Utilization of straw and other stem residues within the framework of the circular bioeconomy

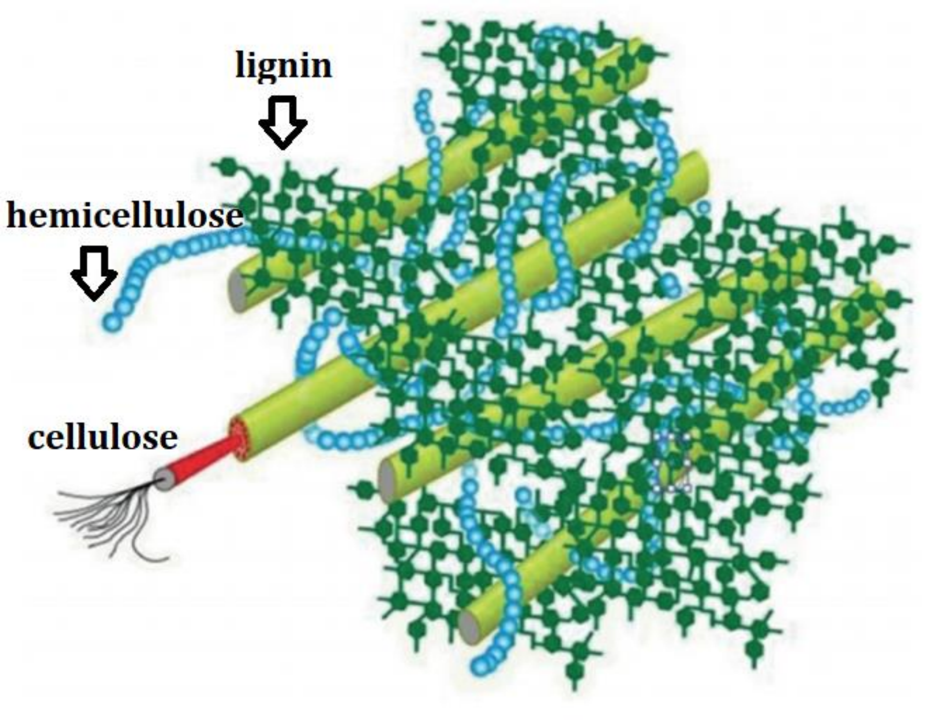
The fate of straw

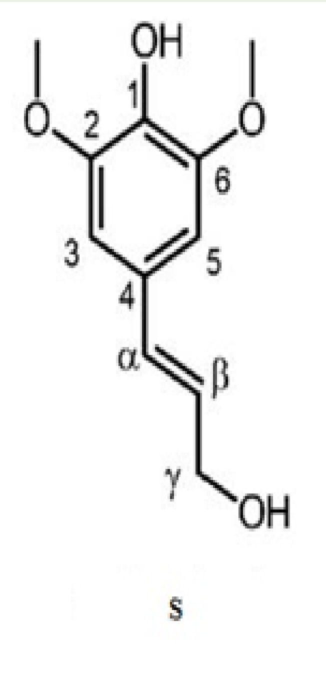
- Burning on the ground or in the heating plant
- chopping and blowing, then plowing into the soil
  - Biochemical transformation to CO_2 and humus
- Gathering by special agricultural machines

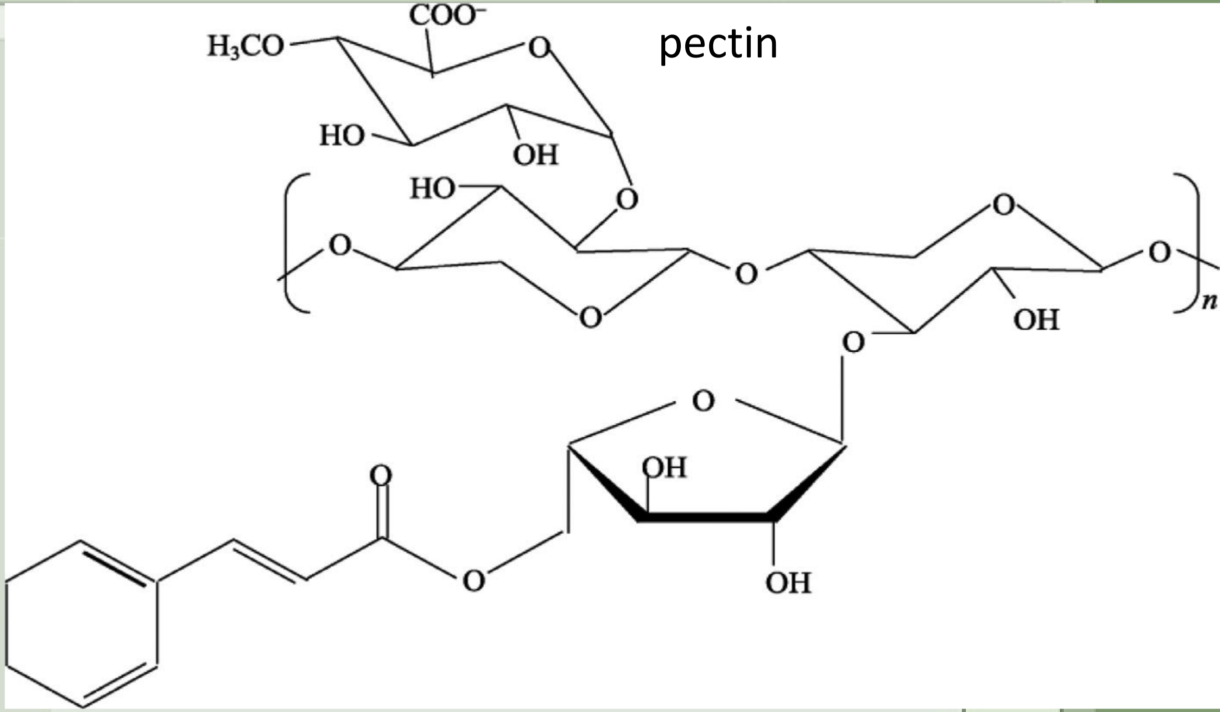
  used as animal bed, solid fuel, thermo isolation, etc.

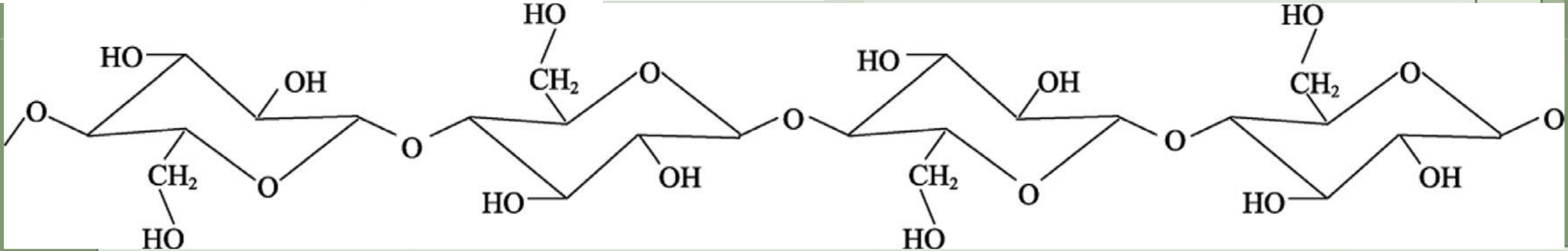
  in the future: chemical raw material

Chemical components of straw and other stem residues









Utilization of cellulose and hemicellulose

- Mostly in several steps.

But generally:

- 1. step – decomposition to monosaccharide (oligosaccharide) by hydrolysis catalyzed by H^+ or enzymes
  - H^+ at higher temperatures without pretreatment
  - enzymes at lower temperatures,
  (need pretreatment, because enzymes are large molecules)
- 2. step – utilization of monosaccharides (+ oligosaccharides)
- 3. step – isolation of products

Utilization of cellulose and hemicellulose

- Enzymatic hydrolysis is used by ruminants (more precisely microorganisms in their rumen), pretreatment is rumination. *(monosaccharides are utilized by ruminants as a feed)*
- Enzymatic hydrolysis is used by microorganisms during the formation of biogas in fermenters. To reach economic rates of biogas formation need pretreatment.
  (monosaccharides are utilized by other microorganisms to produce CH_4 and CO_2). The same process and similar microorganisms produces biogas in lakes, marshlands, slow rivers.
- Enzymatic hydrolysis is used by microorganisms during the formation of humus in the soil. No pretreatment – the decomposition of lignocellulose is slow. *(monosaccharides are utilized by other microorganisms to produce energy and CO_2. The unused part of lignocellulose is humus)*

Utilization of cellulose and hemicellulose

- Enzymatic hydrolysis is used by microorganisms and/or biochemists, prior to the formation of bioethanol from lignocellulose in fermenters. To reach economic rates of bioethanol formation chemists need pretreatment.
  (In the fermenters monosaccharides are utilized by other microorganisms(yeasts) to produce bioethanol and CO_2*)*
- *production of bioethanol from lignocellulose – presented by Blažej Horváth*
- *Utilization of bioethanol – presented by Barthos Róbert*

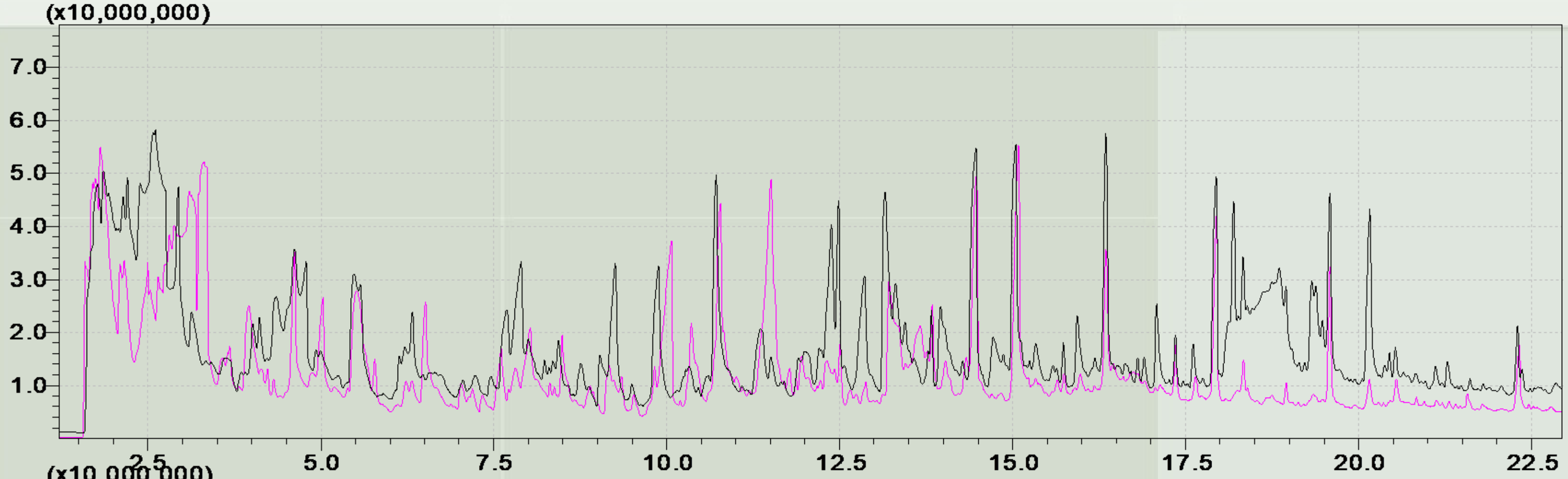
Utilization of cellulose and hemicellulose

- Acid hydrolysis is used by chemists, to produce furfural. In this process all steps (hydrolysis, transformation and separation) are realized in one autoclave. H^+ catalyzes hydrolysis of polysaccharides to monosaccharides and their dehydration to furfural. Furfural is distilled by water vapors. From corn stalks the yield is around 10%. To reach economic yields of furfural, chemists need pretreatment and utilization of by-product wet acidic stalks with partially decomposed polysaccharides.

  -*production of furfural from lignocellulose and its utilization – was presented by Tomáš Soták*

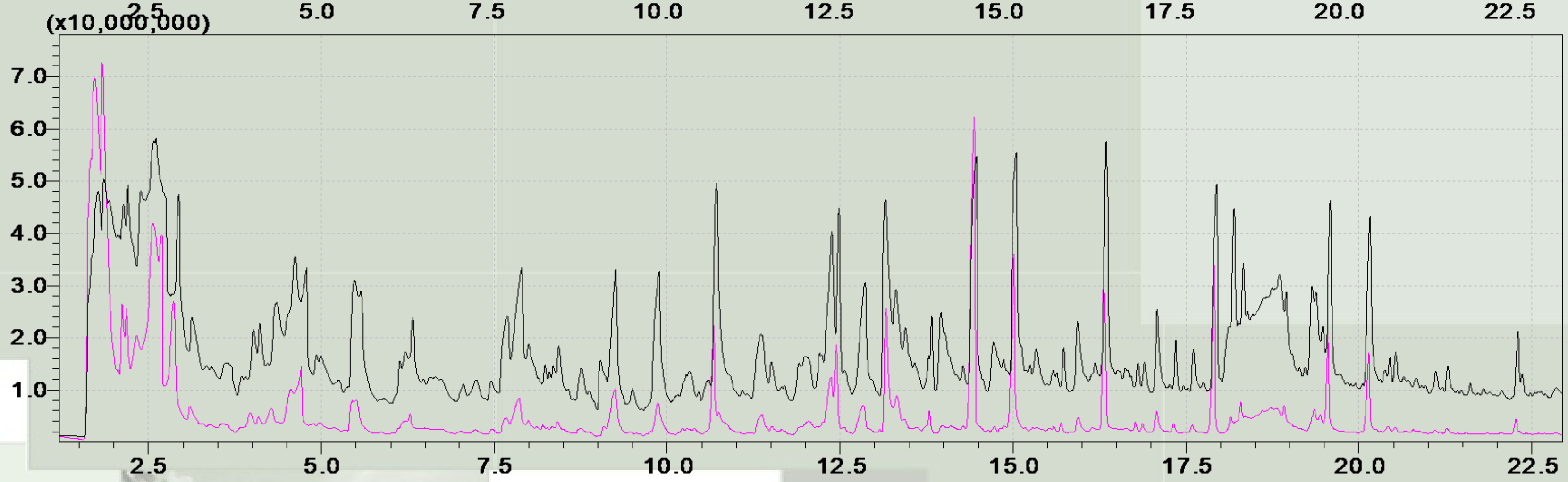
- *Utilization of lignin was presented by Novodárszki Gyula.*

Pyrograms of wheat straw in the soil



Pink – original- JUN

Black – After 70 days-summer



Black – after 70 days-summer

Pink – after 130 days summer + autumn

Conclusions

- During summer and autumn mainly cellulose and hemicellulose is decomposed in the soil to CO_2.
- During next year all lignocellulose is decomposed including lignin to CO_2. The rest of organic material in the soil is negligible.
- Reed and grape stalks (with high content of lignin) were after 650 days decomposed only partially. The decomposition started with cellulose and hemicellulose.

All lignocellulosic waste in nature is oxidized to CO_2. If we are producing fuel only from carbons of this waste, we are producing real green fuel, because after using this fuel, the same CO_2 is formed as in the natural decomposition processes.

Green bioethanol, green biomethane and green hydrogen

- Bioethanol produced from cellulose and hemicellulose of agricultural waste can be green bioethanol
- Biomethane separated from biogas made from waste lignocellulose can be green methane.
- Hydrogen produced from green methane can be real green bhydrogen.

All lignocellulosic waste in nature is oxidized to $CO_{2.}$ *If we are producing fuel only from carbons of this waste, we are producing real green fuel, because after using this fuel, the same* CO_2 *is formed as in the natural decomposition processes. However, the time interval of* CO_2 *producing is not the same.*

Thermal decomposition of lignocellulose

- Heating up to 1000 °C at the presence of water, synthesis gas (CO,H_2) is formed with content of water vapors, light hydrocarbons and CO_2. This mixture can be transformed to **green hydrogen** or can be a row material for Fischer Tropsch processes.
- Heating up to 1000 °C without presence of water or air (O_2), mainly methane, H_2, CO, and CO_2 is formed as a gas product, biochar as a solid product with some content of liquid. This gas mixture can be also transformed to **green hydrogen. Biochar can be used in agricultural application instead of humus.**
- Heating up to 500 - 600 °C without presence of water or air (O_2) produces mainly biooil. The yield of biooil increases by the rate of heating up to 85-9O %.

Thermal decomposition of lignocellulose – to biooil

- At first glance, bio-oil (mainly because of its color) looks like petroleum, but in reality it is a mixture of completely different substances. While crude oil consists primarily of carbon and hydrogen-based organic materials, almost all components of bio-oil contain oxygen.
- Bio-oil cannot be associated with petroleum or its fractions. With the technologies used in the processing of crude oil, neither fuel that meets today's requirements nor specific chemical substances can be produced from it. Completely new technologies must be developed.

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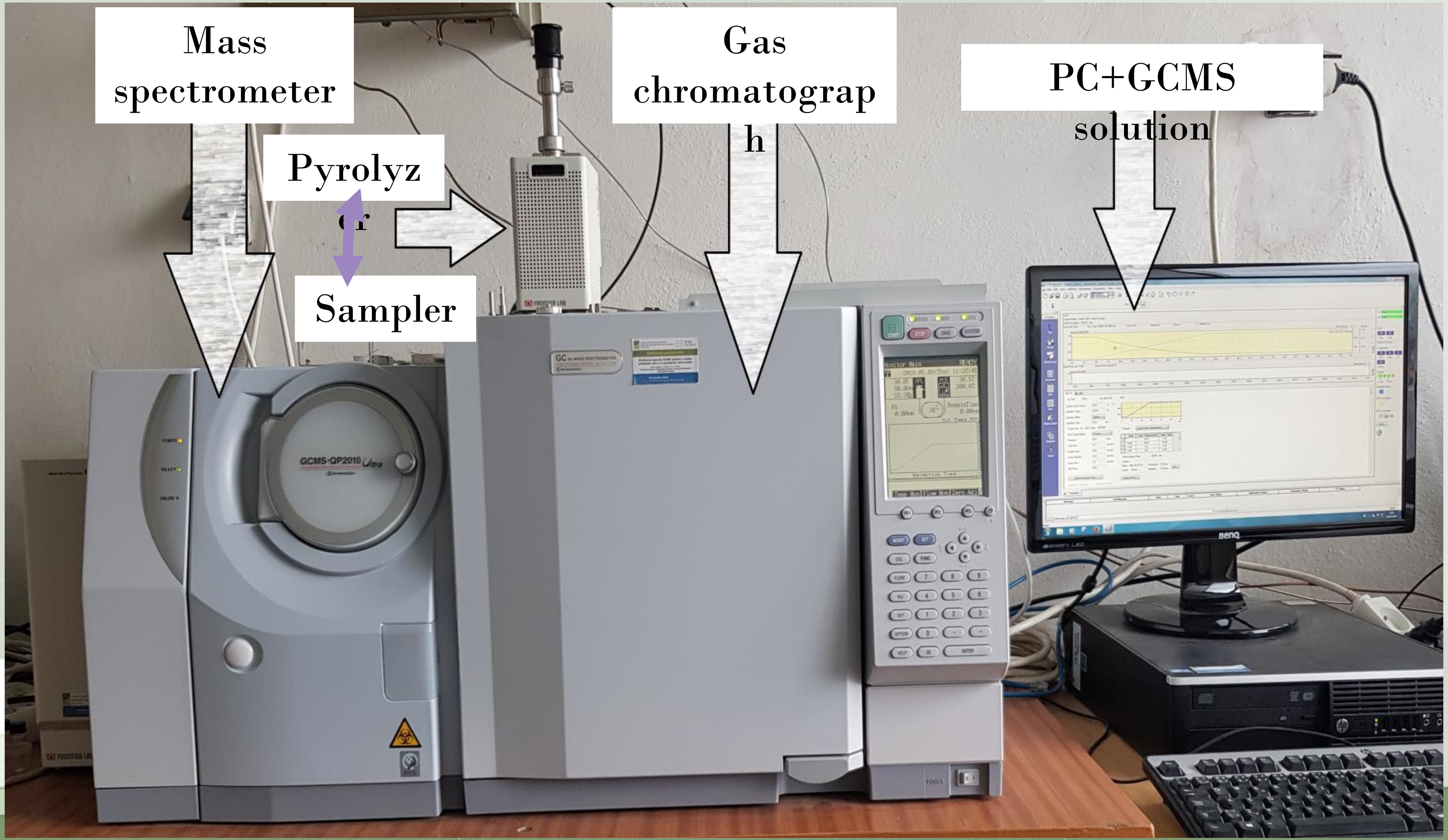
Thank you for your kind attention !

Acknowledgement

European Regional Development Fund
Interreg, SKHU/1902/4.1/001/Bioeconomy)
www.skhu.eu

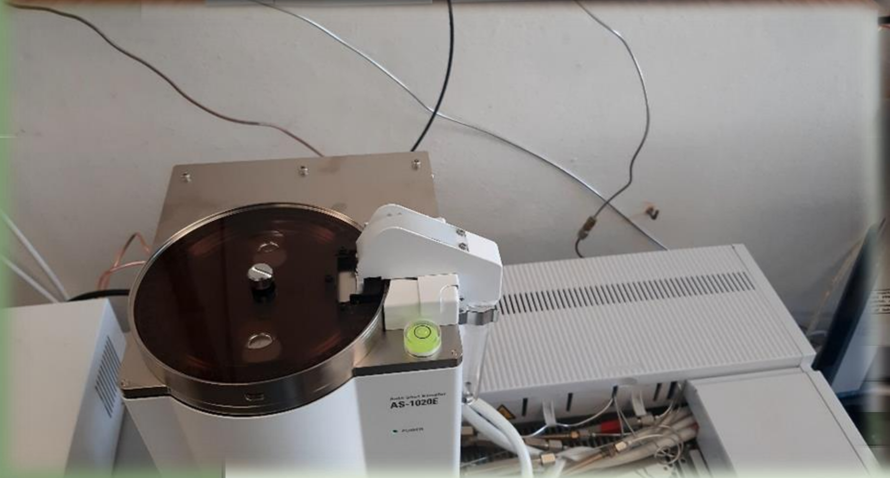
Equipment

GC-MS-QP2010 ULTRA



Equipments purchased during the project

AUTO-SHOT SAMPLER
(AS-1020E)



Common server in TTK

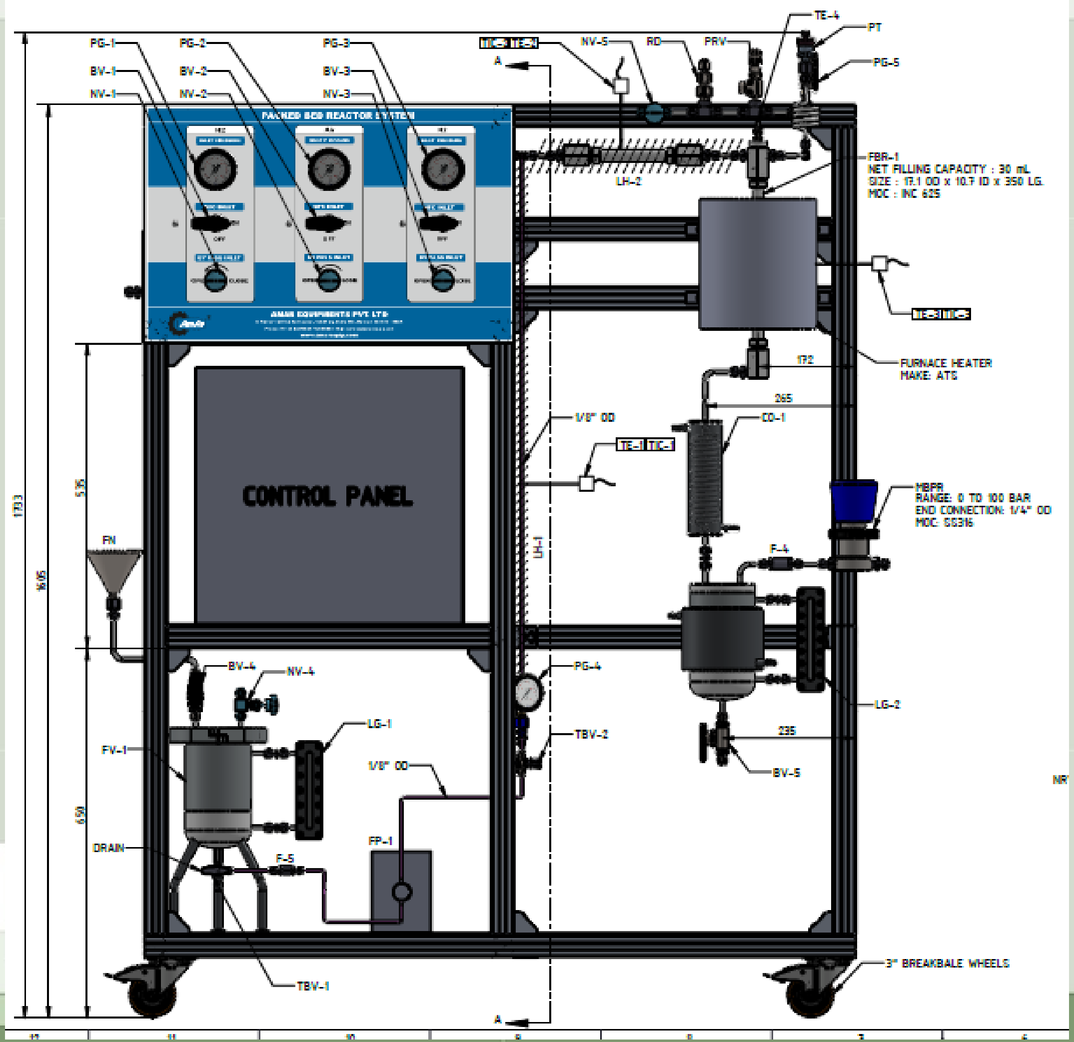
Synology DS920+ NAS desktop

Advanced Polymer Chromatograph (APC)/
Ultra High Performance Liquid Chromatograph (UHPLC)

Equipments purchased during the project

- Batch reactors

The planned tube reactor



Thank you again for your attention !