Mini Review

pISSN: 2345-5357
eISSN: 2423-4214

APPLIED FOOD BIOTECHNOLOGY, 2021, 8 (4):329-337
Journal homepage: www.journals.sbmu.ac.ir/afb

OPEN ACCESS

Beer as a vehicle for probiotics

Fatemeh Zendeboodi[1], Mohammad Mahdi Gholian[2], Elham Khanniri[1], Sara Sohrabvandi[3*], Amir Mohammad Mortazavian[4]

1- Student Research Committee, Department of Food Science and Technology, Faculty of Nutrition Sciences and Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, P.O. Box 19395-4741, Tehran.

2- Grape Processing and Preservation Department, Research Institute for Grapes and Raisin (RIGR), Malayer University, Malayer, Iran

3- Department of Food Technology Research, Faculty of Nutrition Sciences and Food Technology/National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran

4- Department of Food Science and Technology, Faculty of Nutrition Sciences, National Nutrition and Food Technology Research Institute, Food Science and Technology, Shahid Beheshti University of Medical Sciences

Abstract

Background and Objective: Beer is one of the most consumed beverages worldwide that can be used to transfer probiotics to the host. The aim of this study was to generally review technological parameters incorporated in the production of probiotic beers. Probiotic beer production needs solving technical problems that are linked to processing stages. Although use of probiotics in fermented dairy products has been searched in available scientific literatures, beer is a relatively novel matrix for the incorporation of probiotics and hence a review on its capability as a probiotic carrier can be advantageous. Therefore, objective of the recent review was to investigate the most recent method for the production of probiotic beers. Furthermore, factors affecting the viability of probiotics in the final product were studied.

Results and Conclusion: Scientific literatures verified that probiotic beers could be produced with a few modifications from the non-probiotic beers. As probiotic species include poor growth abilities and probiotic viability is the most important factor considering a product as a probiotic product, multiple criteria for the production of probiotic beers include selecting an alcohol and acid-tolerant probiotic strain, administration of encapsulated probiotics, eliminating thermal and filtration processes, controlling oxygen concentration during fermentation process and after inoculation with probiotic strain, inhabiting severe acidic condition during the probiotic beer production and holding temperature below 5 ˚C during storage and transportation. However, several researches are needed to clarify limiting factors to achieve optimum conditions for the production of appropriate probiotic beers. However, incorporation of nonviable probiotics as alternate germs can be considered as a novel method for the production of health improving beers.

Conflict of interest: The authors declare no conflict of interest.

Article Information

Article history:
- Received 26 June 2021
- Revised 22 July 2021
- Accepted 9 Sept 2021

Keywords:
- Beneficial Health effect
- Non-dairy beverage
- Probiotic beer
- *Saccharomyces boulardii*
- Viability

***Corresponding author:**

Sara Sohrabvandi *
Department of Food Technology Research, Faculty of Nutrition Sciences and Food Technology/National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Tel: 021-88471697
E-mail: sohrabv@sbmu.ac.ir

How to cite this article

Zendeboodi F, Razavi SH, Gholian MM, Khanniri E, Sara Sohrabvandi, Amir Mohammad Mortazavian. Beer as a vehicle for probiotics. Appl Food Biotechnol. 2021; 8(4): 329-337. http://dx.doi.org/10.22037/afb.v8i4.35303

1. Introduction

Continuous development of the novel food products is a response to the consumer demands for healthy and tasty products. One of the methods; in which, brewery and health criteria can be combined is use of health-benefiting probiotic microorganisms [1]. Probiotics are viable microorganisms that confer health benefits on their hosts if administered in adequate amounts. Probiotic foods should include a sufficient population of viable probiotic microorganisms that are incorporated in a proper matrix. Furthermore, metabolic activity and viability of the microorganisms must be preserved at all stages of food processing from manufacturing to consumption by the consumers. Moreover, probiotic microorganisms should be able to preserve their viabilities in the gastrointestinal tract [2-4]. Based on the

studies, concentration of the viable probiotic microorganisms is necessary for biological health effects depending on the strain and desired health effects. Overall, a processed product must contain the minimum viable concentration of 10^6-10^7 CFU g^{-1} of a probiotic, which is established as a therapeutic population of probiotics in the final food products. Daily consumption of nearly 10^8-10^9 CFU g^{-1} probiotics in the form of food products promotes health in humans [3,5]. Several health effects observed by the consumption of probiotic food products include suppressing pathogenic bacteria, inhibiting and terminating antibiotic-associated diarrhea, decreasing symptoms of lactose intolerance, eliminating carcinogens by binding to mutagenic substances, decreasing serum cholesterol and stimulating and modulating the immune system [3,6-8].

Beverage industries have discovered probiotic micro-organisms as novel tools for the development of novel probiotic and functional foods. Diary based beverages are the major carriers for the probiotics. Several products are produced and consumed in the world, including Boza (wheat-based), Bushera (sorghum-based), Mahewu and Pozole (maize-based), probiotic fruit juices and probiotic beers [9-11]. Various probiotic products are available for the consumers. As stated previously, a wide variety of non-diary beverages are cereal-based ones [6,12,13]. Beer is one of the fermented cereal-based beverages, which is produced globally [14]. This product is the most popular and commonly consumed drink within alcoholic beverages worldwide. Brewers investigate novel products to fulfill the consumer demands for novel health-promoting products. Indeed, category of this beverage includes five major associated products such as decreased-calorie, low-alcohol, alcohol-free, fruity-flavored, gluten-free and functional beers. Functional beers are produced by the administration of non-conventional ingredients, which are able to produce or transform production inputs into compounds with benefits for the human health. Beer is a source of valuable and nutritious elements such as proteins, minerals, carbohydrates and vitamins that can be used as a medium for probiotics [15]. Studies have demonstrated that moderate consumption of a beverage containing live probiotic microorganisms is more beneficial for human health than products with inactive microorganisms [2,9]. Generally, adequate number of live probiotic cells in products is necessary to describe the products as probiotic ones. However, the microbial population may vary depending on the strain and species of microrganisms. The present study was carried out for the introduction of technical parameters of probiotic beer production. Although use of probiotics in other beverages and specially fermented beverages has been assessed in numerous studies, beer is a novel matrix for the probiotics and therefore a review for introducing potentials of the beer as a probiotic carrier can be useful.

2. Beer production

Major raw materials used as ingredients in brewing include water, malted barley, hops and yeast. The brewing process involves sugar solutions from malted barley carbohydrates that contain several essential elements as well as using the solutions as media for the yeast growth in anaerobic conditions. Yeast fermentation converts sugar into energy, ethanol and flavoring agents. Natural enzymes from barley and yeast play major roles in catalyzing biological changes during the brewing process. Heat exchange, separation and clarification are the rest of the brewery process, which cause minor changes in the final product compositions in comparison to brewing enzymes [11,14]. *Saccharomyces* (*S.*) *cerevisiae* plays a major role in beer production [16]. Beer batch fermentation technology is the most applicable method for the production of beers, including primary (main) and secondary (maturation) stages [14]. In the primary stage, the wort aerating is needed for achieving rapid start of the process. Wort aeration results in increases in ergosterol and unsaturated fatty acids that are needed in yeast cell membranes. At the main fermentation stage, carbohydrates (e.g. glucose and maltose) are broken by the yeasts through glycolysis and Krebs cycle within the first hours of the process. Oxidation of carbohydrates (glucose) can produce large quantities of energy ($NADH_2^+$) [17]. Alcohol and CO_2 are two actual products that are produced in the fermentation process. Flocculation of yeast occurs at the end of the main fermentation stage. Each floccule contains more than thousands of yeast cells that adhere to each other [18]. Maturation stage begins immediately after the end of the main fermentation stage, when a desired concentration of diacetyl is produced by yeasts after 24 h. Increases in glucose concentration of the wort decrease oxidative metabolisms (the CRAB-tree effect), which affect the final ethanol production in beers. Nowadays, it is generally known that changing in the metabolism of carbon flux (overexpression of GDP1 gene) in microorganisms can decrease ethanol production and enhance formation of other valuable fermentation products, affecting beer maturation time. Temperature includes signifycant effects on each stage. Appropriate concentration of the fermentative metabolites achieved by changing the temperature is linked to the substrate concentration [9,14,19].

3. Probiotic beer processing

Probiotic beer is one of the innovations in functional beers, which is produced by incorporating probiotic microorganisms as fermentative microorganisms or incorporation of live probiotic microorganisms into the final products. Integration of probiotic microorganisms into beers is a valuable method. Beer not only is a source of valuable nutrients such as vitamins, amino acids and phenolic

compounds, it is well accepted and consumed by the majority of people worldwide. The *S. cerevisiae* var. *boulardii*, an alternative probiotic yeast to *S. cerevisiae*, and probiotic bacteria (*Bifidobacterium* and *Lactobacillus*) are suggested as fermenting microorganisms in production of probiotic beers [1,4,20]. The conventional beer fermentation yeast (*S. cerevisiae)* does not survive passage through the gastrointestinal tract; therefore, the bacteria cannot impose therapeutic effects on the host [17,21]. Generally, probiotic beer processing stages are as follows: reception/checking and weighing of the raw materials (malted barley, water, flavoring agents and yeast), malt milling, mashing, wort separation and boiling, wort clarification and cooling, and the fermentation. Processing stages to fermentation step lead to the production of beer formulation. The fermentation of sterilized wort is carried out after pitching probiotic yeasts at 8 ˚C for 8-10 days [1]. If *S. boulardii* or other probiotic bacteria are used as a starter culture in fermentation, thermal stage (pasteurization) and filtration steps are removed from the production for the survival of the probiotics. When other species of *saccharomyces* are used as fermentative microorganisms, addition of probiotic cultures is carried out after cooling stage of the pasteurized beers and before the aseptic packaging stages. Regarding probiotic co-fermentation, probiotic bacteria are inoculated into unhopped wort and incubated at 37˚C for 24 h for achieving desired cell counts. Subsequently, probiotic yeasts are inoculated into the mixture and incubated at 20˚C for 48 h [22]. Packaged products must be cool during transport, marketing distribution and storage. Control of the product temperature during the highlighted steps is a critical point in survival of the probiotic population [1, 4]. Overall, the beer matrix can be a good carrier for the probiotics due to its nutritional composition. Moreover, a probiotic product should include relatively high pH values (e.g. beers with pH 5-6) for improving the survival of probiotic yeast cultures during storage [23].

3.1. Regulatory requirements for the incorporation of probiotics into beers

However probiotic foods are known as vehicles for the health benefiting microorganisms, studying methods of transforming these microorganisms is critical. The first general rule in production of probiotic foods is assuring sufficient viability values of the microorganisms in food matrices during storage, conferring therapeutic effects on consumers without decreasing sensorial and functional characteristics of the final products. Moreover, the fact that growth and viability of the probiotics are strain-dependent has recently been reported. Even though several beer formulations are rich in sugar and alcohol, beer is considered as a nutritive product due to the presence of nutritive elements. Addition of probiotic yeasts and bacteria (including *S. boulardii*, *Lactobacillus* (*L.*) *acidophilus* and *Bifidobacterium* (*B.*) *lactis)* to beers may improve the food beneficial health effects [23].

3.1.1. Level and survival of the probiotics in probiotic beers

Despite the fact that the most probiotics are bacteria, but *S. boulardii* is the only probiotic yeast is used in the pharmaceutical industry, extensively [24,25]. Several researchers have found that the *S. boulardii* strains include probiotic effects such as decreasing enteric bacterial pathogens, increasing epithelial barrier integrity, decreasing human colon cell response to pro-inflammatory cytokines, stimulating host immune cells and enhancing cell membrane enzymes in the host [26-28]. Furthermore, researches have reported incorporation of probiotic bacteria into beers, including *L. acidophilus* La-5, *Bacillus* (*B.*) *lactis* Bb-12 [4], *L. paracasei* L26 (Chan, 2019), *L. paracasei* DTA-81 [29], *B. velezensis* DU14 [30] and *S. boulardii* [31]. Since probiotics are susceptible to heat processing, every process stage must be optimized to increase the microbial survival (Table 1).

Table 1. Technological hurdles faced during the processing of beer containing probiotic cultures

Step	Problem	Solutions
Inoculum probiotic microorganism	The viability of some probiotic bacteria and yeasts are diminished in the brewery	Selection some stress-tolerant strains
Fermentation	Formation of excessive amounts of lactic acid and a decline in pH value production of a high amount of ethanol during the fermentation step	Selection of tolerant strains when exposed to low pH values monitoring pH changes and inhibit pH decline less than 4
Aerating	Dissolved oxygen is toxic for some probiotics	Selection of tolerant strains to oxygen control the amount of oxygen dissolved in the packed beer
Storage	Beer storage cause at least 1 log cycle decrease in the probiotic population	Increase inoculum concentration Inhibit temperature changes during the storage period

This means that pasteurization and filtration processes in the conventional production of beers are two challenging stages in development of probiotic beers. Naturally, pasteurization and filtration can destroy and remove probiotics, respectively. Incorporation of probiotics into beers after the pasteurization or filtration is suggested as an alternate method for the production of probiotic beers [1,32]. As viable probiotics have health effects on their host, the survival of these microorganisms in the final products is a critical factor. Although viability of the probiotic microorganisms after long storages is reported unsatisfactory even at refrigeration temperatures [4], encapsulation of probiotics has been suggested as a useful method for enhancing probiotic survival. Haffner and Pasc [33] produced probiotic beers with encapsulated microorganisms. The study included incorporation of freeze-dried encapsulated probiotics with alginate or silica beads for the enhancement of probiotic viability in alcoholic beers (5% vt alcohol). Based on the study, silica-coated beads included a viability of 10^5 CFU ml^{-1} after one week of storage at 4 ˚C. Although one log loss was observed in silica-coated beads after one week of storage, silica-coated beads prevented leak of probiotics into beers and protected the probiotics better than that the alginate did. Due to the fact that probiotic cells were in direct contact with methanol during the silica synthesis, these cells adopted to severe alcoholic conditions and could better tolerate the alcohol when ethanol was included in beers. Furthermore, it has been demonstrated that nonviable probiotics can include their beneficial health effects on the hosts. Despite the fact that the World Health Organization/Food and Agriculture Organization (WHO/-FAO) have considered probiotics as viable health benefiting microorganisms, beneficial health effects of nonviable probiotic microorganisms have recently been verified as well, including anti-cancer, anti-pathogen, immune system modulating, blood cholesterol lowering, oral health enhancing and psychological benefit effects. Indeed, administration of such nonviable cells could be an effective method in response to concerns about the probiotic viability. Overall, technological methods for the incorporation of viable probiotics into beers in the processing should be well known and optimized. Process stages such as heating and filtration in beer production may decrease survival of the probiotics during storage. Moreover, methods of adding probiotics can affect viability of the microorganisms in the final products. In addition, optimization of encapsulation methods and materials should be well carried out for achieving the best condition of probiotic beer production.

3.1.2. Factors affecting viability of the probiotics in beers

In general, incorporation of probiotics into food products is difficult since probiotic products are microbiologically sensitive. Naturally, bifidobacteria include weak growth rates and need anaerobic conditions [34]. However, *S. boulardii* is heat and acid resistant in comparison to other yeast strains used in the brewery [21]. Survival of these valuable microorganisms in fermented products depends on various factors such as the microbial strains, interactions between cultures and beer components, final acidity, presence of growth inhibitors or enhancers, oxygen concentration, incubation temperature, fermentation duration and storage temperature [34,35].

3.1.3. Beer acidity

Decreases in growth media pH of the probiotics is considered as a lethal factor during fermentation and storage In addition, metabolite production (e.g. organic acids) during fermentation and storage further decreases pH. According to Sohrabvandi et al. [4], one of the major constraining factors affecting the use of probiotic cultures in fermented products is pH intolerance of the microbial species and strains. In addition to increases in lactic acid concentrations of the media, pH decreases during fermentation. Decreases in pH may continue after fermentation and during storage at low temperatures, resulting in over acidification [34]. Over acidification can be controlled using appropriate cultures with low acid production [6]. Viabilities of the bacteria and yeasts depend on the pH of the media. Several researchers have demonstrated negative effects of pH < 4.4 on probiotic cell survival during the storage. Sohrabvandi et al. [4] revealed that the viability of *L. acidophilus* used as a probiotic microorganism in beers was lost because of the low pH of the beers; however, *B. lactis* cells preserved their viabilities after 20 days of storage at refrigerating temperatures. These results were verified by Mortazavian et al. [36] and Playne et al. [37], who reported that *L. acidophilus* was lost in fermented milk products at pH < 4.0. In contrast, Angelov et al. [24] concluded that pH 4.2 included no fetal effects on *L. plantarum* used as a probiotic in production of a novel oat-based drink during 8 h of fermentation. Regarding *S. boulardii* as a probiotic yeast in brewery, it has widely been reported that this strain is highly resistant to temperature and acidic conditions (gastric pH 1-4) which are important factors for considering micro-organisms as fermenting agents in production of probiotic beers [6,12].

Overall, pH of beers may decrease to 3.5, which may inhibit growth of the probiotics, especially *Bifidobacterium* and *Lactobacillus* because their growth decreases at pH < 5.0 [34,38]. For achieving better results in production of probiotic beers, pH of the final products should be higher than 4.0. Furthermore, lowering storage temperature of the probiotic beers can inhibit over-acidification. Encapsulation is another promising method for increasing survival of the microorganisms in acidic conditions during the food processing and storage as well as passage through the gastrointestinal tract [12,25]. Graff et al. [6] reported that alginate microsphere could protect *S. boulardii* from acidic conditions and microspheres included faster releases of viable cells in the intestines. Based on the results by Arslan

et al. [25], encapsulation of *S. boulardii* with gelatin materials improves viability of the yeasts when exposed to severe acidic conditions of the gastrointestinal tract, compared to the free cells. Since proteins contain less polar hydroxyl groups than that the polysaccharides do, the cell wall proteins protect core of the microcapsules from acid. Indeed, detrimental effects of acidic condition decrease by the administration of encapsulated probiotics and can ensure industries that adequate numbers of the probiotics are viable in the small intestine and hence production of probiotic beers with therapeutic effects is true. In addition to the protective effects of capsule, encapsulation decreases production and accumulation of organic acids and acidification of the environment of the probiotics.

3.1.4. The microbial species and strains

The appropriate strain selection contributes to survival and performance of a strain in brewery. Viability of the probiotic bacteria and yeasts is destroyed under high concentrations of ethanol and severe acidic conditions, respectively [39]. Moreover, the correct strain selection is necessary to ensure production of high-quality probiotic beers. Ability to grow and viability during the storage are the major criteria that must be considered for the selection of bifidobacteria and lactobacilli as probiotic microorganisms. Selection of the yeast strains in beers indicates production of further volatiles that improve quality of the final products in addition to their microbial survival in beers after storage at 7˚C [5,24,33]. Silva et al. [29] have produced probiotic beers by incorporation of *L. paracasei* and various *Saccharomyces* strains (*S. boulardii*, *S. cerevisiae* S-04 and *S. cerevisiae* NT. Based on the results, activity of *L. paracasei* was inhibited at ethanol concentrations greater than 7.0%, while *Saccharomyces* strains survived [40]. Moreover, *S. cerevisiae* S-04 produced 4.0% ethanol in beerd, which was below *L. paracasei* sensitivity to alcohol. Indeed, *L. paracasei* might survive in beers fermented by *S. cerevisiae* S-04. Regarding acid resistance, *S. cerevisiae* S-04 was more resistant than the other microorganisms against acidic conditions and its viability did not decrease at pH 4.0 as lactic acid bacteria (LAB) included abilities to convert carbohydrates into acids. Therefore, those probiotic yeasts could not survive in beers containing LAB. Large-scale production of special yeasts is another factor that is important for the culture providers. Population of the selected microbial strains must be 10^{10}-10^{11} CFU g^{-1} to ensure expected efficiency during the commercial-scale brewing processes [35].

3.1.5. Co-culture and species interactions

Presence of other microbial species in fermentation process has been shown to affect viability of the probiotics in beers. Media such as probiotic beers include metabolites produced by other non-probiotic microorganisms, which can affect survival of the probiotics in beers. Sohrabvandi et al. [4] reported that the growth of *L. acidophilus* and *B. lactis* was inhibited in beers fermented *by S. cerevisiae*, compared to those fermented by *Zygosaccharomyces rouxi.* In a study by Capece et al. [23], a mixed fermentation of *S. boulardii* and five strains of *S. cerevisiae* was assessed. Based on the results, *S. boulardii* dominated the other strains at the end of storage (15 days). However, the final population of *S. boulardii* in the beer was less than that of *S. cerevisiae*. Chan et al. [22] have concluded that the presence of *S. cerevisiae* S-04 was not detrimental to *L. paracasei* L26, as the probiotic growth and viability at the stationary phase were not significantly affected. During the storage, probiotic viability was at the maximum level in presence of live yeasts. The *B. lactis* included no proteolytic activities; indeed, its growth depended on other microorganisms in media. These strains could be grown in presence of other proteolytic microorganisms such as *S. boulardii* and *L. acidophilus*, which secreted proteases for the easy consumption of available proteins as nitrogen sources [34,41]. Although, proteolytic microorganisms provided necessary stimulants for these probiotic strains; however, effects of *B. lactic* or other bifidobacteria on the growth of *S. boulardii* have not been investigated.

3.1.6. Molecular oxygen

Aeration is a critical process in beer production, when yeasts are used as fermentative systems [42]. Oxygen penetrates in beers during brewery processes. Oxygen also penetrates during packaging processes and storage. Since bifidobacteria are anaerobic microorganisms, aeration after incorporation of such bacteria into the beer may cause oxygen toxicity and thereby fatally affecting bifidobacteria. Indeed, beers with low dissolved oxygen levels must be used to ensure survival and growth of bifidobacteria [34]. Naturally, LAB are known as resistant genera toward CO_2 [43]. Moreover, LAB are able to tolerate low oxygen concentrations as they are anaerobic or aerotolerant microorganisms [44]. Since beer production is carried out under controlled aerobic conditions, oxygen concentration is an important and critical factor in viability and proliferation of the fermentative yeasts. However, ethanol and other volatile products are produced in the fermentation stage under low aerobic conditions. Oxygen penetrates into packaged beers during the storage [45]. To inhibit oxygen toxicity, it has been suggested to incorporate oxygen tolerant mutants of bifidobacteria, which preserve their growth in presence of oxygen [46].

3.1.7. Storage conditions

Temperature is a critical factor that significantly affects beer quality and sensory properties through affecting chemical reactions. Vanderhaegen et al. [47] compared developments of flavoring components in beers, when stored at 40 and 20 ˚C. Based on the results, flavor deterioration of the beers stored at 40 ˚C was more than that of other beers. Otherwise, storage of beers at refrigerate temperatures could prevent oxidation in beers for several months [45,47]. Regarding probiotic beers, storage temperature is an important factor that affects survival of the probiotics since most of these microorganisms are susceptible to high temperatures [48].

Population of *B. lactis* in beers stored at 5 ˚C for 20 days was more than that of *L. acidophilus* [4]; however, Sohrabvandi et al. [4] have reported that beers might not be appropriate carriers for the probiotics as surviving population of the probiotics in beers was less than 10^7 CFU ml^{-1} (therapeutic population of probiotics) after 20 days of storage at 5 ˚C. According to Sohrabvandi et al. [4], population of the probiotics in samples inoculated with *B. lactis* was greater than that in samples contained *L. acidophilus* after the storage (refrigerated storage conditions). The authors [4] revealed that selection of a proper probiotic strain was important in addition to storage conditions. However, the beneficial health effects of probiotics were reported in presence of nonviable probiotic cells. Most studies have demonstrated that the survival proportion of *Lactobacillus* spp. is high at low storing temperatures [49]. Survival of *S. boulardii* also depends on the storage temperature; however, it has been addressed as a resistant strain to the temperature stress in brewery industries [26]. Incorporating encapsulated probiotics into beers improves storage stability and survival of the probiotics. Haffner and Pasc [33] investigated effects of the alginate-silica matrix on the release and survival of *L. rhamnosus* in beers. Alginate silica capsules decreased release of the microorganisms into the beers after one week of storage at 4˚C and preserved viability of the cells at high levels that the stored beers included favorite counts of the probiotics.

4. Sensory properties of the probiotic beers

During the fermentation of beers, organic acids are produced that can affect sensory properties of the beers [50]. Esterifiaction of acetic acid leads to production of ethyl ester that results in fruity tastes. Overall, probiotic cultures do no decrease sensory properties of the final beers. According to a recent study, addition of *S. boulardii* enhanced overall acceptance of the beers. Based on this study, aroma, flavor and appearance of the probiotic beers were better than those of beers with no probiotics [51]. According to Mulero-Cerezo et al. [52], probiotic craft beers fermented by *S. boulardii* included similar sensorial attributes to non-probiotic ones and administration of such probiotic yeasts did not decrease overall acceptance of the final products, compared to craft beers produced with *S. cerevisiae* [23].

5. The future prospective

Beers could be appropriate beverages as carriers of probiotics, when considering their high volumes of consumption by all ages and nationalities. Brewery is an early step in the production of effective probiotic products for human uses. Brewing industries need methods to compensate for adverse health effects of alcoholic beers by producing nutritious and low-alcohol beers. Incorporation of probiotics into these nutritious beers can be considered as an attractive method for enhancing social health. Various factors in brewery stages should be optimized to protect probiotics from detrimental factors, preserving probiotic viability and activity. Considering this goal, several criterion factors should be controlled, including selection of the appropriate probiotic microorganism and concentration of the inoculum, optimization of the brewery process, inhibition of the over acidification, control of the aeration, control of the refrigerated storage and strict control of the transportation temperature. In conclusion, encapsulated probiotic cultures normally present good viabilities during processing and storage. However, positive health effects of nonviable probiotics and their cell free metabolites have been revealed in recent years. Administration of nonviable probiotics and their metabolites can include health effects with no worries about their viability and stability during processing, storage and consumption. Indeed, nonviable probiotics have opened a new era for brewing industries and scientists. Although several researches have reported adequate viability of the probiotic cultures during processing and storage of beers, further studies on the clinical effects of probiotic beers are suggested. Moreover, it is necessary to verify that the administered probiotics are capable of conferring similar health benefits to those with shorter shelf-lives (e.g. yogurts) after long storage times. In addition, educational groups must encourage people to consume probiotic beers, showing health benefits of such valuable products.

6. Conclusion

Little knowledge about probiotic beers is available since most probiotic products are dairy-based. As probiotic species include poor growth abilities, several studies are needed to clarify limiting factors to achieve the optimum conditions for the microbial as well as effects of food types and microbial survival conditions. Up-to-day, several criteria for the production of probiotic beers have been described such as selecting appropriate microbial strains, eliminating thermal pasteurization and filtration processes in brewery, monitoring concentration of the molecular oxygen during processing and storage of the probiotic beers with respect to anaerobic strains, controlling pH of the products, inhibiting pH decreases during fermentation and storage and eliminating temperature changes during storage.

7. Acknowledgements

This study was financially supported by Shahid Beheshti University of Medical Sciences, Tehran, Iran (Project No. 21658). We appreciate Shahid Beheshti University of Medical Sciences for their financial support of this study.

8. Conflict of Interest

The authors report no conflict of interest.

References

1. Senkarcinova B, Dias IAG, Nespor J, Branyik T. Probiotic alcohol-free beer made with *Saccharomyces cerevisiae* var. *boulardii*. LWT. 2019; 100: 362-367. doi: 10.1016/j.lwt.2018.10.082

2. Sampaolesi S, Gamba RR, De Antoni GL, Pelaez AML. Potentiality of yeasts obtained as beer fermentation residue to be used as probiotics. LWT. 2019; 113: 108251. doi: S002364381930581X

3. Martinez-Martinez MI, Calabuig-Tolsa R, Cauli O. The effect of probiotics as a treatment for constipation in elderly people: A systematic review. Arch Gerontol Geriat. 2017; 71: 142-149. doi: 10.1016/j.archger.2017.04.004

4. Sohrabvandi S, Razavi SH, Mousavi SM, Mortazavian AM. Viability of probiotic bacteria in low alcohol-and non-alcoholic beer during refrigerated storage. Philipp Agric Sci. 2010; 93(1): 24-28. doi: S016749431730211X

5. Kayode AP, Deh DC, Lamine B-M, Kotchoni SO, Hounhouigan JD. Stabilization and preservation of probiotic properties of the traditional starter of African opaque sorghum beers. African J Biotechnol. 2012; 11(30):7725-7730. doi: 10.5897/AJB11.3231

6. Graff S, Chaumeil J-C, Boy P, Lai-Kuen R, Charrueau C. Influence of pH conditions on the viability of Saccharomyces boulardii yeast. J Gen Appl Microbiol. 2008; 54(4): 221-227. dio: 10.2323/jgam.54.221

7. Norouzbeigi S, Vahid-Dastjerdi L, Yekta R, Sohrabvandi S, Zendeboodi F, Mortazavian AM. Celiac therapy by administration of probiotics in food products: a review. Curr Opin Food Sci. 2020; 32: 58-66. doi: S2214799320300059

8. Zendeboodi F, Khorshidian N, Mortazavian AM, da Cruz AG. Probiotic: Conceptualization from a new approach. Curr Opin Food Sci. 2020. doi: 10.1016/j.cofs.2020.03.009

9. Rodrigues KL, Araujo TH, Schneedorf JM, de Souza Ferreira C, Moraes GdOI, Coimbra RS, Rodrigues MR. A novel beer fermented by kefir enhances anti-inflammatory and anti-ulcerogenic activities found isolated in its constituents. J Funct Food. 2016; 21: 58-69. doi: 10.1016/j.jff.2015.11.035

10. Sohrabvandi S, Mortazavian A, Rezaei K. Health-related aspects of beer: a review. Int J Food Prop. 2012; 15(2):350-373. doi: 10.1080/10942912.2010.487627

11. Yeo HQ, Liu SQ. An overview of selected specialty beers: Developments, challenges and prospects. Int J Food Sci Technol. 2014; 49(7): 1607-1618. doi: 10.1111/ijfs.12488

12. Graff S, Chaumeil J-C, Boy P, Lai-Kuen R, Charrueau C. Formulations for protecting the probiotic *Saccharomyces boulardii* from degradation in acidic condition. Biol Pharm Bull. 2008; 31(2): 266-272. doi: 10.1248/bpb.31.266

13. Reitenbach AF, Iwassa IJ, Barros BCB. Production of functional beer with the addition of probiotic: *Saccharomyces boulardii*. Res Soc Develop. 2021; 10(2): 1-10. doi: 10.33448/rsd-v10i2.12211

14. Willaert R. The beer brewing process: Wort production and beer. Handbook of Food Products Manufacturing, 2 Volume Set. 2007; 443. doi: 10.1002/9780470113554.ch20

15. Preedy VR. Beer in Health and Disease Prevention: Academic Press; I st Edition, 2011; 213.

16. Swanson KM. Microorganisms in Foods: Use of Data for Assessing Process Control and Product Acceptance: Springer Science; 2011; 389.

17. Salari R, Salari R. Investigation of the best *Saccharomyces cerevisiae* growth condition. Electron Physician. 2017; 9(1): 3592. doi: 10.19082/3592

18. Ferreira IM, Guido LF. Impact of wort amino acids on beer flavour: A review. Fermentation. 2018; 4(2): 1-13. doi: 10.3390/fermentation4020023

19. Sohrabvandi S, Mousavi SM, Razavi SH, Mortazavian AM, Rezaei K. Alcohol-free beer: methods of production, sensorial defects, and healthful effects. Food Rev Int. 2010; 26(4): 335-352. doi: 10.1080/87559129.2010.496022

20. Walker G, Stewart G. *Saccharomyces cerevisiae* in the production of fermented beverages. Beverages. 2016; 2(4): 1-12. doi: 10.3390/beverages2040030

21. Fietto JL, Araujo RS, Valadao FN, Fietto LG, Brandao RL, Neves MJ, Gomes FC, Nicoli JR, Castro IM. Molecular and physiological comparisons between *Saccharomyces cerevisiae* and *Saccharomyces boulardii*. Can. J Microbiol. 2004; 50(8): 615-621. doi: 10.1139/w04-050

22. Chan MZA, Chua JY, Toh M, Liu S-Q. Survival of probiotic strain *Lactobacillus paracasei* L26 during co-fermentation with *S. cerevisiae* for the development of a novel beer beverage. Food microbiol. 2019; 82: 541-550. doi: 10.1016/j.fm.2019.04.001

23. Capece A, Romaniello R, Pietrafesa A, Siesto G, Pietrafesa R, Zambuto M, Romano P. Use of *Saccharomyces cerevisiae* var. *boulardii* in co-fermentations with *S. cerevisiae* for the production of craft beers with potential healthy value-added. Int J Food Microbiol. 2018; 284: 22-30. doi: 10.1016/j.ijfoodmicro.2018.06.028

24. Angelov A, Gotcheva V, Kuncheva R, Hristozova T. Development of a new oat-based probiotic drink. Int J Food Microbiol. 2006; 112(1): 75-80. doi: 10.1016/j.ijfoodmicro.2006.05.015

25. Arslan S, Erbas M, Tontul I, Topuz A. Microencapsulation of probiotic *Saccharomyces cerevisiae* var. boulardii with different wall materials by spray drying. LWT-Food Sci Technol. 2015; 63(1):685-690. doi: 10.1016/j.lwt.2017.03.060

26. Buts J-P. Twenty-five years of research on *Saccharomyces boulardii* trophic effects: updates and perspectives. Digestive diseases and sciences. 2009; 54(1): 15-18. doi: 10.1007/s10620-008-0322-y

27. Dahan S, Dalmasso G, Imbert V, Peyron J-F, Rampal P, Czerucka D. *Saccharomyces boulardii* interferes with enterohemorrhagic *Escherichia coli*-induced signaling pathways in T84 cells. Infect Immun. 2003; 71(2): 766-773. doi: 10.1128/IAI.71.2.766-773.2003

28. Panghal A, Janghu S, Virkar K, Gat Y, Kumar V, Chhikara N. Potential non-dairy probiotic products-a healthy approach. Food Biosci. 2018; 21: 80-89. doi: 10.1016/j.fbio.2017.12.003

29. Silva L, Schmidt G, Alves L, Oliveira VS, Laureano-Melo R, Stutz E, Martins J, Paula BP, Luchese RH, Guerra AF. Use of probiotic strains to produce beers by axenic or semi-separated co-culture system. Food Bioprod Process. 2020; 124: 408-418. doi: 10.1016/j.fbp.2020.10.001

30. Borah T, Gogoi B, Khataniar A, Gogoi M, Das A, Borah D. Probiotic characterization of indigenous *Bacillus velezensis* strain DU14 isolated from Apong, a traditionally fermented rice beer of Assam. Biocataly Agric Biotechnol. 2019; 18: 60-78. doi: 10.1016/j.bcab.2019.01.046

31. de Paula BP, de Souza Lago H, Firmino L, Junior WJFL, Correa MFD, Guerra AF, Pereira KS, Coelho MAZ. Technological features of *Saccharomyces cerevisiae* var. *boulardii* for potential probiotic wheat beer development. LWT. 2021; 135: 233-241. doi: 10.1016/j.lwt.2020.110233

32. Zendeboodi F, Jannat B, Sohrabvandi S, Khanniri E, Mortazavian AM, Khosravi K, Gholian Mm, Sarmadi B, Haji Seyed Javadi N. Detection of Non-Alcoholic beer spoilage microorganisms at critical points of production by polymerase chain reaction. Biointerface Res Appl Chem. 2021; 11(2): 9658-9668. doi: 10.33263/BRIAC112.96589668

33. Haffner FB, Pasc A. Freeze-dried alginate-silica microparticles as carriers of probiotic bacteria in apple juice and beer. LWT. 2018; 91: 175-179. doi: 10.1016/j.lwt.2018.01.050

34. Lourens-Hattingh A, Viljoen BC. Yogurt as probiotic carrier food. Int Dairy J. 2001; 11(1-2): 1-17. doi: 10.1016/S0958-6946(01)00036-X

35. Cruz AG, Antunes AE, Sousa ALO, Faria JA, Saad SM. Ice-cream as a probiotic food carrier. Food Res Int. 2009; 42(9):1233-1239. doi: 10.1016/j.foodres.2009.03.020

36. Mortazavian A, Ehsani M, Azizi A, Razavi S, Mousavi S, Sohrabvandi S, Reinheimer JA. Viability of calcium-alginate-microencapsulated probiotic bacteria in Iranian yogurt drink (Doogh) during refrigerated storage and under simulated gastrointestinal conditions. Aust J Dairy Technol. 2008; 63(1): 25.

37. Playne MJ, Bennett L, Smithers G. Functional dairy foods and ingredients. Aust J Dairy Technol. 2003; 58(3): 242-264. doi: 57a910f308aed1b226244dbe

38. Shah N. Probiotic bacteria: selective enumeration and survival in dairy foods. J dairy Sci. 2000; 83(4): 894-907. doi: 10.3168/jds.S0022-0302(00)74953-8

39. Canonico L, Zannini E, Ciani M, Comitini F. Assessment of non-conventional yeasts with potential probiotic for protein-fortified craft beer production. LWT. 2021; 145: 111361. doi: 10.1016/j.lwt.2021.111361

40. Ramirez-Cota GY, Lopez-Villegas EO, Jimenez-Aparicio AR, Hernandez-Sanchez H. Modeling the ethanol tolerance of the probiotic yeast *Saccharomyces cerevisiae* var. *boulardii* CNCM I-745 for its possible use in a functional beer. Probiotics Antimicro. 2021; 13(1): 187-194. doi: 10.1007/s12602-020-09680-5

41. Valdes-Varela L, Gueimonde M, Ruas-Madiedo P. Probiotics for prevention and treatment of *Clostridium difficile* infection. Adv Exp Med Biol. 2018:161-76. doi: 10.1007/978-3-319-72799-8_10

42. Lin Y, Zhang W, Li C, Sakakibara K, Tanaka S, Kong H. Factors affecting ethanol fermentation using *Saccharomyces cerevisiae* BY4742. Biomass Bioenerg. 2012; 47: 395-401. doi: 10.1016/B978-0-12-819233-7.00017-3

43. Pellissery AJ, Vinayamohan PG, Amalaradjou MA, Venkitanarayanan K. Spoilage Bacteria and Meat Quality. In Meat Quality Analysis. Academic Press. 2020: 307-334. doi: 10.1016/B978-0-12-819233-7.00017-3

44. Von Wright A, Axelsson L. Lactic Acid Bacteria: an Introduction. Lactic acid Bacteria: CRC Press; 2019: pp. 1-16.

45. Jaskula-Goiris B, De Causmaecker B, De Rouck G, Aerts G, Paternoster A, Braet J, De Cooman L. Influence of transport and storage conditions on beer quality and flavour stability. J I Brewing. 2019; 125(1): 60-8. doi: 10.1002/jib.535

46. Asadzadeh A, Jalali H, Azizi MH, Nafchi AM. Production of oat bran functional probiotic beverage using *Bifidobacterium lactis*. J Food Meas Charact. 2021; 15(2): 1301-9. doi: 10.1007/s11694-020-00726-4

47. Vanderhaegen B, Neven H, Coghe S, Verstrepen KJ, Verachtert H, Derdelinckx G. Evolution of chemical and sensory properties during aging of top-fermented beer. J Agric Food Chem. 2003; 51(23): 6782-6790.

48. Ostlie HM, Treimo J, Narvhus JA. Effect of temperature on growth and metabolism of probiotic bacteria in milk. Int Dairy J. 2005; 15(10): 989-997. doi: 10.1016/j.idairyj.2004.08.015

49. Lopes LA, Carvalho RD, Magalhaes NS, Madruga MS, Athayde AJ, Portela IA, Barao CE, Pimentel TC, Magnani M, Stamford TC. Microencapsulation of *Lactobacillus acidophilus* La-05 and incorporation in vegan milks: Physicochemical characteristics and survival during storage, exposure to stress conditions, and simulated gastrointestinal digestion. Food Rese Int. 2020; 135:109295. doi: 10.1016/j.foodres.2020.109295

50. Kunze W. Technology Brewing and malting. VLB, Berlin. 2014: 356-60.

51. Amorim JC, Piccoli RH, Duarte WF. Probiotic potential of yeasts isolated from pineapple and their use in the elaboration of potentially functional fermented beverages. Food Res Int. 2018; 107: 518-527. doi: 10.1016/j.foodres.2018.02.054

52. Mulero-Cerezo J, Briz-Redon A, Serrano-Aroca A. *Saccharomyces cerevisiae* var. *boulardii*: Valuable probiotic starter for craft beer production. Appl Sci. 2019; 9(16): 3250. doi: 10.3390/app9163250

Mini Review

pISSN: 2345-5357
eISSN: 2423-4214

OPEN ACCESS

APPLIED FOOD BIOTECHNOLOGY, 2021, 8 (4): 329-337
Journal homepage: www.journals.sbmu.ac.ir/afb

آبجو به عنوان حاملی برای زیست‌یارها

فاطمه زنده‌بودی[۱]، محمد مهدی قلیان[۲]، الهام خان‌نیری[۱]، سارا سهراب‌وندی[۳*]، امیرمحمد مرتضویان[۴]

۱- کمیته پژوهشی دانشجویان، گروه علوم و صنایع غذایی، دانشکده علوم تغذیه و صنایع غذایی، انستیتو تحقیقات تغذیه‌ای و صنایع غذایی کشور، دانشگاه علوم پزشکی شهید بهشتی، تهران، ایران.
۲- گروه فرایند و نگهداری انگور، انستیتو تحقیقات انگور و کشمش (RIGR)، دانشگاه ملایر، ملایر، ایران.
۳- گروه تحقیقات صنایع غذایی، دانشکده علوم تغذیه و صنایع غذایی، انستیتو تحقیقات تغذیه‌ای و صنایع غذایی کشور، دانشگاه علوم پزشکی شهید بهشتی، تهران، ایران.
۴- گروه علوم و صنایع غذایی، دانشکده علوم تغذیه و صنایع غذایی، انستیتو تحقیقات تغذیه‌ای و صنایع غذایی کشور، دانشگاه علوم پزشکی شهید بهشتی، تهران، ایران.

چکیده

سابقه و هدف: آبجو یکی از پرمصرف ترین نوشیدنی جهان می‌باشد، که می‌تواند برای انتقال زیست‌یارها[۱] مورد استفاده قرار گیرد. هدف این مقاله مرورکلی شاخص‌های فناورانه مورد استفاده در تولید آبجوی زیست‌یار بود. تولید آبجوی زیست‌یار، نیازمند رفع مشکلات فنی مرتبط با مراحل فرایند می‌باشد. علی‌رغم دردسترس بودن منابع علمی در زمینه تحقیقات انجام شده برای استفاده از زیست‌یارها در فرآورده‌های تخمیری لبنی، آبجو ماتریس نسبتا جدید برای انتقال زیست‌یارهاست، از این‌رو، مروری بر قابلیت آن به‌عنوان حامل زیست‌یارمی‌تواند مفید باشد. بنابرین هدف مقاله مروری حاضر بررسی جدیدترین روش تولید آبجو زیست‌یار می‌باشد. علاوه‌براین، عوامل موثر بر زنده‌مانی زیست‌یارها در فرآورده نهایی مورد مطالعه قرار گرفته است.

یافته‌ها و نتیجه‌گیری: منابع علمی تایید کرده‌اند که با اصلاحات جزئی آبجوهای غیر زیست‌یار می‌توان آبجوهای زیست‌یار تولید کرد. ازآنجاکه توانایی رشد سویه‌های زیست‌یار ضعیف است و زنده‌مانی زیست‌یارها مهمترین عامل در تولید یک محصول زیست‌یار محسوب می‌شود، معیارهای متعددی برای تولید آبجو زیست‌یار وجود دارند، مانند انتخاب سویه زیست‌یار مقاوم به اسید و الکل، ریزپوشانی زیست‌یارها، حذف فرایندهای حرارتی و فیلتر کردن، کنترل غلظت اکسیژن هنگام فرایند تخمیر و تلقیح بعدی سویه زیست‌یار، حفظ شرایط اسیدی شدید در هنگام تولید آبجو زیست‌یار و نگهداری و حمل آن در درجه حرارت پایین‌تر از ۵ درجه سلسیوس. هرچند بسیاری از محققان برای بهینه‌سازی شرایط تولید آبجو زیست‌یار مناسب، نیازمند شفاف‌سازی عوامل محدودکننده می‌باشند. با این حال ، ترکیب زیست-یارهای غیرزنده به‌عنوان میکروب‌های جایگزین می‌تواند به عنوان روشی جدید برای تولید آبجوهایی با اثر سلامتی‌بخش درنظر گرفته شود.

تعارض منافع: نویسندگان اعلام می‌کنند که هیچ نوع تعارض منافعی مرتبط با انتشار این مقاله ندارند.

تاریخچه مقاله

دریافت ۲۶ ژوئن ۲۰۲۱
داوری ۲۲ جولای ۲۰۲۱
پذیرش۹ سپتانبر ۲۰۲۱

واژگان کلیدی

- اثرات مفید سلامتی‌بخش
- نوشیدنی غیرلبنی
- آبجو زیست‌یار
- *ساکارومیسس بولاردی*
- زنده‌مانی

***نویسنده مسئول**

سارا سهراب‌وندی

کمیته پژوهشی دانشجویان، گروه علوم و صنایع غذایی، دانشکده علوم تغذیه و صنایع غذایی، انستیتو تحقیقات تغذیه‌ای و صنایع غذایی کشور، دانشگاه علوم پزشکی شهید بهشتی، تهران، ایران
تلفن: ۸۸۴۷۱۶۹۷-۲۱+

پست الکترونیک:
sohrabv@sbmu.ac.ir

[۱] Probiotics