High-yield furfural production from rice husk via two-step process and green solvent system

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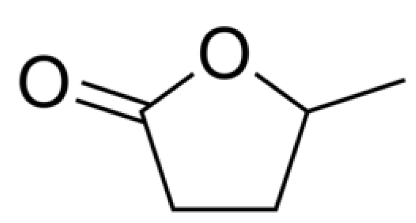
Introduction

This study is part of a broader initiative to develop a biorefinery concept for rice husk (RH), an abundant by-product of rice milling. Due to its hemicellulose content, RH is a promising feedstock for furfural, a pivotal platform chemical. Emerging two-step routes with green solvents outperform conventional single-step production by improving efficiency, lowering environmental impact, and enabling better biomass valorization.

Materials and methods



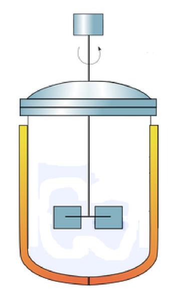
γ-Valerolactone (GVL)

A versatile green solvent derived from cellulosic biomass through levulinic acid hydrogenation. Renewable, biodegradable, and non-toxic, GVL offers a sustainable alternative to conventional solvents.

Rice Husk

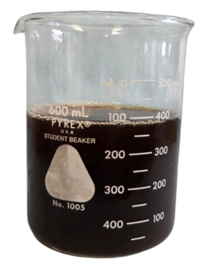
Glucan: 34.0 ± 1.3 %
Xylan: 16.8 ± 0.9 %
Arabinan: 1.3 ± 0.1 %
Lignin: 20.6 ± 0.1 %
Acetyl groups: 2.8 ± 0.1%
Extractives: 9.5 ± 0.0%
Ash: 15.0 ± 0.9%
Strach: 2.7 ± 0.4%

Autohydrolysis



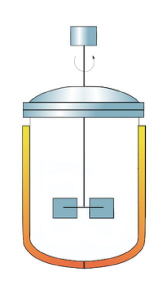
Temperature: 180 °C
Time: 30 min
Solid-liquid ratio: 1-5

Autohydrolysis liquor



Glucose: 3.87 ± 0.01 g/L
Xylose: 16.87 ± 0.05 g/L
Arabinose: 1.84 ± 0.01 g/L
Formic acid: 0.55 ± 0.01 g/L
Acetic Acid: 8.57 ± 0.31 g/L
HMF: 0.18 ± 0.03 g/L
Furfural: 1.31 ± 0.03 g/L

Hydrolysis



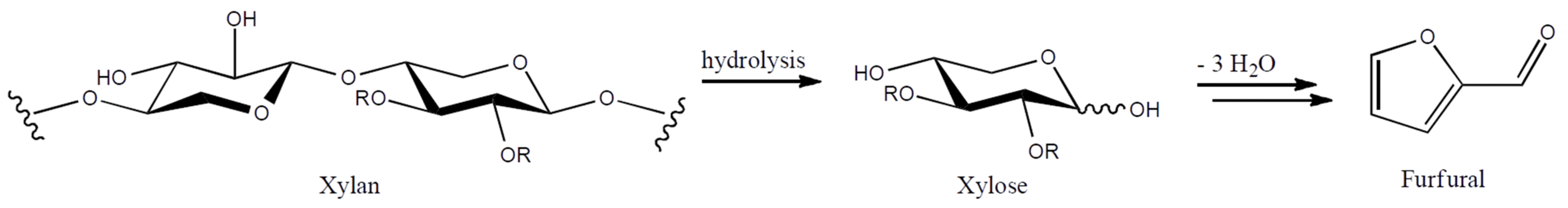
Temperature: 160, 170°C
Time: 20 min
GVL: 60, 80 %
H_2SO_4: 1.0, 1.5 2.0 %

Furfural

Chemical composition using NREL protocols. 1.A. Sluiter et al. (2008). NREL/TP-510-42618 1.A. Sluiter et al. (2008). NREL/TP-510-42619 1.A. Sluiter et al. (2008). NREL/TP-510-42622 1.A. Sluiter et al. (2008). NREL/TP-510-42623

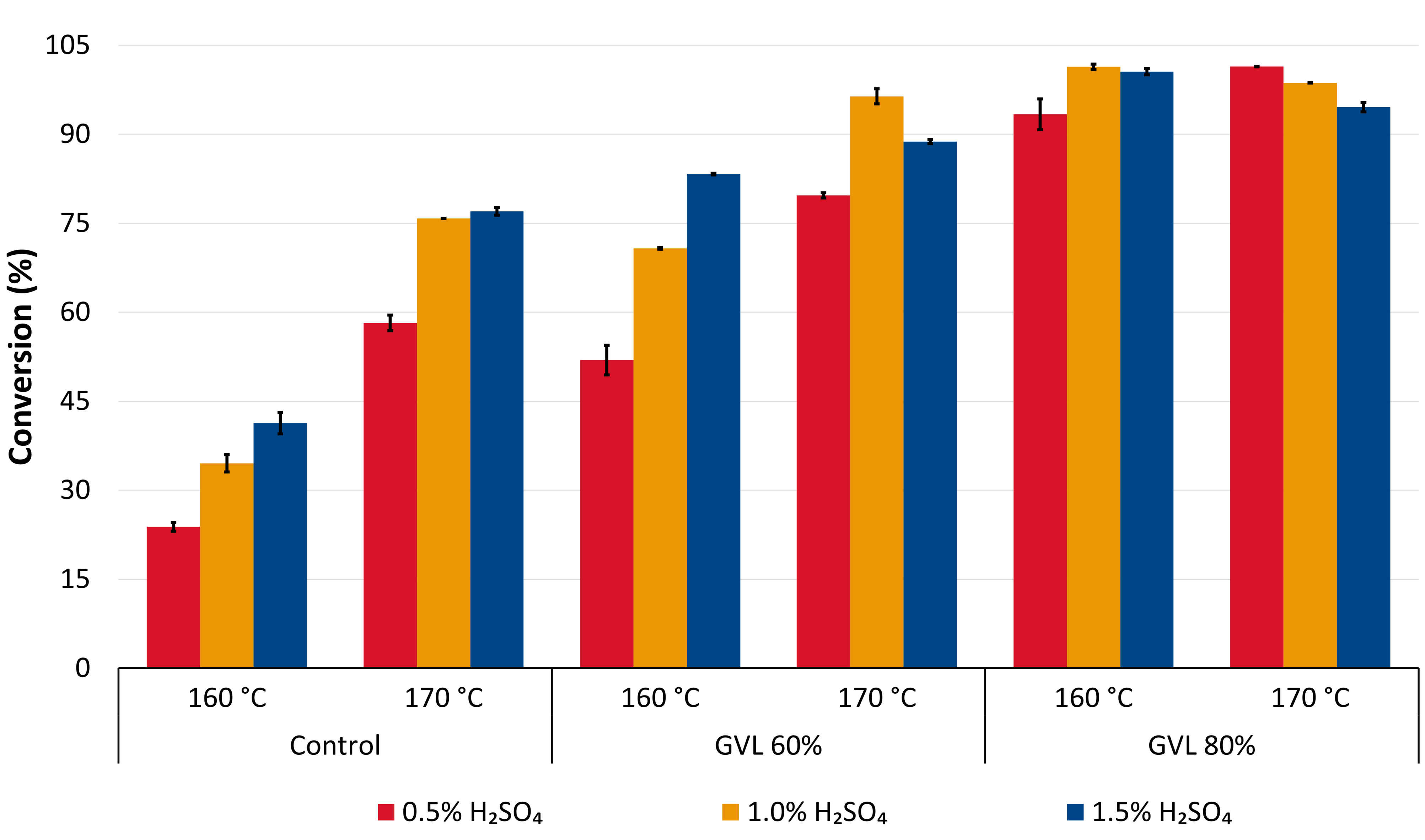
Results and discusions

The stoichiometric conversion of xylose to furfural was used as the basis for yield calculations.



Xylan hydrolysis into xylose and xylose dehydration into furfural

Xylose Conversion to Furfural under GVL/Water and Acid Conditions



- **Comparison with Control**
  - Conversions without GVL were significantly lower. The addition of **GVL** markedly **enhances performance**.
- **GVL Content**
  - At 60% GVL, conversions reached 80–96% at 170 °C and 52–83% at 160 °C, indicating that **high solvent concentrations** are **NOT always essential** for substantial yields.
- **Effect of Temperature**
  - Raising temperature from 160 °C to 170 °C **improved conversions** across all conditions, reflecting faster dehydration kinetics.
- **Influence of Acid Concentration**
  - Higher H_2SO_4 levels (0.5–1.5%) **boosted conversions**, but gains were marginal beyond 1.0%, with optimal performance at this intermediate concentration.
- **GVL–Acid Synergy**
  - The results confirm a **synergistic effect**, where GVL facilitates furfural stability, complementing acid-catalyzed dehydration.
- **Practical and Industrial Considerations**
  - While the best yield was obtained with 80% GVL, its cost and recovery are limiting factors. Therefore, the condition of 170 °C + 60% GVL + 1.0% H_2SO_4 stands out as the **most practical option for scaling up.**

These findings advance furfural production from rice husk hydrolysates, promoting greener, high-yield biorefineries under mild conditions. Future work should address furfural separation and GVL recycling.

Conclusions

- Two-step process shows strong technical potential for converting rice husk into furfural, achieving yields above 90% under relatively mild conditions.
- The combination of 170 °C, 60% GVL, and 1.0% sulfuric acid stands out as a practical and promising alternative
- It confirms the synergistic effect between GVL and acid in enhancing conversion.

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