

Production of enhanced pyrolysis oil through co-pyrolysis of biomass and plastic waste in a semi-continuous reactor

Yehya JAAFAR^{1,2}, Lokmane ABDELOUAHED¹, Roland EL HAGE², Antoine EL SAMARANI²,

Bechara TAOUK^{1,*}

¹ Normandie Univ, INSA Rouen Normandie, UNIROUEN, Laboratoire de Sécurité des Procédés Chimiques, LSPC EA-4704, 76000 Rouen, France ;

² Lebanese University, EDST, Plateforme de Recherche en Nano Sciences et Nano Technologie (PR2N), Fanar, Lebanon

* bechara.taouk@insa-rouen.fr

INTRODUCTION

Pyrolysis has been considered an effective route for biomass valorization where the desired product is liquid bio-oil, which can be used as a fuel or fuel substitute for petro-sourced products after treatment. However, due to biomass's oxygenated nature (43 wt.% oxygen), the produced bio-oil consequently will be almost entirely dominated by oxygenated compounds. The high oxygen content causes a relatively low calorific value, high viscosity, corrosion, and unstable bio-oil, accordingly inappropriate for direct use. Various approaches have been applied to improve bio-oil quality, mainly catalytic deoxygenation, steam reforming, esterification, and hydrodeoxygenation. An alternative more practical approach lies via co-pyrolysis. Co-pyrolysis describes the thermo-chemical decomposition of organic material with two different feedstocks at the same time to improve the quality and quantity of the produced liquid oil. In this work the co-pyrolysis of certain types of municipal plastic waste (PP, PS, HDPE, LDPE) with beech wood (*Fagus sylvatica*) (BW) as lignocellulosic forestry residue, for the production of pyrolytic oils of improved quality.

Experimental setup

Pyrolysis was executed in a semi-continuous tubular reactor ($\phi = 50$ mm, $L=1050$ mm) composed of a quartz tube inserted horizontally in a tubular furnace. A stainless-steel sample carrier "spoon" was inserted from one end of the reactor, while the other end was connected to a condenser and a cold bath for liquid collection. First, a total mass balance was done to quantify the gas, liquid, and solid product. The incondensable gases were collected and analyzed using GC-FID/TCD and liquid bio-oil recovered was analyzed using GC-FID and GC-MS to identify and quantify the liquid products. The parameters chosen were the biomass/plastic ratio and operating temperature.

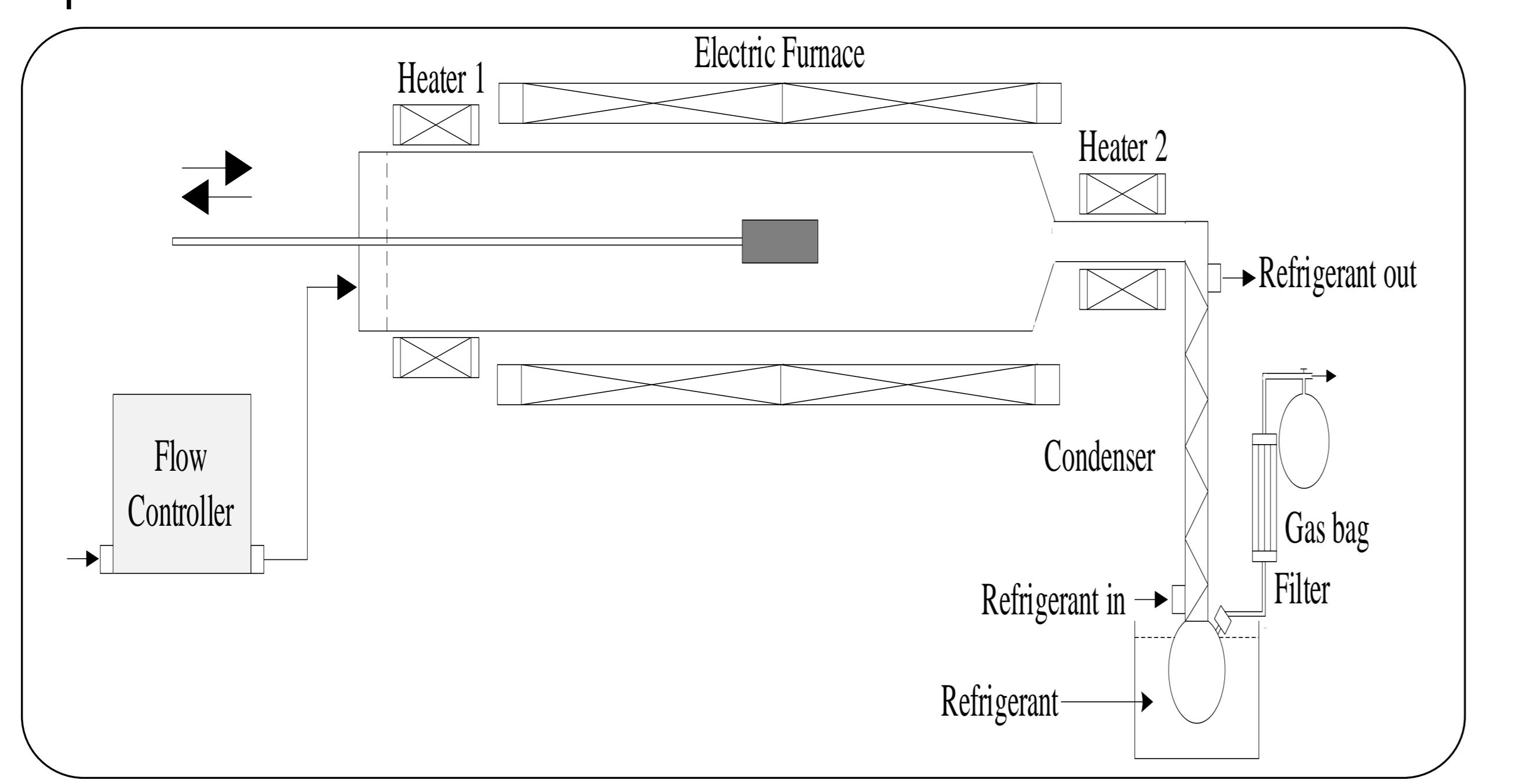


Fig. 1: Setup batch reactor

Results: Co-pyrolysis

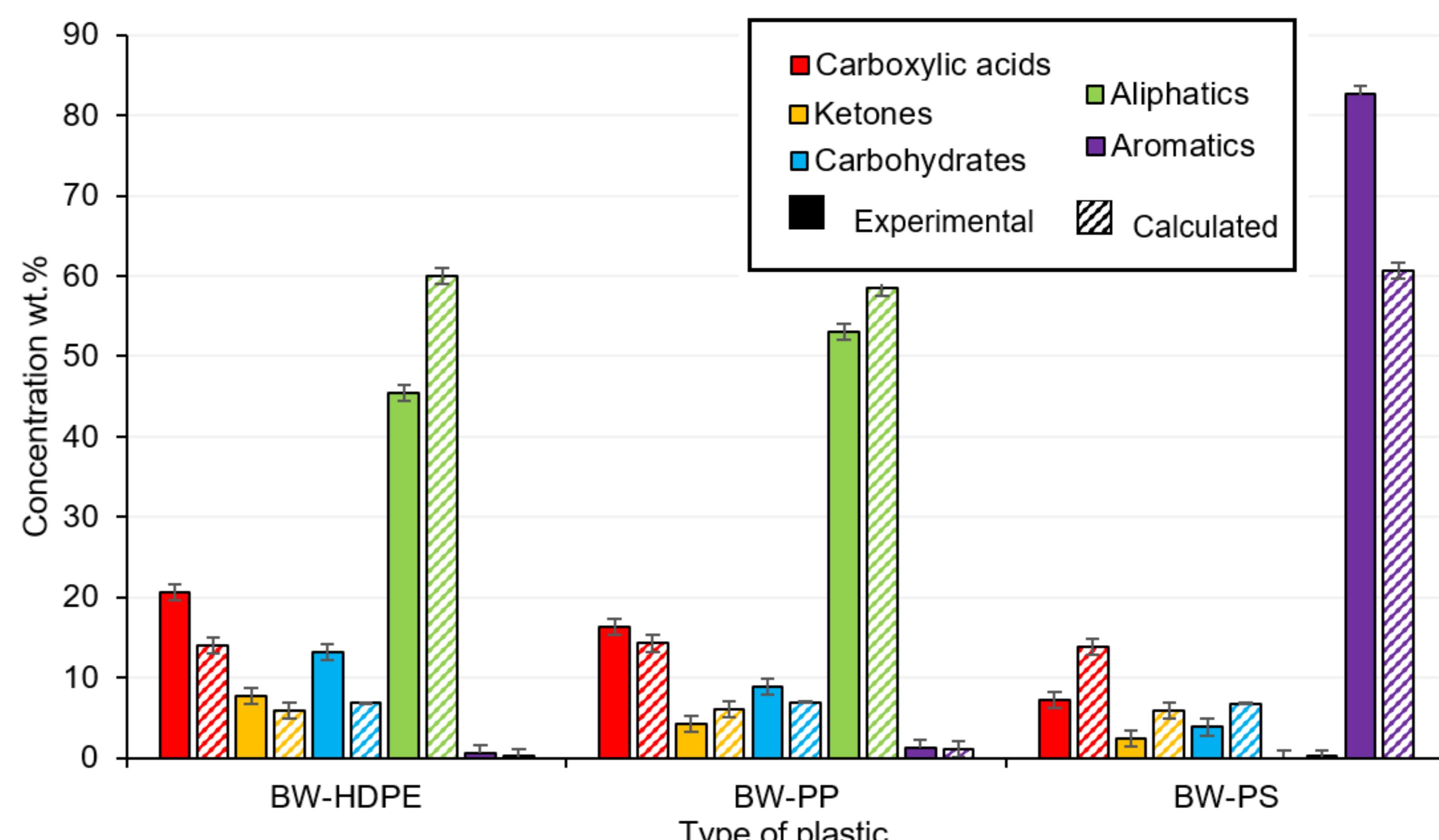


Fig. 3: Synergy comparison between the different polymers studied with a 50-50 BW/plastic ratio.

Results: BW pyrolysis

- ✓ Plastic and biomass with respective particle size of 2 mm and 0.4 mm
- ✓ Homogeneous mixing
- ✓ Beech wood percentages of 0-25-50-75-100 %
- ✓ Nitrogen flow rate of around 400 ml/min
- ✓ Operating temperature varying 450-600 °C

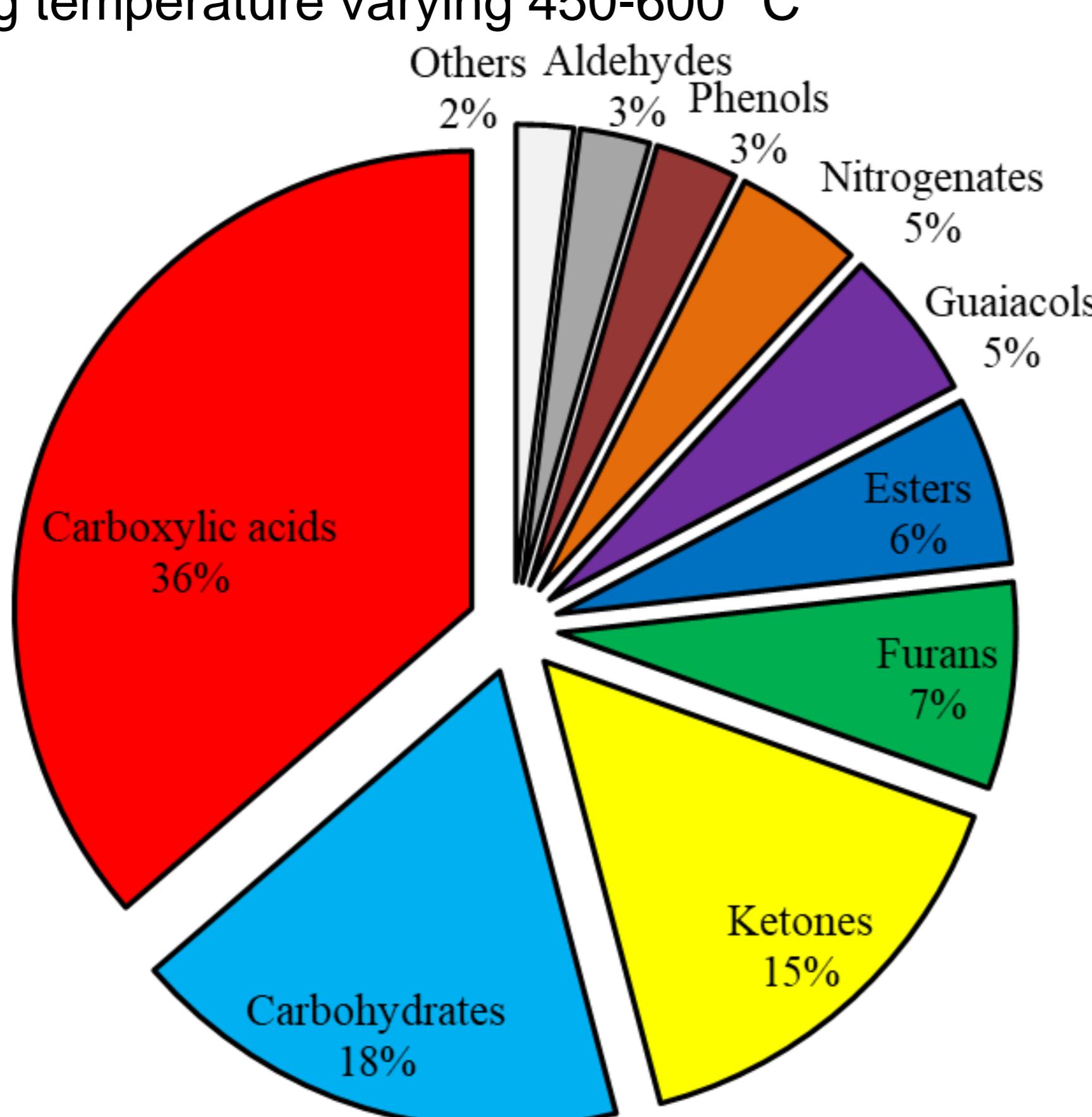


Fig. 2: Chemical families in BW pyrolytic oil at 500°C.

- BW bio-oil was mainly comprised of carboxylic acids (acetic acid), carbohydrates (levoglucosan), and ketones.
- High Oxygen content of about 41 wt.%
- Low LHV of about 18 MJ/kg

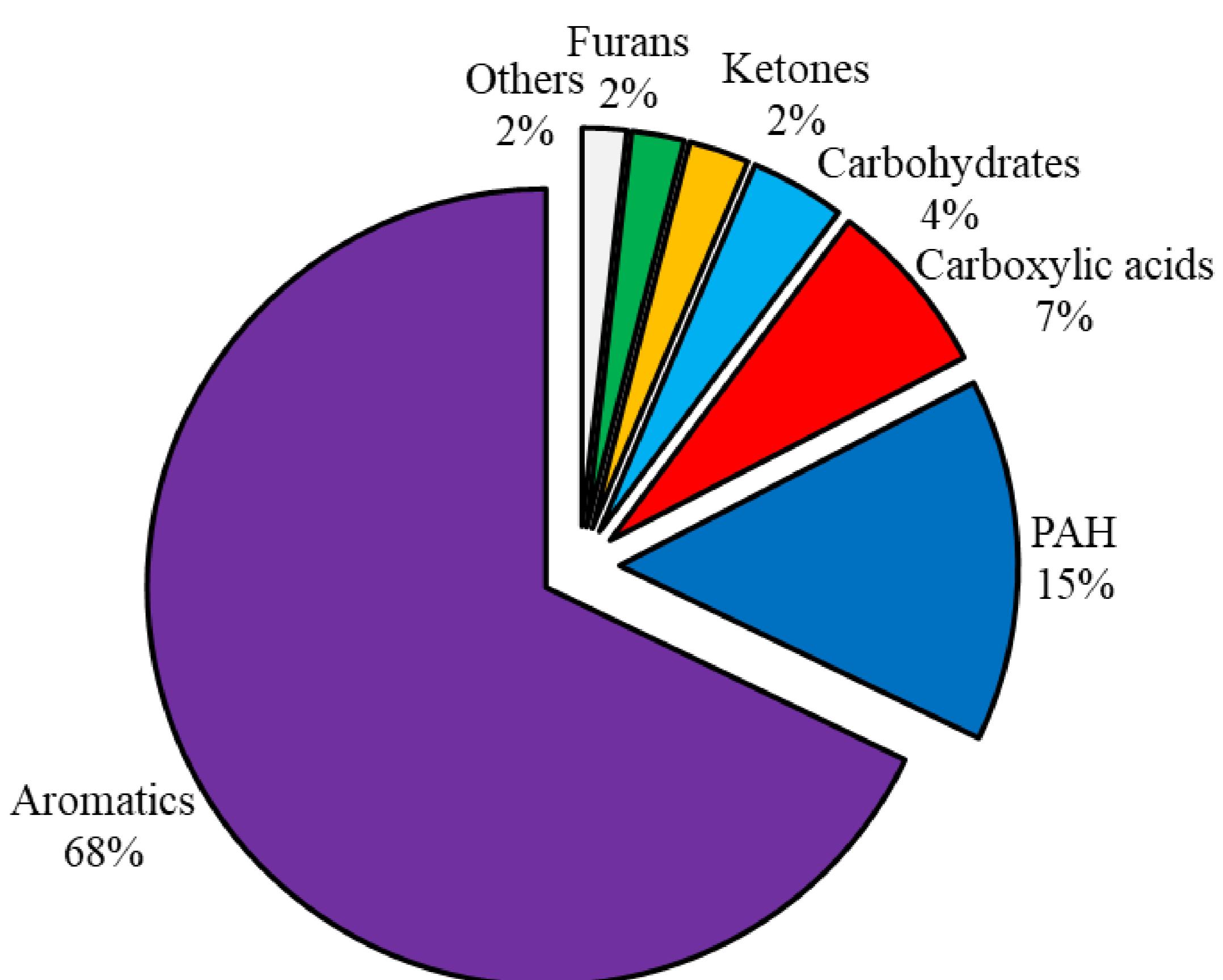


Fig. 4: Chemical families in BW-PS 50-50 liquid oil at 500 °C.

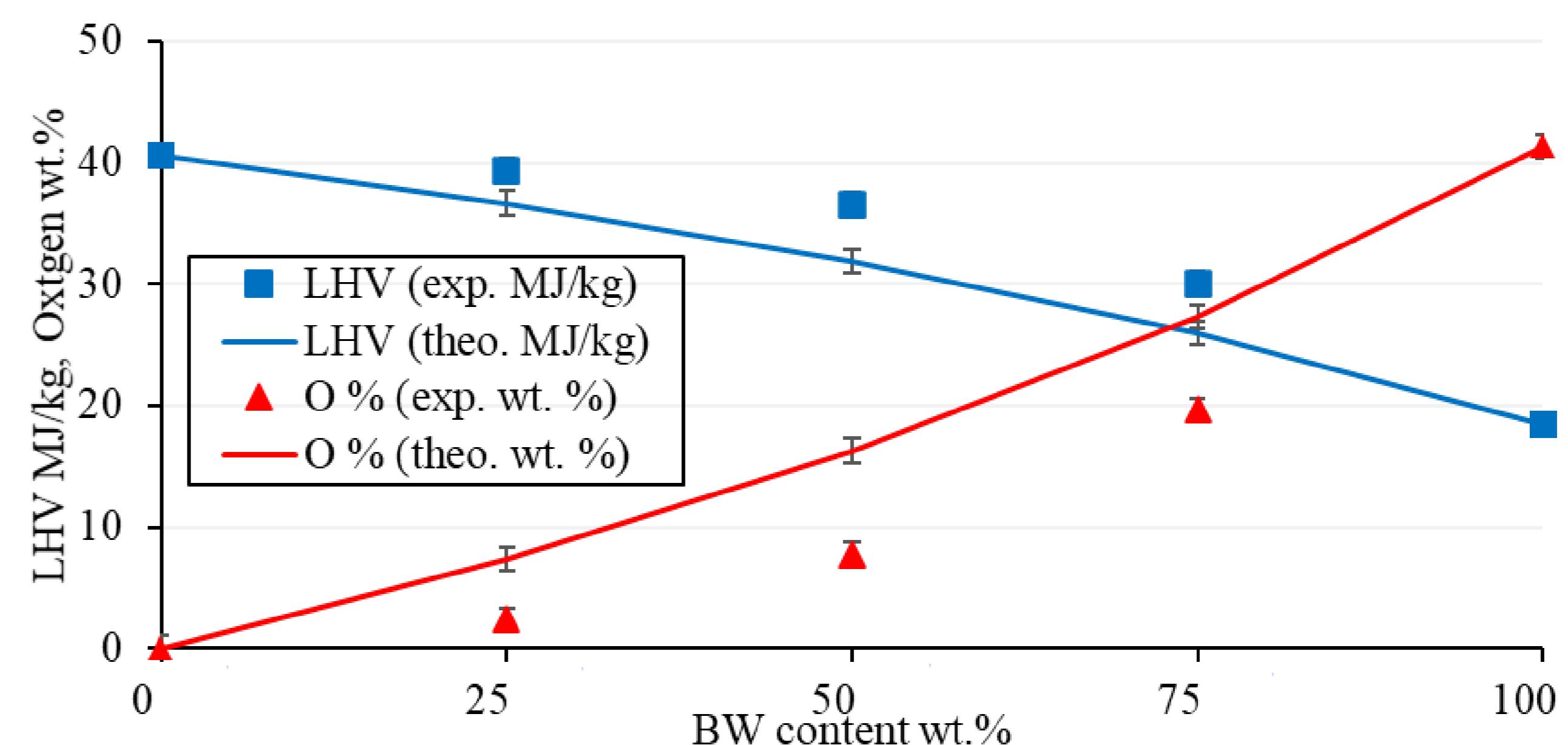


Fig. 5: The evolution of LHV (MJ/kg) and O % (wt.%) in BW-PS liquid oil as per BW content.

Comments and conclusions

- ✓ Results showed that for beech wood polystyrene mix an increase of aromatic compounds compared to the theoretical value.
- ✓ The oil was mainly constituted of aromatics of about 68 wt.% for the 50-50 mixture. The liquid oil experiences a great reduction in the oxygen content from 41 wt.% (beech wood) to just 8 wt.% for the polystyrene-beech wood 50-50 mixture.
- ✓ The oil also exhibited a high heating value of 37 MJ/kg with high aromatic content making the oil suitable to be blended with high mass proportions in the gasoline pool.
- ✓ In contrast, a negative synergy was observed between beech wood and polyolefins leading to an increase in acids and carbohydrates of 7 wt.% to 10 wt.% for polyethylene and polypropylene respectively compared with the theoretical value.
- ✓ Regarding the temperature variation of 450 to 600 °C, no remarkable change in oxygenated compounds is observed. Thus, the oxygen content and heating values remained the same.