Waste biorefinery technologies for accelerating sustainable energy processes

BIOREFINERY APPROACH FOR PRODUCING BIOFUELS AND BIOPOLYMERS FROM RESIDUES OF QUINOA HARVEST AND PROCESSING

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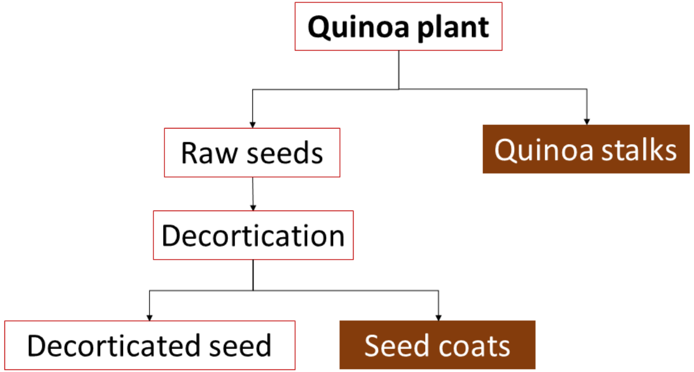
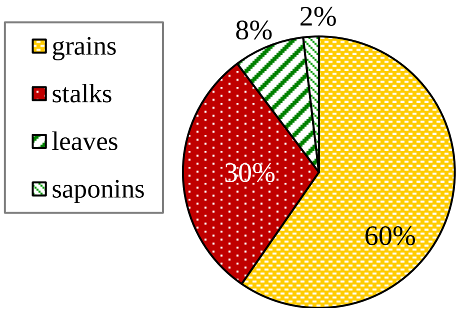
Outline

- Quinoa residues as biorefinery feedstocks
- Our research on biorefining of quinoa residues
- Halotolerant bacteria for production of biopolymers
- Our quinoa biorefinery vision

Quinoa residues as biorefinery feedstocks

Quinoa (*Chenopodium quinoa* Willd.) is widely cultivated in Bolivia (*~70 000 tons in 2019)*

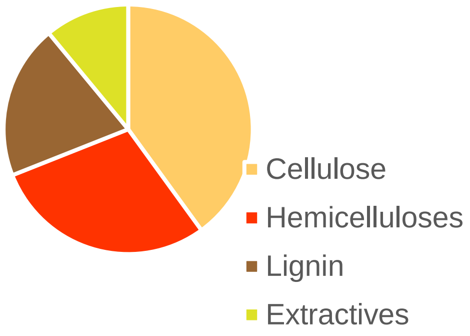


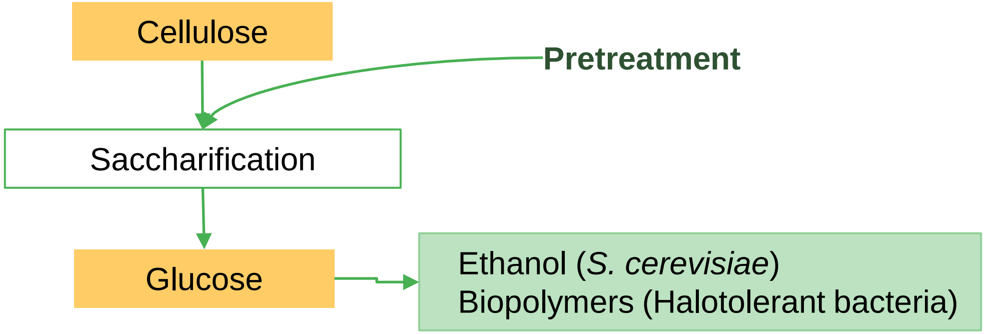


Quinoa stalks are rich in carbohydrates, abundant, cheap, and renewable – **Potential feedstock** for sugar platform-based bio-products

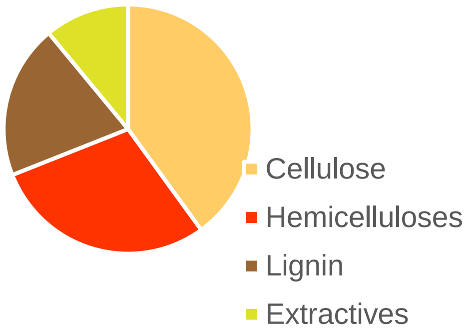
Quinoa seed coatings are rich in saponins – are also of interest in biorefining

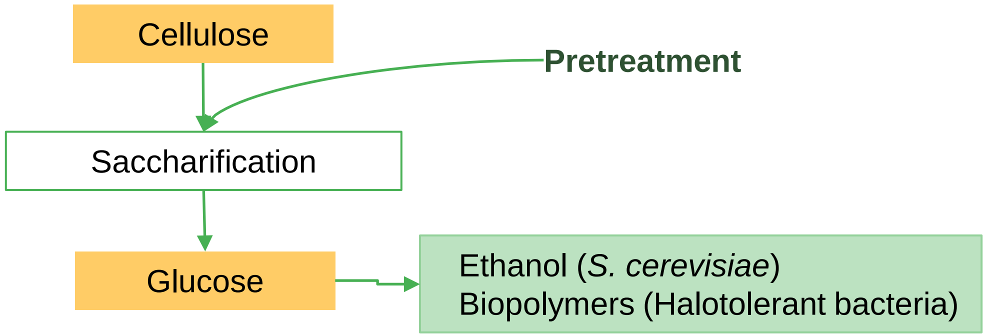
Quinoa stalks biorefinery routes

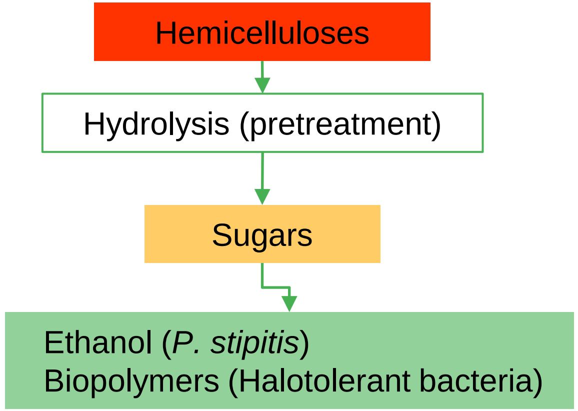




Quinoa stalks biorefinery routes







Quinoa stalks biorefinery routes

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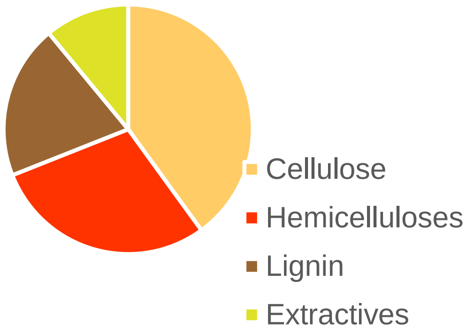
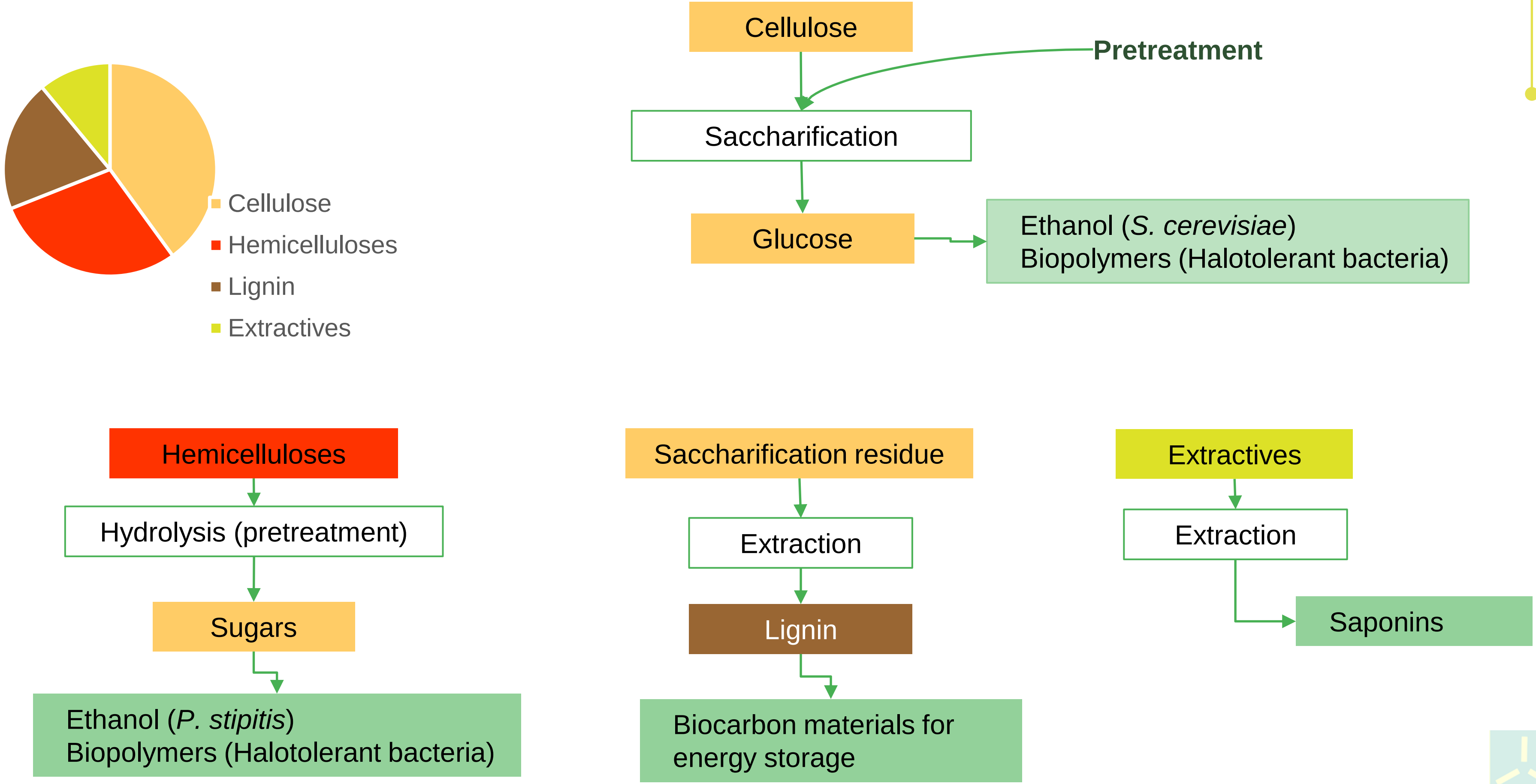


Cellulose → Saccharification (Pretreatment) → Glucose → Ethanol (*S. cerevisiae*) / Biopolymers (Halotolerant bacteria)

Hemicelluloses → Hydrolysis (pretreatment) → Sugars → Ethanol (*P. stipitis*) / Biopolymers (Halotolerant bacteria)

Saccharification residue → Extraction → Lignin → Biocarbon materials for energy storage

Quinoa stalks biorefinery routes



Our research on biorefining of quinoa residues

Extraction of saponins from seed coatings

Evaluation as enhancers of enzymatic saccharification and in soil bioremediation

Oliva-Taravilla et al.
Molecules 25, 3559, 2020

Hydrothermal pretreatment of quinoa stalks

Enzymatic saccharification of hydrolysates

Carrasco et al.
Energies 14, 4102, 2021

Microbial fermentations

Biopolymers (EPS by *B. atrophaeus* and PHB by *H. boliviensis*)

Ethanol *by S. cerevisiae* and *P. stipitis*

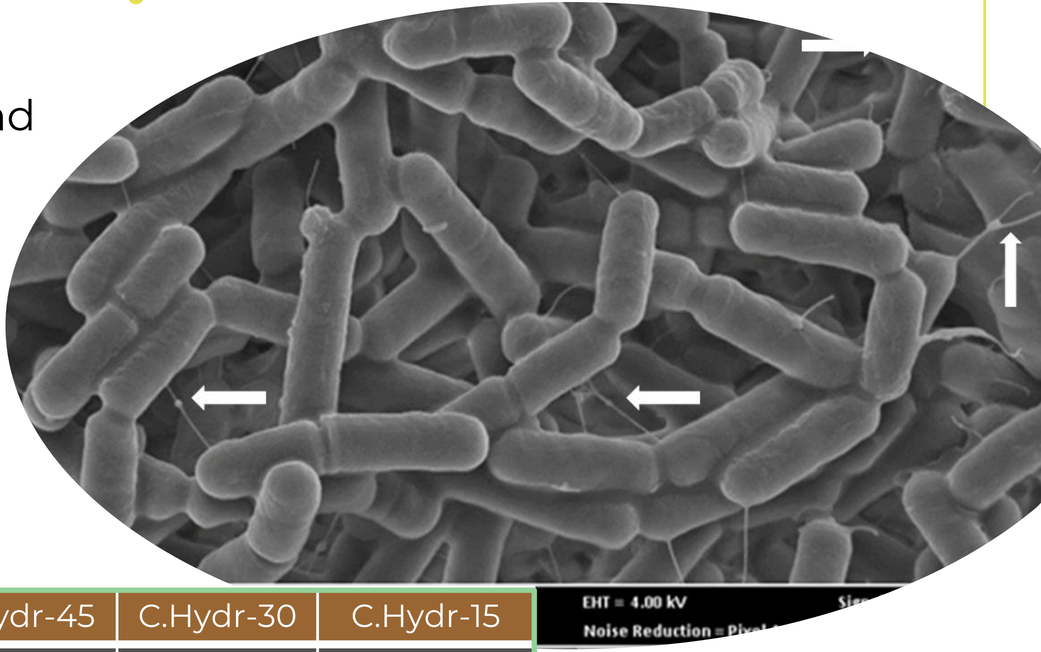
Chambi et al.
Fermentation 8, 79, 2022

Halotolerant bacteria

- Isolated from Bolivian Altiplano
- Produce biopolymers, e.g., **exopolysaccharides** (EPS) as adaptive mechanism to support growth under high salinity
- *Halomonas boliviensis, Halomonas andesensis,* ***Bacillus atrophaeus***

Bacillus atrophaeus BU4

- Cultivated in synthetic media and in hydrolysates (cellulosic and hemicellulosic) of quinoa stalks



Glucose-based media

	GSM-45	GSM-30	GSM-15	C.Hydr-45	C.Hydr-30	C.Hydr-15
Glucose	45	30	15	45	30	15
Xylose	5			5	3.3	1.7

Xylose-based media

	XSM-16	XSM-8	HC.Hydr-16	HC.Hydr-8
Xylose	16	8	16	8

Cultivation of *B. atrophaeus* BU4

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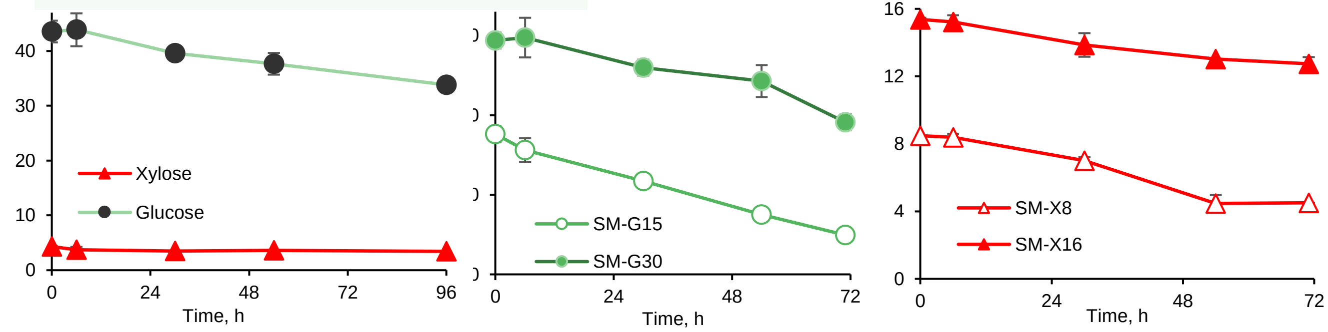
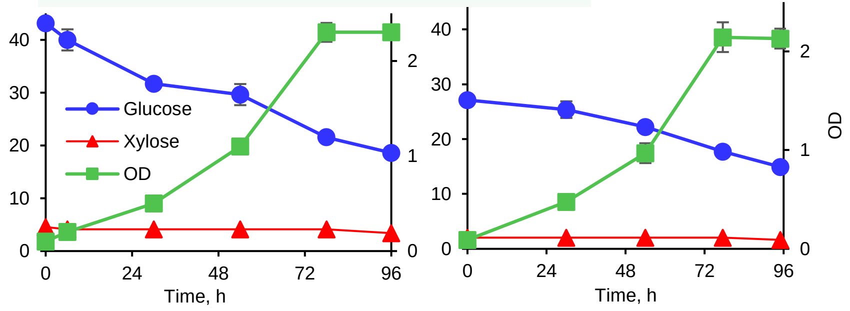
Cultivation in synthetic media

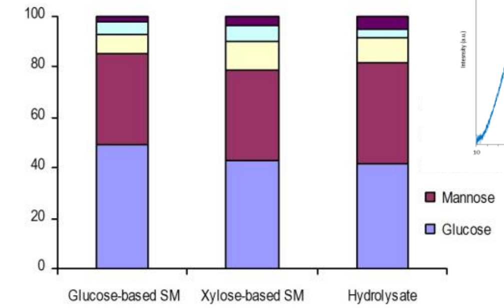


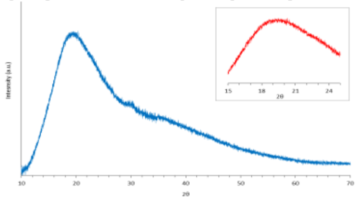
Cultivation in hydrolysate

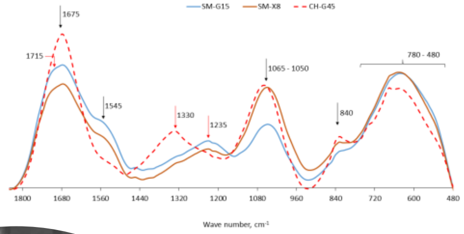


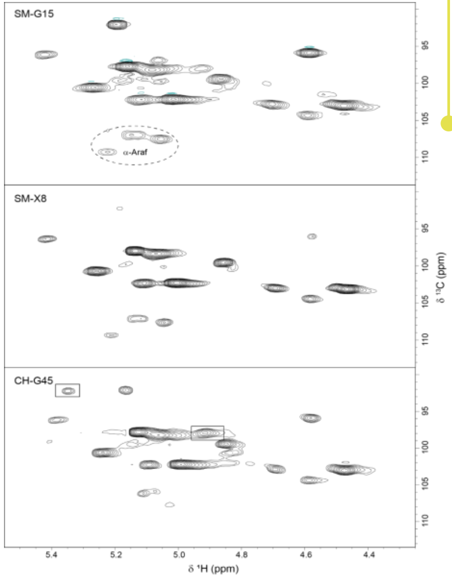
- Higher glucose consumption than that of xylose
- More dynamic cultivations at lower initial sugar concentrations
- EPS yield per consumed sugar increased with decrease of initial concentration
- EPS yield slightly higher for glucose
- EPS yield comparable in SM and hydrolysate

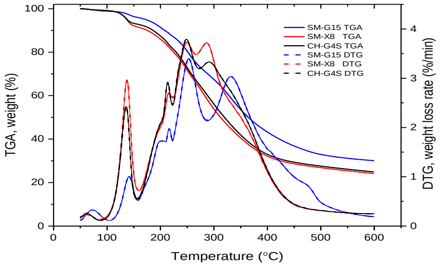
EPS characterization

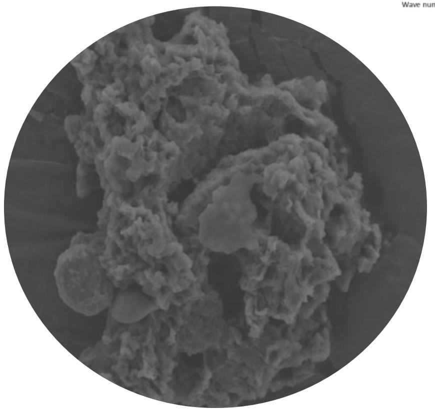






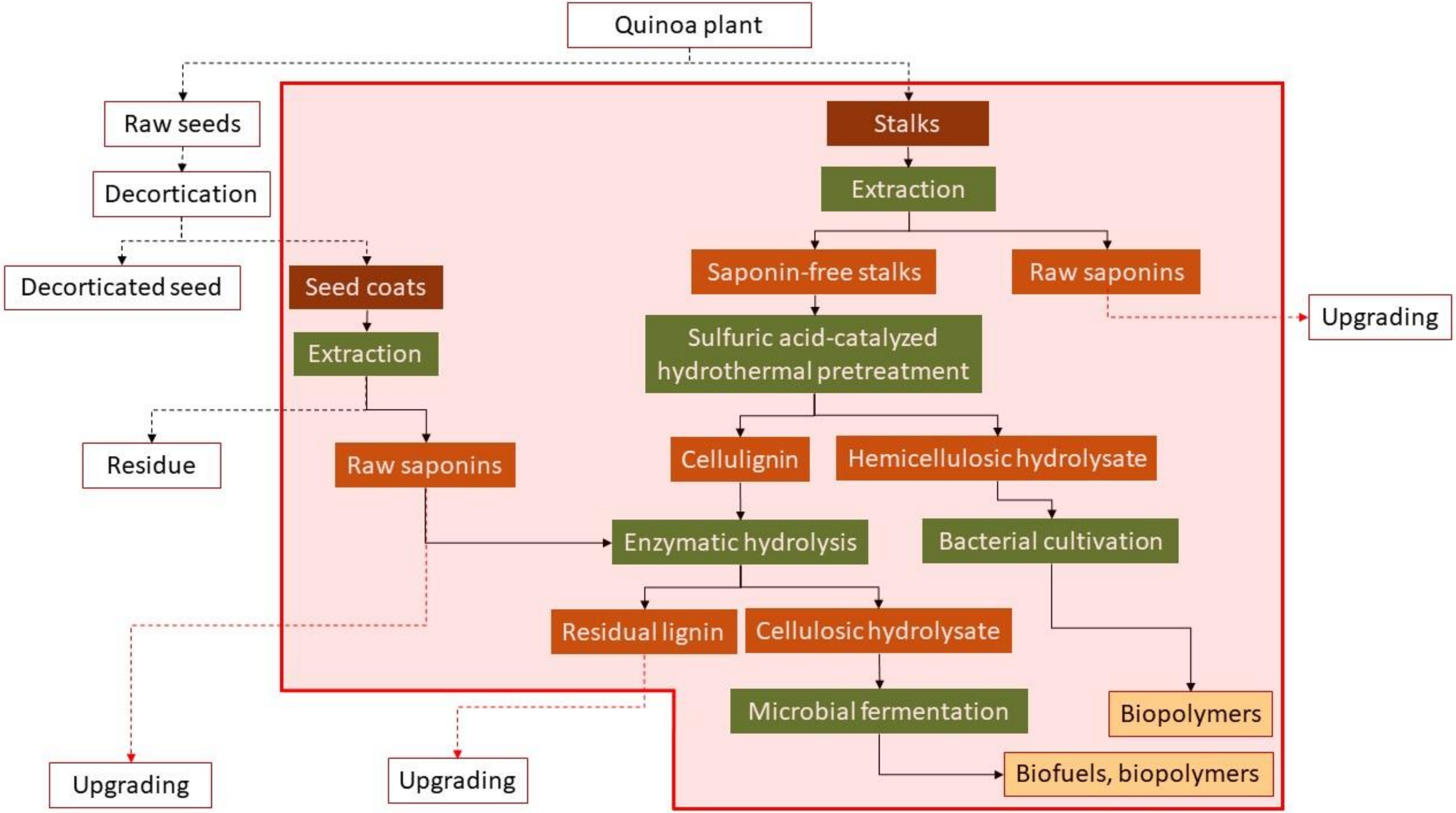






- ✓ NMR, HPSEC, FTIR, SEM and TGA revealed similarities between EPS from glucose- and xylose-based synthetic media
- ✓ EPS from cellulosic hydrolysates are slightly different
- ✓ Good thermal stability, amorphous nature, and water-retention capacity
- ✓ Useful features for applications in the food and pharmaceutical industries

Our quinoa biorefinery vision



Final remarks

Biorefining of quinoa residues for producing biofuels and biopolymers deserves attention as an industrialization alternative for quinoa-producing areas, e.g., Bolivian Altiplano

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Removal of saponins is a favorable strategy for improving the effectiveness of hydrothermal pretreatment of quinoa stalks.

Final remarks

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Quinoa saponins are effective additives for enhancing enzymatic saccharification of pretreated lignocellulose.

Final remarks

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Removal of saponins is a favorable strategy for improving the effectiveness of hydrothermal pretreatment of quinoa stalks.

EPS produced from quinoa stalk hydrolysates using halotolerant *B. atrophaeus* BU4 exhibit useful features for applications in the food and pharmaceutical industries

Quinoa saponins are effective additives for enhancing enzymatic saccharification of pretreated lignocellulose.

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Thanks a lot, dear friends!
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Special issue announcements

- ✓ “**Chemistry in biorefineries**” – *RSC Advances* https://blogs.rsc.org/ra/2022/05/26/call-for-papers-chemistry-in-biorefineries/
- ✓ "**Pretreatment and Bioconversion of Crop Residues II**“ – *Agronomy* https://www.mdpi.com/journal/agronomy/special_issues/crop_residues
- ✓ “**Lignocellulosic biomass II**” – Molecules https://www.mdpi.com/journal/molecules/special_issues/lignocellulosic_II