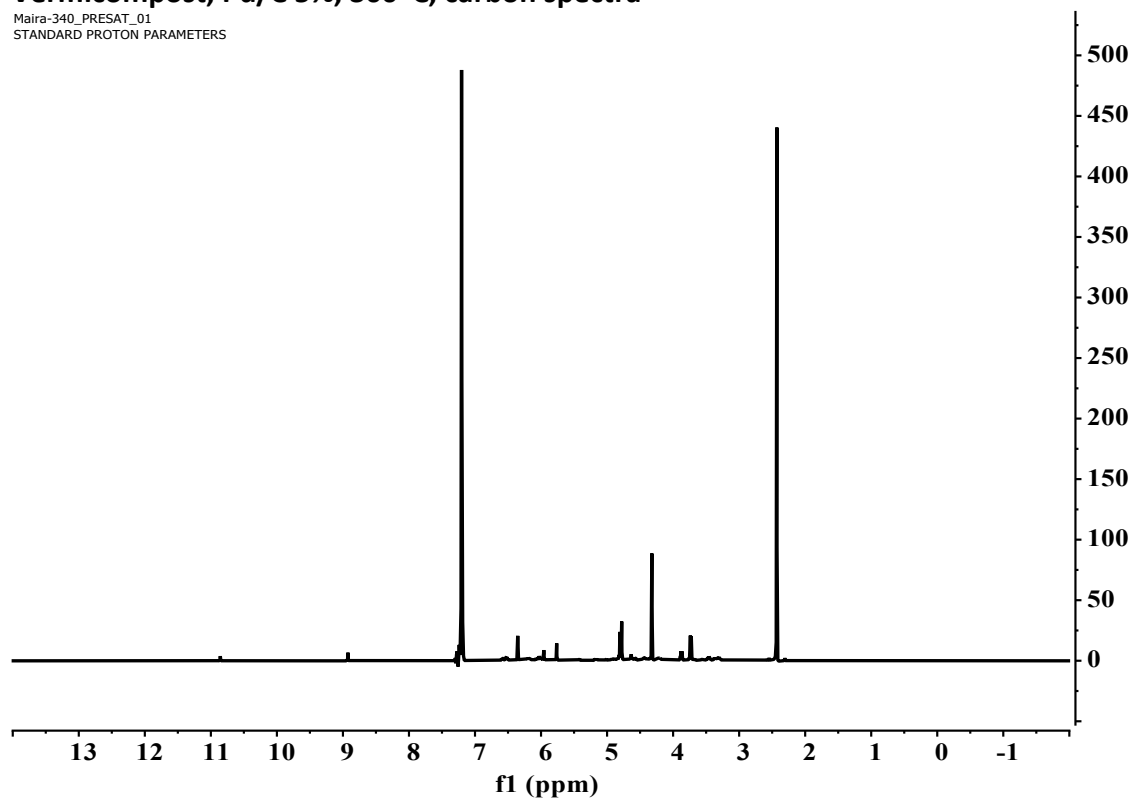
Vermicompost, Pd/C 5%, 300ºC, proton spectra

Maira-340_CARBON_01
STANDARD CARBON PARAMETERS

18
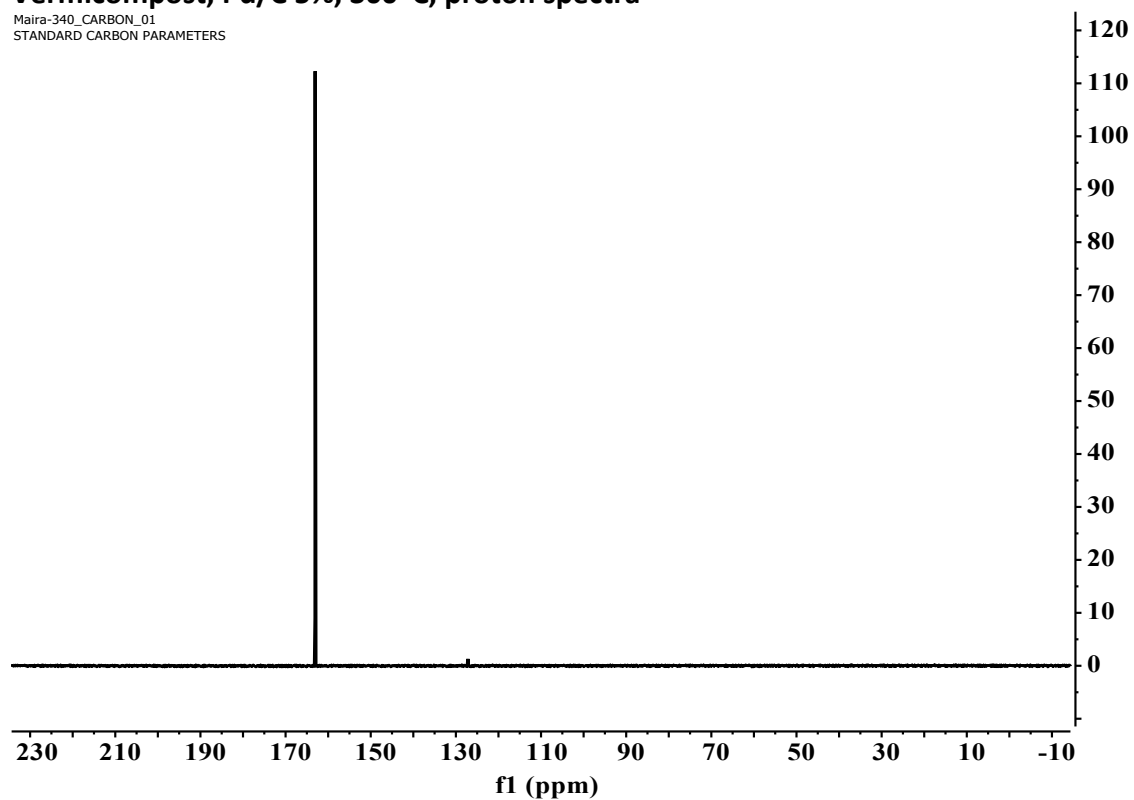
Sugarcane bagasse, Pd/C 5%, 300ºC, carbon spectra

Maira-341_CARBON_01
STANDARD CARBON PARAMETERS
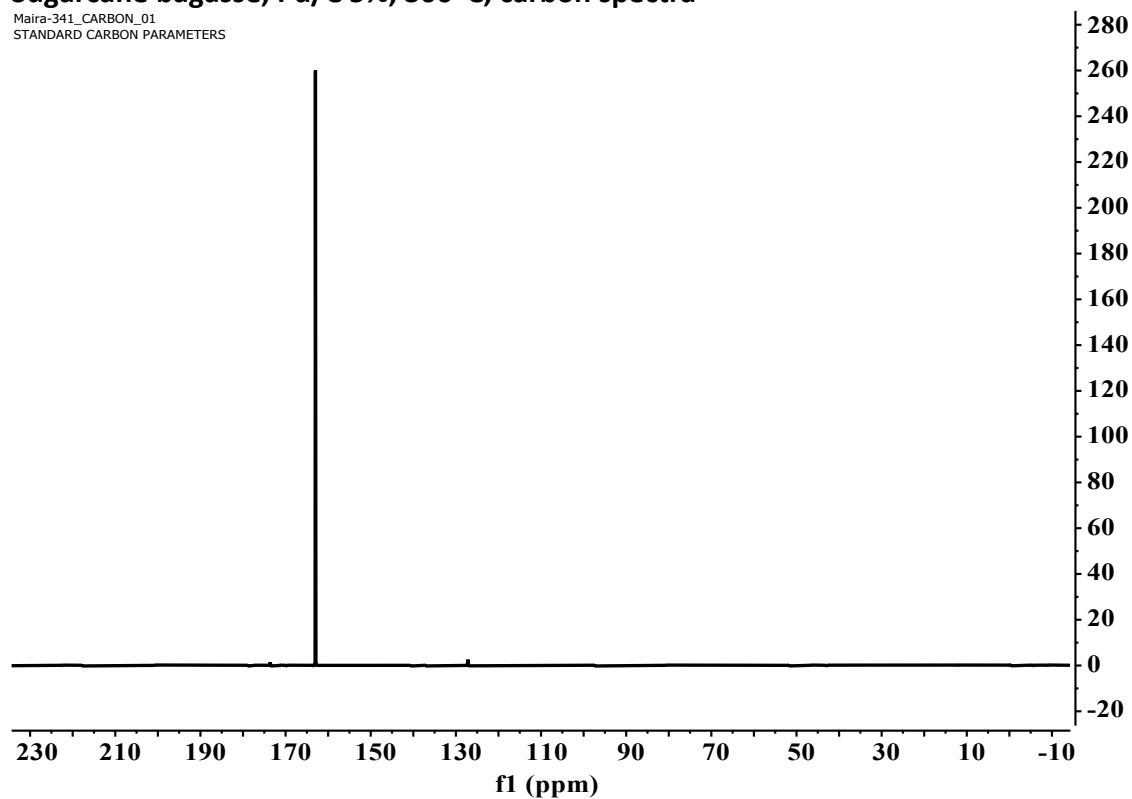
Sugarcane bagasse, Pd/C 5%, 300ºC, proton spectra

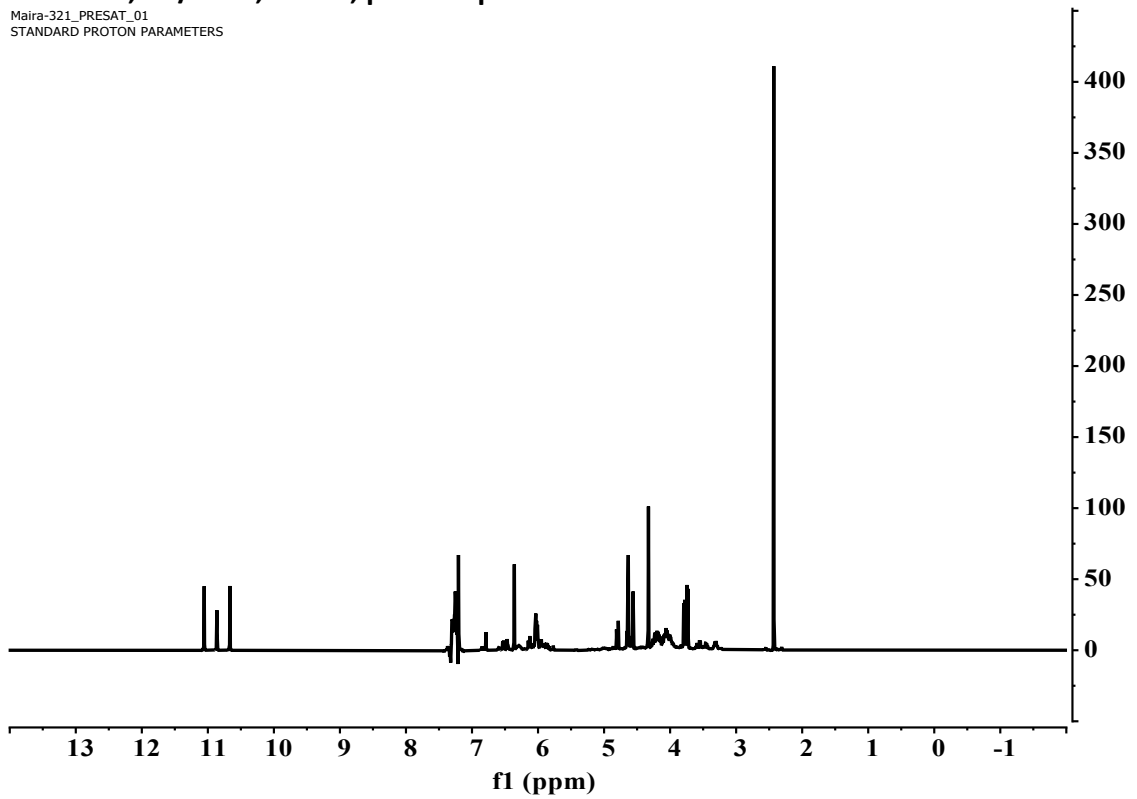Maira-341_PRESAT_01
STANDARD PROTON PARAMETERS
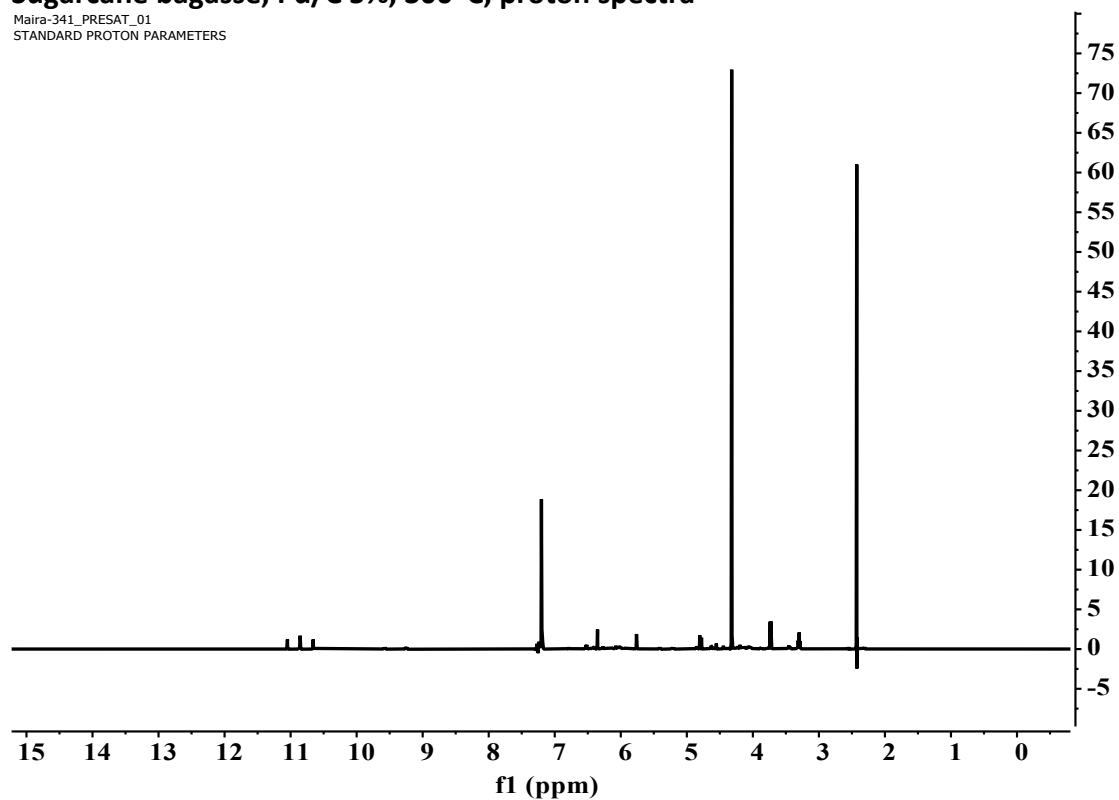
Cellulose, Pd/C 5%, 300ºC, carbon spectra
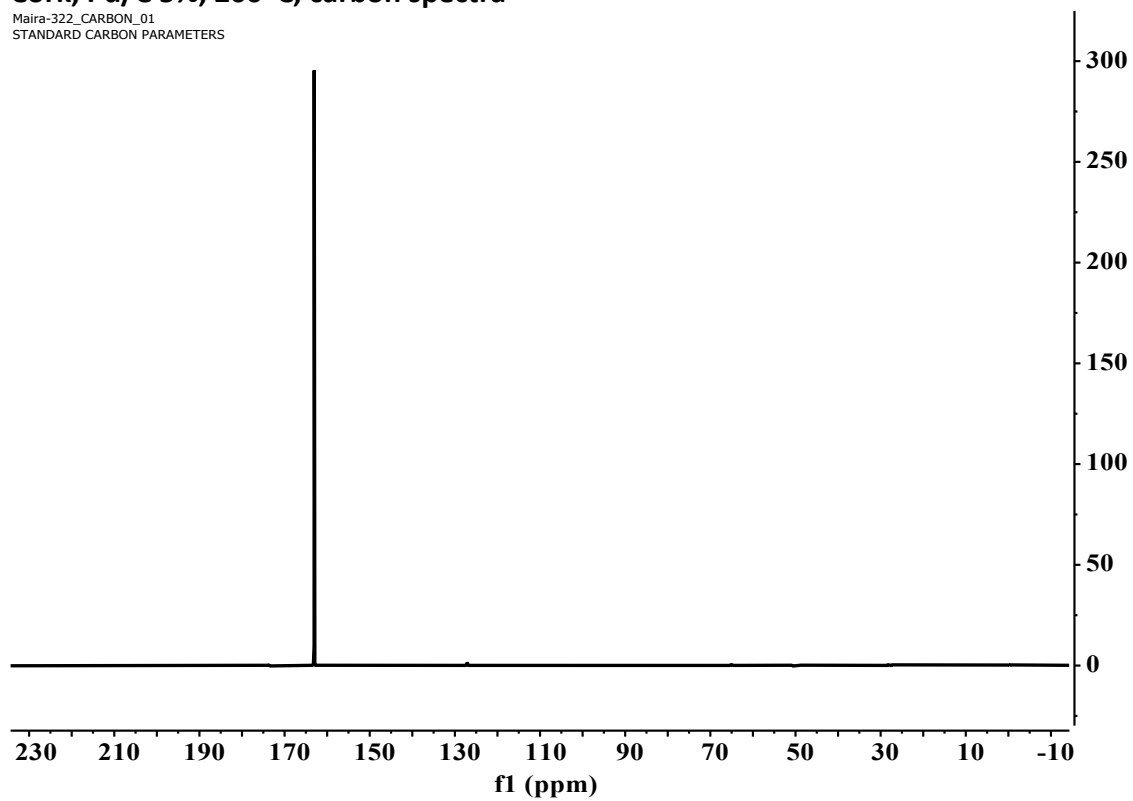
Maira-342_CARBON_01
STANDARD CARBON PARAMETERS
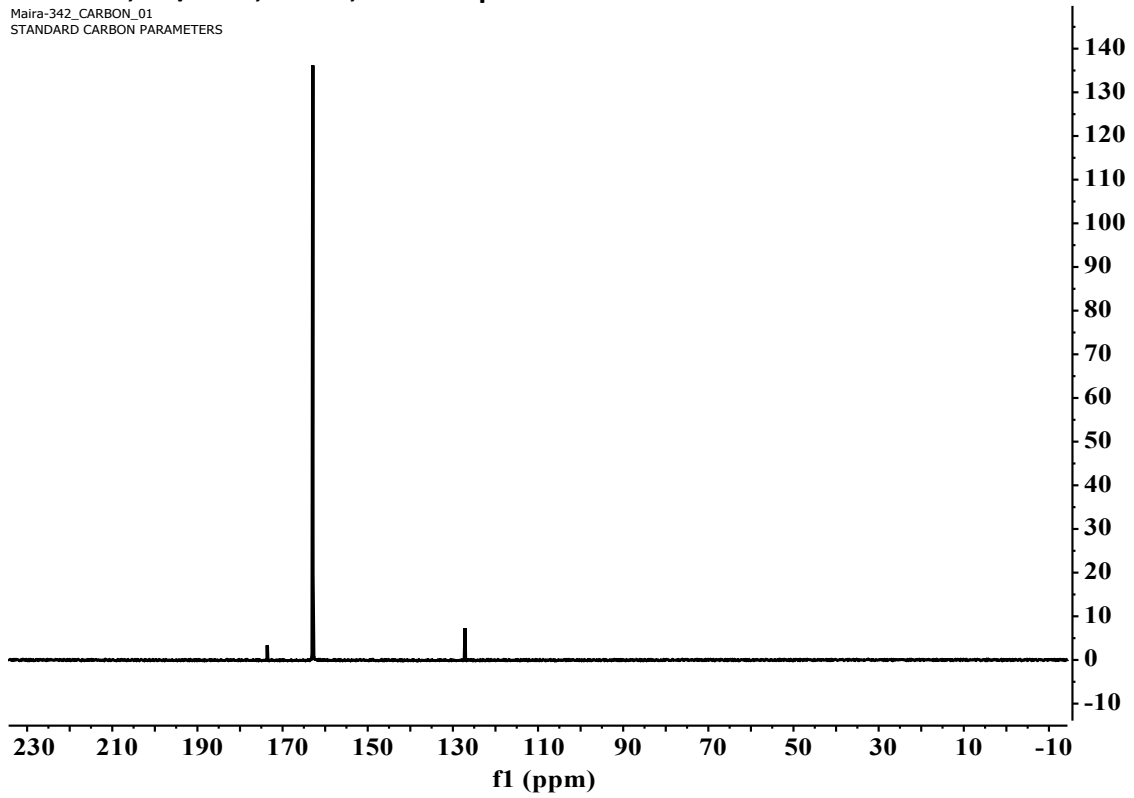
Cellulose, Pd/C 5%, 300ºC, carbon spectra

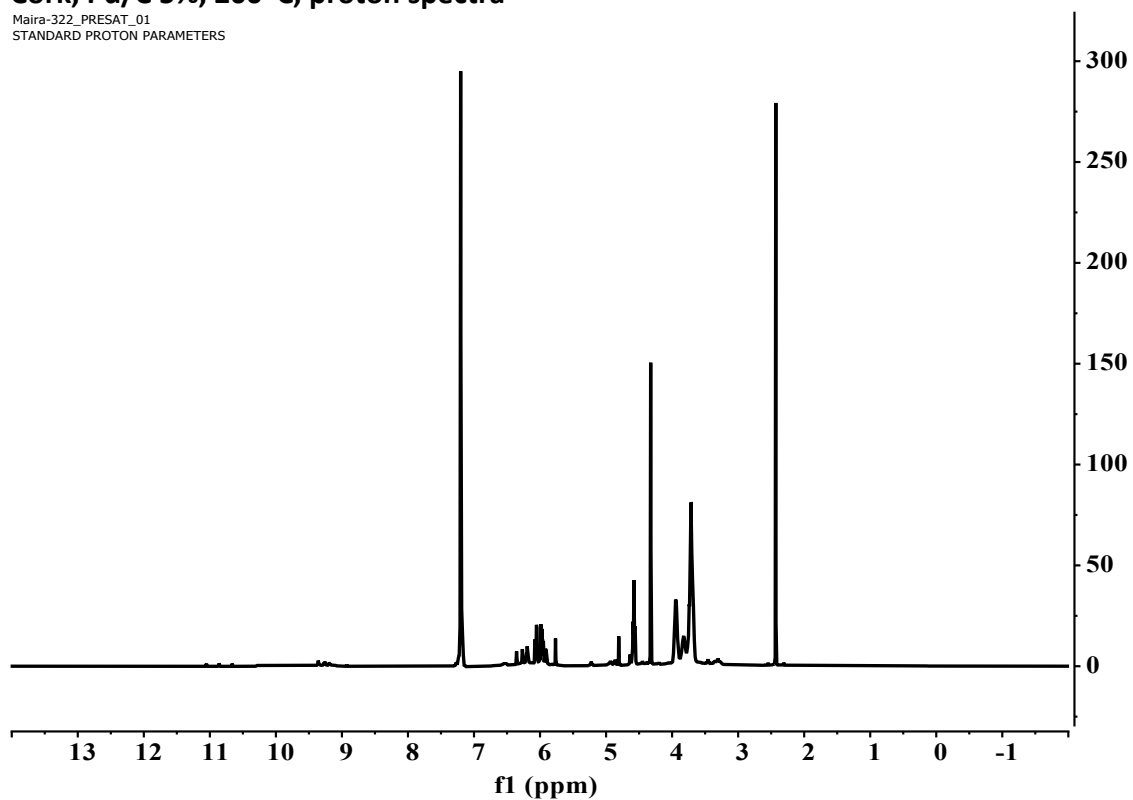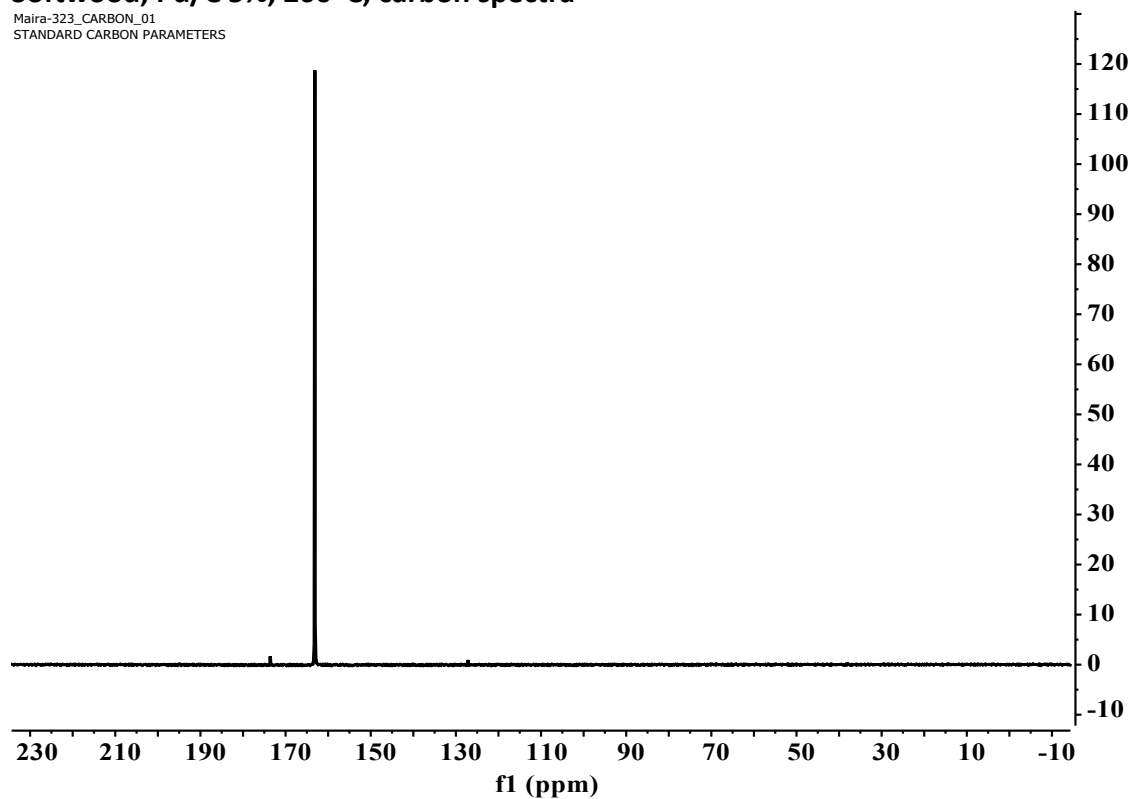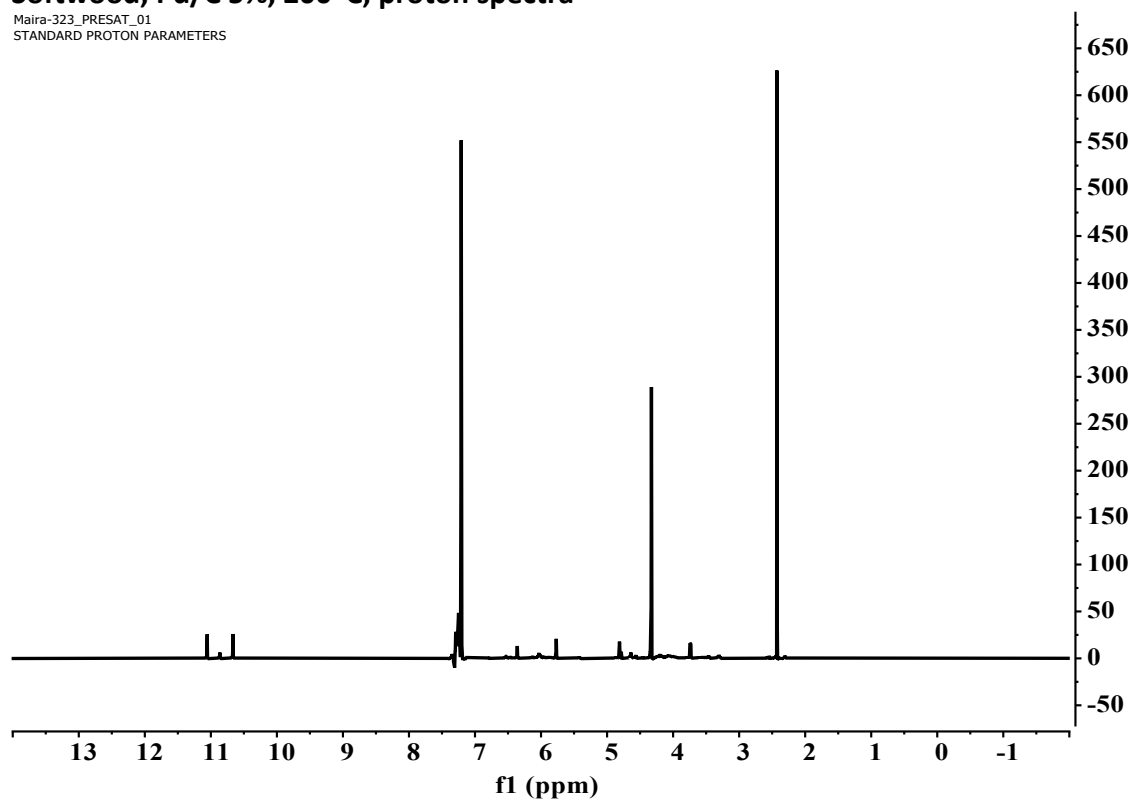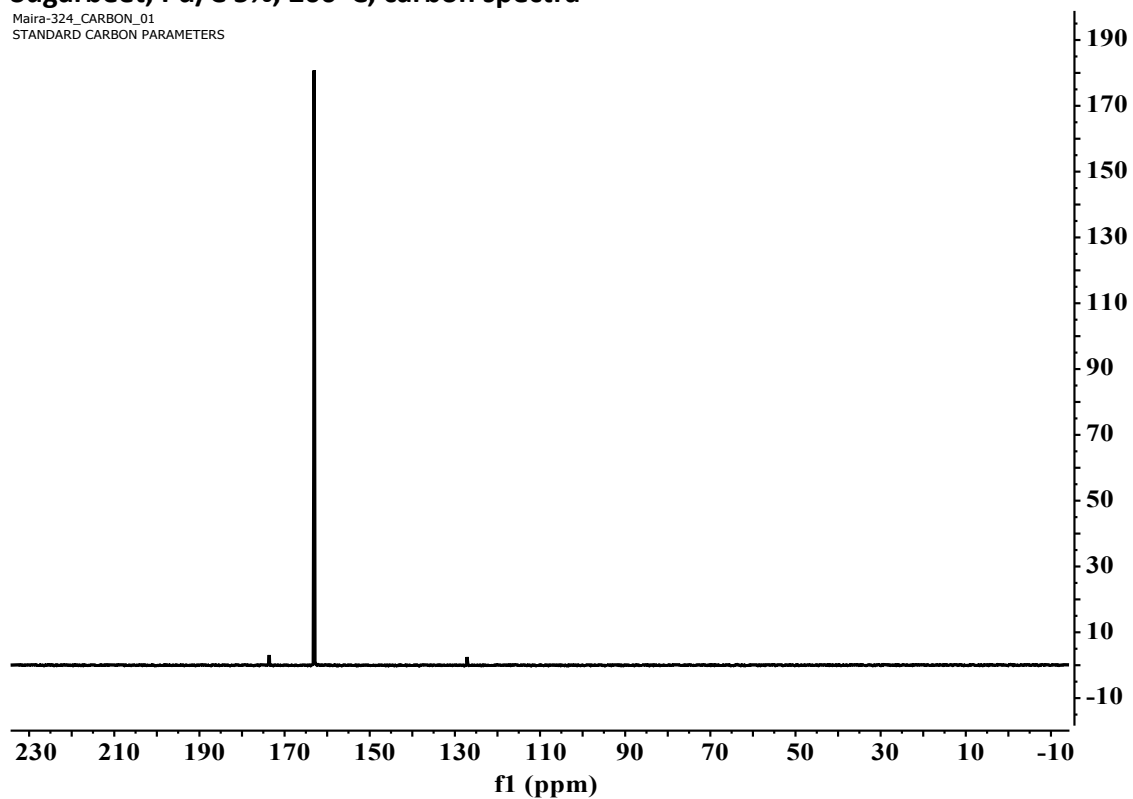Maira-342_PRESAT_01
STANDARD PROTON PARAMETERS

Cork, Pd/C 5%, 300ºC, carbon spectra

Cork, Pd/C 5%, 300ºC, proton spectra

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Softwood, Pd/C 5%, 300ºC, carbon spectra

Maira-344_CARBON_01
STANDARD CARBON PARAMETERS

f1 (ppm)
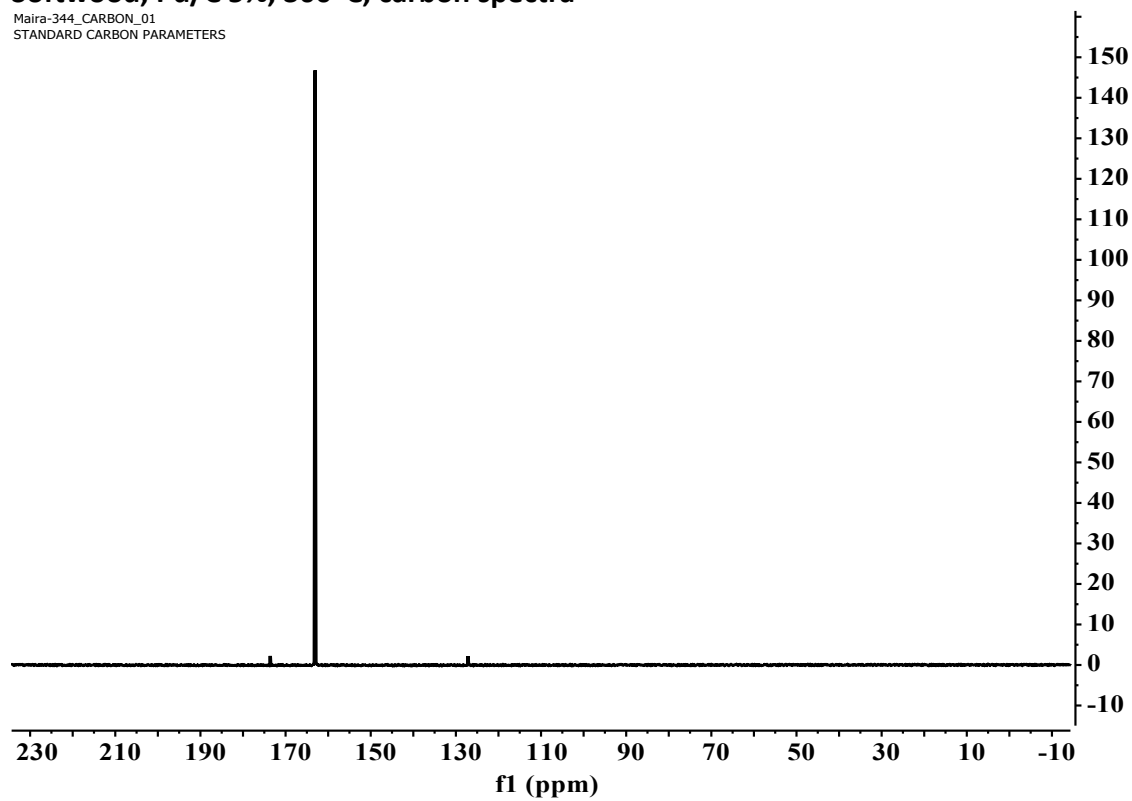
Softwood, Pd/C 5%, 300ºC, proton spectra

Maira-344_PRESAT_01
STANDARD PROTON PARAMETERS

f1 (ppm)
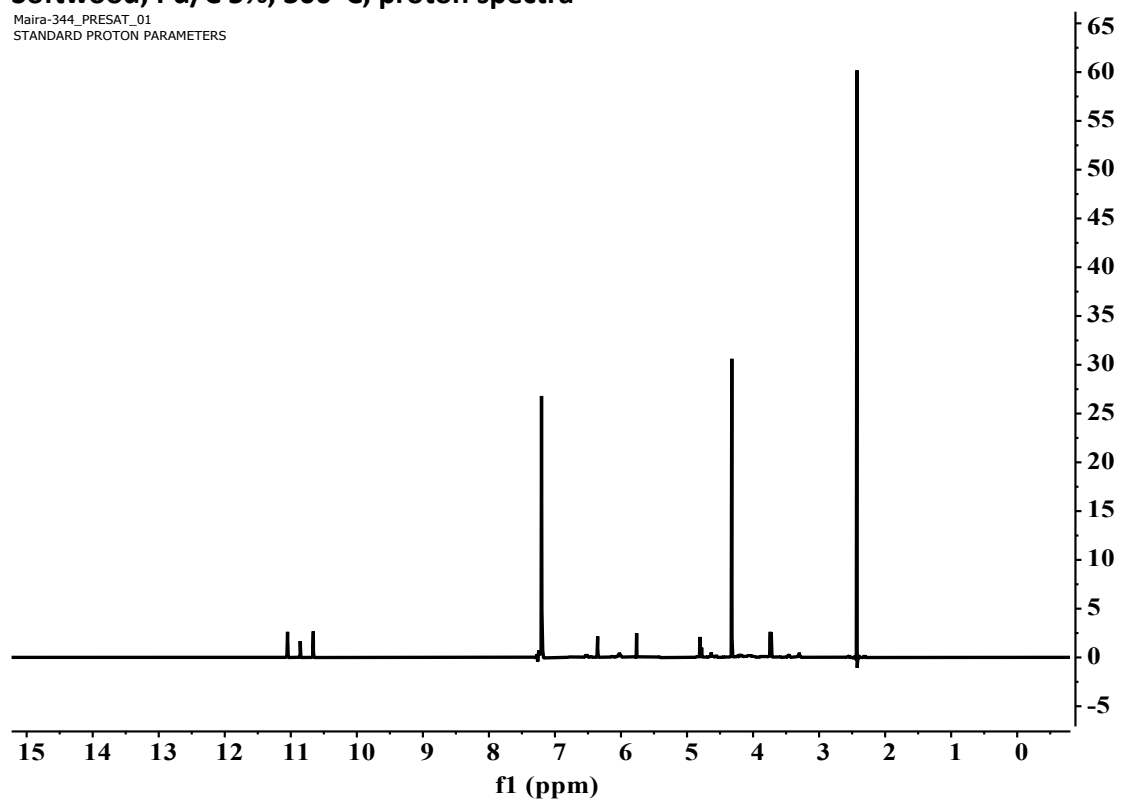
1st EXPERIMENTS AT 200ºC

Sugarbeet, Pd/C 5%, 200ºC, carbon spectra

Maira-317_CARBON_01
STANDARD CARBON PARAMETERS
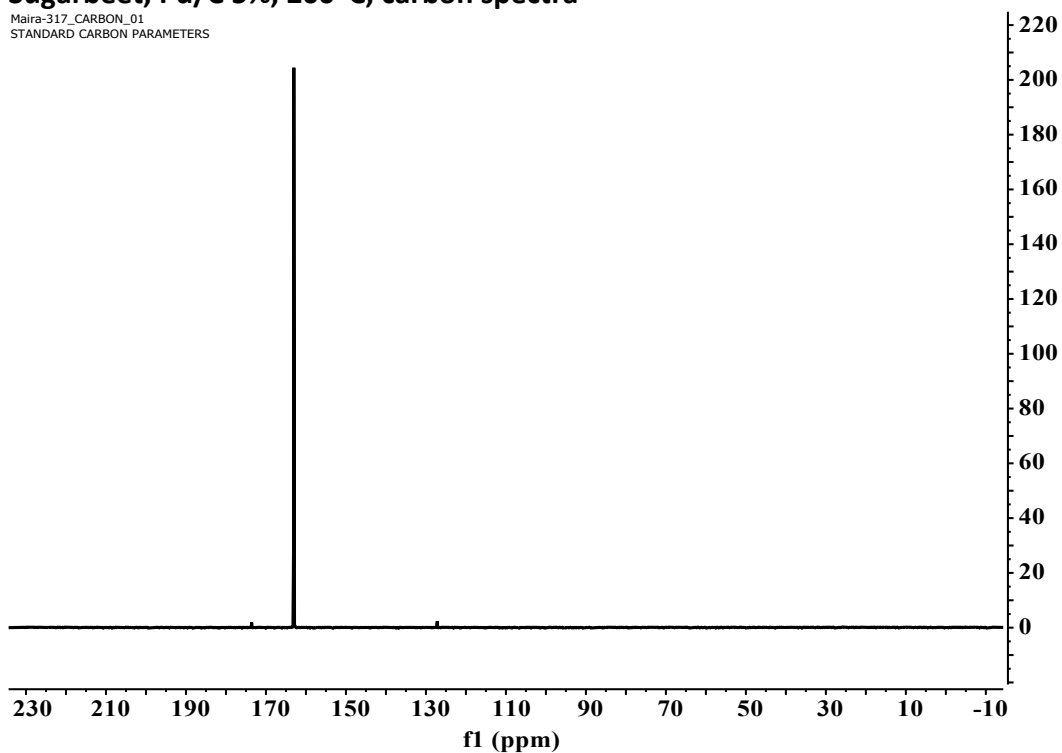
Sugarbeet, Pd/C 5%, 200ºC, proton spectra

Maira-317_PRESAT_01

Pine needles, Pd/C 5%, 200ºC, carbon spectra

Maira-318_CARBON_01
STANDARD CARBON PARAMETERS

Pine needles, Pd/C 5%, 200ºC, proton spectra

Maira-318_PRESAT_01
STANDARD PROTON PARAMETERS
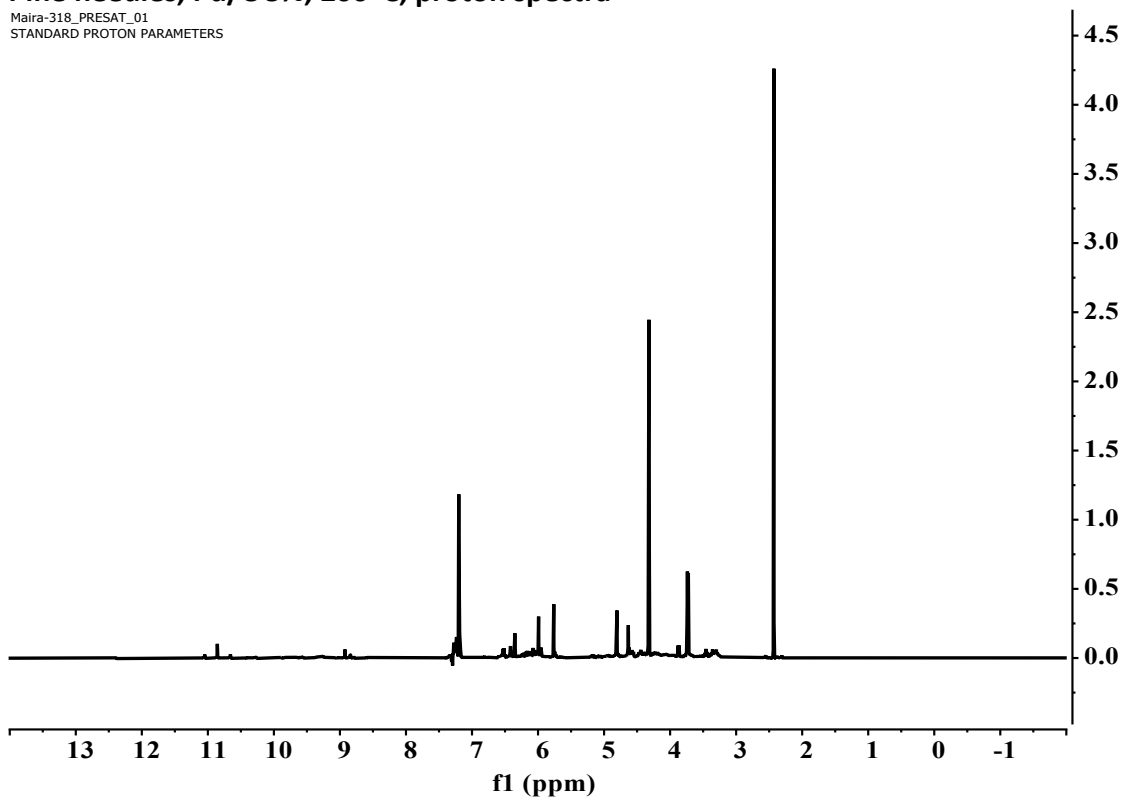
Vermicompost, Pd/C 5%, 200ºC, carbon spectra
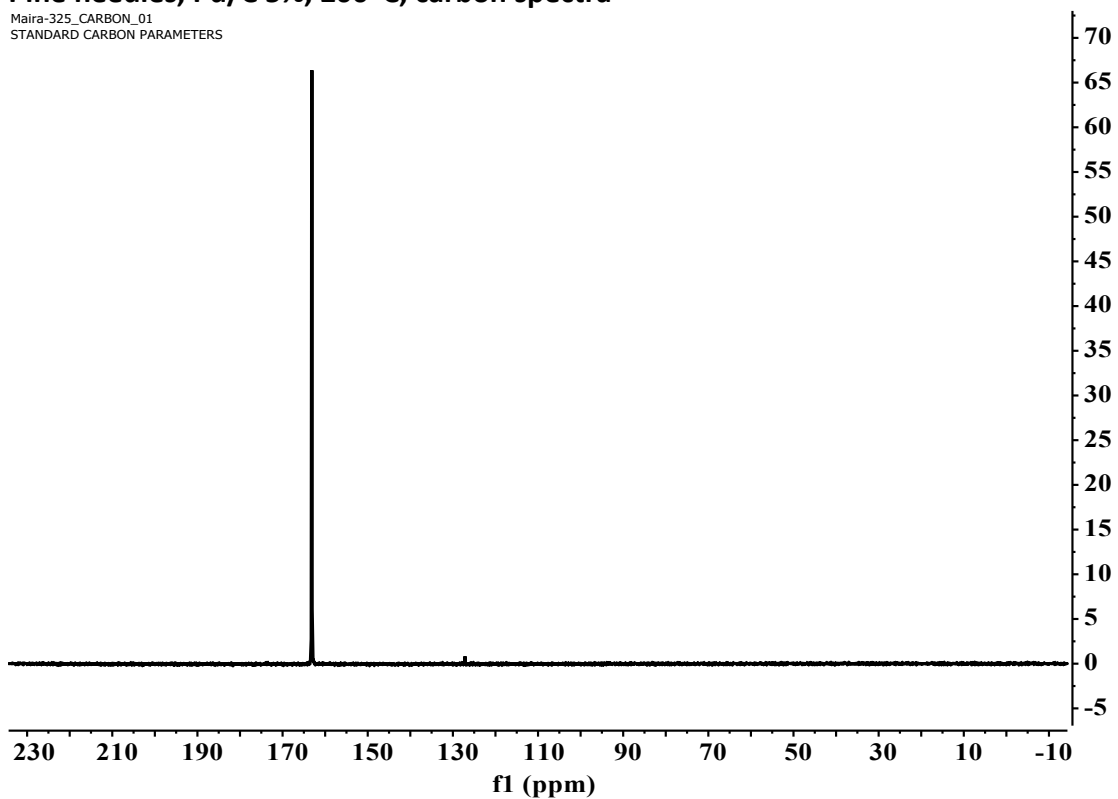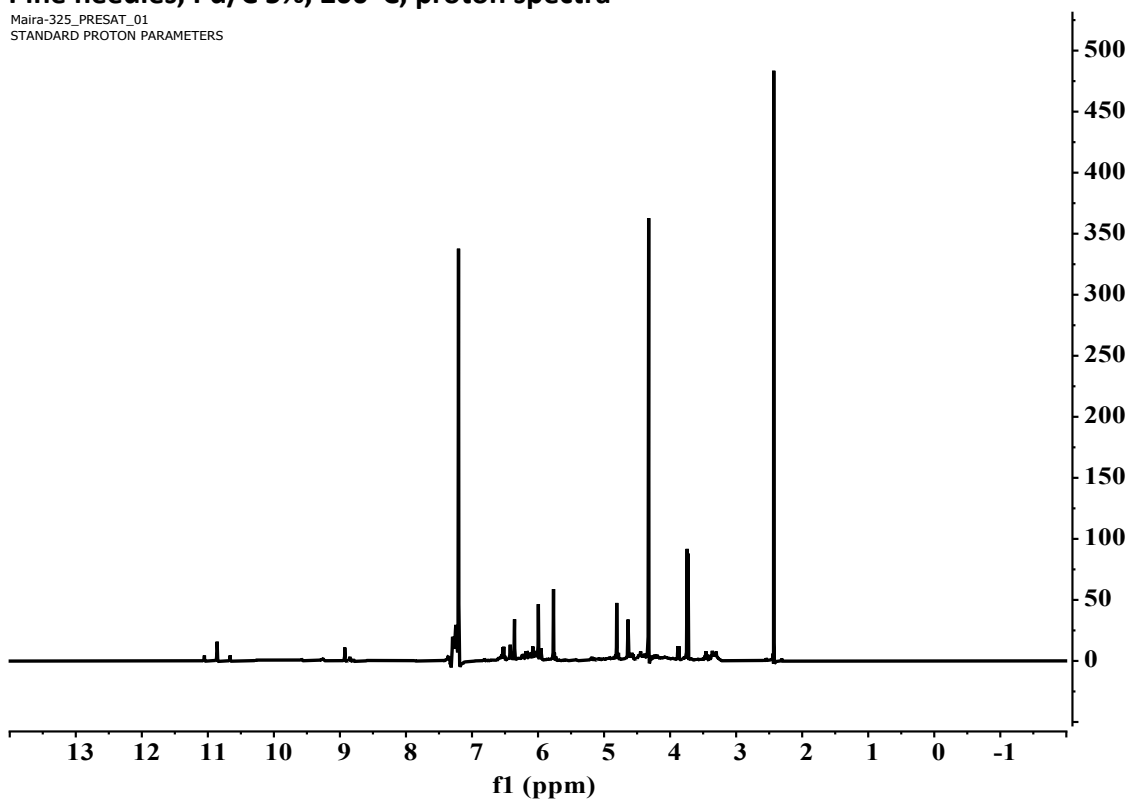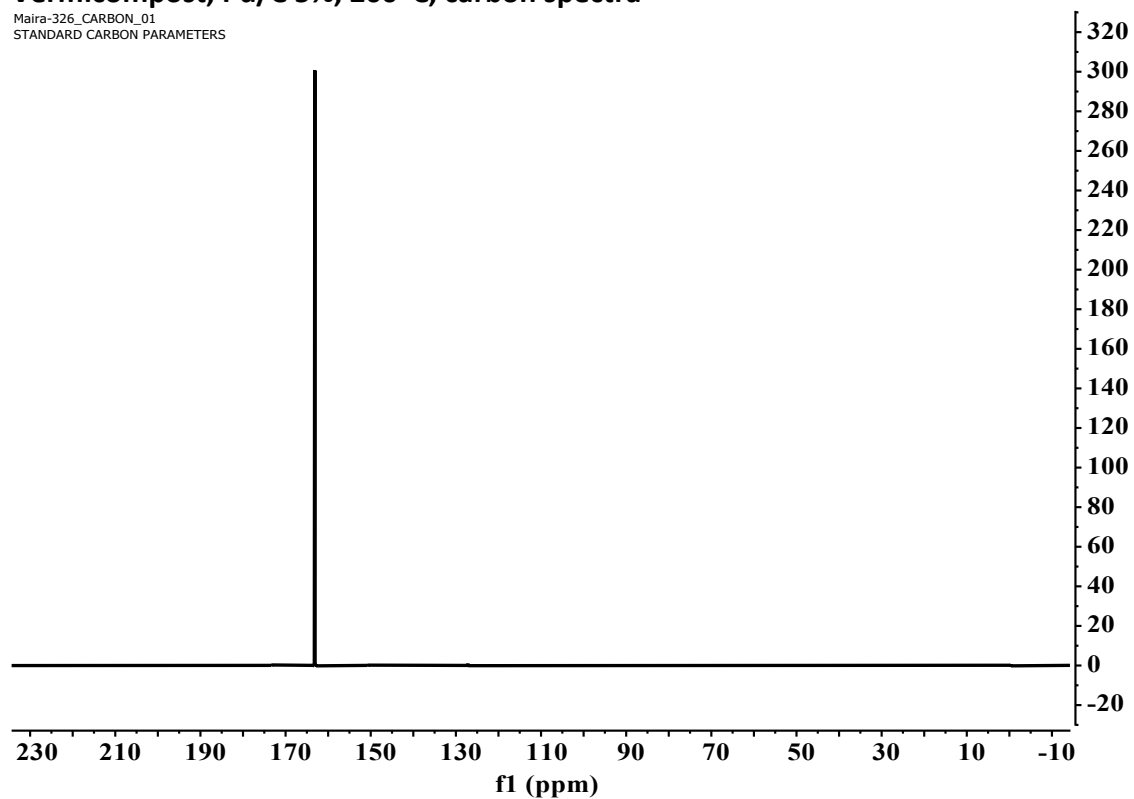
Maira-319_CARBON_01
STANDARD CARBON PARAMETERS

f1 (ppm)

Vermicompost, Pd/C 5%, 200ºC, proton spectra

Maira-319_PRESAT_01
STANDARD PROTON PARAMETERS

f1 (ppm)

Sugarcane bagasse, Pd/C 5%, 200ºC, carbon spectra

Maira-320_CARBON_01
STANDARD CARBON PARAMETERS

Sugarcane bagasse, Pd/C 5%, 200ºC, proton spectra

Maira-320_PRESAT_01
STANDARD PROTON PARAMETERS

Cellulose, Pd/C 5%, 200ºC, carbon spectra

Maira-321_CARBON_01
STANDARD CARBON PARAMETERS

Cellulose, Pd/C 5%, 200ºC, proton spectra
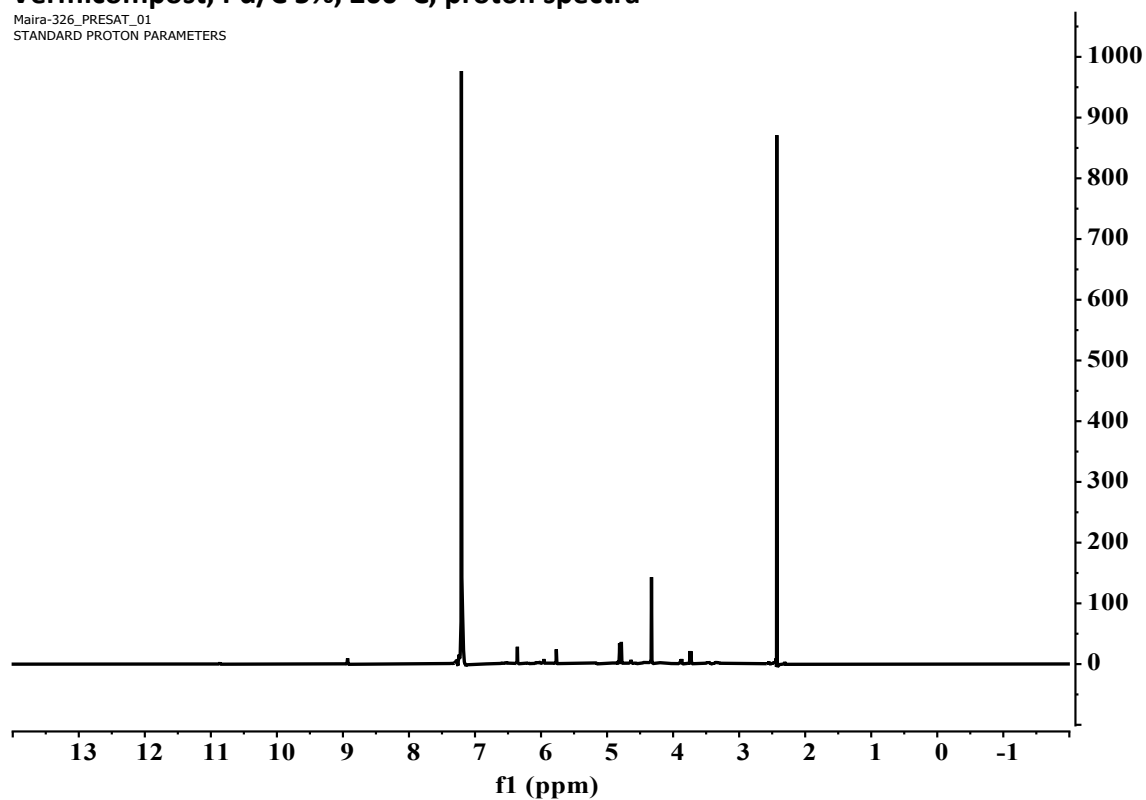
Maira-321_PRESAT_01
STANDARD PROTON PARAMETERS

Cork, Pd/C 5%, 200ºC, carbon spectra

Maira-322_CARBON_01
STANDARD CARBON PARAMETERS
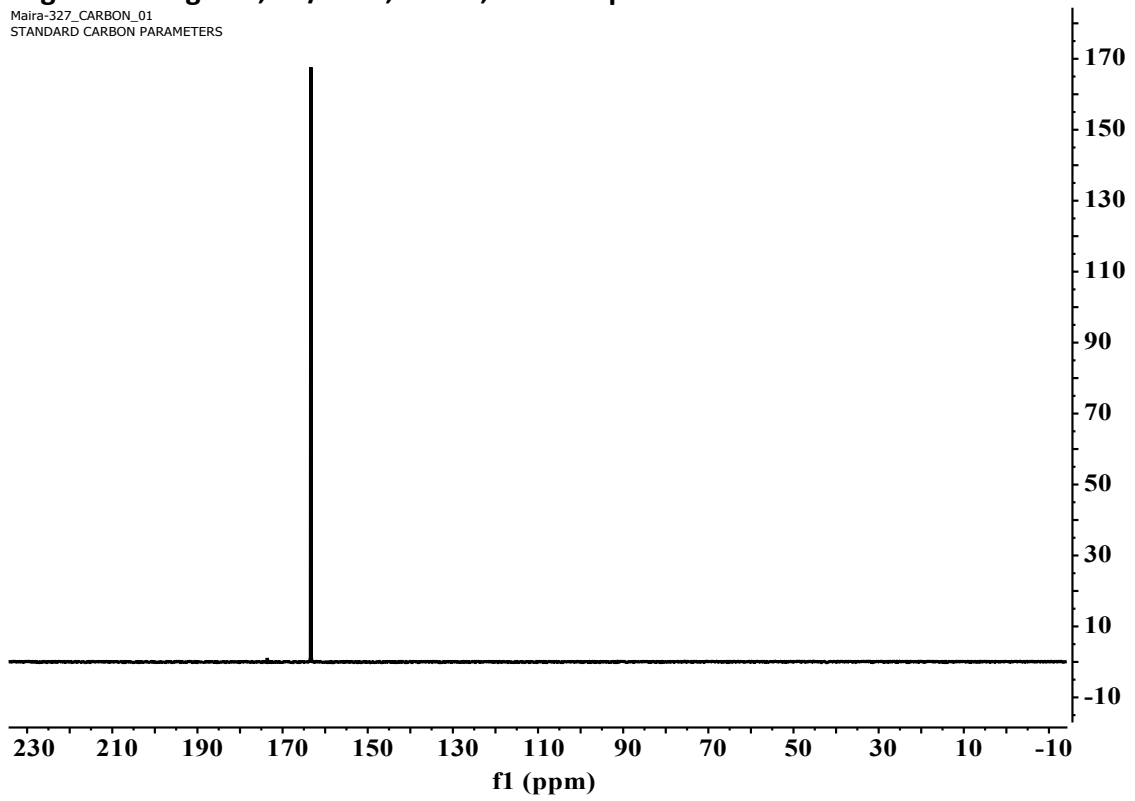

f1 (ppm)

Cork, Pd/C 5%, 200ºC, proton spectra

Maira-322_PRESAT_01
STANDARD PROTON PARAMETERS

f1 (ppm)

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Softwood, Pd/C 5%, 200ºC, carbon spectra

Maira-323_CARBON_01
STANDARD CARBON PARAMETERS

Softwood, Pd/C 5%, 200ºC, proton spectra

Maira-323_PRESAT_01
STANDARD PROTON PARAMETERS

Sugarbeet, Pd/C 5%, 200ºC, carbon spectra

Maira-324_CARBON_01
STANDARD CARBON PARAMETERS

f1 (ppm)

Sugarbeet, Pd/C 5%, 200ºC, proton spectra

Maira-324_PRESAT_01
STANDARD PROTON PARAMETERS

f1 (ppm)
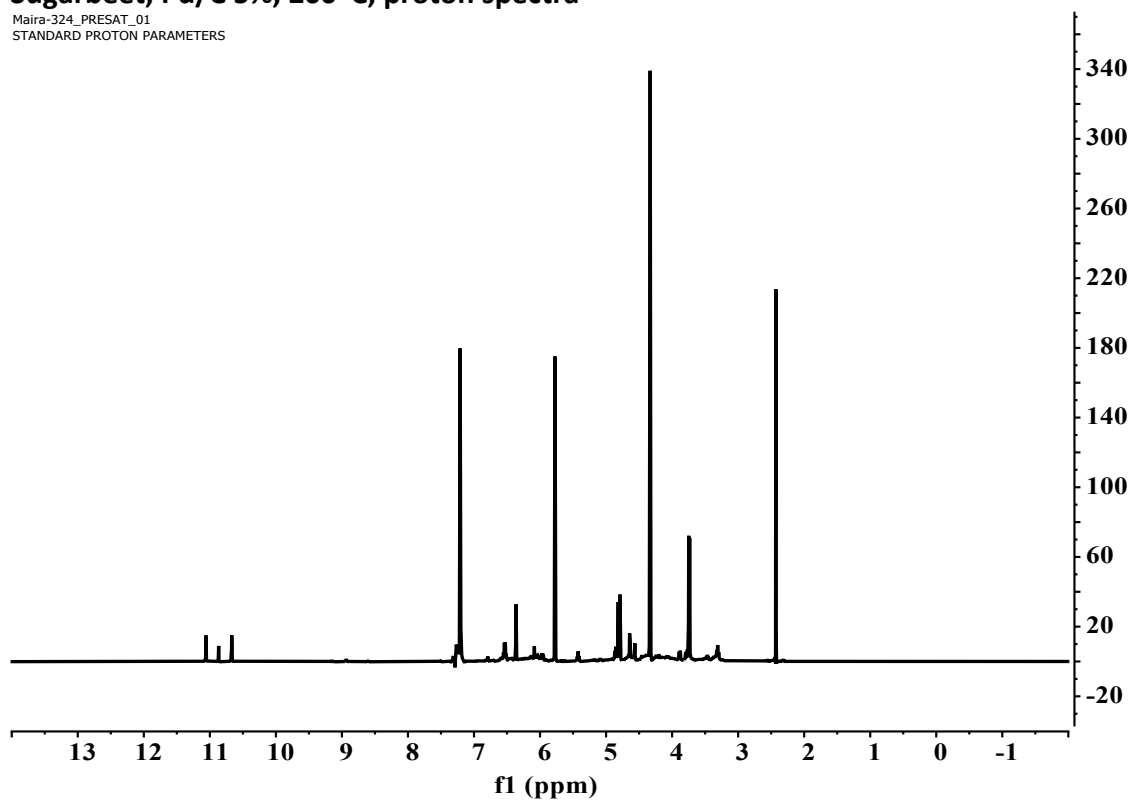
Pine needles, Pd/C 5%, 200ºC, carbon spectra

Maira-325_CARBON_01
STANDARD CARBON PARAMETERS

f1 (ppm)

Pine needles, Pd/C 5%, 200ºC, proton spectra

Maira-325_PRESAT_01
STANDARD PROTON PARAMETERS

f1 (ppm)

Vermicompost, Pd/C 5%, 200ºC, carbon spectra

Maira-326_CARBON_01
STANDARD CARBON PARAMETERS

Vermicompost, Pd/C 5%, 200ºC, proton spectra

Maira-326_PRESAT_01
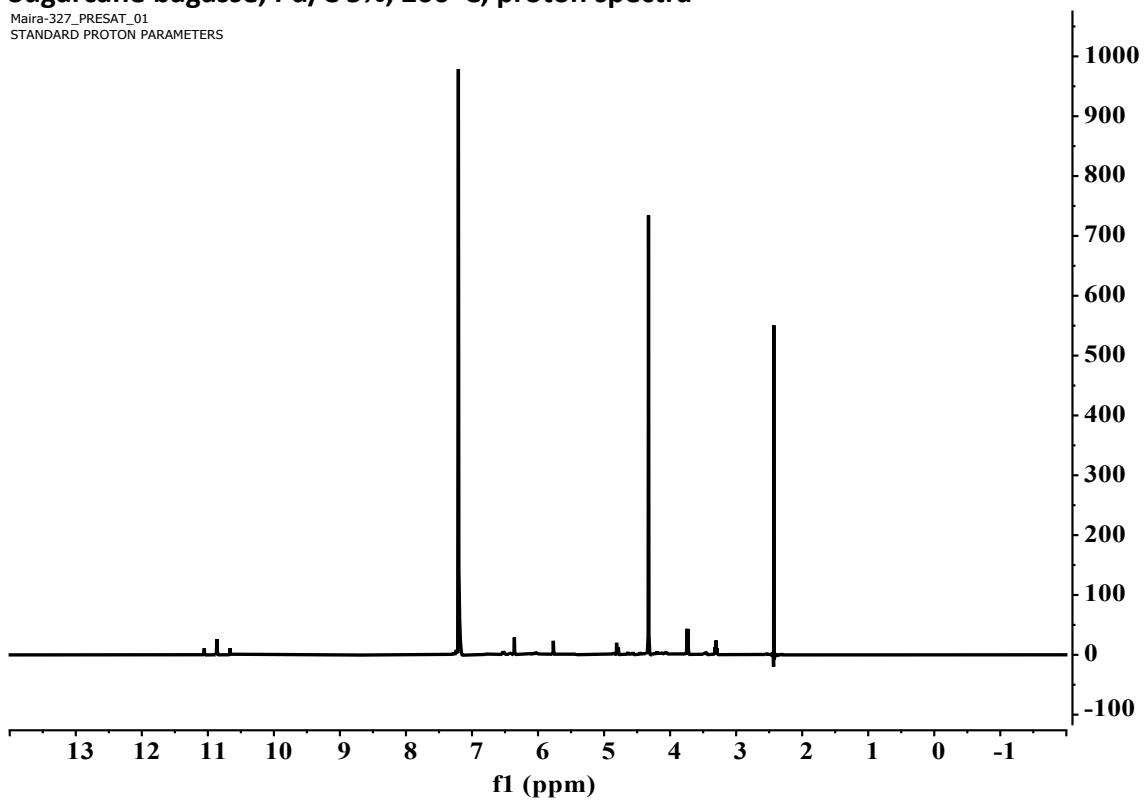STANDARD PROTON PARAMETERS

2nd EXPERIMENTS AT 200ºC

Sugarcane bagasse, Pd/C 5%, 200ºC, carbon spectra

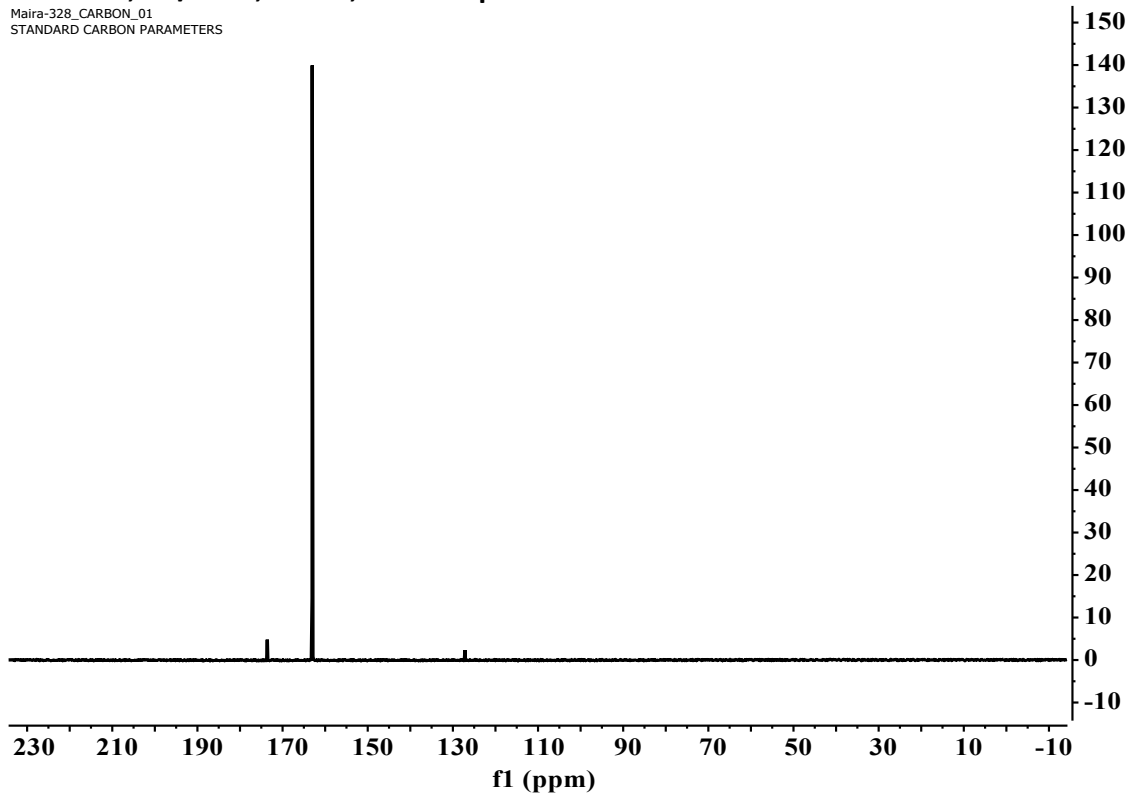Maira-327_CARBON_01
STANDARD CARBON PARAMETERS

Sugarcane bagasse, Pd/C 5%, 200ºC, proton spectra
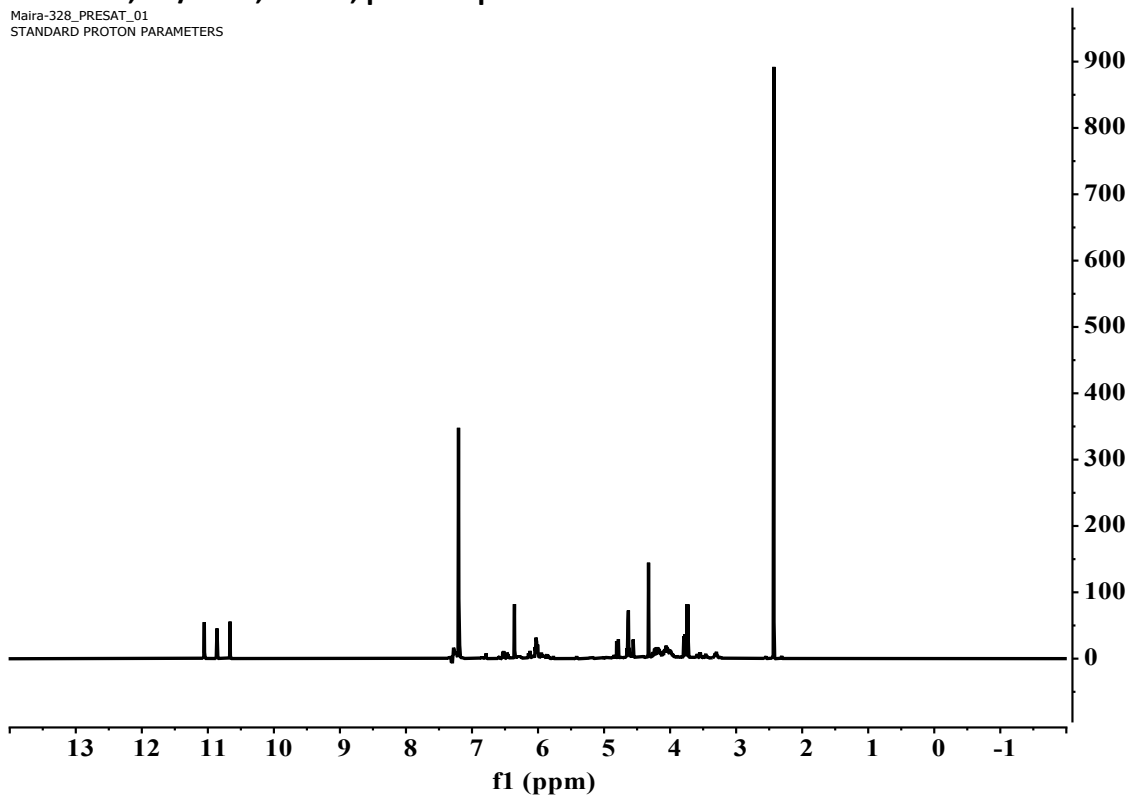
Maira-327_PRESAT_01
STANDARD PROTON PARAMETERS

Cellulose, Pd/C 5%, 200ºC, carbon spectra

Maira-328_CARBON_01
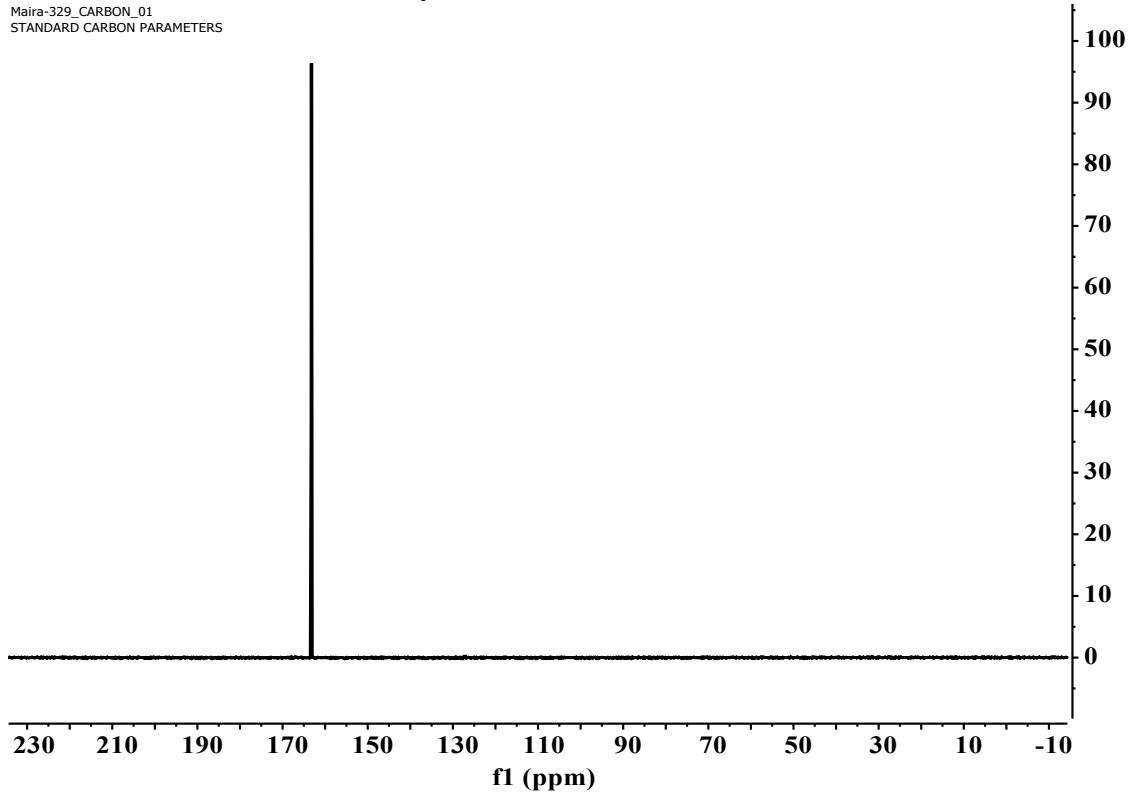STANDARD CARBON PARAMETERS

Cellulose, Pd/C 5%, 200ºC, proton spectra
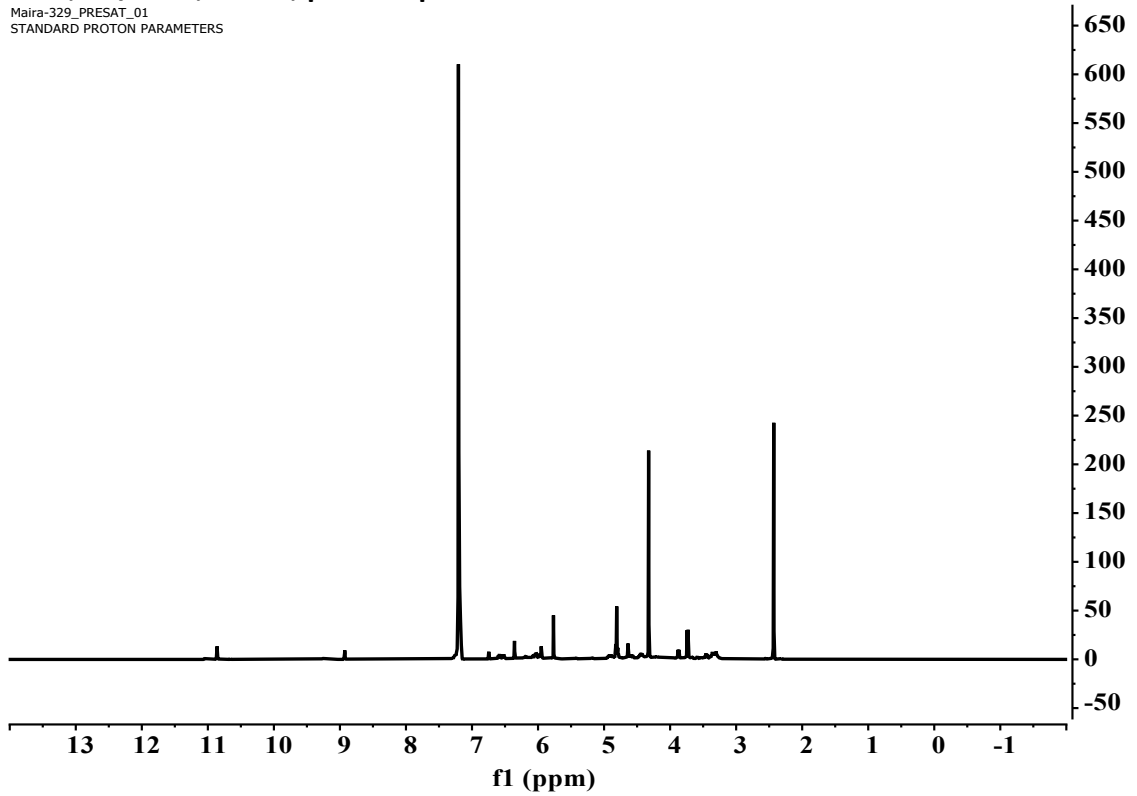
Maira-328_PRESAT_01
STANDARD PROTON PARAMETERS

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Cork, Pd/C 5%, 200ºC, carbon spectra

Maira-329_CARBON_01
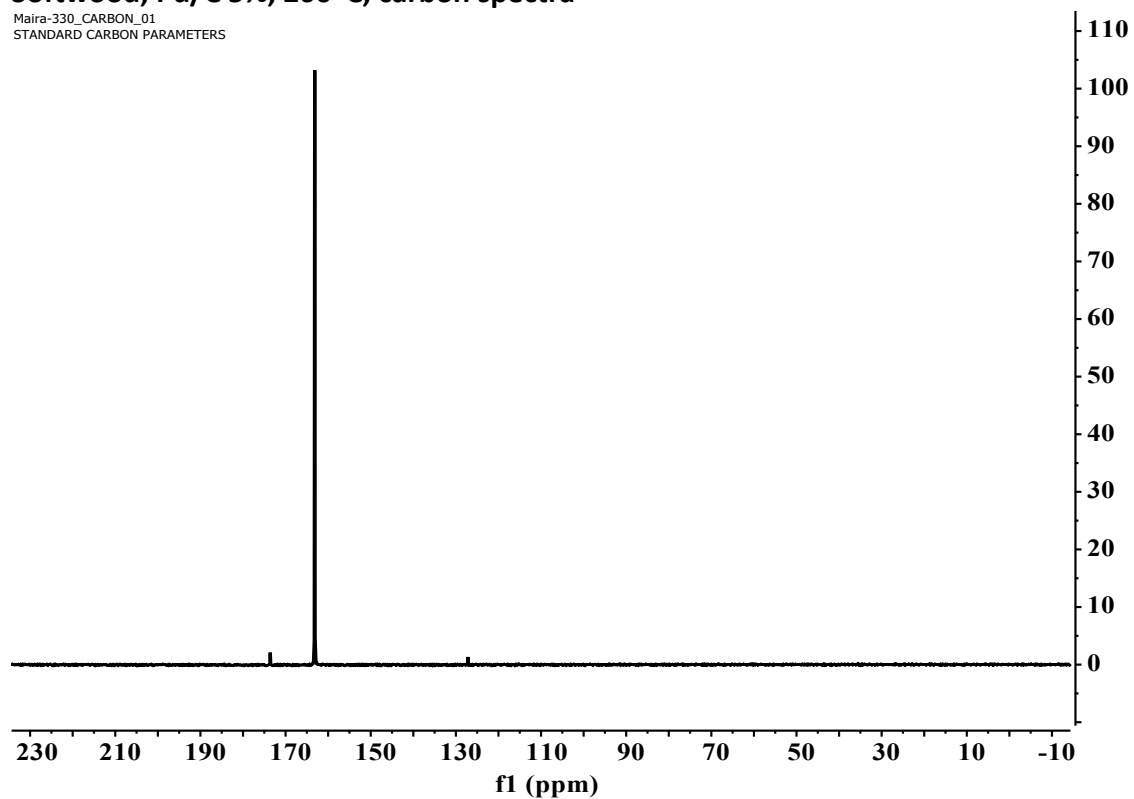STANDARD CARBON PARAMETERS

Cork, Pd/C 5%, 200ºC, proton spectra

Maira-329_PRESAT_01
STANDARD PROTON PARAMETERS

Softwood, Pd/C 5%, 200ºC, carbon spectra

Maira-330_CARBON_01
STANDARD CARBON PARAMETERS

Softwood, Pd/C 5%, 200ºC, proton spectra

Maira-330_PRESAT_01
STANDARD PROTON PARAMETERS