RENEWABLE ENERGY EVALUATION OF RECYCLED WOOD THROUGH THERMOCHEMICAL CONVERSION PATHWAY AND ARTIFICIAL INTELLIGENCE OPTIMIZATION

Physicochemical, thermodegradation, and flammability behaviours

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OBJECTIVE: Woody Biomass Energy

As a feasible technique for converting woody waste biomass into useful products like "heat" — COMBUSTION, one of the thermochemical processes with Artificial Intelligence (AI) application is proposed.

Wood waste is a rich **lignocellulosic-based** biomass that is considered an **abundantly sustainable material** (biomass fuel - **biofuel),** through a **Waste-to-Renewable energy** pathway in a **circular bioeconomy scheme**.

Annually, **50.2 mio** tons of **wood waste** are generated within **28 EU countries.**

(Potential energy resources)

38-51%
17-38%
2-31%
3%

Hardwood

Lignocellulosic Composition
- Cellulose
- Hemicelluloses
- Lignin
- Extractives

33-42%
22-40%
27-32%
2-3.5%

Softwood

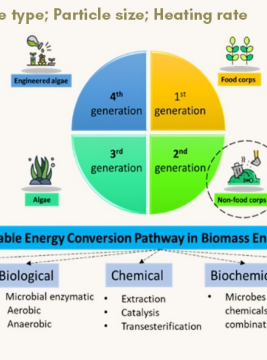
Keywords: Wood valorization; thermodegradation; bioenergy-bioexergy; flammability index; Taguchi method; artificial neural network model

Framework Conversion Technology

Research execution

Factors:
- Wood waste type; Particle size; Heating rate

Levels:
- Low
- Medium
- High



Samples:
- Softwood (SW)
  Fir: *Abies alba*
- Hardwood (HW)
  Beech: *Fagus sylvatica*
- Wood Blend (WB)
  HW:SW = 50wt% : 50wt%

To **provide a comprehensive study, the TGA** biomass energy (**bioenergy**) and biomass exergy (**bioexergy**) evaluations of wood waste via the combustion process are performed.

Energy and Exergy Evaluation

The complexity of biomass composition, bioenergy analysis using calorific value - higher heating value (HHV) is not adequate, thus, specific chemical biomass exergy (SCB) derived from the 2nd Law of Thermodynamic is utilized - a new term feasible method to determine the actual energy of the biofuel based on the chemical composition.

Physicochemical Analysis

Woody Biomass Characterization

Biomass properties	HW	SW	WB
Proximate Analysis (wt%)			
Moisture (M)*	5.94	4.00	3.00
Volatile matter (VM)	84.05	83.50	83.67
Fixed carbon (FC)	10.00	12.50	13.32
Ash (A)*	<0.01	<0.01	<0.01
Elemental Analysis (wt%)			
Carbon (C)	45.99	47.26	46.58
Hydrogen (H)	5.77	5.86	5.86
Oxygen (O)	45.05	44.36	45.32
Nitrogen (N)*	<0.05	<0.05	<0.05
Sulfur (S)*	<0.05	<0.05	<0.05
Bioenergy - HHV and Bioexergy -SCB (MJ/kg)			
HHV ; SCB	18.20 ; 19.03	18.84 ; 19.65	18.52 ; 19.32

* : low amount

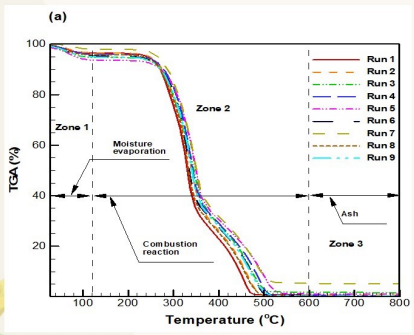
Energy density
- Moisture ↓
- Nitrogen (N) ↓
- Sulfur (S) ↓

Low NOx (negligible)
Low SOx (negligible)

Sample has no potential Air pollution production: NOx, SOx

Themodegradation Profile

TGA/DTG



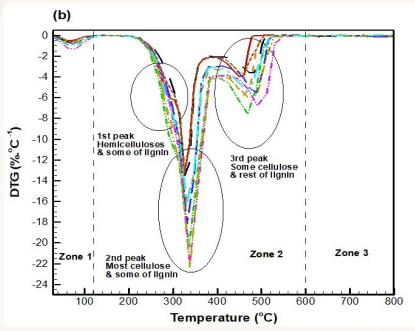
TG setup:

Heating rates (° C/min)
- ❑ 10
- ❑ 15
- ❑ 20

RT to 800 °C

In Oxidative Gas

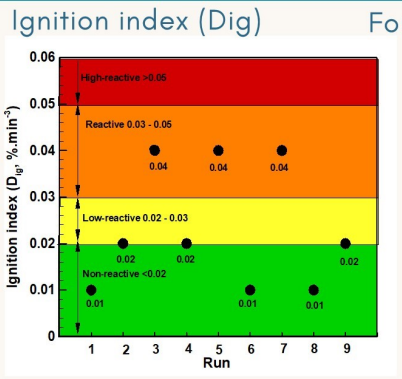
3 Zones detected: room temperature (RT) to 600 °C



3 Peaks discovered in Zone 2 (110 - 600 °C)

Flammability and Functional Group

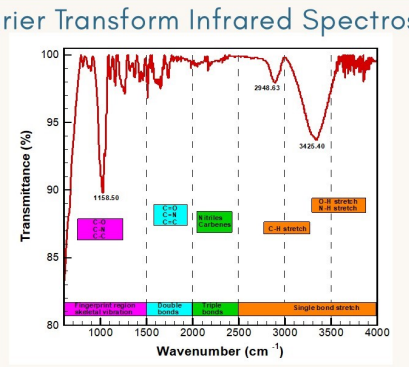
Ignition index (Dig)



Self-ignition criterion
- Non-reactive (Dig 0.00-0.02)
- Low-reactive (Dig 0.021-0.03)
- Reactive (Dig 0.031-0.05)
- High-reactive (Dig >0.051)

Woody biomass samples are noticed in 3 Classes.

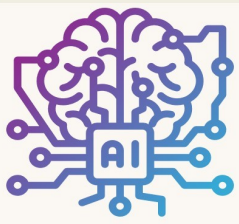
Fourier Transform Infrared Spectroscopy

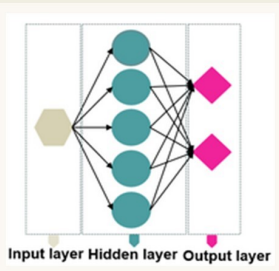


Polysaccharides functional group test:
1.(1,158.50 cm^{-1})
C-O-C: cellulose, mannose group (hemicelluloses)
2. (2,948.63 cm^{-1})
CH2: xylan and mannose (hemicelluloses)
3. (3,425.40 cm^{-1})
OH: cellulose and hemicelluloses

Experimental combination Runs are designed by utilizing the **Taguchi Orthogonal** array method.
3 factors and 3 levels: L9 (9 Runs).
All experiment is performed in duplicate.

AI-Artificial Neural Network (ANN) Model





ANN is a computer programming model that mimics the behavior of biological neurons in the human brain to discover patterns in data.

ANN Model Configuration
- **5 neurons**
- **1 hidden layer**

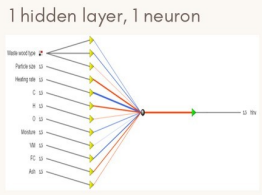
- ✓ Low standard deviation
- ✓ Fit quality, R^2=1
- ✓ No over- / underfitting

ANN Prediction
HHV
SCB

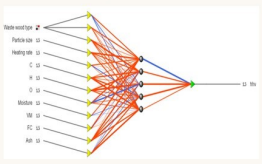
BEST QUALITY

Most influence parameters
1. Wood waste type
2. Proximate analysis
3. Elemental analysis
4. Particle size
5. Heating rate

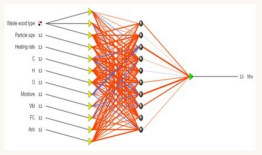
1 hidden layer, 1 neuron



1 hidden layer, 5 neuron



1 hidden layer, 10 neuron



•Reproducibility of the experiment is controlled under 5% error.

Conclussions

The TGA/DTG curves suggest there are 3 zones distinguished and 3 peaks detected. Meanwhile, flammability indexes indicate that wood waste has 4 classes (3 classes noticed) of ignition index. The optimum experimental run is achieved with SW 250 um particle size at 20 °C/min. The ANN prediction model is succesfully trained to predict the values of HHV and SCB.

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