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Evaluation of properties of fast pyrolysis products obtained from Canadian waste biomass using a mobile pyrolysis unit

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Introduction-I

- ***To find solutions for energy problems and some current environmental concerns such as GHG emissions and global warming, use of renewable resources such as biomass is one the main strategies used in last two decades.***

- ***There are abundant amount of waste biomass in North America.***

Agricultural wastes

1,147 million dry tons per year in USA (Jones et al., 2007)

18 million dry tons per year in Canada (Gronowska et al., 2009)

Forest wastes

100 million dry tons per year in USA (Gronowska et al., 2009)

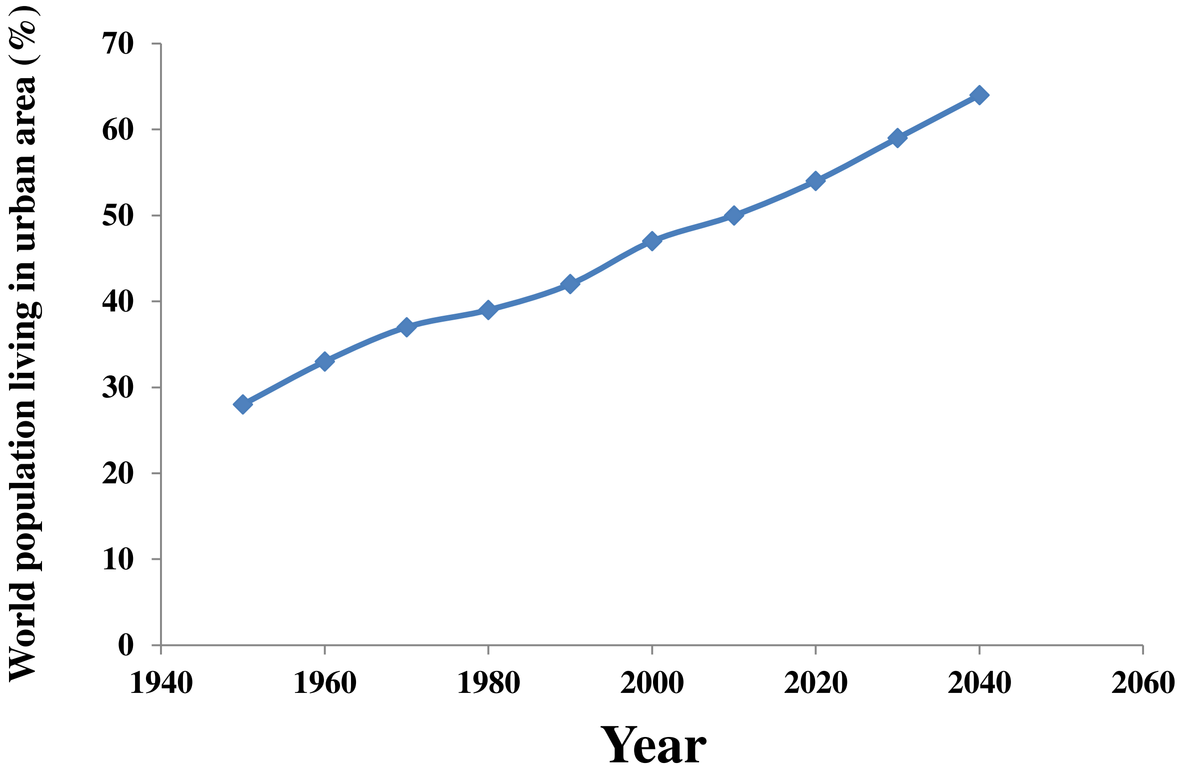
46 million dry tons per year in Canada (Mabee and Saddler, 2008)

Energy crops

3,383 million dry tons per year in USA (Jones et al., 2007)

433 million dry tons per year in Canada (Yemshanov and McKenney, 2008)

Introduction-II



Projected change in world population living in urban centres with time

Dhungana et al, 2012 .

Details on mobile pyrolysis unit and experimental conditions

- ✓ Auger pyrolysis system
- ✓ Steel beads are used as heat carrier
- ✓ No need for fluidizing gas
- ✓ Precursors: wheat straw, flax straw, sawdust and poultry litter
- ✓ Atmospheric process
- ✓ Vapor residence time : ~ 1 sec
- ✓ Bio-char res. time : ~ 15 min
- ✓ Feed flow-rate : ~ 200 g/min
- ✓ Run time : ~ 8 hours
- ✓ Pyrolysis temperatures: 400, 475 and 550 ^{o}C

ABRI Tech Inc., Quebec, Canada

Characterization methods

- ✓ **Biomass:** Proximate analysis, elemental analysis and particle size distribution

- ✓ **Bio-char:** Proximate analysis, elemental analysis, heating value, porous characteristics, pH, Raman analysis, electrical conductivity and particle size distribution

- ✓ **Bio-oil:** Density, viscosity, elemental analysis, total acid number, heating value, and gas chromatography analysis to identify and quantify types of chemicals present in bio-oil

- ✓ **Gaseous product:** Gas chromatography analysis to identify and quantify gas compounds

R. Azargohar, K. L. Jacobson, and A. K. Dalai, submitted to Journal of Analytical and Applied Pyrolysis (2013)

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Biomass characterization

Biomass		Cellulose (wt %)	Hemicellulose (wt %)	Lignin (wt %)
	Wheat straw	**35.4 ± 0.2**	**29.7 ± 0.3**	**20.8 ± 0.3**
	Flax straw	**32.3 ± 0.2**	**27.5 ± 0.3**	**20.1 ± 0.3**
	Sawdust	**37.7 ± 0.2**	**31.4 ± 0.3**	**15.9 ± 0.3**
	Poultry litter	**31.2 ± 1.6**	**36.3 ± 1.8**	**15.6 ± 0.8**

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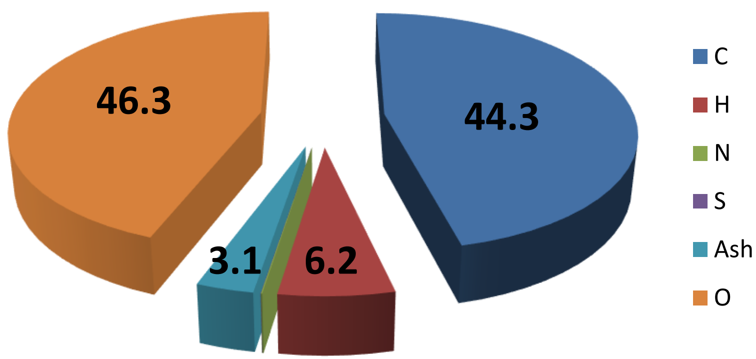
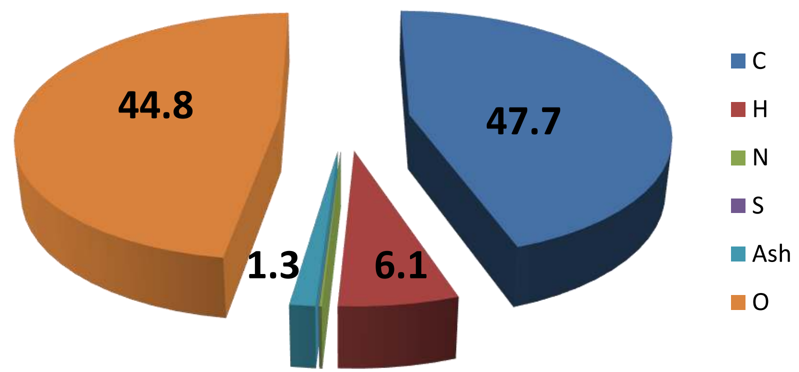
Biomass characterization (Elemental analysis)

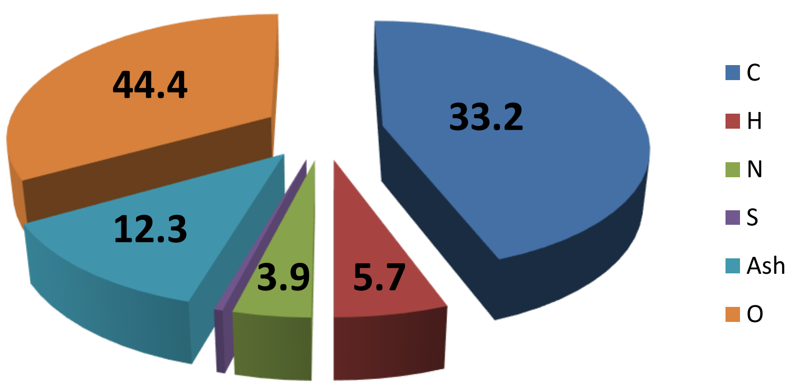
Flax straw



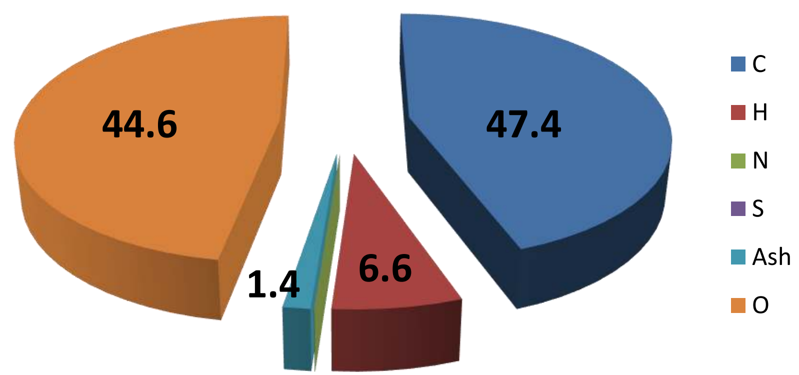
Wheat straw



Poultry litter



Sawdust



Bio-char applications

Bio-char as the solid product of pyrolysis process has various applications some which some are as follows:

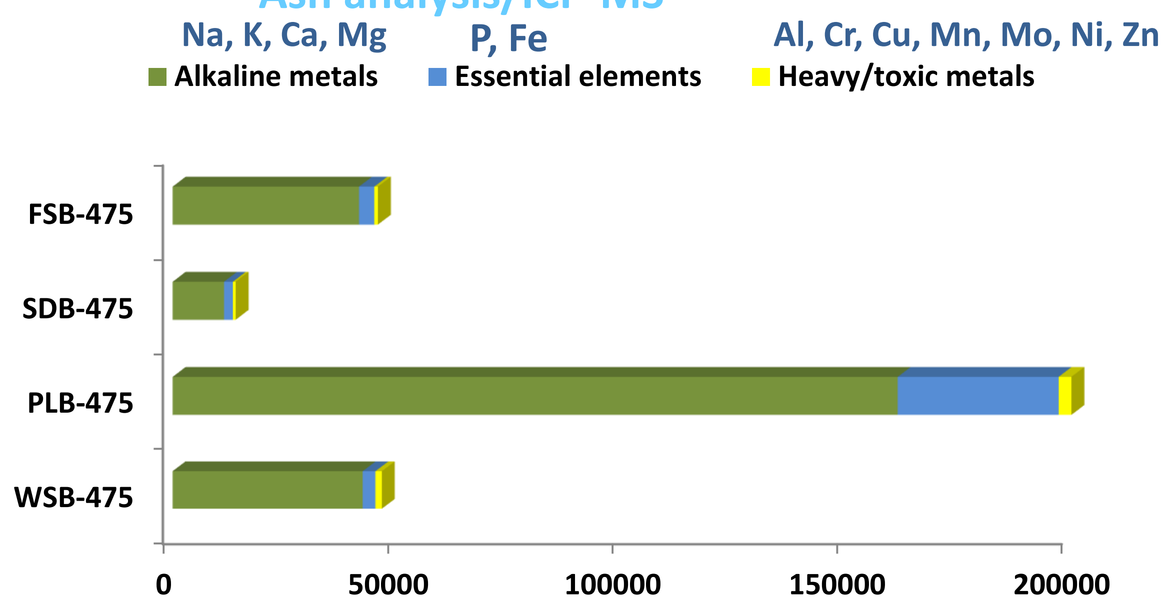
- ✓ ***Energy applications:*** *Bio-char has higher energy density (~ 20 MJ/kg) and lower moisture content compared with those for biomass which make it more suitable for fuel applications.*

- ✓ ***Environmental applications:*** *Bio-char in the original form or after conversion to value added products such as activated carbon can be used as adsorbent, catalyst or catalyst support for removal of different pollutants produced in chemical processes.*

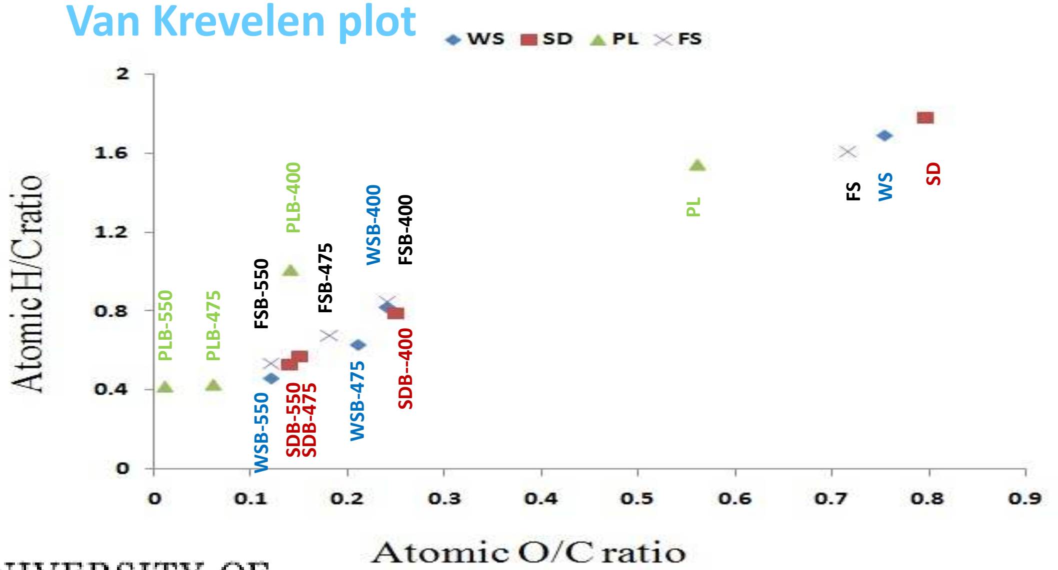
- ✓ ***Agricultural applications:*** *Bio-char can be added to soil to mitigate global warming problem and improve soil fertility based on its negative-carbon balance, ability to retain nutrients, high stability compared with waste biomass, and improvement of N-fixation by plant.*

Bio-char characterization (Ash analysis/ICP, Van Krevelen plot)

Ash analysis/ICP-MS



Van Krevelen plot



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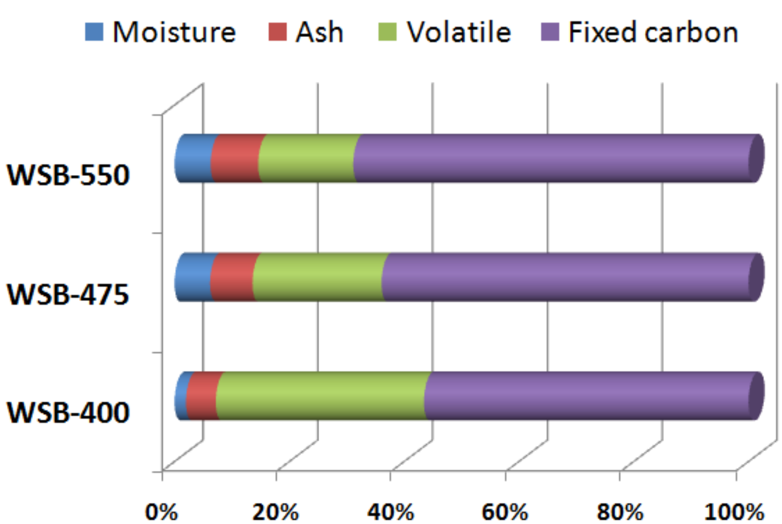
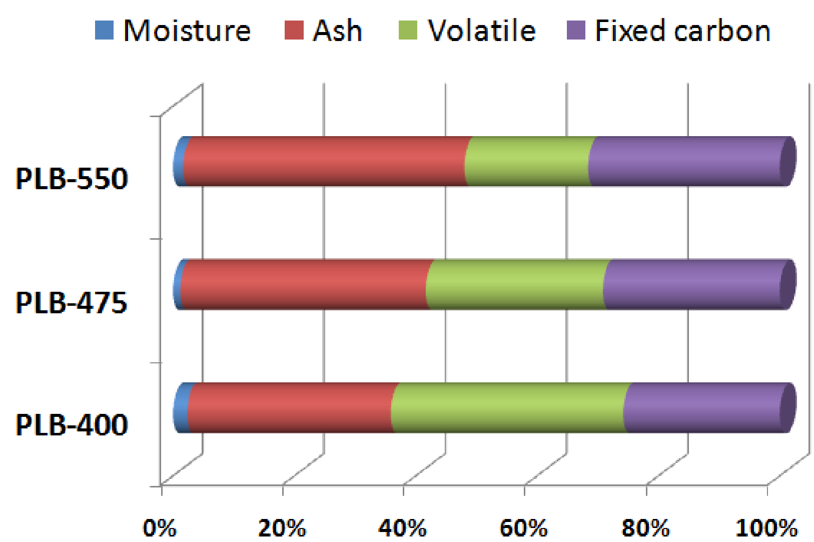
Bio-char characterization (Proximate and elemental analyses)



Proximate Analysis

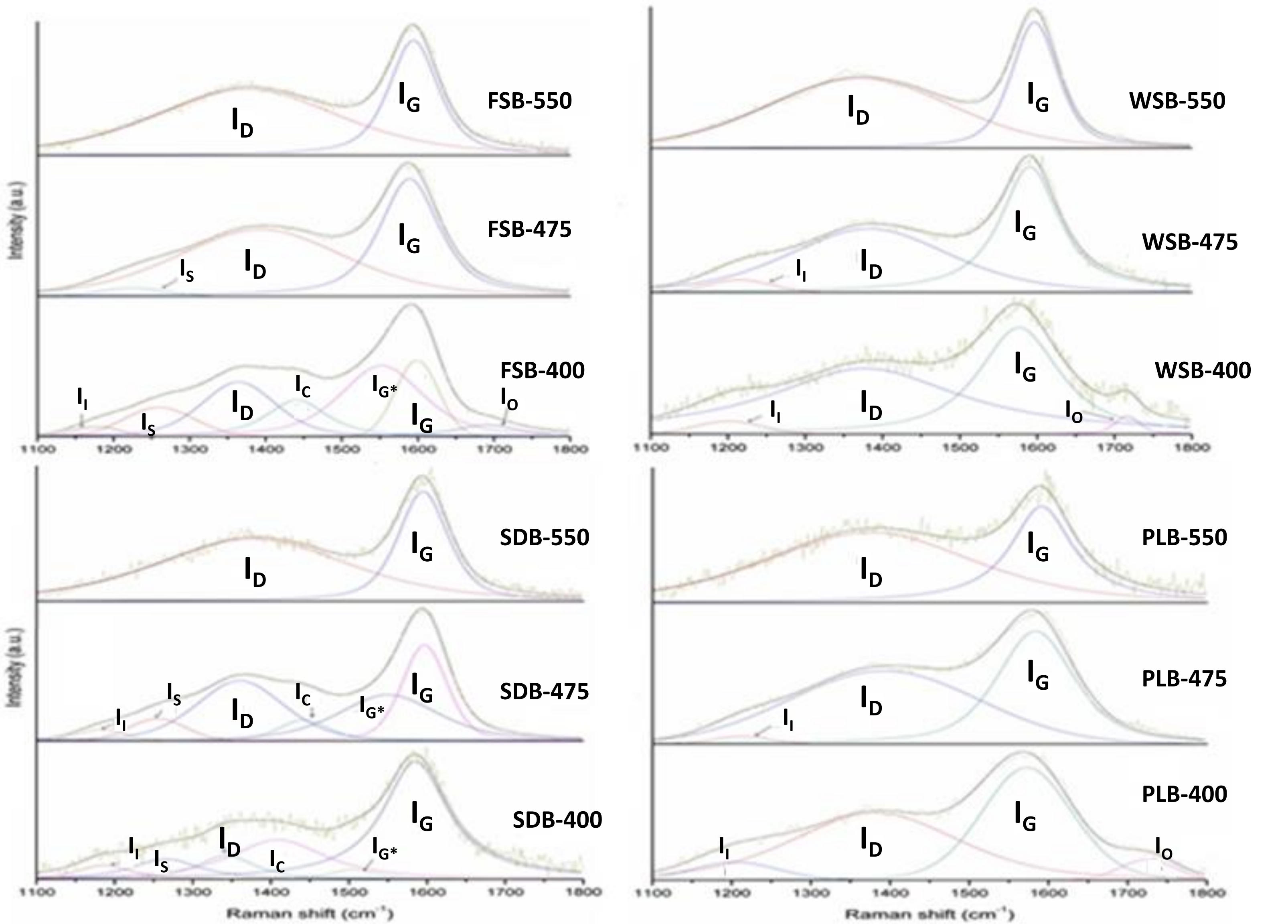


Proximate Analysis

	C (wt%)	O (wt%)	N (wt%)
WSB	71-83	12-22	< 0.7
PLB	69-83	1-13	8-9
FSB	71-82	12-22	< 1.2
SDB	71-81	14-23	< 0.2

Elemental Analysis

Bio-char characterization (Raman spectroscopy)



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Bio-char characterization (Raman spectroscopy)

Bio-char	I_D/I_G	H/C	O/C
PLB-400	1.11	0.28	0.09
PLB-475	1.32	0.43	0.06
PLB-550	1.82	0.42	0.01
SDB-400	0.17	0.79	0.25
SDB-475	1.20	0.57	0.15
SDB-550	1.89	0.53	0.14
FSB-400	1.37	0.85	0.24
FSB-475	1.37	0.68	0.18
FSB-550	1.83	0.54	0.12
WSB-400	1.30	0.82	0.24
WSB-475	1.10	0.63	0.21
WSB-550	1.88	0.46	0.12

Bio-char characterization (HHV, pH and electrical conductivity)

Bio-char	*Heating value (MJ/kg)*	*pH*	EC (μs)
PLB-400	21.9	7.8	2270
PLB-475	25.2	9.5	2009
PLB-550	25.8	9.6	1771
SDB-400	24.4	4.4	1348
SDB-475	28.6	4.8	743
SDB-550	26.0	5.1	435
FSB-400	21.8	6.0	7550
FSB-475	26.3	7.2	5590
FSB-550	30.1	8.0	1963
WSB-400	23.9	7.8	9270
WSB-475	18.9	9.4	5030
WSB-550	18.7	9.5	3860

Bio-oil applications

Bio-oil is CO_2/GHG neutral and has various applications:

- ✓ ***It can be used in engine, turbine and burners.***

- ✓ ***It can be upgraded to superior quality bio-fuels using current technologies such as hydrodeoxygenation, catalytic cracking and steam reforming.***

- ✓ ***It can be converted to syngas and then to transportation fuels using thermo-chemical/hydro-thermal processes followed by Fisher-Tropsh process or higher alcohol synthesis.***

- ✓ ***It can be used as a source of chemicals using conventional extraction processes or super-critical extraction technique.***

Bio-oil characterization

Feedstock for pyrolysis	*Pyrolysis Temp. (^oC)*	*Bio-oil collected from liquid product (wt %)*	*Total acid number[1] (mg KOH/g of sample)*	*Heating value[1] (MJ/kg)*	*Viscosity (cP)*	*Density (g/cm^3)*
Wheat straw	**400**	**9.2**	**109.3**	**26.8**	**169**	**1.157**
	475	**19.2**	**92.3**	**22.6**	**147**	**1.033**
	550	**43.5**	**47.1**	**29.1**	**133**	**1.024**
Saw dust	**400**	**28.0**	**146.6**	**24.9**	**24**	**1.239**
	475	**52.0**	**117.4**	**23.9**	**43**	**1.156**
	550	**44.5**	**61.9**	**28.8**	**63**	**1.099**
Flax straw	**400**	**34.8**	**100.8**	**27.3**	**130**	**0.923**
	475	**41.9**	**93.8**	**29.9**	**173**	**1.050**
	550	**28.7**	**18.8**	**29.9**	**323**	**1.142**
Poultry litter	**400**	**26.5**	**69.8**	**31.8**	**418**	**0.910**
	475	**30.8**	**61.9**	**34.0**	**-**	**1.076**
	550	**48.0**	**38.3**	**20.5**	**-**	**1.114**

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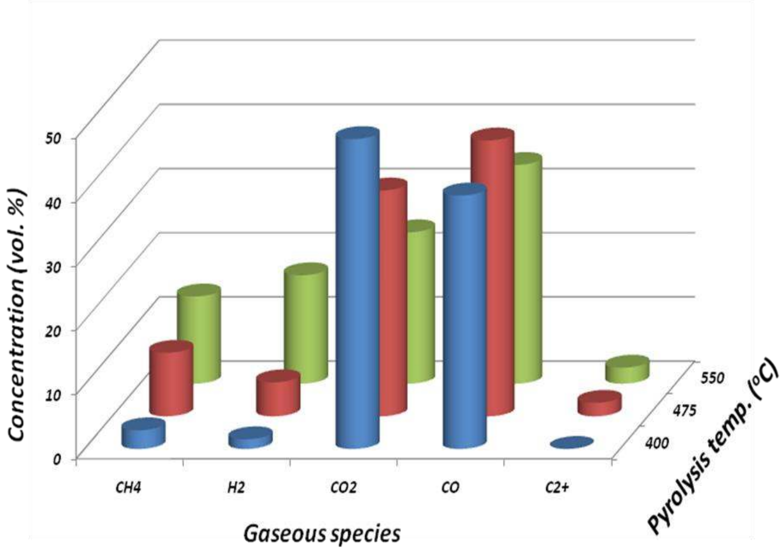
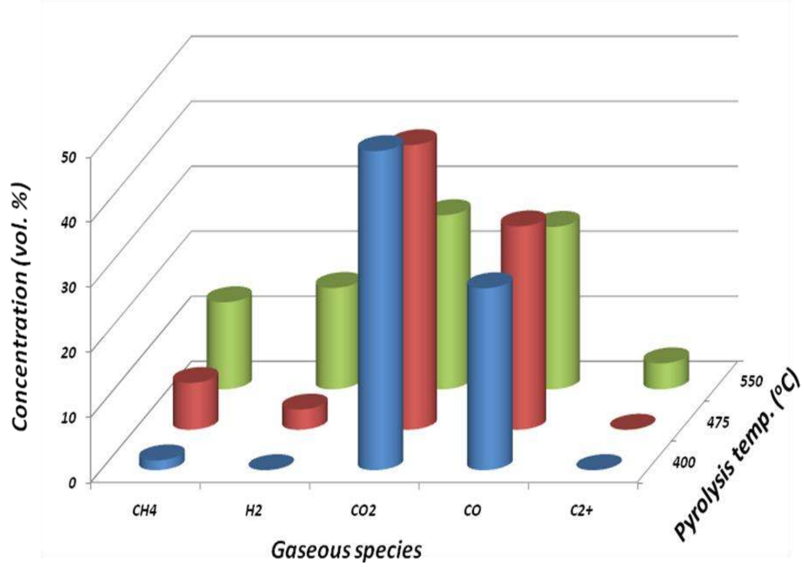
Bio-oil characterization (Gas chromatography technique)

	WS-400	WS-475	WS-550	SD-400	SD-475	SD-550	PL-400	PL-475	PL-550	FS-400	FS-475	FS-550
Phenols	38.6	23.5	13.0	18.8	11.3	29.3	17.9	12.5	14.7	52.4	47.1	62.6
Ketones	11.0	7.8	1.2	13.3	6.1	0.0	0.0	0.0	0.0	0.9	5.6	9.9
Alcohols	0.0	5.9	0.0	0.0	3.5	2.7	6.2	6.7	4.5	2.0	2.1	3.3
Acids	0.0	0.0	2.8	9.0	0.6	0.0	0.0	3.0	3.7	1.7	0.0	0.0
Aldehydes	4.7	12.1	5.5	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N compounds	0.0	0.0	0.0	0.0	0.0	0.0	35.8	12.2	13.6	0.0	0.0	0.0
Other compounds	0.0	0.0	0.0	3.0	3.9	12.4	0.0	0.0	0.0	0.0	6.5	1.4
Identified	54.3	49.3	22.5	44.1	31.0	44.4	60.0	33.4	36.6	57.0	61.2	77.2

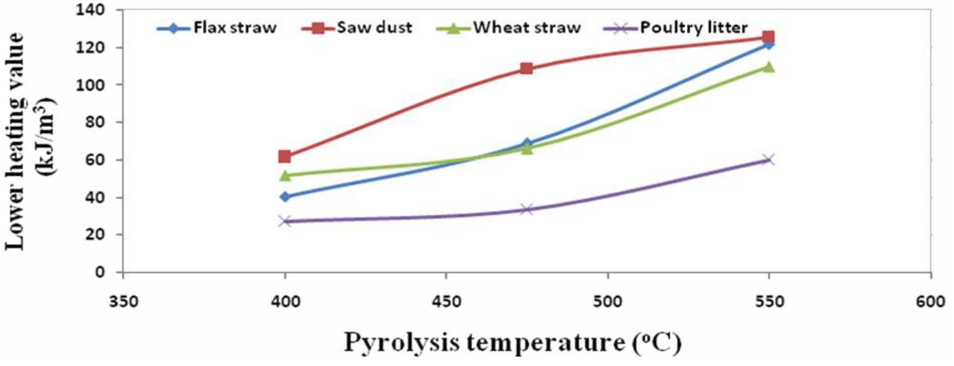
Gas product characterization



A. Saw dust



B. Flax straw



Lower heating value vs. pyrolysis temperature

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Conclusions

- ✓ Mobile pyrolysis unit is used effectively for fast pyrolysis of Canadian waste biomass from different sources. This method can be a solution for waste disposal in rural centers and produces value-added products from waste biomass.

- ✓ Acidity of bio-oils decreased by an increase in the pyrolysis temperature. Yield of bio-oil obtained from liquid product of pyrolysis increased by an increase in pyrolysis temperature. Phenolic compounds were the most abundant compounds in bio-oil.

- ✓ Bio-chars produced from wheat straw and poultry litter were basic, but sawdust-based bio-chars were acidic. Increase in pyrolysis temperature produced a highly condensed aromatic structure for bio-chars. Large amount of alkaline metals and essential elements in ash part of bio-chars show their potential for agricultural applications, especially for bio-chars prepared from poultry litter.

- ✓ Hydrogen and methane concentration as well as heating value (LHV) in gas product increased by an increase in the pyrolysis temperature.

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Thank you!