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Technological aspects of *Saccharomyces cerevisiae* var. *boulardii* applications in fermented alcoholic beverages: A review

Karina Nascimento Pereira[1], Handray Fernandes de Souza[1], Amanda Cristina Dias de Oliveira[1], Marcela Aparecida Deziderio[1], Marina Vieira de Carvalho[1], Ramon S. Rocha[2], Adriano G. Cruz[2], Carlos Augusto Fernandes de Oliveira[1]*, Eliana Setsuko Kamimura[1]

[1]*Department of Food Engineering, School of Animal Science and Food Engineering, University of São Paulo, São Paulo, Brazil;* [2]*Food Department, Federal Institute of Rio de Janeiro, Rio de Janeiro, RJ, Brazil*

***Corresponding Author:** Carlos Augusto Fernandes de Oliveira, Department of Food Engineering, School of Animal Science and Food Engineering, University of São Paulo, Av. Duque de Caxias Norte, 225, 13634-900, Pirassununga, São Paulo, Brazil. Email: carlosaf@usp.br

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REVIEW ARTICLE

Abstract

This review examines the technological basis underlying the applications of *Saccharomyces cerevisiae* var. *boulardii* in the development of innovative products, considering current trends in its use as described in previously published papers, with a focus on fermented alcoholic beverages. The ability of *S. cerevisiae* var. *boulardii* to maintain viability and improve sensory and functional attributes has been demonstrated in craft beers, wines, and meads by providing adequate alcohol content and presence of bioactive compounds such as phenolics and antioxidants in final products. As a first review on the use of *S. cerevisiae* var. *boulardii* in fermented alcoholic beverages, this study highlights the innovations and challenges associated with the technological applications of this probiotic yeast. Future studies are needed to optimize the fermentation process, describe the effects on sensory properties, and characterize the probiotic functionality of *S. cerevisiae* var. *boulardii,* aiming at expanding its applications in the food industry.

Keywords: probiotic yeast; fermented foods; fermented beverages

Introduction

The search for healthy foods and food habits by consumers has increased in recent years, mainly due to aspects related to longevity and improvements in quality of life (Mete *et al.*, 2019). Access to reliable food products associated with healthy eating habits is essential for the proper food selection, since it can provide important nutritional sources and enhance safe and healthy food consumption (Koirala and Anal, 2021). In this context, the demand for functional and probiotic foods and beverages stands out due to their benefits to the consumers' health (Pandey *et al.*, 2015).

According to the International Scientific Association for Probiotics and Prebiotics (ISAPP), probiotics are defined as microorganisms that, when administered in appropriate doses, promote health benefits for the host (Hill *et al.*, 2014). Recently, a new concept has been presented defining probiotics as "viable or nonviable microbial cells

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(vegetative or sporulated; intact or damaged) that offer the host potential health benefits" (Zendeboodi *et al.*, 2020). However, it is necessary to clarify that the presence of probiotic microorganisms alone is not enough for a food product to be considered as probiotic, since those microorganisms must be able to survive under gastric and intestinal conditions (Brasil, 2018).

Although most of the probiotics discussed in the literature are lactic acid bacteria (LAB) (Neffe-Skocińska *et al.*, 2018), recent studies have presented several potentially probiotic yeast species (Souza *et al.*, 2022; Staniszewski and Kordowska-Wiater, 2021). Among these, *Saccharomyces cerevisiae* var. *boulardii is* the most studied one, with well-defined probiotic functions (Sen and Mansell, 2020). *S. cerevisiae* var. *boulardii* was first isolated from the bark of lychee and mangosteen in 1923 by the French scientist Henri Boulard (Altmann, 2017). Since then, it has been widely used to treat gastrointestinal diseases, particularly diarrhea (Mahyar *et al.*, 2021; Moré and Swidsinski, 2015). In terms of genetic characteristics, *S. cerevisiae* var. *boulardii* and *S. cerevisiae* are very similar, as each contains 16 chromosomes with more than 99% kinship by average nucleotide identity (Khatri *et al.*, 2017). It should be noted that a major genetic difference between *S. cerevisiae* var. *boulardii* and other *S. cerevisiae* is the trisomy of chromosome IX in *S. cerevisiae* var. *boulardii*, which is absent in the latter (Sen and Mansell, 2020). Thus, due to the high degree of similarity between the yeasts, *S. cerevisiae* var. *boulardii* is denoted as a variation of *S. cerevisiae*. In food, *S. cerevisiae* var. *boulardii* has gained prominence due to its fermentative potential, in both single fermentations and co-fermentations, for the production of functional foods (Domingos *et al.*, 2025). Its application in various food matrices adds probiotic and functional characteristics to products (Chan and Liu, 2022; Lazo-Vélez *et al.*, 2018; Staniszewski and Kordowska-Wiater, 2021). This yeast is more resistant to high temperatures, acid stress, and moderate concentrations of ethanol. During fermentation, it can metabolize glucose, fructose, sucrose, and maltose, but does not use galactose as a carbon source. Unlike other strains of the genus, *S. cerevisiae* var. *boulardii* does not produce spores. Although it is considered a subspecies of *S. cerevisiae*, there are differences in its physiology and metabolism, thus attributing unique functional characteristics (Domingos *et al.*, 2025; Khatri *et al.*, 2017; Pais *et al.*, 2020). Figure 1 presents an overview of the potential applications of *S. cerevisiae* var. *boulardii* in the pharmaceutical and food industries.

Recently, a review by Souza *et al.* (2022) documented the use of probiotic yeasts in the development of food products, as well as the use of *S. cerevisiae* var. *boulardii* in plant-based and bakery products, and fermented alcoholic and nonalcoholic beverages (Souza *et al.*, 2022). A study by Sadegli *et al.* (2022) described the recent findings on the use of probiotic yeasts with promising techno-functional, postbiotic, and protective capacities in foods, particularly the potential application of *S. cerevisiae* var. *boulardii*. Furthermore, the market for probiotic beverages is on the rise, with an expected turnover of

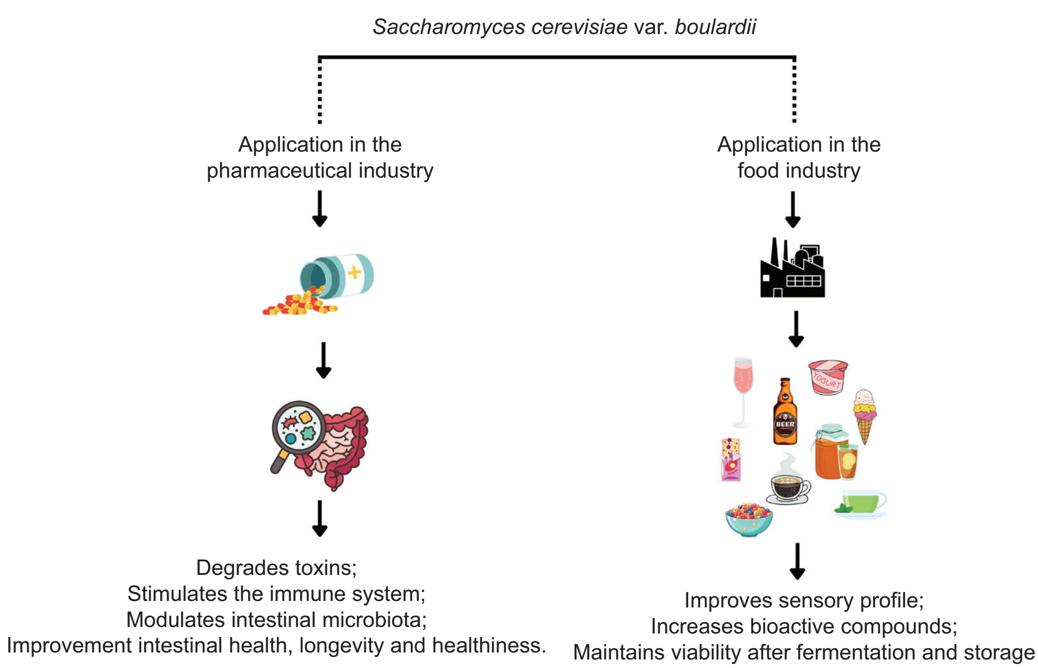

Figure 1. Overview of potential applications of *Saccharomyces boulardii* in the pharmaceutical and food industry.

US$ 21.9 million by 2027. This growth is encouraged by consumers who are concerned about their diet and are on the lookout for the health benefits attributed to these products (Grand View Research, 2019). However, the technological aspects for the application of *S. cerevisiae* var. *boulardii* in the production of fermented alcoholic beverages remain an important and largely unexplored research field. The remarkable ability of *S. cerevisiae* var. *boulardii*, compared with other probiotics, to add bioactive compounds and confer organoleptic characteristics in alcoholic beverages and its capacity to survive the different fermentation processes and maintain viability in functional foods and beverages have not been reviewed so far. Thus, the objective of this review was to present and provide a comprehensive discussion on the technological applications of *S. cerevisiae* var. *boulardii* in the food industry, with a special focus on the development of fermented alcoholic beverages. Relevant studies published in the past 10 years (2016 to present) were selected to provide insights on the application of *S. cerevisiae* var. *boulardii* in probiotic food products and fermented alcoholic beverages. The inclusion criteria for selection of studies were the main outcomes described in the articles, such as effects on sensory attributes, antioxidant activity, probiotic characteristics, and cell viability of *S. cerevisiae* var. *boulardii* in the alcohol environment.

Phylogenetic, Physiological, and Metabolic Characteristics of *Saccharomyces cerevisiae* var. *boulardii*

Although *S. cerevisiae var. boulardii* is classified as a subspecies of *S. cerevisiae*, many of its physiological and metabolic characteristics initially suggested that it could be considered a distinct species within the genus *Saccharomyces*. This initial classification was largely supported by its inability to consume galactose, lack of sporulation, and its formation of a separate cluster. However, molecular analyses confirmed that *S. cerevisiae* var. *boulardii* belongs to the same species as *S. cerevisiae*, despite its specific physiological adaptations (Khatri *et al.*, 2017). Despite the phylogenetic relationship between these strains, *S. cerevisiae* var. *boulardii* has distinct characteristics that make it a remarkable microorganism for a wide range of applications in food matrices. This is related to its ability to withstand relatively acidic pH levels, compared to other *S. cerevisiae* strains, for example. Thus, in fermentation processes, *S. cerevisiae* var. *boulardii* stands out from other strains, especially when it comes to obtaining a probiotic product (Domingos *et al.*, 2025). This enhanced resistance to acidic pH may be related to the genes responsible for the yeast's stress responses. Phylogenetic studies have identified that *S. cerevisiae* var. *boulardii* has genes involved in stress response pathways (HSP78, HSP26, HSP42, PBS2, SED1, and SSA3), which are essential in protecting and adapting the yeast to its environment (Pais *et al.*, 2020). In addition, the greater production of acetic acid by *S. cerevisiae* var. *boulardii* is associated with alterations in the SDH1 and WHI2 genes (Offei *et al.*, 2019).

Some of the metabolites produced by *S. cerevisiae* var. *boulardii* are mainly responsible for its microbiological control properties, as they can inhibit the secretion of toxins produced by pathogens. In addition, probiotic yeast produces more phenolic acids and nucleosides during fermentation, which are essential for the yeast and for the sensory and functional profile of the fermented beverage (Fu *et al.*, 2023). This difference in metabolite profiles is linked to the different metabolic pathways in these yeast strains. When examining the glutamate metabolic pathway, it was observed that *S. cerevisiae* produces gamma-aminobutyric acid from glutamate, while *S. cerevisiae* var. *boulardii* tends to produce N-acetylornithine, as well as aspartic acid, which standard yeast converts into nicotinic acid, while *S. cerevisiae* var. *boulardii* produces uridine (Fu *et al.*, 2023). In summary, the phylogenetic and physiological differences between *S. cerevisiae* and the subspecies *S. cerevisiae* var. *boulardii* explain many of the probiotic characteristics that make the latter promising. Several of its metabolic processes have been preserved throughout fermentation processes, as well as its antioxidant activity, making it an option with great potential for applications in different beverages and functional foods.

Applications of *Saccharomyces cerevisiae* var. *boulardii* within the Food Industry

Recent studies have pointed out the inclusion of probiotic yeasts in foods, particularly *S. cerevisiae* var. *boulardii* (Gutiérrez-Nava *et al.*, 2024; Sadegli *et al.*, 2022; Staniszewski and Kordowska-Wiater, 2021). In general, the application of *S. cerevisiae* var. *boulardii* for the development of innovative and functional foods has been subject to new emerging approaches, as summarized in Table 1. However, even though the incorporation of yeast into food matrices has been very well defined over the years, the application of probiotic strains such as *S. cerevisiae* var. *boulardii* proves to be a challenging option.

To develop potentially probiotic cereal bars, Bastos *et al.* (2014) used *S. cerevisiae* var. *boulardii* and *Lactobacillus acidophilus*, both encapsulated in calcium alginate, as functional microorganisms. The study results suggested that the microorganisms did not interfere with the texture or sensory qualities of the product. Also, the viable cell count observed (Log 8.09 ± 0.10 CFU/g) was sufficient for the product to be considered a probiotic food (Bastos *et al.*, 2014). In yogurt, the application of *S. cerevisiae* var. *boulardii* resulted in greater viability when inulin fiber was added to the product, with an initial count of ≥ Log 8.0 CFU/g that decreased to Log 5.5 CFU/g after 28 days of storage (Sarwar *et al.*, 2019). Sarwar *et al.* (2021) demonstrated that the addition of 1 and 2% inulin promoted higher probiotic yeast counts (Log 6.0 CFU/g) in ice cream, especially after 120 days of storage, when compared with ice cream without the addition of inulin (Log 5.0 CFU/g), besides improving the physicochemical properties of the product such as firmness and storage stability. However, further investigations on the technological aspects of *S. cerevisiae* var. *boulardii* when applied in fermented food products should be encouraged.

Recent studies have discussed the applications of *S. cerevisiae* var. *boulardii* in baking and fruit juices. In one such study, Cielecka-Piontek *et al.* (2020) developed a biofunctional fruit-filled, chocolate-covered snack containing different probiotic microorganisms. The chocolate-coated snack consisting of *S. cerevisiae* var. *boulardii* showed viable cell counts of Log 8.9 CFU/g after 6 months of storage at 4°C. To produce pro- and prebiotic corn flakes, Singu *et al.* (2020) used coating solutions containing *S. cerevisiae* var. *boulardii* and different concentrations of acacia gum. The authors evaluated the resistance to gastrointestinal conditions and concluded that gum arabic protected the yeast in these simulated conditions, containing Log 5.3 ± 0.1 CFU/g. In simulated thermal conditions at 70°C, the viability increased and reached cell counts of Log 7.3 CFU/g. During the production of probiotic coffee infusion using microorganisms as part of single (only *S. cerevisiae* var. *boulardii boulardii*) or mixed (*L. rhamnosus* GG and *S. cerevisiae* var. *boulardii*) fermentations, *S. cerevisiae* var. *boulardii* maintained a cell viability above Log 6.0 CFU/mL in both products during 14 weeks of storage at room temperatures, 4 and 25°C, respectively (Chan *et al.*, 2021).

In general, recent advances in the scientific literature highlight the application of *S. cerevisiae* var. *boulardii* for the development of food products in various segments of the food industry, including fermentation and the production of fruit juices (Patelski *et al.*, 2024; Santana *et al.*, 2020), coffee (Chan *et al.*, 2021; Chan and Liu, 2022), green tea (Wang *et al.*, 2022a; 2022b), ice cream (Goktas *et al.*, 2022; Sarwar *et al.*, 2021), and yogurt (Mehaya *et al.*, 2023; Sarwar *et al.*, 2019), among others.

Technological Basis for *Saccharomyces cerevisiae* var. *boulardii* Applications in Fermented Alcoholic Beverages

The probiotic yeast *S. cerevisiae* var. *boulardii* has shown significant potential for the development of fermented alcoholic beverages, especially craft beer, mainly because of its resistance to ethanol and capacity to maintain adequate viability at the end of the fermentation process (Capece *et al.*, 2018; Cerezo *et al.*, 2019; Paula *et al.*, 2021). In addition to craft beers, wines and meads are the main fermented alcoholic beverages that provide proper conditions for adequate cell viability and survival of *S. cerevisiae* var. *boulardii*, whose characteristics are illustrated in Figure 2.

S. cerevisiae var. *boulardii* and *S. cerevisiae* have distinct characteristics and uses in fermentation processes. Although *S. cerevisiae* is the primary yeast optimized for ethanol production, baking, and brewing, *S. cerevisiae* var. *boulardii* also has important fermentation features that can be useful in industrial processes. The yeast S. *cerevisiae* var. *boulardii* stands out for its efficiency in adverse environments, showing greater resistance to ethanol. In addition, the bioactive compounds produced during fermentation have an impact on the functional properties of alcoholic beverages. Figure 3 shows the performance metrics of *S. cerevisiae* var. *boulardii* compared with those of *S. cerevisiae* yeasts in the production of alcoholic beverages. However, the use of *S. cerevisiae* var. *boulardii* in the fermentation process of alcoholic beverages has markedly advanced in recent years. Table 2 presents a summary of recent applications of the probiotic yeast *S. cerevisiae* var. *boulardii* in the production of alcoholic fermented beverages in the last 5 years.

It is important to note that maintaining the viable characteristics of the probiotic strain in the harsh conditions of alcoholic beverages, while guaranteeing adequate alcohol content in the final products, is a major challenge for the industry (Diaz *et al.*, 2023). These difficulties were pointed out in the review study by Santos *et al.* (2023), who discussed the maintenance of probiotic potential in the production of alcoholic beverages with a focus on the application of more prominent microorganisms with functional potential, such as *S. cerevisiae* var. *boulardii*, kefir microorganisms, *Lactobacillus* spp., *Leuconostoc* spp., and *Bifidobacterium* spp., among other LAB. The other aspects that must be observed are the ability of the probiotic strain to contribute to favorable sensory characteristics, as well as adding bioactive compounds of interest such as phenolic compounds and antioxidants with functional aspects, when compared with conventional and nonprobiotic strains (Cerezo *et al.*, 2019, 2023; Diaz *et al.*, 2023). Thus, the challenges and advances in the application of *S. cerevisiae* var. *boulardii* in the fermentation of probiotic alcoholic beverages represent an innovative field of research with the capacity to transform the probiotic fermented beverage industry. In this sense, studies in the scientific literature that support these characteristics are discussed in the following sections.

Table 1. **Recent applications of *Saccharomyces cerevisiae* var. *boulardii* in the development of probiotic food products.**

Type of product	*S. cerevisiae* var. *boulardii* strain	CYBF (Log CFU/mL or g)	CYAF (Log CFU/mL or g)	Applications/Main outcomes	Reference
Barley wort fermented beverage	NI	3.0 or 4.0	NI	Development of a probiotic beverage with co-fermentation of *S. cerevisiae* var. *boulardii* from the fermentation of barley wort	Gutiérrez-Nava *et al.* (2024)
Beer	Isolated from food supplements	6.0	5.0	Production of a probiotic nonalcoholic beer fermented by *S. cerevisiae* var. *boulardii*, with optimized process variables and higher production of volatile compounds	Senkarcinova *et al.* (2019)
Cashew juice	Isolated from Floratil®	7.8–8.5	7.5–8.3	Successful production of a probiotic cashew juice containing different sweeteners, with high viability of *S. cerevisiae* var. *boulardii* stored at 7°C for 28 days	Santana *et al.* (2020)
Cheese whey permeate	CCT 4308	8.2–8.3	NI	Successful production of a synbiotic product containing galacto-oligosaccharides and *S. cerevisiae* var. *boulardii,* simultaneously, through an enzymatic–fermentative method	Passos *et al.* (2021)
Coffee	CNCM-I745	6.0	7.2	Development of probiotic coffee infusions containing glucose and inactivated yeast derivatives as growth factors, with increased survival of *S. cerevisiae* var. *boulardii* CNCM-I745 and/or *Lactobacillus rhamnosus* GG	Chan *et al.* (2016, 2021)
Coffee	CNCM-I745	NI	7.3	Successful co-fermentation of *S. cerevisiae* var. *boulardii* CNCM-I745 with four different probiotic lactobacilli in coffee brews	Chan and Liu, 2022
Cornflakes	NCYC-3264	9.0	8.0–11.0	Development of thermostable probiotic corn flakes with co-fermentation of *S. cerevisiae* var. *boulardii* using hydrocolloids as coating agent	Singu *et al.* (2020)
Fermented drinks	Isolated from Repoflor®	9.0	8.0–11.0	Production of probiotic beverages made from sprouted and unsprouted grains (lentils, brown rice, and sorghum)	Andrade and Castro (2023)
Fermented fruit pulp	CNCM I-745	5.0	NI	Increased antioxidant and anti-inflammatory properties of products prepared with passion fruit and graviola pulps fermented by ul co-fermentation of *S. cerevisiae* var. *boulardii*	Mendoza *et al.* (2023)
Green tea	CNCM I-745	5.0-7.0	NI	Co-fermentation of *S. cerevisiae* var. *boulardii* CNCM I-745 and *Lactiplantibacillus plantarum* 299V yielded higher production of aromatic compounds and also improved the fruity and minty flavors	Wang *et al.* (2022a)
Ice cream	Isolated from food supplements	7.3	6.2	Functional ice cream was successfully produced with co-fermentation of *S. cerevisiae* var. *boulardii* in combination with *L. rhamnosus* GC	Goktas *et al.* (2022)
Ice cream	CNCM I-745	9.0	5.5–6.53	Successful production of a synbiotic product with co-fermentation of *S. cerevisiae* var. *boulardii* CNCM I-745 in combination with inulin	Sarwar et *al.* (2021)
Lentil and adzuki bean sprouts	Isolated from a probiotic preparation	7.0	7.0	Successful production of probiotic lentil and azuki bean sprouts as carriers of ul co-fermentation of *S. cerevisiae* var. *boulardii*	Swieca *et al.* (2019)
Lychee	CNCM I-745	5.0	6.8	Production of three formulations of a probiotic lychee beverage using the yeast *S. cerevisiae* var. *boulardii*, evaluating cell viability, physicochemical characteristics and sensory acceptance after 28 days of storage.	Terhaag *et al.* (2025b)
Orange and black currant juices	CNCM-I-745 - Enterol 250 (Biocodex, France)	250[b]	NI	Development of orange and black currant juices from the co-fermentation of *S. cerevisiae* var. *boulardii*	Patelski *et al.* (2024)

(*continues*)

Table 1. Continued.

Type of product	*S. cerevisiae* var. *boulardii* strain	CYBF (Log CFU/mL or g)	CYAF (Log CFU/mL or g)	Applications/Main outcomes	Reference
Soy yogurt	CNCMI-745	7.0	8.0	Improved nutritional and physicochemical characteristics of soy yogurt manufactured with *L. plantarum* KU985432 and co-fermentation of *S. cerevisiae* var. *boulardii* CNCMI-745	Mehaya *et al.* (2023)
Yam	NI	NI	NI	Application of co-fermentation of *S. cerevisiae* var. *boulardii* in yam fermentation to improve the bioactivity of polysaccharides	Shao *et al.* (2021)
Yogurt	CNCM I-745	9.3	9.8	Development of synbiotic yogurt with co-fermentation of *S. cerevisiae* var. *boulardii* CNCM I-745 in combination with prebiotic inulin	Sarwar *et al.* (2019)

CFU: colony forming units; CYAF: concentration of yeast after fermentation; [a]CYBF: concentration of yeast before fermentation; NI: not informed.
[b]Expressed as mg of dry matter of cells/L.

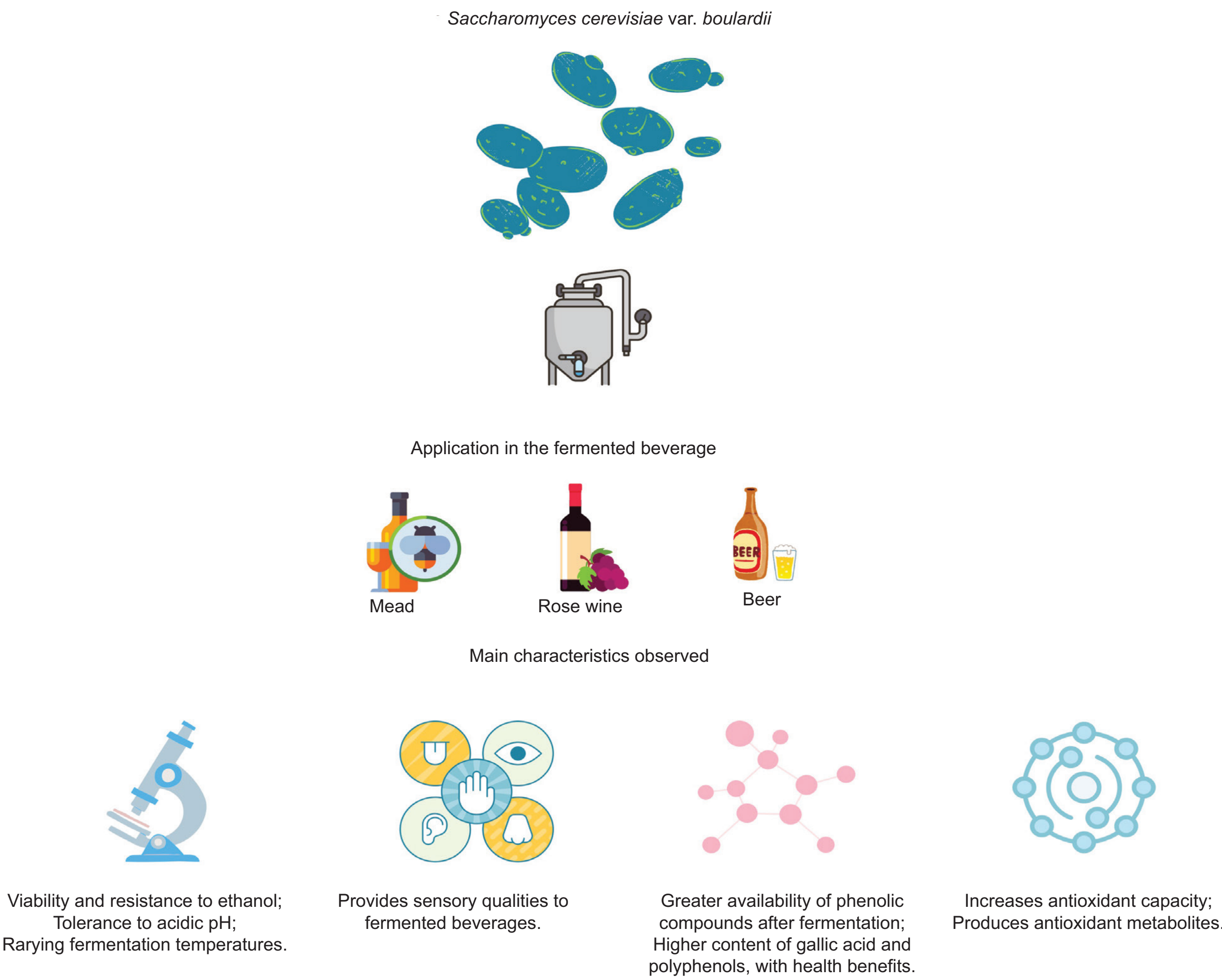

Figure 2. Applications and characteristics of *Saccharomyces cerevisiae* var. *boulardii* in fermented beverages.

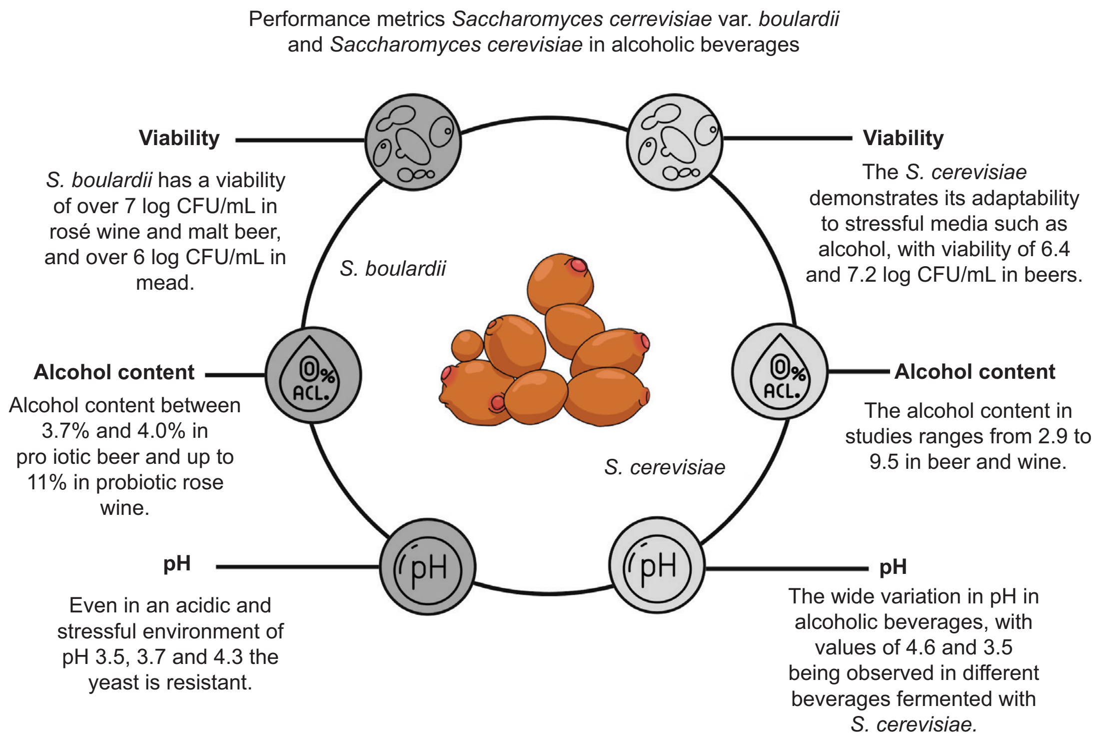

Figure 3. Summary of performance metrics of probiotic yeast *Saccharomyces cerevisiae* var. *boulardii* compared with *S. cerevisiae* in the production of alcoholic beverages.

Cell viability and survival of *Saccharomyces cerevisiae* var. *boulardii*

The viability and survival of a microorganism in a given food depend on several factors, such as the chemical composition of the substrate, concentration of metabolites, production, and storage temperature (Neffe-Skocińska *et al.*, 2018). In fermented alcoholic beverages, the survival of microorganisms is associated with the initial concentration of microorganisms and alcohol content of the final product, storage conditions, storage period, and excessive acidity (Zendeboodi *et al.*, 2021). In the case of probiotic yeasts, for example, they can easily adapt to various stressful environments and are resistant to adverse food conditions, types of food treatment and processing, different environmental ecosystems, as well as factors including low and high temperatures, different pHs, salts, and/or organic solvents, among others (Sadegli *et al.*, 2022). Thus, the viability and survival of yeasts are very important factors for obtaining and maintaining alcoholic and probiotic beverages.

Recent studies demonstrate the superior resistance of *S. cerevisiae* var. *boulardii* compared to other fermentative yeasts. The high tolerance of *S. cerevisiae* var. *boulardii* to fermentative stress is related to various adaptive protection mechanisms. The increase in cell wall thickness aims to improve the protective barrier, reducing the damage caused by ethanol to the plasma membrane. Furthermore, the cell vacuole expands in response to ethanol stress, helping with homeostasis and the sequestration of toxic compounds. The production of amino acids, such as proline, tryptophan, and arginine, also plays a protective role by stabilizing membranes, reducing oxidative stress, and contributing to the maintenance of cell viability (Auesukaree, 2017; Ramirez-Cota *et al.*, 2021). These mechanisms help yeast to survive in stressful fermentation environments.

In the study by Paula *et al.* (2021), *S. cerevisiae* var. *boulardii* cells maintained high viability at storage temperatures around 0°C and after simulated digestive conditions. The authors also demonstrated consistent viability of the yeast during the whole storage period, with average viable cell counts of Log 8.23 and 7.05 CFU/mL at the start and after 60 days, respectively. Compared with the commercial yeast *S. cerevisiae*, the use of probiotic yeast *S. cerevisiae* var. *boulardii* to produce craft beer resulted in increased viability, with an average viable cell count of Log 6.9 CFU/mL, while *S. cerevisiae* presented an average viability of Log 5.0 CFU/mL (Cerezo *et al.*, 2019). In another study using *S. cerevisiae* var. *boulardii* for beer production, Capece *et al.* (2018) observed viable cell counts between Log 6.9 and 7.8 CFU/mL after co-fermentation with yeasts isolated from different food sources. Silva *et al.* (2020) demonstrated that

Table 2. Recent applications of *Saccharomyces cerevisiae* var. *boulardii* in the manufacture of fermented alcoholic beverages.

Type of product	*S. cerevisiae* var. *boulardii* strain	CYBF (Log CFU/mL)	CYAF (Log CFU/mL)	Applications/Main outcomes	Reference
Alcoholic beverages	Isolated from Floratil®	0.3–2.3	6.6–8.5	Probiotic alcoholic beverages containing *S. cerevisiae* var. *boulardii* exhibited high resistance to alcohol and gastric and intestinal conditions.	Paula *et al.* (2019)
Beer	Isolated from Enterol®	6.9	6.0	Higher beer quality was produced with *S. cerevisiae* var. *boulardii*, compared with commercial yeasts (*S. cerevisiae*), with CYBF and CYAF 6.3 and 5.0 Log CFU/mL, respectively.	Manshin *et al.* (2022)
Beer	ATCC (not specified)	7.0	8.3–8.4	Improved physicochemical and microbiological parameters of probiotic beers fermented by selenized *S. cerevisiae* var. *boulardii*	González-Salitre *et al.* (2023)
Beer	CECT1474	6.0	8.0	Successful development of probiotic beers with *S. cerevisiae* var. *boulardii* as an alternative to conventional brewer's yeast (*S. cerevisiae*), with CYBF and CYAF 6.0 and 7.0 Log CFU/mL, respectively.	Diaz *et al.* (2023)
Beer (craft)	Isolated from Floratil®	6.0	6.0–7.0	Successful co-fermentation of probiotic craft beer wort by *S. cerevisiae* var. *boulardii* and 17 selected *S. cerevisiae* strains. The CYBF of these *S. cerevisiae* strains was 6.0 Log CFU/mL, and the CYAF varied from 6.0 to 7.0 Log CFU/mL.	Capece *et al.* (2018)
Beer (craft)	CECT 1474	6.0	5.0	Production of probiotic craft beer with higher antioxidant activity and lower alcohol content by *S. cerevisiae* var. *boulardii*	Cerezo *et al.* (2019)
Beer (craft)	NI	6.0	6.8–7.9	Successful production of a protein-enriched craft beer	Canonico *et al.* (2021)
Beer (Pilsen-type)	Isolated from Floratil®	6.0	6.0	Development of a functional beer with *S. cerevisiae* var. *boulardii* with improved sensorial characteristics	Reitenbach *et al.* (2021)
Beer (wheat)	Isolated from Floratil®	6.7	7.4	Successful development of a probiotic wheat beer, compared with *S. cerevisiae* strain WB-06 (CYBF: 6.7 Log CFU/mL; CYAF: not informed)	Paula *et al.* (2021)
Lychee wine with yerba mate	CNCM I-745	3.0	7.4–7.5	Production and sensory acceptance of lychee wine produced with *S. cerevisiae* var. *boulardii*, plus yerba mate.	Terhaag *et al.* (2025a)
Mead	CCT 4308	0.2–0.3	6.5	Higher sensory acceptance and purchase intention of probiotic meads produced with *S. cerevisiae* var. *boulardii*, compared with *S. cerevisiae* (CYBF: 0.2–0.3 Log CFU/mL; CYAF: 6.5 Log CFU/mL)	Souza *et al.* (2023b)
Mead with kombucha	CCT 4308 (UFPEDA 1176)	0.5–1.0	8.12	Production of potentially probiotic mead from the co-fermentation of *S. boulardii* and kombucha microorganisms. *S. cerevisiae* was also used, whose CYBF and CYAF were 0.5–1.0 and 8.24 Log CFU/mL, respectively.	Souza *et al.* (2024b)
Wine (Rosé)	CECT 1474	6.0	6.0	Production of probiotic alcoholic and nonalcoholic Rosé wines with higher health benefits, compared with *S. cerevisiae* strain Safale S-04 (CYBF and CYAF: 6.0 and 0.5 Log CFU/mL, respectively)	Cerezo *et al.* (2023)
Mead with water kefir	CCT 4308 (UFPEDA 1176)	0.5–1.0	9.3	Production of probiotic mead from mixed fermentation of water kefir with *S. cerevisiae* var. *boulardii*. *S. cerevisiae* was also used, where CYBF and CYAF were 0.5–1.0 and 8.2 Log CFU/mL, respectively.	Souza *et al.* (2024a)

CFU: colony forming units; CYAF: concentration of yeast after fermentation; [a]CYBF: concentration of yeast before fermentation; NI: not informed.

S. cerevisiae var. *boulardii* offers adequate cell viability even after 156 h of fermentation, during the production of probiotic wheat beer, with different temperatures and mashing times showing initial and final viable cell counts of Log 6.5 ± 0.10 and 8.0 ± 0.07 CFU/mL, respectively. Additionally, the authors found that, after 60 days of storage, the viable cell count was Log 7.0 ± 0.02 CFU/mL, sufficient for beer production with probiotic properties.

In the study by González-Salitre *et al.* (2023), the authors evaluated the fermentation capacity of selenized *S. cerevisiae* var. *boulardii*. The results showed that the selenized yeast had a 24-hour delay in the start of fermentation compared to the non-selenized yeast. Despite this initial delay, after 120 h of fermentation, the cell viability of the selenized *S. cerevisiae* var. *boulardii (*8.3 Log CFU/mL) was equivalent to that of the control yeast (8.4 Log CFU/mL), indicating that the selenization process did not compromise its long-term viability. According to Terhaag *et al.* (2025b), even after 15 days of fermentation, lychee wine using *S. cerevisiae* var. *boulardii* maintained its ability to provide positive health effects. In this study, the authors observed that the yeast remained viable in a stressful fermentation medium with cell concentrations of 7.4 log CFU/mL in lychee wine and 7.5 log CFU/mL in lychee wine with yerba mate. Cerezo *et al.* (2023) investigated the use of *S. cerevisiae* var. *boulardii* in the production of probiotic wine. The authors evaluated the yeast after fermentation and post-distillation of rosé wine to obtain a nonalcoholic wine. The authors observed that even after 6 months of storage, the distilled wine had a cell count above 6 log CFU/mL, demonstrating its resistance to the prolonged storage period.

Recently, Souza *et al.* (2024a) applied *S. cerevisiae* var. *boulardii* in a mixed fermentation with water kefir to develop a probiotic mead and observed that the probiotic yeast had a high cell viability rate of Log 9.4 CFU/mL and an alcohol content of 7.05% in the mead. In addition, the authors demonstrated that *S. cerevisiae* var. *boulardii* is resistant to simulated digestive conditions, with viable cell counts greater than Log 7.0 CFU/mL after the intestinal phase. In summary, the scientific evidence indicates that the probiotic yeast *S. cerevisiae* var. *boulardii* is resistant to high alcohol content and can survive under simulated digestive conditions, thus supporting its application for the development of beers, wines, and meads (Cerezo *et al.*, 2023; Paula *et al.*, 2021; Silva *et al.*, 2020; Souza *et al.*, 2024a).

Influence of *Saccharomyces cerevisiae* var. *boulardii* on sensory characteristics

The sensory characteristics of fermented beverages are critical for their acceptance by the consumer market and commercial success. Sensory parameters vary according to each beverage, although flavor and aroma remain indispensable aspects that need to be evaluated during processing and on the final product. Therefore, the use of yeasts that guarantee acceptable sensory attributes is essential, given that their metabolism is directly related to the beverage's final organoleptic characteristics (Carrau *et al.*, 2015). The volatile and nonvolatile metabolites produced by yeasts during the production of fermented beverages affect sensory properties associated with aroma and flavor. These compounds include esters (fruity character), higher alcohols (floral flavor and alcoholic notes), organic acids (acidity and freshness), and volatile phenols (spicy and smoky characteristics), which provide enhanced aromatic qualities to fermented beverages (Ávila *et al.*, 2024; Radu *et al.*, 2024). Because there is still little information available on the impact of *S. cerevisiae* var. *boulardii* on the sensory profile of foods and beverages, sensory studies constitute a major gap in terms of knowledge of this probiotic strain (Costa *et al.*, 2020; Cruz *et al.*, 2021; Silva *et al.*, 2021). Working on the development of probiotic beer, Paula *et al.* (2021) demonstrated that the yeast *S. cerevisiae* var. *boulardii* produced acetic acid and glycerol, and although no sensory analysis was conducted, the authors suggested that the probiotic yeast *S. cerevisiae* var. *boulardii* may produce a bitter or sour taste due to the presence of these compounds in the beverage. However, the study by Cerezo *et al.* (2019) indicated that consumers did not perceive a significant difference in appearance, aroma, taste, and bitterness attributes among beers produced with *S. cerevisiae* or *S. cerevisiae* var. *boulardii*, as shown in Table 3.

S. cerevisiae var. *boulardii* is highly regarded as a probiotic yeast capable of adding favorable sensory characteristics to fermented alcoholic beverages (Cerezo *et al.*, 2023; Diaz *et al.*, 2023). Using the same food matrix, Diaz *et al.* (2023) analyzed beers produced with *S. cerevisiae* var. *boulardii* and with *S. cerevisiae*. The authors found that the beverage produced with probiotic yeast showed a greater intensity of aromas related to the cereal descriptor when compared to that fermented with standard yeast. However, when evaluating the overall impression, both drinks received similar sensory acceptance. This suggests that *S. cerevisiae* var. *boulardii* did not alter the sensory characteristics of the beer, which can be considered positive for its application in beer production. In rosé wines, *S. cerevisiae* var. *boulardii* provided sensory characteristics close to those of commercial wines (produced with *S. cerevisiae* EC-1118), also providing more citric and sweet-flavored products (Cerezo *et al.*, 2023). Terhaag *et al.* (2025a) evaluated the sensory characteristics of lychee wine and observed that samples with the shortest fermentation time (7 days) showed greater perception of gas, as well as a sparkling texture,

Table 3. Effects of the application of *S. cerevisiae* var. *boulardii* on sensory characteristics, antioxidant activity and generation of phenolic compounds in alcoholic fermented beverages.

Type of Product	Effects on sensory characteristics	Effects on antioxidant activity and generation of phenolic compounds	Reference
Beer	Modification of organoleptic profiles of the beer, providing a more intense cereal aroma; the overall impression was similar to commercial yeast	NI	Diaz *et al.* (2023)
Beer (craft)	NI	Beers fermented with mixed cultures using *S. cerevisiae* var. *boulardii* showed higher antioxidant activity and polyphenols, compared with mixed cultures of *S. cerevisiae*	Capece *et al.* (2018)
Beer (craft)	No significant differences were found between beers brewed with commercial yeast in terms of appearance, aroma, taste, and bitterness	No significant differences were found in the phenolic compounds of beers brewed with *S. cerevisiae* or *S. cerevisiae* var. *boulardii*; the beer brewed with *S. cerevisiae* var. *boulardii* showed greater antioxidant activity	Cerezo *et al.* (2019)
Beer (Pilsen-type)	The beverage produced with probiotic yeast obtained higher values in the taste, aroma, and overall impression attributes, compared with commercial beer and beer without probiotic yeast	NI	Reitenbach *et al.* (2021)
Mead	Mead with initial soluble solids of 30° Brix in the most and *S. cerevisiae* var. *boulardii* (0.030 g/L) had the highest grades on a 9-point hedonic scale and the highest purchase intention	The mead formulations produced with *S. cerevisiae* var. *boulardii* showed higher values for antioxidant activity and phenolic compounds	Souza *et al.* (2023a, 2023b)
Wine (Rosé)	The wine made with *S. cerevisiae* var. *boulardii* was more citrusy and sweeter to taste, though with sensory characteristics similar to other commercial wines	NI	Cerezo *et al.* (2023)
Mead with water kefir	NI	Two mead formulations were evaluated, and the beverage produced *with S. cerevisiae* var. *boulardii* showed no statistical difference from that produced with commercial yeast for the ABTS and FRAP methodologies in the evaluation of antioxidant activity; however, the probiotic yeast provided lower levels of phenolic compounds	Souza *et al.* (2024a)
Mead with kombucha	NI	The mead made with *S. cerevisiae* var. *boulardii* and kombucha had high levels of total phenolics (17.34 ± 0.22 mg GAE/100 mL) and antioxidants (62.92 ± 5.54 μmol TE/100 mL, ABTS; 4.93 ± 0.09 μmol TE/100 mL, FRAP)	Souza *et al.* (2024b)
Lychee wine with yerba mate	Wines produced with lychee alone had alcoholic, sweet and fruity flavors	Both wine formulations were made with *S. cerevisiae* var. *boulardii*, but the wine with yerba mate showed a higher content of total phenolic compounds and antioxidant activity	Terhaag *et al.* (2025a)

NI: Not informed.

characteristics that were associated with CO_2 from fermentation by *S. cerevisiae* var. *boulardii*. In addition, the wines produced with lychee alone were described by the tasters as sweeter and fruitier. Thus, the performance of the yeast could be associated with the attributes of flavor, aroma, and texture, characteristics that received scores above 6 on the sensory scale. In addition, *S. cerevisiae* var. *boulardii* was able to ferment the must without causing noticeable changes in aroma or flavor, thus preserving the vineyard's original properties. In another type of fermented alcoholic beverage (mead) produced with *S. cerevisiae* var. *boulardii*, Souza *et al.* (2023b) observed improved sensory acceptance and higher purchase intention, along with a tendency of the product toward yellow color (Souza *et al.*, 2023b).

Although more studies need to be carried out to investigate the effects of *S. cerevisiae* var. *boulardii* on the profile and sensory characteristics of fermented alcoholic beverages, the available scientific literature indicates that this probiotic yeast has no negative influence on sensorial properties of beverages such as beers (Capece *et al.*, 2018; Cerezo *et al.*, 2019) and wines (Cerezo *et al.*, 2023), and also contributes to the improvement of the sensory characteristics of final products (Cerezo *et al.*, 2023; Senkarcinova et al., 2019).

Antioxidant Activity and Total Phenolic Content Generated by *Saccharomyces cerevisiae* var. *boulardii*

Bioactive compounds are substances that interact with the living tissues and participate in several biological activities within the human body, including antioxidant, cardioprotective, and anti-inflammatory activities. These compounds can be found in fruits, greens, vegetables, cereals, legumes, teas, and fermented products (Banwo *et al.*, 2021). Many phenolic compounds are found in beers, including some of the most common and well-known substances such as vanillic acid, gallic acid, and ferulic acid, with the latter two found in most commercial beers. In addition to playing an indispensable role in the beer's antioxidant activity, these compounds also preserve the sensory stability of the product by reducing the oxidation of aromatic compounds, by maintaining fruity notes and preventing the development of unpleasant flavors (Yang and Gao, 2021).

The antioxidant activity of *S. cerevisiae* var. *boulardii* was successfully demonstrated in a few studies conducted with fermented alcoholic beverages. In one study, beers produced with commercial and probiotic yeast under the same conditions had no significant differences in the antioxidant activity (Cerezo *et al.*, 2019). However, when the antioxidant activity was evaluated by the radical 1,1-diphenyl-2-picrylhydrazyl (DPPH) technique, the beer with *S. cerevisiae* var. *boulardii* presented significantly higher results (11.51% ± 0.36 for *S. cerevisiae*; 16.80% ± 0.31 for *S. cerevisiae* var. *boulardii*), which can be attributed to the metabolites produced by this yeast (Cerezo *et al.*, 2019). Using *S. cerevisiae* var. *boulardii* in the production of potentially probiotic mead, Souza *et al.* (2023a) confirmed the presence of total phenolics and natural antioxidants. As such, the presence of these bioactive compounds in fermented alcoholic beverages can provide functional characteristics due to their ability to inhibit free radicals that can cause damage to cells. Recently, another study evaluated the application of water kefir in mixed fermentation with *S. cerevisiae* var. *boulardii* in the development of probiotic mead (Souza *et al.*, 2024a). The beverage produced by the probiotic yeast provided amounts of total phenolics of 15.24 mg of gallic acid equivalent (GAE) per 100 mL, and antioxidants of 83.15 µmol of Trolox equivalents (TE)/100 mL by the ABTS method and 4.52 µmol TE/100 mL by FRAP (Souza *et al.*, 2024a). The authors concluded that although the presence of phenolic compounds and antioxidants in fermented alcoholic beverages depends on various factors, the mead beverage developed with *S. cerevisiae* var. *boulardii* was a significant source of these bioactive compounds (Souza *et al.*, 2023a, 2024a). In addition, there is no regulatory restriction regarding bioactive compounds in functional beverages.

Terhaag *et al.* (2025a) analyzed phenolic compounds and antioxidant activity in wines made from lychee and lychee with yerba mate using the yeast *S. cerevisiae* var. *boulardii.* In the results for total phenolic compounds, the yerba mate wine (1194.55 µg GAE mL) stood out from the lychee wine (320.18 µg GAE mL) due to the prefermentation of the drink. The antioxidant capacity measured by the FRAP methodology was 0.56 µmol TE mL in the lychee wine, while the product with yerba mate had 4.12 µmol TE mL after the second fermentation. However, the yerba mate had little or no influence on this formulation of lychee wine, since the higher values of total phenolic compounds and antioxidant activity were directly enhanced by this raw material.

In the study by Capece *et al*. (2018) on beers fermented with *S. cerevisiae* var. *boulardii* and mixed cultures of *S. cerevisiae*, the ones prepared with the mixed cultures (except for one trial) showed higher polyphenols content (400.87 ± 15.35 mg GAE/L) and antioxidant activity (4.23 ± 0.57 mgTE/L) when compared to beers with a single strain of *S. cerevisiae* (302.61 ± 4.71 GAE/L and 0.75 ± 0.38 mgTE/L, respectively). These results indicate the contribution of *S. cerevisiae* var. *boulardii* in the production of bioactive compounds in beer, which act directly on the shelf life of the drink and promote antioxidant and anti-inflammatory effects with beneficial impacts on consumers' health.

Alcohol Content Produced by *Saccharomyces cerevisiae* var. *boulardii*

The alcohol content of fermented beverages is related to various factors, such as the availability of sugars, fermentation temperature, the quality and appropriate choice of yeast for the fermentation process, among others. In view of this, the selection of appropriate yeasts plays an important role in obtaining fermented alcoholic beverages as they are directly associated with the efficiency of converting sugars into alcohol (Iglesias *et al.*, 2014). In the fermentation process, fermentable sugars are converted into ethanol by the action of yeasts. Inside the cell, the monosaccharides undergo glycolysis, a set of enzymatic reactions that convert glucose into pyruvic acid (pyruvate), producing ATP and NADH. Pyruvate is then converted into acetaldehyde, releasing carbon dioxide (CO_2). Finally, acetaldehyde is reduced to ethanol, regenerating NAD to maintain the glycolysis process (Kumar *et al.*, 2024). Alcoholic beverages are obtained by fermentation by yeast, which have different alcohol production capacities, and therefore numerous application possibilities (Iorizzo *et al.*, 2021; Yildirim, 2021). Among these fermented alcoholic beverages are beers, wines and meads (Souza *et al.*, 2023a; Starowicz and Granovogl, 2020), due to the high fermentative performance of the commercial strain in metabolizing sugars and producing alcohol (Prestianni *et al.*, 2022). Non-conventional yeasts used to produce fermented alcoholic beverages provide specific characteristics on the final product, including functional character, organoleptic characteristics, differentiation from commercially available beers and lower alcohol content (Cubillos *et al.*, 2019). In the case of yeast strains with probiotic characteristics such as *S. cerevisiae* var. *boulardii*, lower alcohol content in the products becomes interesting since high alcohol content can make fermented alcoholic beverages a stressful environment for the maintenance of probiotic strains (Paula *et al.*, 2021), and can reduce vitality and increase cell death (Paula *et al.*, 2019). Thus, studies in the literature have already shown the potential of *S. cerevisiae* var. *boulardii* for obtaining fermented beverages with adequate alcohol content and maintaining cell viability.

Ramírez-Cota *et al.* (2021) tested *S. cerevisiae* var. *boulardii* using dose-response curves for ethanol tolerance and observed that the yeast is tolerant to up to 5% ethanol at 37°C, and to a range between 6 and 8% ethanol at 28°C, thus concluding that its use in beer production is appropriate. Additionally, when the ethanol effect on the yeast cell structure was evaluated under the ideal temperature of 28°C, an increase in cell wall thickness was observed, indicating that this temperature may offer some protection against the toxic effects of ethanol. In another study, in which *S. cerevisiae* var. *boulardii* was used in the production of probiotic beer, the wort was well fermented and showed an alcohol content of 4.0% of alcohol per volume at the end of fermentation (Silva *et al.*, 2020). Using *S. cerevisiae* var. *boulardii* during fermentation to produce wheat beer with probiotic potential, Paula *et al.* (2021) changed the malt concentration in the wort and the temperature profile of the mashing ramp, with the aim of benefiting the activity of the β-amylase enzyme, leading to increased availability of maltose in the wort and improving yeast metabolism. After the modifications, the authors observed a compromise in ethanol production, suggesting that better fermentation conditions should be sought (Paula *et al.*, 2021).

Reitenbach *et al.* (2021) developed a Pilsen-type beer with functional properties by adding *S. cerevisiae* var. *boulardii*, observing an alcohol content of 6.06% after 28 days of storage. Manshin *et al.* (2022) studied the fermentation performance of *S. cerevisiae* var. *boulardii* compared with top-fermenting brewer's yeast strains in the fermentation process of model nutrient media and beer wort. The authors determined alcohol contents of 5.56% in the final beer with *S. cerevisiae* var. *boulardii* with viable yeast cell count at Log 7.1 CFU/mL, and 5.85% alcohol content for commercial *S. cerevisiae* 047A with Log 5.2 CFU/mL of viable cells. However, it should be noted that the alcohol content of beers made with *S. cerevisiae* var. *boulardii* may be influenced by the composition and type of wort. For example, beers made with Pils Wort (PW), Pils + lentil wort (PLW, pils wort added with 20% lentil wort) and Pils + chickpea wort (PCW, pils wort added with 20% chickpea wort) had alcohol contents of 3.3, 4.1 and 0.5%, respectively (Canonico *et al.*, 2021). On the other hand, the yeast concentration and fermentation time have great influence on fermented alcoholic beverages. Souza *et al.* (2023a), studying the growth conditions of *S. cerevisiae* var. *boulardii* for the development of potentially probiotic mead, observed that a higher yeast concentration and longer fermentation time resulted in higher alcohol content. However, the increase in alcohol content has a negative influence, reducing cell viability. It is therefore necessary to find a balance between the concentration of inoculum and fermentation time, to adequately favor the alcohol content of fermented alcoholic beverages.

The yeast *S. cerevisiae* var. *boulardii* was also used in the production of lychee wine (Terhaag *et al.*, 2025a). After 15 days of fermentation, the wines produced with lychee and lychee with yerba mate had an alcohol content of 7.8 and 7.6% respectively. The authors also assessed sugar consumption by the yeast and found that sucrose was exhausted in both the first and second fermentations, indicating total utilization of this energy source by *S. cerevisiae* var. *boulardii*. A recent study for development of probiotic mead demonstrated that *S. cerevisiae* var. *boulardii* in mixed fermentation with water kefir achieved lower alcohol content (7.05%), when compared with mead obtained by mixed fermentation of commercial *S. cerevisiae* and water kefir (alcohol content: 8.22%) after 9 days of fermentation (Souza *et al.*, 2024a). These results indicate that *S. cerevisiae* var. *boulardii* has an adequate alcohol production capacity, which is a positive aspect for the management of fermented alcoholic beverages.

Concluding Remarks and Future Prospects

The probiotic yeast *S. cerevisiae* var. *boulardii* has been used in the development of various products in the food industry, such as dairy foods and beverages, non-dairy beverages and other cereal-based products. According to the literature, several studies provide science-based evidence to support the application of *S. cerevisiae* var. *boulardii* in the production of fermented alcoholic beverages, especially craft beers, wines and mead. In addition, the proper application of *S. cerevisiae* var. *boulardii* in these alcoholic products provides good viability and adequate cell survival, adding desirable sensory characteristics and allowing for an adequate alcohol content in the final product. Therefore, *S. cerevisiae* var. *boulardii* has the potential to produce fermented alcoholic beverages with probiotic character and additional functional effects. However, the addition of probiotic strains to alcoholic beverages faces significant challenges, especially those related to the fermentation environment, since it is a stressful environment that compromises cell survival in high concentrations of alcohol. The interaction of *S. cerevisiae* var. *boulardii* with other yeasts and bacteria during the fermentation process also needs clarification, in order to guarantee the majority presence of this probiotic yeast in the food product. Although recent research has investigated the sensory properties of foods produced with *S. cerevisiae* var. *boulardii,* its effects on beverages have not yet been fully established, as the yeast behaves differently depending on the raw material it is used in. Challenges related to scaling up the production of different alcoholic beverages using *S. cerevisiae* var. *boulardii* must also be addressed, especially the costs involved in the manufacturing process, since they require the use of selected strains, product development and specialized logistics, which directly impact on the final value for the consumer.

The positive impacts of consuming *S. cerevisiae* var. *boulardii* on the microbiota are already well established, yet the beneficial effects of consuming probiotic alcoholic beverages on the intestinal microbiota have not yet been fully elucidated. Regarding regulatory obstacles, probiotic alcoholic beverages must meet requirements related to proving the safety and efficacy of the microorganism used, as well as product labeling and the safety of the food supplied. Thus, large-scale tests are essential to strengthen the application of the yeast *S. cerevisiae* var. *boulardii* in probiotic alcoholic beverages, including distilled products, with a view to expanding its application in the beverage industry. In this context, future investigations into the potential application of *S. cerevisiae* var. *boulardii* should focus on research gaps such as optimization of fermentation conditions, effects on sensory properties and characterization of probiotic functionality and stability in different beverage products during storage. Further research efforts should also focus on studies aiming at demonstrating the beneficial effects of *S. cerevisiae* var. *boulardii* consumption in alcoholic beverages on the intestinal microbiota in *in vivo* animal models and clinical trials.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Authors Contributions

K.N.P. and H.F.S. contributed to the conceptualization, methodology, validation, formal analysis, investigation, resources, and data curation. All authors contributed to the writing – review and editing, visualization, supervision, project administration, and funding acquisition of this study.

Conflicts of Interest

The authors declare no conflicts of interest.

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