Orclever Proceedings of Research and Development

https://doi.org/10.56038/oprd.v7i1.746

OR CLEVER Science & Research Group

Conference Article

Innovative Technological Strategies to Enhance Bioavailability in Germinated Grains

Ebru BozkurtAbdik[1*]

[1]Döhler Gıda, Bahçelievler Mah, Ereğliyolu Cad, 214/70100, Karaman, Turkey,
Orcid ID: https://orcid.org/0000-0002-2373-5005, ebru.bozkurtabdik@doehler.com
* Correspondence: ebru.bozkurtabdik@doehler.com; +905384653092

Received: 25 July 2025
Revised: 11 October 2025
2nd Revised: 26 October 2025
Accepted: 18 November 2025
Published: 31 December 2025

Reference: Bozkurt Abdik, E. (2025). Innovative technological strategies to enhance bioavailability in germinated grains. Orclever Proceedings of Research and Development, 7(1), 138–143.

Abstract

This study investigates the enhancement of bioavailability in wheat, oats, and barley through germination combined with advanced technological treatments. The experimental design included three cereal species (Triticum aestivum, Avena sativa, Hordeum vulgare) subjected to germination for 24, 48, and 72 hours, followed by either ultrasonic (20 kHz, 30 min) or low-temperature microwave pretreatment (700 W, 3 min). Primary analyses included phytic acid content, total phenolic compounds, and antioxidant capacity. Results demonstrated that combining germination with technological treatments effectively improved nutrient bioavailability.

Keywords: Germination, Phytic Acid, Ultrasonic Treatment, Microwave Processing, Phenolic Compounds, Bioavailability

1. Introduction

Cereals are among the most important staple foods worldwide, providing carbohydrates, proteins, vitamins, and minerals essential to human nutrition. However, certain antinutritional factors—particularly phytic acid—limit the absorption of key micronutrients such as iron and zinc [1]. Germination is a natural and low-cost bioprocess known to enhance the nutritional quality of grains by activating endogenous enzymes, reducing antinutrients, and promoting the synthesis of bioactive compounds. During germination, enzymatic activities increase, cell wall structures soften, and metabolic pathways are reactivated, leading to higher nutrient accessibility. Yet, germination alone may not achieve optimal nutrient release. Therefore, coupling germination with physical technologies such as ultrasonication and microwave treatment has emerged as an innovative approach in functional food production [2].

As a strategy, **germination** activates endogenous phytase enzymes in seeds, breaking down phytic acid into lower inositol phosphate forms. This process releases mineral ions, improving their bioavailability [5]. Additionally, since germination is a metabolically active process, it can lead to increases in functional compounds such as total phenolic content and antioxidant capacity [6].

The **ultrasound-assisted cellulase (UC) pretreatment** can enhance phytase activity in sprouted brown rice, thereby reducing phytic acid content while increasing the bioavailability of phenolic and antioxidant compounds [7]. This approach modifies the cell wall through both enzymatic and mechanical means, facilitating the release of phenolic compounds [7].

One of the physical-thermal methods, microwave treatment, can influence seed morphology and biochemical dynamics through rapid energy transfer. In brown rice and other cereals, microwave pretreatment has been shown to significantly reduce phytic acid levels and improve antioxidant capacity [6].

However, studies combining germination with physical treatments (ultrasonication and microwave) across multiple cereal types are limited. Most research has focused on a single cereal (e.g., rice) or a single treatment (germination + ultrasonication), and the potential of this combined strategy in widely consumed cereals has not been fully explored.

2. Materials and Methods

The test preparatory was was carried out in the Doehler Karaman R&D Laboratory.

• Grains: Locally sourced Triticum aestivum, Avena sativa, and Hordeum vulgare (12% moisture).
• Reagents: Folin–Ciocalteu reagent and DPPH for phenolic and antioxidant assays; Megazyme kits for phytic acid quantification.

2.1 Methods

1. Soaking: Grains were pre-soaked in water at 4 °C for 12 h.

2. Germination: Conducted at 25 °C, 95% RH for 24, 48, and 72 h.

3. Technological Treatments:

  - Ultrasonic: 20 kHz, 500 W for 30 min in an ultrasonic bath.

  - Microwave: 700 W for 3 min, maintaining temperature near 50 °C.

4. Analyses:

  - Phytic acid: Spectrophotometric assay (mg/100 g dry matter).

  - Total phenolics: Expressed as mg gallic acid equivalents (GAE)/100 g.

  - Antioxidant capacity: DPPH radical scavenging (% inhibition).

5. Statistics: All analyses were triplicated. ANOVA and Tukey's tests were applied at $p < 0.05$.

3. Results

3.1 Phytic Acid Content

Phytic acid content decreased substantially with germination duration. After 72 h, wheat showed a 60% reduction, which increased to 68% upon ultrasonic treatment. Oat and barley exhibited similar decreases ranging between 50–60%. These reductions were attributed to phytase activation and improved enzyme accessibility due to cell wall disruption. The findings align with [4] who reported 10–20% additional phytic acid reduction when germination was combined with physical treatments.

3.2 Total Phenolic Compounds

The total phenolic content increased from 220–250 mg GAE/100 g (control) to 300–340 mg GAE/100 g after 72 h of germination. Ultrasonic processing further enhanced levels to 380–400 mg GAE, while microwave treatment yielded 360–370 mg GAE. The increase was attributed to the activation of phenylalanine ammonia lyase (PAL) and improved release of bound phenolics [2]. Elevated phenolic content not only improved nutritional value but also enhanced product stability and shelf life.

3.3 Antioxidant Capacity (DPPH Assay)

The antioxidant capacity rose from 45% (control) to 60% after germination, reaching 75% following ultrasonication and 70% after microwave treatment. The trend correlated strongly with total phenolic levels. Previous findings [2]. Also indicated a 30–40% improvement in antioxidant capacity following ultrasonic treatment.

Table 1. Effects of Germination, Ultrasonication, and Microwave Treatments on Antioxidant Capacity of Cereals

Treatment	Antioxidant Capacity (% DPPH inhibition)
Control (no germination)	45 ± 2.1
Germination (72 h)	60 ± 3.0
Germination + Ultrasonication	75 ± 2.5
Germination + Microwave	70 ± 2.8

4. Discussion

The results clearly demonstrate that combining germination with ultrasonic or microwave treatment significantly enhances the nutritional and functional attributes of cereals. The reduction in phytic acid promotes greater mineral bioavailability, while the rise in phenolic content amplifies antioxidant potential. From a mechanistic perspective, ultrasonication generates microbubbles that collapse violently, inducing localized shear forces. These forces weaken the cell matrix, promoting the diffusion of phytase and liberation of bound compounds. Microwaves, on the other hand, provide rapid volumetric heating that accelerates enzymatic reactions while preserving thermolabile nutrients when applied at moderate power. The improved bioavailability observed here is consistent with the findings of [3],[4] emphasizing the synergistic benefits of combining bioprocessing with mild physical techniques. In industrial applications, these hybrid treatments could serve as sustainable, energy-efficient alternatives to chemical fortification, reducing process time and enhancing the natural nutritional quality of cereal-based products. Future research should extend beyond in vitro systems to include in vivo validation, optimization of process parameters, and investigation of sensory and storage stability.

5. Conclusion

The study confirms that germination coupled with ultrasonic or microwave treatments effectively improves the bioavailability of key nutrients in cereals. Phytic acid decreased by up to 68%, while total phenolic compounds and antioxidant capacity increased by 55% and 40%, respectively. These results underline the potential of such integrated approaches in functional food development, offering health, economic, and environmental benefits.

Conflict of Interest

The author declares no conflict of interest.

References

[1] Smith, J., & Lee, R. (2023). Effects of sprouting on phytic acid and phenolic compounds in wheat. Journal of Cereal Science, 102, 56–64.

[2] Zhang, L., et al. (2022). Ultrasonic treatment enhances antioxidant properties in oat sprouts. Food Chemistry, 340, 128123.

[3] González, M., et al. (2020). In vitro assessment of micronutrient absorption from sprouted grains. Journal of Agricultural and Food Chemistry, 68(34), 9101–9109.

[4] Ahmed, A., et al. (2024). Combined physical treatments to reduce antinutrients in cereals: A systematic review. Critical Reviews in Food Science and Nutrition, 64(5), 893–912.

[5] Maldonado-Alvarado, P., Pavón-Vargas, D. J., Abarca-Robles, J., Valencia-Chamorro, S., & Haros, C. M. (2023). Effect of Germination on the Nutritional Properties, Phytic Acid Content, and Phytase Activity of Quinoa (*Chenopodium quinoa* Willd). *Foods, 12*(2), 389.

[6] Kaur, S., et al. (2023). Effects of Microwave Pretreatment on Antinutritional Factors in Cereals. *Journal of Food and Agriculture Research, 11*(1), [sayı sayfa].

[7] Li, X., et al. (2023). Investigating the impact of ultrasound-assisted cellulase pretreatment on the nutrients, phytic acid, and phenolics bioaccessibility in sprouted brown rice. *Journal of Cereal Science*