A full insight into the valorization of wheat by-products

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1. Introduction

Wheat has been a cornerstone of human nutrition since its domestication over 10,000 years ago, contributing nearly 20% of the global calorie and protein intake [1,2]. However, the milling process generates substantial by-products—namely, wheat bran and wheat germ—that are often relegated to low-value uses despite their rich content of bioactive compounds. Each year, the milling process yields approximately 150 million tonnes of wheat bran and 25 million tonnes of wheat germ globally [3,4].

Recent advances in processing technologies, particularly enzymatic hydrolysis and fermentation, have opened new avenues for transforming these by-products into high-value ingredients for food, nutraceutical, cosmetic, and biodegradable packaging applications [5,6,7].

This poster provides a comprehensive review and comparative analysis of state-of-the-art processing methods, highlighting their potential to unlock the full nutritional and economic value of wheat by-products. By identifying current challenges and exploring sustainable processing techniques, our work brings a new perspective that could inspire future innovations in both industrial processing and circular economy practices.

2. Wheat grain

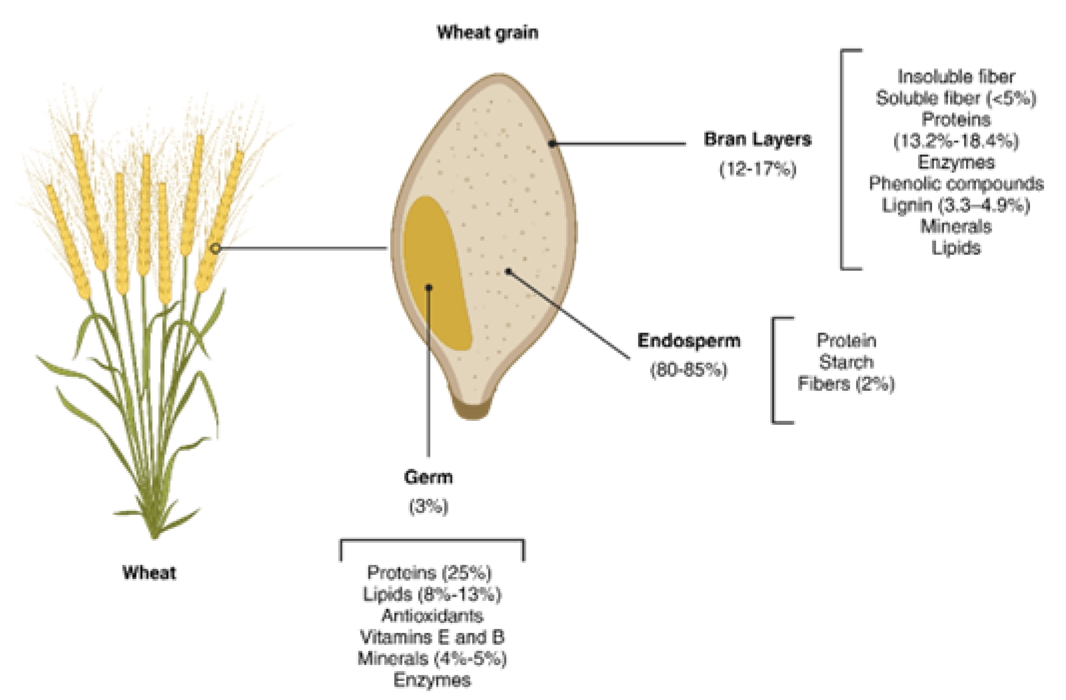

Figure 1. Chemical constituents in different parts of wheat grain. (inspired from) [3,4]

3. Processing methods

To maximize the valorization of wheat by-products, various processing methods have been explored. The choice of the most suitable method depends on several factors, such as the efficiency in recovering bioactive compounds, environmental impact, and economic feasibility. Below, are the main techniques used and their achievements.

Table 1. Processing methods of valuable products from wheat byproducts

Byproduct	Process	Main Achievements	Ref.
Wheat Bran	Enzymatic Hydrolysis	Increased capacity to scavenge oxygen radicals and chelate transition metals and anti-inflammatory effects	[7]
	Alkaline Extraction	Originated enriched substrates in essential amino acids, phytosterols, and retained some phenolic acids. Moreover, the samples presented antioxidant activity	[8]
	Solid state-fermentation	Increased solubility of dietary fiber, total flavonoid content, total phenolic content, swelling capacity, oil absorption capacity and antioxidant activities	[9]
	Ultrasonic-assisted extraction	The extracts showed improved structural integrity and functionality	[10]
	Hydrothermal extraction	The hydrothermal extraction still does not yet achieve the extract purity and quality obtained through the alkaline/oxidative method, which remains the standard due to its superior efficiency in preserving the molecular mass and purity of AX.	[11]
	Steam explosion treatment	The solubility yield was between 18.88% and 40.32%, also the solubilized fragments presented lower molecular weight comparing to previous the treatment	[12]
Wheat Germ Protein	Enzymatic Hydrolysis	Antioxidant activity results were as follows: ABTS 77%, DPPH 72.89%, total capacity 245.13 µmol α-tocopherol/ml, and Fe^{2+} chelation 58.48%	[13]
	Solvent and Aqueous extraction	The extraction with 100% ethanol produced the extract with the highest antioxidant activity by ABTS, and the 70% ethanol extracts presented the highest activity measured by DPPH. The extracts mentioned presented a total phenolic content from 13.98 to 16.75 mg GAE/g	[14]
	Fermentation	The fermentation using the bacteria yielded a total phenolic content of 3.33 mg gallic acid equivalents/g, a content of dimethoxy benzoquinone of 0.56 mg DMBQ/g, and an antioxidant activity by DPPH radical scavenging of 86.49%	[15]
	Microwave	The enriched macaroni demonstrated higher protein, fat, and carbohydrate content than the control and maintained desirable organoleptic properties.	[16]
Wheat germ oil	Enzymatic hydrolysis	With the optimal conditions, the oil extraction yield was 66.5%	[17]
	Chloroform/methanol extraction	The fatty acids composition was nearly the same among the three extracted oils. The oil extracted by cold pressing presented the highest anti-inflammatory activity	[18]
	Soxhlet extraction	Essential minerals were detected. Also, the lipidic composition established was 19.9% saturated fatty acid and 80.1% of unsaturated fatty acids	[19]
	Supercritical CO_2	The quality of the oil extracted was similar to the one extracted by hexane, although the yield was higher using the greener method	[20]
	Aqueous extraction	The extraction yield was higher at alkaline pH, 8.0, either with Tris-HCl and Sodium Borate	[21]
	Cold Pressing	The extracts enhanced wound healing within the first 24 hours and inhibiting the growth of *Pseudomonas aeruginosa* and *Staphylococcus aureus* by 15% and 25%, respectively	[22]

4. Applications

To further enhance the utility of wheat by-products, innovative processing methods have been employed. These processes generate innovative, high-value products from wheat by-products. Examples include high-protein food formulations, cosmetic ingredients, and biodegradable packaging materials.

Table 2. Applications of the valorized wheat by-products and their processing methods

By-product	Valorization Process	Obtained Product	Ref.
Wheat Bran	Ultrasound Assisted Alkaline Hydrolysis	Oil-in-water formulation for cosmetic products	[23]
	Wheat Bran Protein Concentrate	Food products	[8]
Wheat Germ	Commercial WG oil by De Wit Specialty oils BV (Netherlands)	Breads formulations	[24]
	WG oil obtained by supercritical CO² extraction method	Nanoemulsions for potential use on cosmetic products and food supplements	[25]
	WG oil extracted using cold press	Hound healing agent	[22]
	Microwaved WG	Macaroni formulations	[16]
	WG Protein Isolate	High-protein pasta	[26]
	Defatted WG bioactive peptides	Coated WGBP film for food packing	[27]
	WG protein isolate	Low cholesterol mayonnaise	[28]

5. Discussion

Our review indicates that enzymatic hydrolysis and fermentation represent the most promising strategies for the complete valorization of wheat by-products. These methods not only maximize the recovery of bioactive compounds and essential nutrients but also offer environmentally friendly and economically viable solutions for the food and related industries. The innovative application of these processing techniques can lead to the production of novel high-protein formulations, natural cosmetic ingredients, and sustainable packaging materials, thus creating a significant market advantage. Future research should focus on optimizing these methods for industrial-scale implementation and exploring integration strategies that foster a circular economy. By bridging current technological gaps and industrial needs, this work lays the groundwork for transformative advancements in wheat processing, turning low-value waste into a reservoir of high-value bioactive ingredients.

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Acknowledgements

The authors are grateful to FEDER Cooperación Interreg VI A Espanha – Portugal (POCTEP) 2021-2027 for financial support through the project TRANSCoLAB PLUS 0112_TRANSCOLAB_PLUS_2_P.

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