Valorizing the functional potential of cereal biomass: emerging fractionation strategies toward green processing

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BACKGROUND

Cereal grains are nutrient-rich, climate-resilient biomass with potential for recovery of proteins, β-glucans, fibers, lipids and phytochemicals.[1,6] Conventional processing often follows linear pathways, leaving valuable fractions underutilized.[2,3]

Sustainable fractionation can convert cereal biomass into functional food ingredients while improving resource efficiency and reducing waste.[4,6]

LITERATURE INSIGHTS

CONCEPT	KEY MESSAGE	WHAT IT MEANS
Whole grain and side-stream → functional fractions	Fractionation allows targeted recovery and enrichment of components	Whole grain & side-stream → Fractionation → Functional fractions: Proteins, β-Glucans, Fibres, Phytochemicals
Green fractionation is advancing	Ultrasound, enzymatic and hybrid approaches → improve efficiency and selectivity Non-thermal methods → preserve functional properties and reduce process intensity	Ultrasound; Enzymatic; Hybrid approaches; Non-thermal methods → Better functionality, Lower intensity
From extraction to biorefinery	Synergistic recovery, fraction precision and yield optimization → emerging priorities Most reported processes – linear than integrated biorefinery systems	Linear pathway: Single product, More waste VS Integrated biorefinery: Multiple products, Resource efficient

Green extraction technologies are promising, but the link between **process conditions**, **selective recovery** of multiple cereal biopolymers, and **sustainable biorefinery integration** remains insufficiently explored.

KEY AREA	WHAT IS KNOWN	WHAT IS MISSING / GAP	WHY IT MATTERS
PROCESS CONDITIONS	Various green extraction methods have been reported.	Systematic **optimization** of key **conditions** for cereal matrices is limited.	Condition–performance relationships are essential for **efficient, scalable** process design.
SELECTIVE RECOVERY	Proteins and β-glucans can be extracted from cereals.	**Selective, simultaneous recovery** of multiple biopolymers is rarely optimized.	Enables production of **multiple functional ingredient streams** with higher value.
BIOREFINERY INTEGRATION	Concepts of cereal biorefineries are proposed.	Few studies connect extraction steps with **whole-system biorefinery integration**.	Integration is key to **circularity** and **resource efficiency**.
SUSTAINABILITY EVIDENCE	Green solvents and non-thermal methods are emerging.	**Sustainability assessments (<5%)** are scarce.	**Environmental and economic impacts** are unknown.

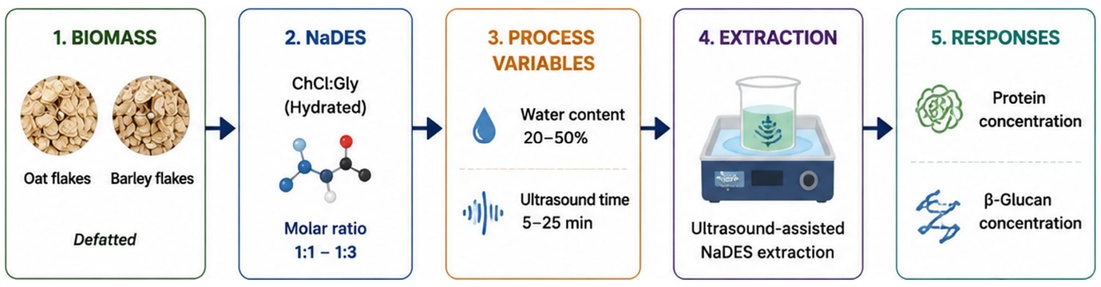
THIS STUDY: ADDRESSING THE GAP

Ultrasound + hydrated ChCl:Gly NaDES → Optimized extraction → Protein- and β-glucan-rich fractions → Oat optimization + Barley comparison

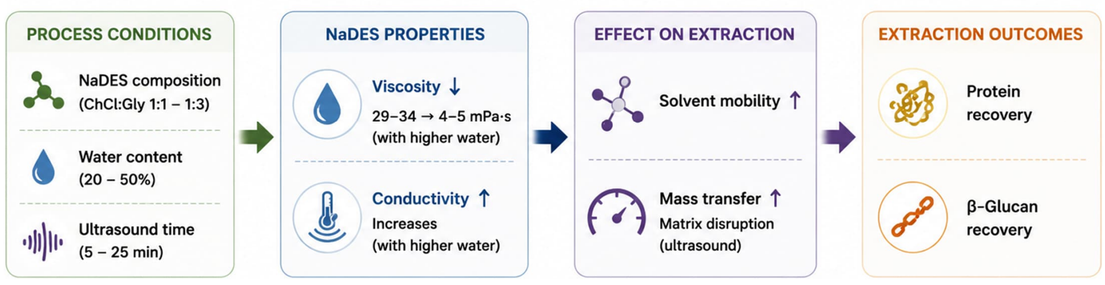
CENTRAL QUESTION

*Can NaDES-assisted ultrasound extraction be **optimized** to improve the **selective recovery** of valuable cereal biopolymers?*

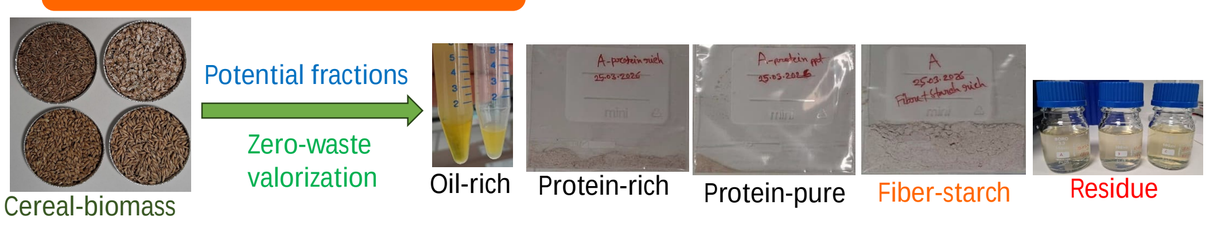
APPROACH

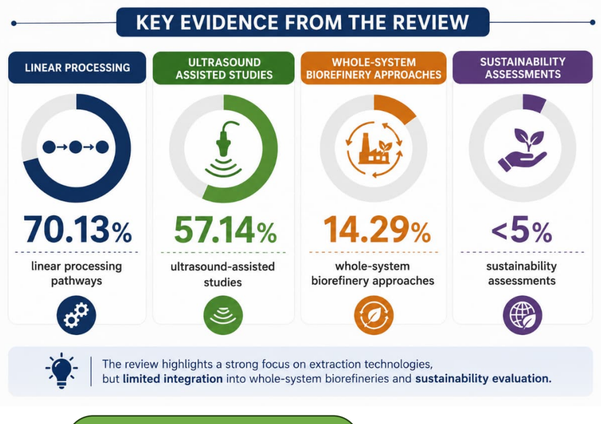


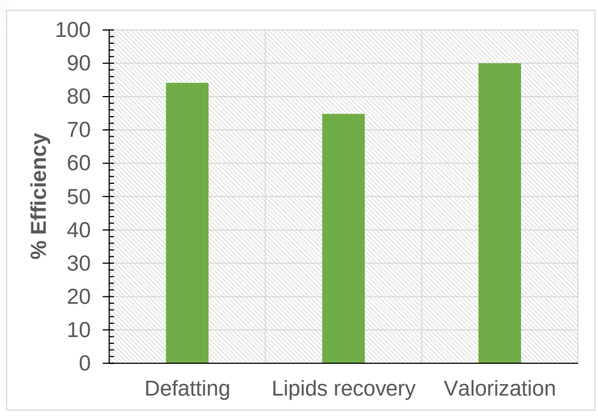
Process conditions → NaDES properties → Mass transfer → Selective recovery



RESULTS







RSM optimization
R2 = 80%
Lack-of-fit (p>0.05)
Validation: alignment

Water
Protein: moderate (oat > barley)
B-glucan: higher (barley > oat)

Cereal matrix influences extraction behavior

Target	Oat: highest observed response	Barley: highest observed response	Interpretation
Protein	17.51 g BSA eq./100 g DW	4.84 g BSA eq./100 g DW	Oat showed substantially higher soluble protein recovery
β-Glucan	0.0813 g/100 mL	0.1139 g/100 mL	Barley showed higher β-glucan concentration

Biomass	Protein-favoring condition	**β**-Glucan-favoring condition
Oat	1:3 ChCl:Gly + 35% water + 25 min US	1:3 ChCl:Gly + 50% water + 15 min US
Barley	1:2 ChCl:Gly + 35% water + 15 min US	1:3 ChCl:Gly + 50% water + 15 min US

The results demonstrate that NaDES hydration and solvent composition strongly influence cereal fractionation, with target- and matrix-specific responses highlighting the need for selective process optimization to recover multiple functional biopolymer fractions.

TAKEAWAYS

LIMITATIONS	→	FUTURE	→	CONCLUISION
Lab scale	→	Scale-up	→	Green fractionation is feasible
No LCA/TEA	→	LCA + TEA	→	Water content is a key driver
No NaDES recycling	→	Solvent recovery	→	Protein ≠ β-glucan optimum
Functionality not tested	→	Food validation	→	Selective recovery needs targeted optimization

FUNDING

This work is a part of the KooRuoKo project (Korkean osaamisen ja kestävän ruokasysteemin Kouvola), funded by Kymenlaakson liitto under the AKKE appropriation (Alueiden kestävän kasvun ja elinvoiman tukeminen- Äkilliseen rakennemuutostilanteeseen vastaaminen, ÄRM).

Reference

1. Gazza, Laura, and Francesca Nocente. 2023. “The Contribution of Minor Cereals to Sustainable Diets and Agro-Food Biodiversity.” Foods. doi:10.3390/foods.
2. Grasso, Simona. 2020. “Extruded Snacks from Industrial By-Products: A Review.” Trends in Food Science and Technology 99:284–94.
3. Hassan, Gul, Muhammad Asim Shabbir, Farah Ahmad, Imran Pasha, Noman Aslam, Talha Ahmad, Abdur Rehman, Muhammad Faisal Manzoor, Muhammad Inam-Ur-Raheem, and Rana Muhammad Aadil. 2021. “Cereal Processing Waste, an Environmental Impact and Value Addition Perspectives: A Comprehensive Treatise.” Food Chemistry 363.
4. Perez-Vega, Samuel B. 2022. “Food Processing and Value Generation Align with Nutrition and Current Environmental Planetary Boundaries.” Sustainable Production and Consumption 33:964–77.
5. Tse, Timothy, and Martin J. T. Reaney. 2025. “Introductory Chapter: Cereal Crops.” in Exploring the World of Cereal Crops, edited by T. Tse. Rijeka: IntechOpen.
6. VYR. 2014. Production of Cereal and Oilseed Crops in Finland. The Finnish Cereal Committee.

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