Non-Alcoholic and Craft Beer

Subjects: Food Science & Technology
Contributor: Liana Claudia Salanță

Beer is the most consumed alcoholic beverage in the world and the third most popular beverage after water and tea. Emerging health-oriented lifestyle trends, demographics, stricter legislation, religious prohibitions, and consumers' preferences have led to a strong and steady growth of interest for non-alcoholic beers (NABs), low-alcohol beers (LABs), as well for craft beers (CBs). Conventional beer, as the worlds most consumed alcoholic beverage, recently gained more recognition also due to its potential functionality associated with the high content of phenolic
antioxidants and low ethanol content. The increasing attention of consumers to health-issues linked to alcohol abuse urges breweries to expand the assortment of conventional beers through novel drinks concepts. The production of these beers employs several techniques that vary in performance, efficiency, and usability. Involved production technologies have been reviewed and evaluated in this paper in terms of efficiency and production costs, given the possibility that craft brewers might want to adapt them and finally introduce novel non-alcoholic drinks in the market.

Keywords: brewing ; dealcoholization ; non-alcoholic beer ; craft beer ; flavour

1. Introduction

Beer is one of the oldest fermented drink and most widely consumed alcoholic beverages in the world, produced 4th-millennium B.C. in the East, and later spread in ancient countries such as Egypt and Rome [1]. The brewing process can be divided into the following steps: Malting, milling, mashing, boiling, cooling, fermentation, maturation, filtration, carbonation, microbiological stabilization, and packaging. However, the advanced techniques have allowed brewers to produce beer in a more sophisticated and efficient way [2]. The huge popularity of beer arises from its pleasant sensory attributes and favorable nutritional characteristics as well as its lower cost, compared to other types of alcoholic beverages [2][3]. Also, beer gains interest due to the potential medicinal properties as a valuable source of vitamins, minerals, and antioxidants providing various health benefits [4]. Studies are suggesting that moderate beer consumption has significant effects on health, such as reducing the risk of cardiovascular disease, blood cholesterol level, diabetes, osteoporosis, dementia, and many others [5][6][7][8]. The potential health benefits of moderate beer consumption are restricted by the negative consequences of its alcohol and energy content [9]. However, there is potential to enhance the bioactive compounds of beer whilst reducing the alcohol and energy content through innovative brewing approaches, in terms of ingredients, brewing methods, and type of fermentation [10].

The production of beers with low alcohol content is a fast-growing segment in the global beer market [11]. Over the last few decades, multiple beer types and beer-like beverages have been developed worldwide, using different brewing process, technologies, and raw ingredients [12]. In Germany, a country with a vast tradition in beer production, according to the Reinheitsgebot, the sole ingredients used for obtaining beer are water, malted barley, hops (*Humulus lupulus* L.) and yeast [13][14]. The case is different in other countries, where laws governing beer production are less stringent and brewers have more flexibility. Wheat, rice, rye, oats, maize, unmalted barley, and to a lesser extent sorghum, millet, and cassava have all been used in brewing [15].

Thus, carbohydrate sources (adjuncts) like cereals (malted or unmalted) and sugar syrups are the most widely used, usually in conjunction with barley malt. Wheat and oat are commonly used as adjuncts due to their ability to promote foam stability, and before the use of hops, other bitter herbs (e.g., spruce twigs, pine needles and tree branches), spices, and flowers are added to spread different sensory profiles and to design special beers [16][17][18][19][20]. Moreover, from ancient times different fruits have also been used in brewing as sources of fermentable extract and as well as flavoring ingredients [12][15]. Fruits, wine, or honey are inoculated in the wort of beer due to their natural yeast sources. Perhaps given the global trend of wanting a healthier lifestyle and of improving product qualities, in the last decade the market of special beers has evolved significantly offering additional product traits such as enhanced functionality, new flavors, and tastes. These improvements went beyond the use of hops, which are nevertheless vital for the brewing industry [21], as they contribute significantly to the sensory properties of beer [22][23][24]. Lately, microbreweries are dedicated to the production of special beers, using fruits, honey, herbs, or spices to enhance the aroma and to provide flavors and colors that cannot be obtained from grains [25][26][27].

The brewers need to keep up with the consumers' interests and needs while designing novel beers [28]. Brewers have adapted to such demands with continuous improvements and attempts to minimize the alcohol content of their products while maintaining other characteristics [29]. Consumers are looking for products as close as possible to the conventional types, from a sensory point of view, especially in what regards flavor characteristics [3][30].

A regular or conventional beer is an alcoholic beverage produced by the saccharification of starch and the fermentation of the resulting sugar. Beers can vary in alcohol content, bitterness, pH, turbidity, color, and most importantly, flavor. Beers are distinguished mainly according to their visual appearance (color and turbidity) and fermentation process. Currently, a wide variety of beers are available and most of them belong to one of three groups: High (or top) fermentation, known as ale; low (or bottom) fermentation, known as lager; non-alcoholic-beers (NAB), which includes the low-alcohol beers (<2.5%, *v*/*v*) and alcohol-free beers (≤1% *v*/*v*) [31]. Low-alcohol beer (LAB), also known as "low alcoholic beer," "lower-alcohol beer," "low-point beer," "alcohol-reduced beer," and sometimes referred to as "light beer," has different definitions and the alcohol by volume limits depend on laws in different countries [29]. In Germany, the USA, and in China, this limit is no more than 0.5% *v*/*v*; in Spain, the maximum value is 1% *v*/*v* alcohol; while in France, is of 1.2% *v*/*v* alcohol [32]. In Islamic countries such as Saudi Arabia and the United Arab Emirates, where alcohol consumption is prohibited by law, non-alcoholic beers (NABs) contain less than 0.5% *v*/*v* alcohol and represent an alternative to other non-alcoholic beverages because these provide some of the main bioactive components of traditional beer [33].

Over the past decade, there has been a global rise in the consumer interest in craft beers (CBs), particularly in traditional ales, and lagers, which are distinctively flavored, have a unique quality value and overall particular sensory properties [15]. Besides CBs are produced locally, in small quantities, are unpasteurized, unfiltered, and without added nitrogen or carbon dioxide pressure [34]. There are three major categories of brewers making CB and these are brewpubs, microbreweries, and regional craft breweries [35]. CBs are usually distributed regionally after they are produced in microbreweries following the basic brewing principles while using different adjuncts and yeast types, according to their consumers' preferences [36].

Nowadays, NABs are experiencing an unprecedented boom on the craft side of the market. This segment of no/low ABV beer has changed drastically and quickly mainly due to the consumer demand (sportives, mothers, drivers, etc.) and advanced technology to brew non-alcoholic beer. This review's purpose is to evaluate and discuss the production techniques of special beers such as NABs, LABs, and CBs focusing on the methods employed to improve their sensory characteristics appeal and to improve their popularity among consumers'.

2. An Overview of Non-Alcoholic and Craft Beer

2.1. Market Landscape and Consumers Preference

A beer's quality is measured by a complex set of sensory characteristics that include appearance, aroma, taste, and texture as it is an incredibly versatile beverage, served in various locations such as clubs, bars, and restaurants. Given this context, there will always be a high demand for beer, particularly from male consumers. The common aim to improve public health without spoiling consumers' enjoyment of certain beer types is an important matter for brewers and retailers [37]. Consumers are becoming ever more educated in what constitutes the appropriate flavor notes and "freshness" of beer [38], therefore there is a great challenge to try and reinvent certain beer types or to come up with completely new beer assortments. The future trends of beer production and products is best forecasted based on past statistics. As we can see, according to the European beer trends statistics report 2019 edition [39], in 2018, the top four beer producers of Europe consisted in Germany, with an overall beer production of 93,652 in 1000 HL, followed by Poland (42,603 in 1000 hL), United Kingdom (42,282 in 1000 hL), and Spain (38,134 in 1000 hL). Another report, the contribution made by beer to the European Economy [40], indicated that in 2018, more than 32 million hectoliters were exported from EU-28 countries outside the EU, which embodies over 8% of total production. This consists of large global brands, craft beers, and specialty brands made for export. It was also stated that there is increased investment in innovation, especially to produce new craft brews, expanding production lines to include cider and stout and to develop new beer flavors. Variety is looked for in all markets, therefore although conventional beer production is still heavily in the lead, craft beers, followed by specialty beers, alcohol-free, and low-alcohol beers, being so unique one to another would surely gain increased interest as time goes by. For example, the production of NAB (including malt beverages) increased in Germany from 5.4% in 2012 to 7.3% in 2018, while in Netherlands it went from 1.5% in 2012 to 5.2% in 2018 [40]. Having this in mind, it is still thought that economies of scope can prevail over economies of scale, at least in what regards beer production. Moreover, it is supposed that standard ale and lager consumption will decrease as consumers progressively choose to drink ‘Better, not more’, getting out of the comfort zone and into the experiment area [41].

3. New Trends Regarding Yeasts Involved in Fermentation of Special Beers

Beer is a perishable product and many factors can diminish a beer’s quality from the time it is brewed to the point of consumption. In the brewing process, the efficiency of fermentation and the character and quality of the final product are intimately linked [42]. The lactic acid bacteria are known as the most frequent bacteria found in beer, accounting for 60–70% of all spoilage incidents. Except some specific strains of lactic acid bacteria, which are found in some special beers, namely the ”sour beers” (Flanders Red Ale, Framboise, Kriek, the latest two also known as fruit Lambic beers), they are considered the spoilage bacteria in beer, which causes off-flavor development, which is mainly attributed to the formation of lactic acid and diacetyl [43][44][45]. The fermentation processes applied to foods and beverages in various technologies and operations are used to convert perishable and indigestible raw materials into pleasant foods and drinkable beverages with added value and high stability [46].

Beer, as a fermented beverage, is based on microbial metabolism for production. *Saccharomyces cerevisiae* is the dominant species, that is used in the production of alcoholic beverages worldwide. The strains of this species employed in fermentation exert a profound influence on the flavor and aroma characteristics of the resulted beverages [47]. Traditionally, strains of *Saccharomyces cerevisiae* and *Saccharomyces pastorianus* (synonym *Saccharomyces carlsbergensis*) are the two species widely used as starter cultures for the production of the two most categories of industrial beer, which are ‘ale’ and ‘lager’ beers, strains known as the top-fermenting and bottom-fermenting yeasts [48][49]. A perfect model of an organism may be considered *Saccharomyces cerevisiae*. Its short replication time, simple cultivation, sporulation efficiency, rare pathogenicity, and small genome size have made it an ideal research organism and placed it at the front of many scientific advances [50]. These strains of yeasts have become dominant, especially *Saccharomyces cerevisiae*, due to their alcohol tolerance and rapid fermentation rates, which are ideal for commercial beer production [10]. The current approaches have led to the exploration of various yeasts in the brewing process. This, akin to many of the developments in modern beer production, special beer production is largely driven by commercial reasons and for improving the product’s biological properties [10][15].

In this context, *Saccharomyces boulardii* is a new type of yeast, that acts as a probiotic yeast and tends to produce less alcohol. The probiotic yeast *Saccharomyces boulardii* is capable of fermenting brewery wort and optimizing the process variables led to improved production of volatile compounds by this yeast. The obtained product has similar sensory qualities with the traditional product, high commercial characteristics, and lower value of pH, which helps to maintain the beer’s shelf life [51]. It has also been described by Mulero-Cerezo et al. (2019) that *Saccharomyces boulardii* show higher viability during the fermentation process, which is ideal for producing a craft beer containing viable probiotic cells [34]. Several studies demonstrated that *Saccharomyces boulardii* can generate bioactive compounds in fermented beverages thus improving their functionality [52][53]. Other strains, such as *Saccharomycodes ludwigii*, *Zygosaccharomyces rouxii* [10], *Torulaspora delbrueckii, Pichia kluyveri* [48], *Lachancea thermotolerans* [54], and *Brettanomyces* spp. [55], have been assessed as candidates, producing a beer that is acceptable to consumers, commercially viable, and low in alcohol.

The new trend in brewing biotechnologies involves non-*Saccharomyces* yeasts in the fermentation process given the improvements they can produce in sensory quality and differentiation, especially in craft beers and low-alcohol beers [56]. For example, *Brettanomyces* spp. are essential in the production of lambic-style beers [49], where they contribute with flavors that are not normally produced by *Saccharomyces* spp. Often, *Brettanomyces* spp. can produce smoky, barnyard, spicy, and medicinal flavors in beverages [50]. On the other hand, *Brettanomyces* can produce β-glucosidase, an enzyme responsible for the hydrolysis of glycosides, commonly found in the hop and other sources. Therefore, this could increase or modify the hop aroma due to the numerous released monoterpenes, which are the key aroma substances from hop [49].

Lachancea thermotolerans is a yeast that can be used successfully in the making of craft beers because of its ability to ferment until 4–9% *v*/*v* producing high amounts of lactic acid from sugars and interesting effects in beer aroma. It is also a good candidate due to the natural biological acidification during the fermentation process [56]. Interestingly, *Lachancea thermotolerans* also can produce lactic acid, which can affect both flavor and mouthfeel. The beers obtained at the lower fermentation temperature (14°C) are associated with sensory-related words such as fruity, floral, sour, clove, melon, and strawberry [54]. Moreover, the ability to produce significant amounts of lactic acid make that strain suitable to be used in the production of acidic beers without the involvement of lactic bacteria [56]. Studies conducted by Zdaniewicz et al. (2020) confirmed that the *Lachancea thermotolerans* strains can produce lower alcohol as compared to *Saccharomyces cerevisiae* strains [57].

Torulaspora delbrueckii is another versatile yeast suitable for beer production [56], as it exhibits low alcohol production ability [58] due to its inability to utilize maltose [59]. This strain has the added advantage of being resistant to the various stress factors encountered during brewing [50] and to produce 2-phenyl ethyl acetate, a floral ester with positive floral aroma, that increases during fermentation [56]. Canonico et al. (2016) reported that the beers obtained with *Torulaspora delbrueckii* were characterized by a good aromatic profile and a low alcohol content (2.66% *v*/*v*) [60]. Following other studies [59][60], this yeast was found to be suitable for brewing applications.

Pichia kluyveri strain can be used for producing NAB or LAB owing to its limited ability to ferment glucose whilst significantly changing hop compounds into positive flavor compounds [61][62]. *Pichia kluyveri* produces much less diacetyl compared with the *Saccharomyces cerevisiae* brewers' yeast strain. Also, the production of desirable ester compounds is high and leads to a lower production of unwanted acids such as octanoic acid and decanoic acid [59].

Zygosaccharomyces rouxii is the most xerotolerant yeast; this high osmotic tolerance could potentially be used in high gravity brewing since some strains have shown to ferment all wort sugars [62]. This yeast strain is also considered suitable for producing fermented beverages with low alcohol content because of its total or partial inability to ferment maltose [48]. After a fermentation process with *Zygosaccharomyces rouxii,* esters and higher alcohols are the main flavor-active compounds identified in beer [59].

References

1. Violino, S.; Figorilli, S.; Costa, C.; Pallottino, F. Internet of beer: A review on smart technologies from mash to pint. Foods 2020, 9, 950.
2. Pereira de Moura, F.; Rocha dos Santos Mathias, T. A comparative study of dry and wet milling of barley malt and its influence on granulometry and wort composition. Beverages 2018, 4, 51.
3. Sohrabvandi, S.; Mousavi, S.M.; Razavi, S.H.; Mortazavian, A.M.; Rezaei, K. Alcohol-free beer: Methods of production, sensorial defects, and healthful effects. Food Rev. Int. 2010, 26, 335–352.
4. Sohrabvandi, S.; Mortazavian, A.M.; Rezaei, K. Advanced analytical methods for the analysis of chemical and microbiological properties of beer. J. Food Drug Anal. 2011, 19, 202–222.
5. Salanţă, L.; Tofană, M.; Pop, C.; Pop, A.; Coldea, T. Beverage alcohol choice among university students: Perception, consumption and preferences. Bull. Univ. Agric. Sci. Vet. Med. 2017, 74, 23.
6. Oak, M.; Auger, C.; Belcastro, E.; Park, S.-H.; Lee, H.; Schini-Kerth, V.B. Potential mechanisms underlying cardiovascular protection by polyphenols: Role of the endothelium. Free Radic. Biol. Med. 2018, 122, 161–170.
7. Neto, O.J.R.; de Oliveira, T.S.; Ghedini, P.C.; Vaz, B.G.; de Souza Gil, E. Antioxidant and vasodilatory activity of commercial beers. J. Funct. Foods 2017, 34, 130–138.
8. Sohrabvandi, S.; Mortazavian, A.M.; Rezaei, K. Health-related aspects of beer: A review. Int. J. Food Prop. 2012, 15, 350–373.
9. De Gaetano, G.; Costanzo, S.; Di Castelnuovo, A.; Badimon, L.; Bejko, D.; Alkerwi, A.; Chiva-Blanch, G.; Estruch, R.; La Vecchia, C.; Panico, S.; et al. Effects of moderate beer consumption on health and disease: A consensus document. Nutr. Metab. Cardiovasc. Dis. 2016, 26, 443–467.
10. Mellor, D.D.; Hanna-Khalil, B.; Carson, R. A review of the potential health benefits of low alcohol and alcohol-free beer: Effects of ingredients and craft brewing processes on potentially bioactive metabolites. Beverages 2020, 6, 25.
11. Bellut, K.; Krogerus, K.; Arendt, E.K. Lachancea fermentati strains isolated from Kombucha: Fundamental insights, and practical application in low alcohol beer brewing. Front. Microbiol. 2020, 11, 1–21.
12. Veljovic, M.; Despotovic, S.; Stojanovic, M.; Pecic, S.; Vukosavljevic, P.; Belovic, M.; Leskosek-Cukalovic, I. The fermentation kinetics and physicochemical properties of special beer with addition of Prokupac grape variety. Chem. Ind. Chem. Eng. Q. 2015, 21, 391–397.
13. Martínez, A.; Vegara, S.; Martí, N.; Valero, M.; Saura, D. Physicochemical characterization of special persimmon fruit beers using bohemian pilsner malt as a base. J. Inst. Brew. 2017, 123, 319–327.
14. Dias M de, O.; Falconi, D. The evolution of craft beer industry in Brazil. J. Econ. Bus. 2018, 1.
15. Humia, B.V.; Santos, K.S.; Barbosa, A.M.; Sawata, M.; da Mendonça, M.C.; Padilha, F.F. Beer molecules and its sensory and biological properties: A review. Molecules 2019, 24, 1568.
16. Bogdan, P.; Kordialik-Bogacka, E. Alternatives to malt in brewing. Trends Food Sci. Technol. 2017, 65, 1–9.

17. Mezgebe, A.G.; Abegaz, K.; Taylor, J.R.N. Relationship between waxy (high amylopectin) and high protein digestibility traits in sorghum and malting quality. J. Cereal Sci. 2018, 79, 319–327.

18. Ducruet, J.; Rébénaque, P.; Diserens, S.; Kosińska-Cagnazzo, A.; Héritier, I.; Andlauer, W. Amber ale beer enriched with goji berries—The effect on bioactive compound content and sensorial properties. Food Chem. 2017, 226, 109–118.

19. Mayer, H.; Ceccaroni, D.; Marconi, O.; Sileoni, V.; Perretti, G.; Fantozzi, P. Development of an all rice malt beer: A gluten free alternative. LWT Food Sci. Technol. 2016, 67, 67–73.

20. Mascia, I.; Fadda, C.; Karabín, M.; Dostálek, P.; Del Caro, A. Aging of craft durum wheat beer fermented with sourdough yeasts. LWT Food Sci. Technol. 2016, 65, 487–494.

21. Salanţă, L.C.; Tofană, M.; Socaci, S.; Pop, A.; Odagiu, A.; Nagy, M.; Cuceu, A. Evaluation of volatile compounds from Hüller Bitterer variety grown in Romania by chemometric methods. J. Agroaliment. Process. Technol. 2015, 21, 231–236.

22. Salanţă, L.C.; Socaci, S.A.; Tofană, M.; Mudura, E.; Pop, C.R.; Nagy, M.; Odagiu, A. Characterization of volatile components in hop pellets using in-tube extraction GC-MS analysis. Rom. Biotechnol. Lett. 2018, 23, 13541–13550.

23. Michiu, D.; Socaci, S.A.; Jimborean, M.A.; Mudura, E.; Fărcaş, A.C.; Biriş-Dorhoi, S.E.; Tofană, M. Determination of Volatile markers from Magnum hops in beer by in-tube extraction–gas chromatography–mass spectrometry. Anal. Lett. 2018, 51, 2967–2980.

24. Oladokun, O.; James, S.; Cowley, T.; Dehrmann, F.; Smart, K.; Hort, J.; Cook, D. Perceived bitterness character of beer in relation to hop variety and the impact of hop aroma. Food Chem. 2017, 230, 215–224.

25. Liu, S.; Ying, A.; Quek, H. Evaluation of beer fermentation with a novel yeast Williopsis saturnus. Food Technol. Biotechnol. 2016, 54, 403–412.

26. Fanari, M.; Forteschi, M.; Sanna, M.; Piu, P.P.; Porcu, M.C.; D'hallewin, G.; Secchi, N.; Zinellu, M.; Pretti, L. Pilot plant production of craft fruit beer using Ohmic-treated fruit puree. J. Food Process. Preserv. 2020, 44, 1–8.

27. Daenen, L.; Sterckx, F.; Delvaux, F.R.; Verachtert, H.; Derdelinckx, G. Evaluation of the glycoside hydrolase activity of a Brettanomyces strain on glycosides from sour cherry (Prunus cerasus L.) used in the production of special fruit beers. FEMS. Yeast Res. 2008, 8, 1103–1114.

28. Rošul, M.; Mandić, A.; Mišan, A.; Đerić, N.; Pejin, J. Review of trends in formulation of functional beer. Food Feed Res. 2019, 46, 23–35.

29. Bellut, K.; Arendt, E.K. Chance and challenge: Non-saccharomyces yeasts in nonalcoholic and low alcohol beer brewing–A review. J. Am. Soc. Brew. Chem. 2019, 77, 77–91.

30. Ignat, V.M.; Salanţă, L.C.; Pop, O.L.; Pop, C.R.; Tofană, M.; Mudura, E.; Coldea, T.E.; Borşa, A.; Pasqualone, A. Current functionality and potential improvements of non-alcoholic fermented cereal beverages. Foods 2020, 9, 1031.

31. Riu-Aumatell, M.; Miró, P.; Serra-Cayuela, A.; Buxaderas, S.; López-Tamames, E. Assessment of the aroma profiles of low-alcohol beers using HS-SPME-GC-MS. Food Res. Int. 2014, 57, 196–202.

32. Jackowski, M.; Trusek, A. Non-alcoholic beer Production–an overview. Pol. J. Chem. Technol. 2018, 20, 32–38.

33. Muller, C.; Neves, L.E.; Gomes, L.; Guimarães, M.; Ghesti, G. Processes for alcohol-free beer production: A review. Food Sci. Technol. 2020, 40, 273–281.

34. Mulero-Cerezo, J.; Briz-Redón, Á.; Serrano-Aroca, Á. Saccharomyces cerevisiae var. boulardii: Valuable probiotic starter for craft beer production. Appl. Sci. 2019, 9, 3250.

35. Pokrivčák, J.; Supeková, S.C.; Lančarič, D.; Savov, R.; Tóth, M.; Vašina, R. Development of beer industry and craft beer expansion. J. Food Nutr. Res. 2019, 58, 63–74.

36. da Costa Jardim, C.; de Souza, D.; Cristina Kasper Machado, I.; Massochin Nunes Pinto, L.; de Souza Ramos, R.; Garavaglia, J. Sensory profile, consumer preference and chemical composition of craft beers from Brazil. Beverages 2018, 4, 106.

37. Liguori, L.; De Francesco, G.; Russo, P.; Albanese, D.; Perretti, G.; Di Matteo, M. Quality improvement of low alcohol craft beer produced by evaporative pertraction. Chem. Eng. Trans. 2015, 43, 13–18.

38. Brewers Association Best Practices Guide to Quality Craft Beer. 2013. Available online: https://www.brewbound.com/news/brewers-association-releases-best-practices-guide-to-quality-craft-beer/ (accessed on 30 October 2020).

39. European beer trends. In European Beer Trends Statistics Reports; The Brewers of Europe: Bruxelles, Belgium, 2019.

40. The Contribution made by Beer to the European Economy; The brewers of Europe: Bruxelles, Belgium, 2020.

41. A Guide on How to Improve the Experience for Your Beer Shoppers; Marston's Off Trade Beer Report; Marston's Beer Company: Wolverhampton, UK, 2018.
42. Michiu, D.; Tofana, M.; Mudura, E.; Muntean, F. Preliminary research concerning the determination of beer wort flavor compounds during primary fermentation. Bull. Univ. Agric. Sci. Vet. Med. Cluj Napoca Agric. 2010, 67, 309–313.
43. Bokulich, N.A.; Bamforth, C.W. The microbiology of malting and brewing. Microbiol. Mol. Biol. Rev. 2013, 77, 157–172.
44. Suzuki, K.; Asano, S.; Iijima, K.; Kitamoto, K. Sake and beer spoilage lactic acid bacteria–A review. J. Inst. Brew. 2008, 114, 209–223.
45. Lawton, M.R.; Alcaine, S.D. Leveraging endogenous barley enzymes to turn lactose-containing dairy by-products into fermentable adjuncts for Saccharomyces cerevisiae-based ethanol fermentations. J. Dairy Sci. 2019, 102, 2044–2050.
46. Vilela, A. The importance of yeasts on fermentation quality and human health-promoting compounds. Fermentation 2019, 5, 46.
47. Walker, G.; Stewart, G. Saccharomyces cerevisiae in the production of fermented beverages. Beverages 2016, 2, 30.
48. Capece, A.; Romaniello, R.; Siesto, G.; Romano, P. Conventional and non-conventional yeasts in beer production. Fermentation 2018, 4, 38.
49. 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.
50. Gibson, B.; Geertman, J.M.A.; Hittinger, C.T.; Krogerus, K.; Libkind, D.; Louis, E.J.; Magalhães, F.; Sampaio, J.P. New yeasts-new brews: Modern approaches to brewing yeast design and development. FEMS Yeast Res. 2017, 17, 1–13.
51. Senkarcinova, B.; Graça Dias, I.A.; Nespor, J.; Branyik, T. Probiotic alcohol-free beer made with Saccharomyces cerevisiae var. boulardii. LWT 2019, 100, 362–367.
52. Değirmencioğlu, N.; Gurbuz, O.; Şahan, Y. The Monitoring, via an in vitro digestion system, of the bioactive content of vegetable juice fermented with Saccharomyces cerevisiae and Saccharomyces boulardii. J. Food Process. Preserv. 2016, 40, 798–811.
53. Lazo-Vélez, M.A.; Serna-Saldívar, S.O.; Rosales-Medina, M.F.; Tinoco-Alvear, M.; Briones-García, M. Application of Saccharomyces cerevisiae var. boulardii in food processing: A review. J. Appl. Microbiol. 2018, 125, 943–951.
54. Domizio, P.; House, J.F.; Joseph, C.M.L.; Bisson, L.F.; Bamforth, C.W. Lachancea thermotolerans as an alternative yeast for the production of beer. J. Inst. Brew. 2016, 122, 599–604.
55. Serra Colomer, M.; Funch, B.; Forster, J. The raise of Brettanomyces yeast species for beer production. Curr. Opin. Biotechnol. 2019, 56, 30–35.
56. Callejo, M.J.; Tesfaye, W.; González, M.C.; Morata, A. Craft beers: Current situation and future trends. In New Advances on Fermentation Processes; Martínez-Espinosa, R.M., Ed.; IntechOpen: London, UK, 2019; pp. 1–18.
57. Zdaniewicz, M.; Satora, P.; Pater, A.; Bogacz, S. Low lactic acid-producing strain of lachancea thermotolerans as a new starter for beer production. Biomolecules 2020, 10, 256.
58. Canonico, L.; Ciani, E.; Galli, E.; Comitini, F.; Ciani, M. Evolution of aromatic profile of Torulaspora delbrueckii mixed fermentation at microbrewery plant. Fermentation 2020, 6, 7.
59. Bellut, K.; Michel, M.; Zarnkow, M.; Hutzler, M.; Jacob, F.; De Schutter, D.P.; Daenen, L.; Lynch, K.M.; Zannini, E.; Arendt, E.K. Application of non-Saccharomyces yeasts isolated from kombucha in the production of alcohol-free beer. Fermentation 2018, 4, 66.
60. Canonico, L.; Agarbati, A.; Comitini, F.; Ciani, M. Torulaspora delbrueckii in the brewing process: A new approach to enhance bioflavour and to reduce ethanol content. Food Microbiol. 2016, 56, 45–51.
61. Wojtyra, B. How and why did craft breweries 'revolutionise' the beer market? The case of Poland. Morav. Geogr. Rep. 2020, 28, 81–97.
62. Michel, M.; Meier-Dörnberg, T.; Jacob, F.; Methner, F.J.; Wagner, R.S.; Hutzler, M. Review: Pure non-Saccharomyces starter cultures for beer fermentation with a focus on secondary metabolites and practical applications. J. Inst. Brew. 2016, 122, 569–587.