Integrated process for PHA production from lignocellulosic waste: A new anaerobic biorefinery

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Context

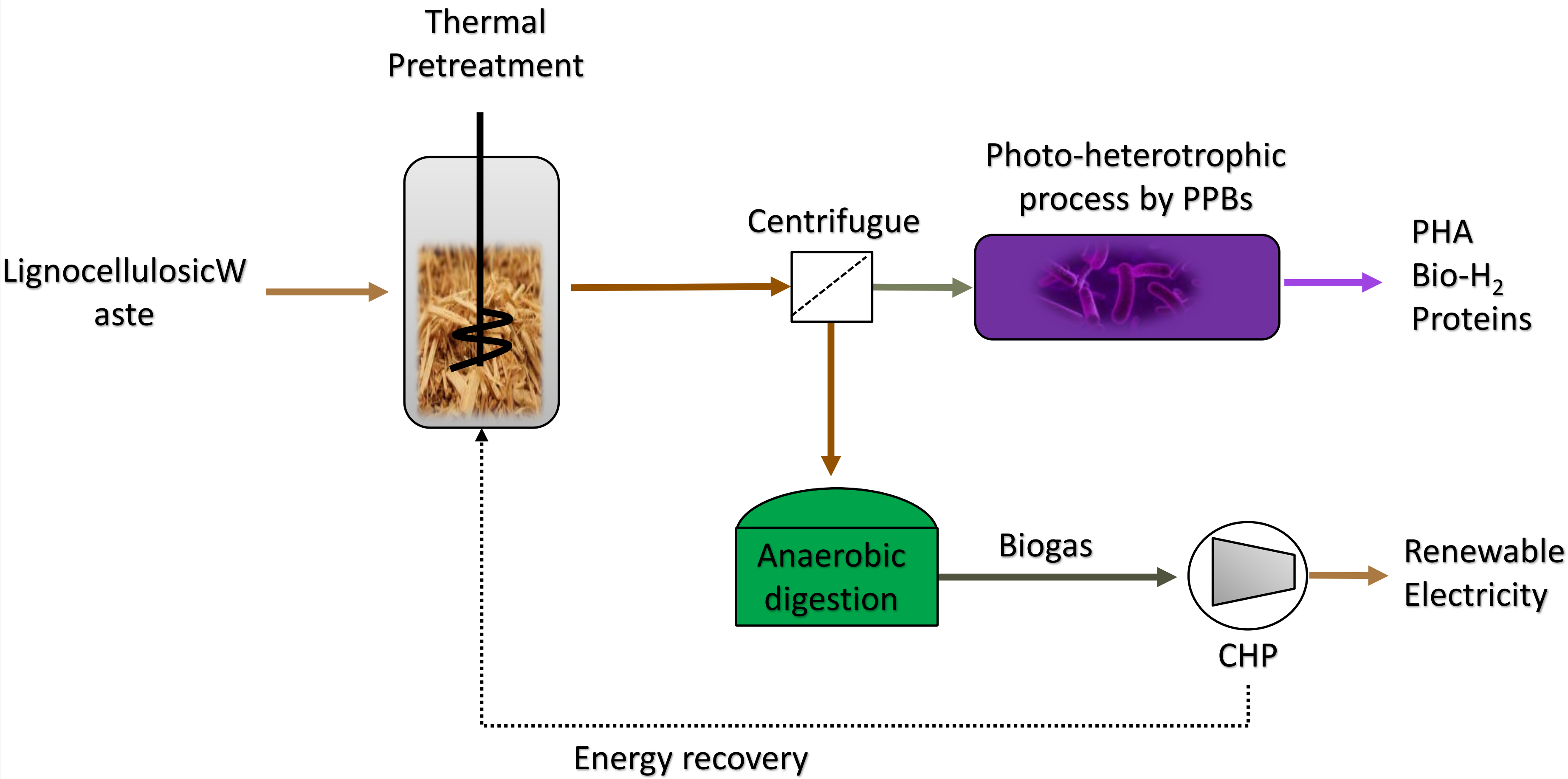
Lignocellulosic waste

The upcycling of waste biomass into high-added value products can be an attractive route for attaining the circular bio-economy as well as environmental sustainability

1. Most abundant natural renewable resource
2. Agricultural, forest, and municipal waste
3. Does not compete with food production

Context

Photo-biorefinary



Material and methods

Lab-scale proof of concept

Pruning waste

120 – 150 – 180 ºC
1:5 water to SV ratio

Severity factor:

$$Ro = \int_0^t exp\left(\frac{T(t) - \mathrm{TRef}}{14.75}\right) dt$$

R_o: 2.1 – 3.1 – 3.9

Specific Phototrophic Activity Test (SPA)

Conditions:
45 W m^{-2} IR Light
1 g DQO L^{-1}
PPB inoculum

Standard BMP test

Results

Thermal hydrolysis

- Crystallinity increase(CR_I)

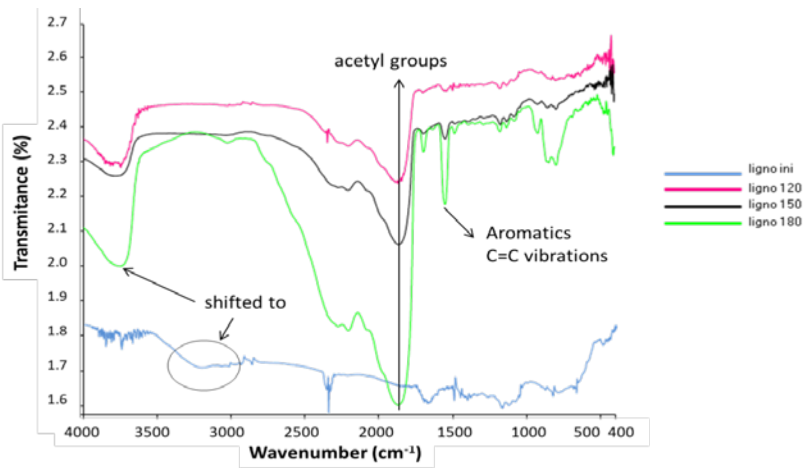


Figure 1: FTIR spectra of the three hydrothermal pretreatments, 120(pink), 150 (black) and 180 ºC (green) and initial (blue) solid phases.

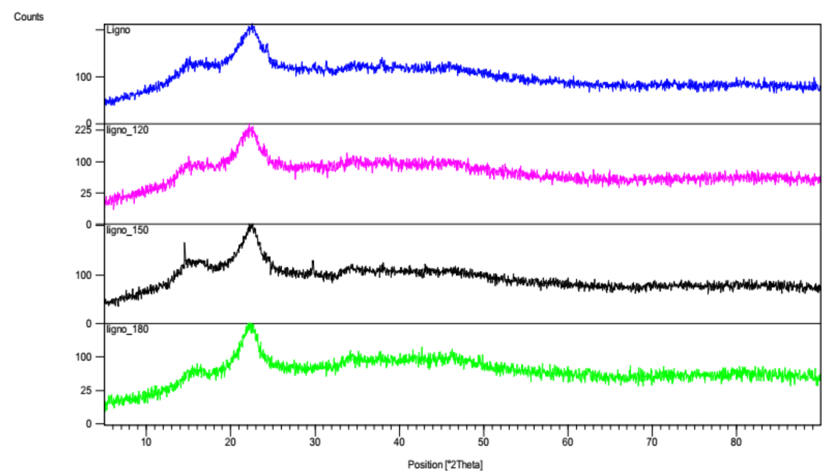


Figure 2: Comparison of DRX spectra of the raw waste (blue) and the hydrothermal pretreatments solid phases were 120 (pink), 150 (black) and 180 ºC (green).

- Solid destruction: 13-29%
- COD solubilization: 9-24%
- DQO/N/P: 100/3/0.5

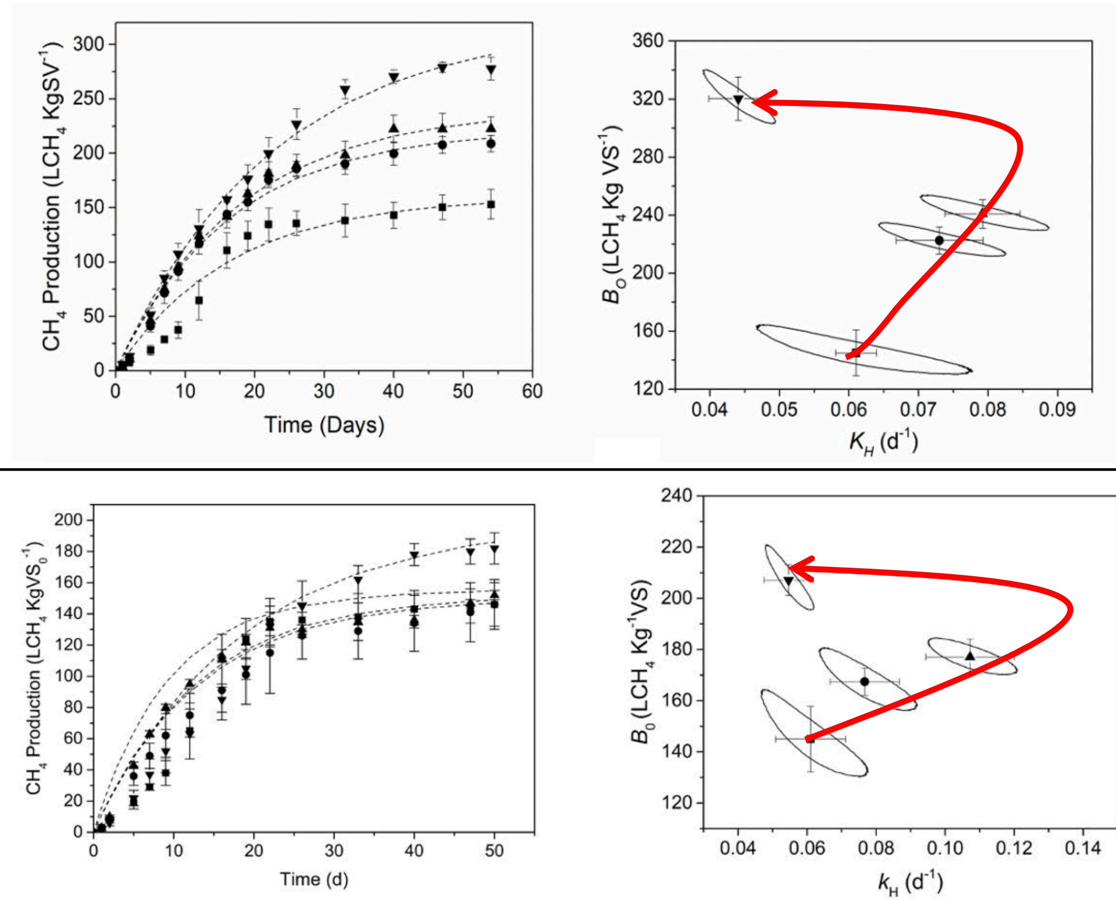
Allegue, L.D., et al. (2021), Integrated sustainable process for polyhydroxyalkanoates production from lignocellulosic waste by purple phototrophic bacteria. GCB Bioenergy, 13: 862-875.

Results

Anaerobic digestion

No elimination of liquid fraction

Elimination of liquid fraction



Control
120ºC
150ºC
180ºC

Potential presence of inhibitory compounds abo
180 ºC.

Figure 3: BMP results and 95% confidence regions for the first-order kinetic parameters.

Allegue, L.D., et al. (2021), Integrated sustainable process for polyhydroxyalkanoates production from lignocellulosic waste by purple phototrophic bacteria. GCB Bioenergy, 13: 862-875.

Results

Energy integration balance

Table: Energy integration balance. Results were simulated for a combined heat and power (CHP) system for electricity and thermal energy production.

Substrate	Total Energy biogas kWh t^{-1}	Thermal Output kWh t^{-1}	Electrical Output kWh t^{-1}	Thermal energy required kWh t^{-1}	Electrical balance kWh t^{-1}	Thermal energy balance kWh t^{-1}	Electric output Euro t^{-1}
Raw	1343	739	443		428	739	64
TH-120°C	1343	739	443	154	408	585	61
TH-150°C	1398	769	461	177	426	592	64
TH-180°C	1693	931	559	210	524	721	79

Positive electrical and thermal balances

Allegue, L.D., et al. (2021), Integrated sustainable process for polyhydroxyalkanoates production from lignocellulosic waste by purple phototrophic bacteria. GCB Bioenergy, 13: 862-875.

Results

Photoheterotrophic process

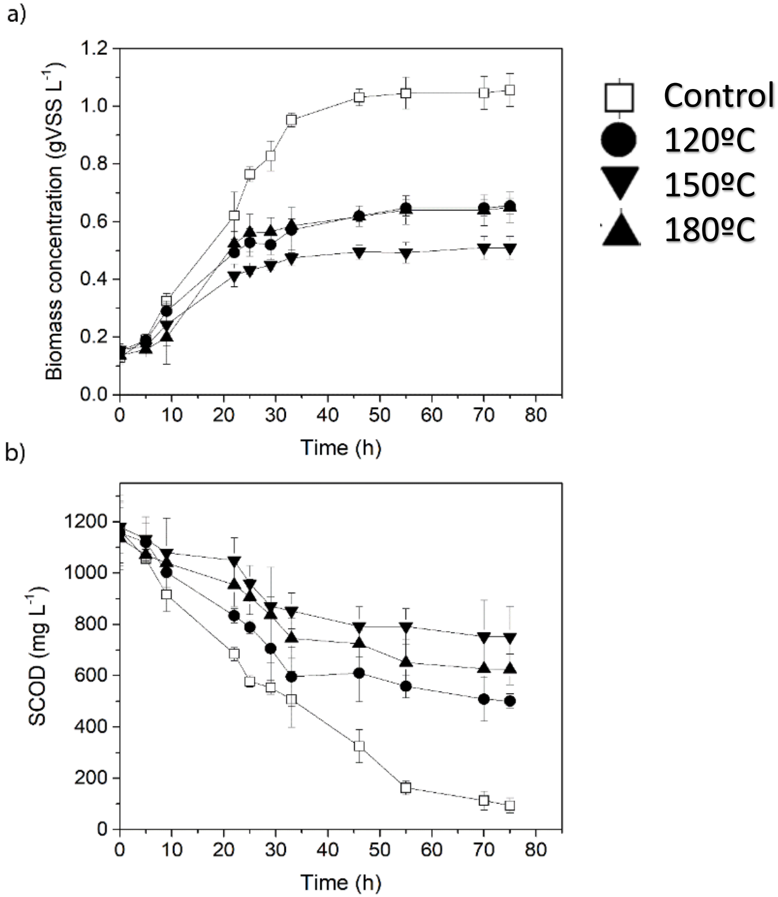


Figure 4: Comparison of biomass growth (a) and SCOD consumption (b) in the SPA tests using the liquid fraction

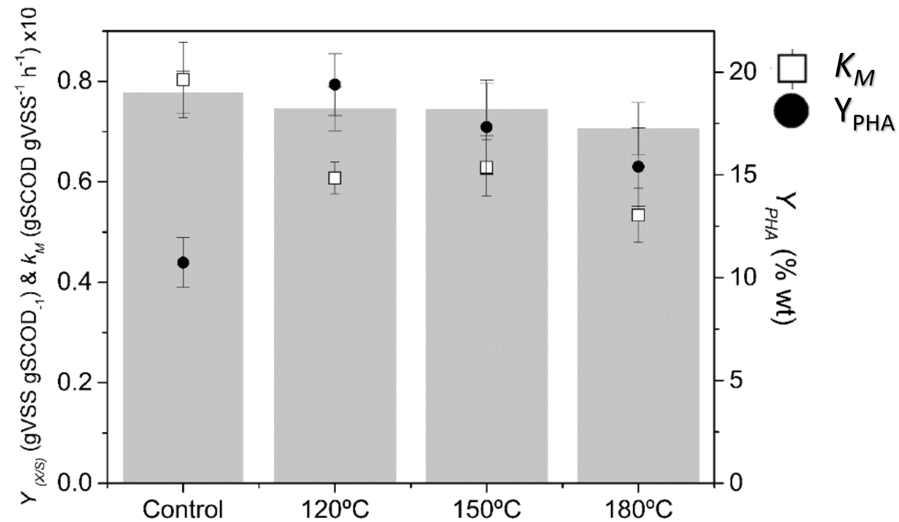


Figure 5: Comparison of biomass yield (YX/S) (columns) with specific phototrophic activity (kM × 10) (open squares) and PHA production yield (YPHA) (black circles) in SPA tests

- 37-60% COD consumption
- Nitrogen limitation
- 15-20% PHA in dry mass

Allegue, L.D., et al. (2021), Integrated sustainable process for polyhydroxyalkanoates production from lignocellulosic waste by purple phototrophic bacteria. GCB Bioenergy, 13: 862-875.

Discussion

Prospects and industrial implications

- Current industrial PHA cost: ≈ 4-8 € t^{-1}
- The theoretical maximum PHA production yield reported by PPBs is 0.9 $mol_{PHA}\ mol_{Acetate}^{-1}$ *. This is vastly higher than any aerobic processes

*Fradinho, et al.. (2016). Beyond feast and famine: Selecting a PHA accumulating photosynthetic mixed culture in a permanent feast regime. Water Research, 105, 421–428.

Conclusions

Key findings

- High temperatures in the thermal pre-treatment lead to better solubilisations, but may produce inhibitory products.
- Up to 180 LCH_4 Kg VS^{-1} produce in BMP test after removal of liquid fraction
- An energetically sustainable process is achieved.
- Up to 20% PHA in dry mass is accumulated by PPB
- The PPB integrated biorefinery concept offers potential for the reduction of PHA production costs, inviting for future research

Thank you!

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