# MODELING AND SIMULATION OF BIOMASS PYROLYSIS AND GASIFICATION PROCESSES

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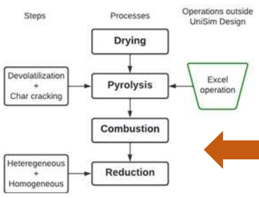
## INTRODUCTION

In computer simulation, the processes and equipment operate following the sequence of input data, data processing, and return output data. Typically, these data are mass flows, temperatures, compositions, and pressures. Specifically, modeling and simulation of gasification systems aid in predicting the outlet gas composition when operating conditions and scale size alter. This assists in planning the construction or retrofitting of existing equipment. UniSim Design is a chemical process modeling software, similar to Aspen Plus and Aspen Hysys. It is used in engineering to create dynamic and steady-state models for plant design, monitoring, troubleshooting, planning, and management [1]. However, regardless of the software used for modeling and simulation of the gasification process, there is a pattern of steps that must be followed in order to successfully perform the simulation. Therefore, this process is divided into 4 main steps: **Drying** or removal of moisture present in the biomass until 5% w/w; followed by **Pyrolysis**, which was split into Devolatilization, and Char cracking, both calculated with the help of Microsoft Excel; **Combustion**, where oxidation equilibrium reactions are added; and finally the **Reduction** step, which is divided in the heterogeneous and homogeneous stages, where equilibrium reactions are also inserted.

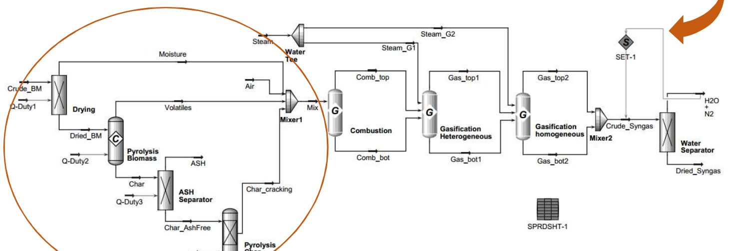
## 1. MODEL



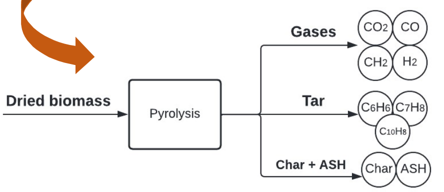

**General structure for gasification processes models**

### General Assumptions

- Operation occurs in Steady-State.
- Peng-Robinson was selected as the thermodynamic Fluid Package (FP).
- Tar constituted of three main components:
  - Benzene (60%), Toluene (20%) and Naphthalene (20%) w/w.
- Char broken into its main constituents: C(s), O, H, N, S(s) and $H_2O$.
- Ash removed in the middle of the process.
- Air is 79% of Nitrogen ($N_2$) and 21% of Oxygen ($O_2$) (molar basis).
- Nitrogen ($N_2$) and Sulfur (S(s)) considered inert during the processes.
- Process operated under atmospheric pressure; pressure drops disregarded.
- Solid Carbon mainly consumed in the Reduction zone.
- Considered the standard high-quality Syngas.
- Process is partially adiabatic.




**Biomass gasification simulation in a Downdraft gasifier**




Pyrolysis products

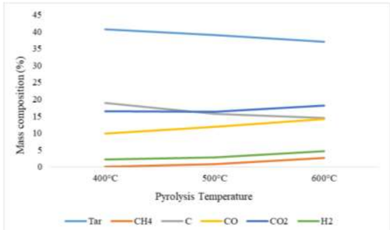
Distribution of products specified according to the original ultimate and proximate compositions of each biomass; yields and stoichiometric coefficients of the reactions in the Pyrolysis process are estimated using a methodology [3] based on second-order equations for the temperature.

Ultimate and Proximate analysis of chosen biomasses

| Ref. | Biomass | Proximate Analysis* | | | | | Ultimate Analysis | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | VM | FC | ASH | Total | C | H | O | N | S | Total |
| [2] | Grape marc | 10.0 | 59.2 | 23.8 | 7.0 | 100.0 | 54.0 | 6.1 | 37.4 | 2.4 | 0.15 | 100.05 |
| [2] | Corn straw | 7.4 | 67.7 | 17.8 | 7.1 | 100.0 | 48.7 | 6.4 | 44.1 | 0.7 | 0.08 | 99.98 |
| [2] | Olive residue | 10.6 | 60.2 | 22.8 | 6.4 | 100.0 | 58.4 | 5.8 | 34.2 | 1.4 | 0.23 | 100.03 |

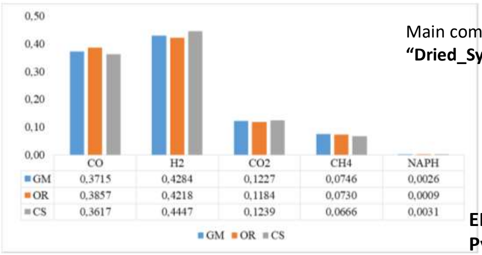
*Moisture (M), Fixed Carbon (FC), Volatile Matter (VM), and Ash (ASH) compositions.

## 2. RESULTS




Component mass variation in stream "**Mix**" according to **Pyrolysis** temperature variation.

**GM – Grape Marc**
**CS – Corn Straw**
**OR – Olive Residue**




Main components present in the stream **"Dried_Syngas"** for each biomass.

**S/B: steam to biomass ratio**

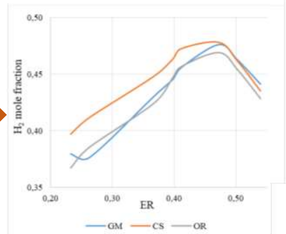
**ER: equivalence ratio**

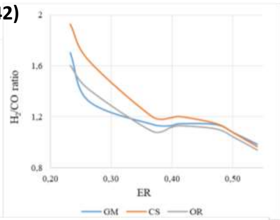
**$(air/fuel)_{actual}/(air/fuel)_{stoic}$**

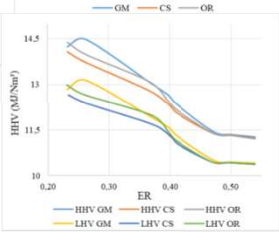
**ER = 0.36; S/B ratio = 0.42**

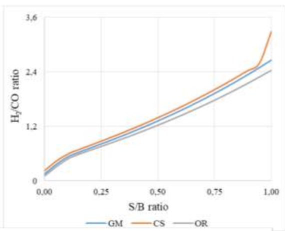
**Pyrolysis temperature: 500°C**

**ER variation (0.23-0.54) - constant S/B ratio (0.42)**

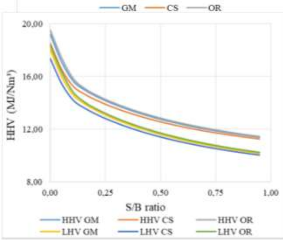


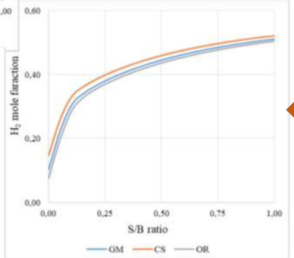




**S/B variation (0-1) - constant ER ratio (0.36)**




## 3. CONCLUSIONS

- ✓ Downdraft gasifier simulations based on the second-order Pyrolysis model provided comparable results with the literature. [4]
- ✓ CS revealed to be, in both simulations (ER and S/B ratio), the $H_2$-richer Syngas producer biomass, while OR is the poorest in this component.
- ✓ An increase in ER had a significant impact on the increase of $H_2$ mole fractions in syngas, while $H_2$/CO, HHV, and LHV were impacted negatively.
- ✓ For the S/B ratio variation, its rise, increased $H_2$ mole fraction in syngas, and consequently $H_2$/CO ratio. On the other hand, LHV and HHV were negatively affected.

## References

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ACKNOWLEDGMENTS

This work was carried out within the framework of the SUBe Project, ref.: PCIF/GVB/0197/2017, funded by the Portuguese Foundation of Science and Technology (FCT). The authors are grateful to the Foundation for Science and Technology (FCT, Portugal) for financial support through national funds FCT/MCTES (PIDDAC) to CIMO (UIDB/00690/2020 and UIDP/00690/2020) and SusTEC (LA/P/0007/2021).