

## Sustainable Solutions for Hops By-Products to Enhance Circular Economy Practices

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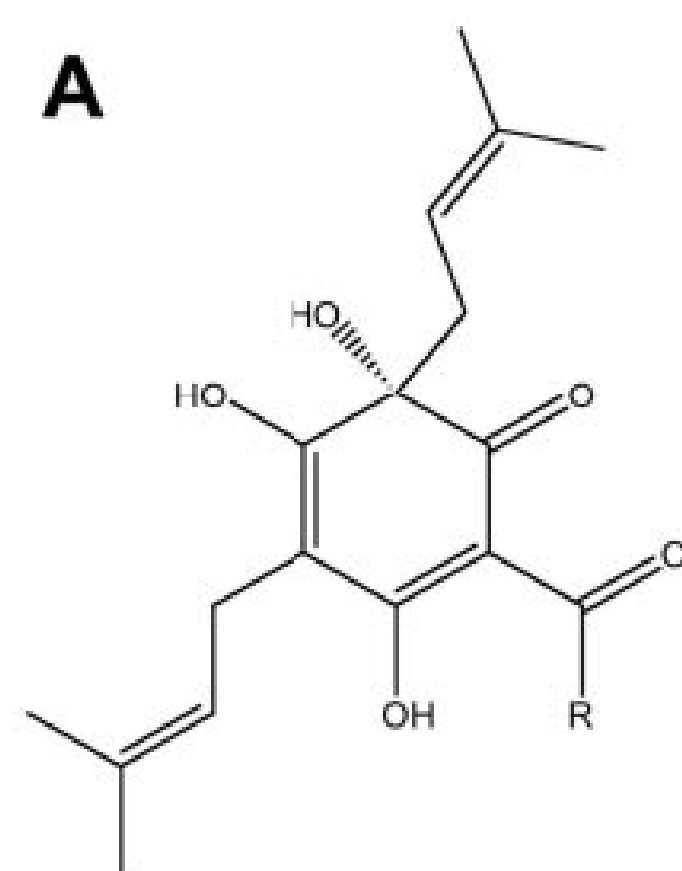
**Purpose:** This bibliographic research utilized a narrative review methodology to synthesize existing evidence on the potential applications of hops by-products.

### Introduction

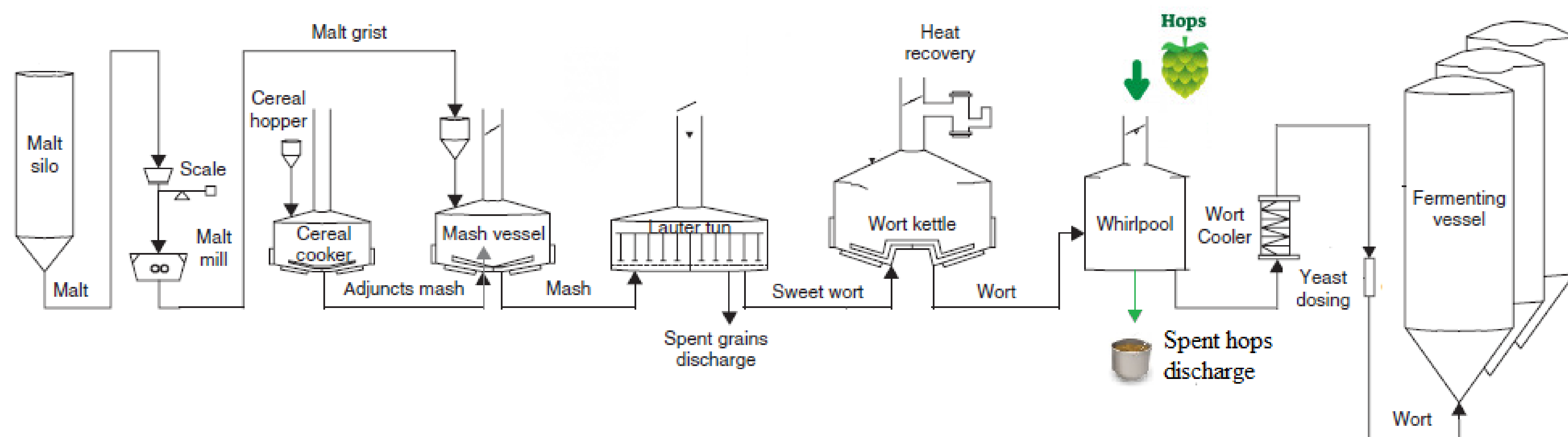
World beer production generates large volumes of waste discharged with every brew. Recently, new methods of reducing and reusing hops waste: hot trub (HT), and brewer-spent hops (BSH) are being exploited to improve the circular economy processes.

### Results and Discussion

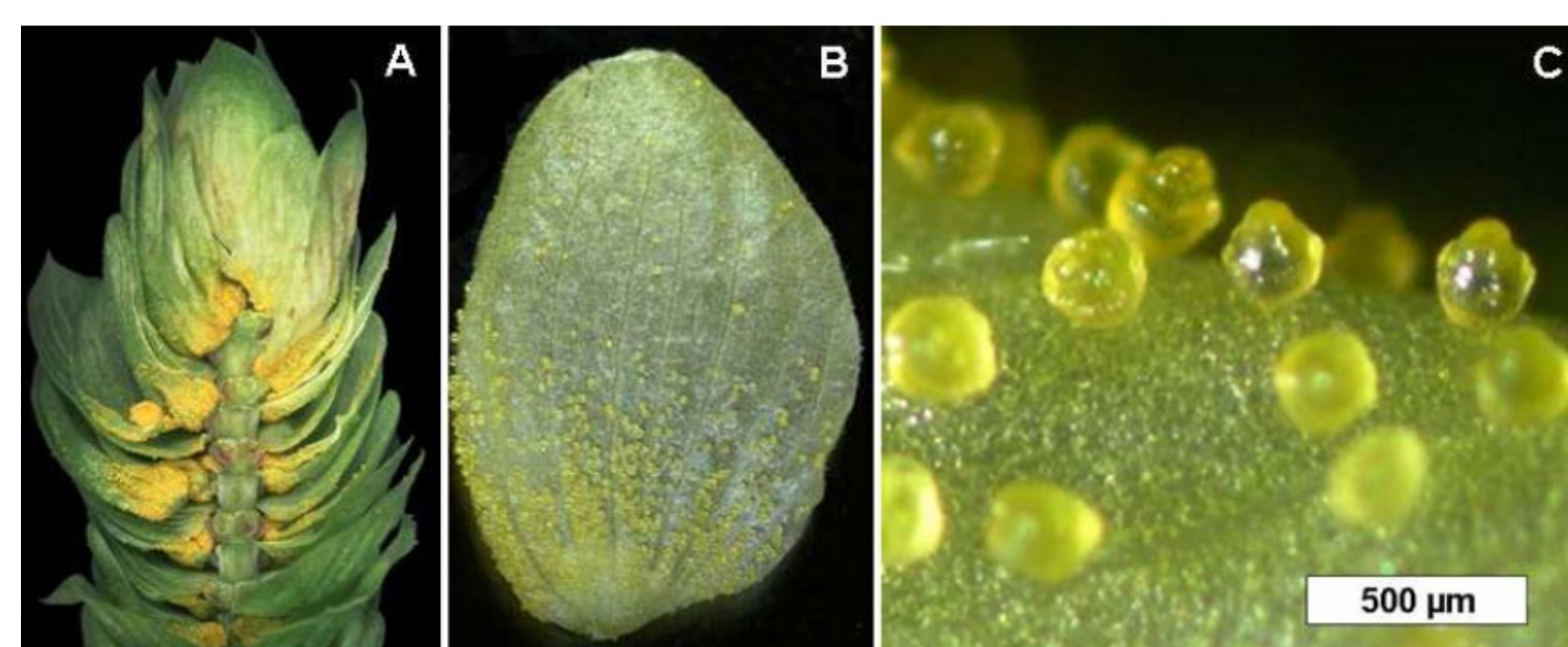
Relevant studies published in the past decade were selected based on their quality, data availability, and relevance to the research topic. Academic databases, including PubMed, Science Direct, Scopus, and Web of Science, were consulted to retrieve relevant studies, while grey literature sources were excluded. The cited studies were selected based on their relevance to the research topic and the quality of their design and methodology. To conduct the search, a combination of keywords such as "hops", "Humulus lupulus L.", "by-products", "waste", "circular economy", "bioactive compounds", "antioxidants", "xanthohumol", "chalcone", and "health benefits" were utilized, along with Boolean operators. Following an in-depth review of various scientific publications, current strategies are discussed as a sustainable alternative to food waste exploitation and an inexpensive source of valuable compounds. Moreover, key aspects concerning the nutritional value of hops waste and the potential to enhance the functional properties of food and beverages are highlighted.



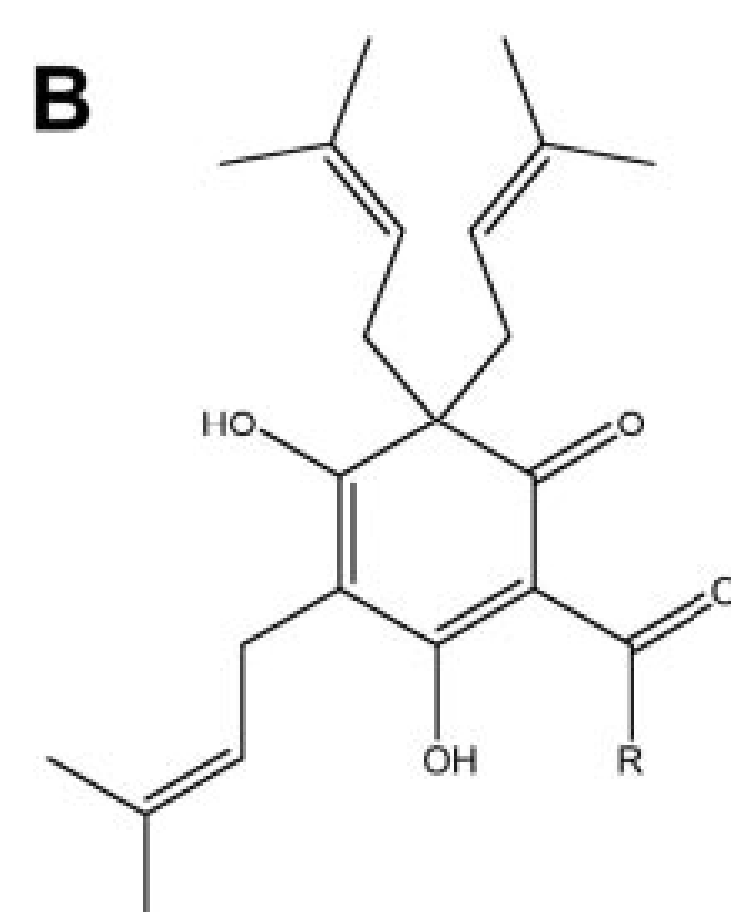
α-Acids	
Compound	R-group
Humulone	CH <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>
Cohumulone	CH <sub>2</sub> (CH <sub>3</sub> ) <sub>2</sub>
Adhumulone	CH(CH <sub>3</sub> )CH <sub>2</sub> CH <sub>3</sub>



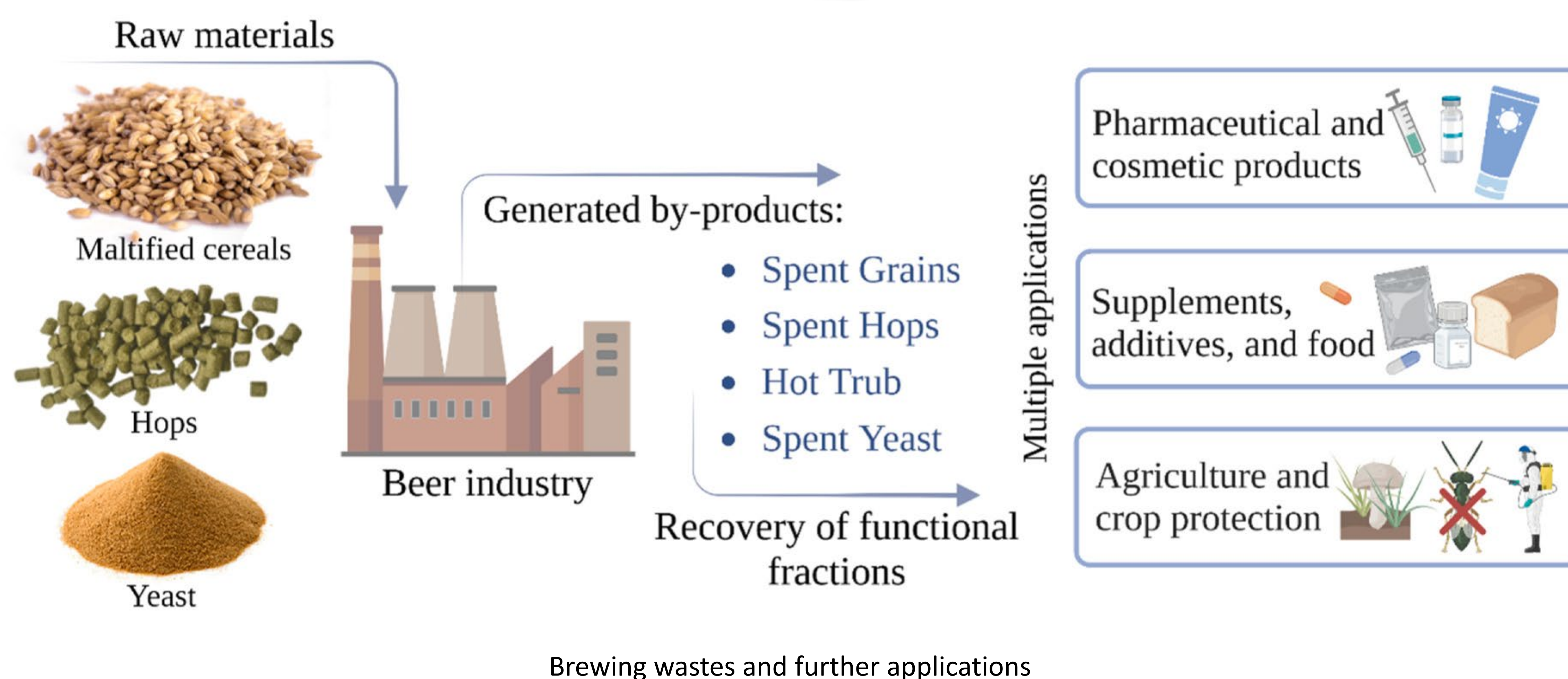
Schematic representation of the process to obtain BSH from beer production



(A) Longitudinal section of a hop cone showing lupulin glands at the base of bracteoles. (B) A single bract showing trichomes mainly on the lower third of the bract. (C) Ripe lupulin glands



β-Acids	
Compound	R-group
Lupulone	CH <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>
Colupulone	CH <sub>2</sub> (CH <sub>3</sub> ) <sub>2</sub>
Adlupulone	CH(CH <sub>3</sub> )CH <sub>2</sub> CH <sub>3</sub>



Brewing wastes and further applications

### Conclusions

Due to their nutritional composition, hops residues may be used as prospective sources of added-value co-products or additives for food enrichment, especially for products rich in fat, or as a new source of vegetable protein.

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