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Chapter

Craft Beers: Current Situation and Future Trends

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Abstract

During the twentieth century, the consolidation of large multi-national beer companies and the homogenization of the specified beer types have led to a considerable growth in the beer industry. However, the growing demand by consumers of a single and distinctive product, with a higher quality and better sensory complexity, is allowing for a new resurgence of craft beer segment in recent years. This chapter reviews some different alternatives of innovation in the craft brewing process: from the bottle fermented beers with non-*Saccharomyces* yeast species, to the use of special malts or specific adjuncts, hop varieties, water quality, etc. All of them open a lot of new possibilities to modulate flavor and other sensory properties of beer, reaching also new consumers looking for a specific story in one of the oldest fermented beverages.

Keywords: craft beer, sour beer, non-*Saccharomyces*, new adjuncts, bottle fermentation

1. Introduction

Beer brewing is an established ancient art in different civilization and cultures, but there is no a precise and unanimous agreement on the origin of beer. Recent evidences predominantly based on the archeological and historical evidences explain the origin of brewing across time and space [1]. The timespan for its existence differs over a wide range of geography, from as far back as "The Neolithic Revolution" to the early horizon in South America. It commenced in the agricultural or "Neolithic" revolution period as early as 9000 BC with the advent of the Sumerians in the lowlands of the Mesopotamian alluvial plane [2, 3]. Evidence of rice-based fermented beverage has been found in between 7000 and 5000 BC in China [4–7] and ancient Mesopotamia back to about 6000 BC [8–10]. Similarly, in Northern Africa highlighting Egypt at about 3500 BC [11], in Europe around 3000 BC [12, 13] and in South America 900-200 BC [14–16], locally fermented alcoholic beverages have been produced. Recent starch [17] and chemical residue studies [18] extend this period as far as 11,000 BC. In broader terms, all these fermented beverages may be considered as a craft beer based on the production scale.

2. Craft beer: as a movement from bottom to top fermentation. The reemergence of craft brewing

Different cultures and different civilization historically produced a number of fermented beverages/beer with different raw materials, which allowed them to have different attributes and different names. Beer is a relatively simple fermented product, mainly water in its composition, which makes easily produced locally; however, for a long time the difficulty to move long distances permits to flourish craft brewers everywhere in the world [19]. However, at present, it is not an impediment due to technological advances and transportation progress.

The craft beer movement or revolution began in the USA after the 13 years of national prohibition of alcohol or "the noble experiment" 1919–1933. In 1965, Fritz Maytag, the man of the craft beer renaissance, bought the Anchor Steam Beer Company of San Francisco with a capacity of 50,000 barrels and developed it as a craft brewery outlet [20, 21]. Regarding the USA, this was the milestone to the expanding innovation and an increasing trend in terms of production and sales of beers with differentiated quality.

Even though this movement marked a shift in several countries recently, to mention some, in 1988 the earliest brewpub lay foundation in Italy [22], while in the Netherlands the craft revolution rouse during the year 1981 [23], in Australia, craft brewing started late 1984 [24]. At the same time, it is very difficult to put a time limit for the beginning of craft beer production in some European countries like the UK, Belgium and Germany where these countries were either with a long tradition in "special beers" or the historical existence of small and local producers back to the 1970s [25, 26].

3. Craft beer: statistical viewpoint

One of the indicators for the expansion of craft beer renaissance in different countries is the statistical approach. However, there is no common shared definition of craft beer but different associations and entities of different countries remark based on the size of the firm, production volume raw materials used to produce such drink, degree of independence and way to brew [27]. Even though there is data scarcity on the numbers of microbreweries of different countries, in **Table 1**, those microbreweries actually existing in different countries of the five continents are represented, where beer production is traditional or its consumption is highly relevant at present. The statistical data reflected in this chapter encompasses all beer producers recognized as craft brewery, artisanal brewery, microbrewery, independent brewery, specialty brewery, Brewpub, local brewery, Regional brewery and Contract brewing company in accordance with the regulation rules of different countries without establishing any distinctions among them.

Even though Mergers and acquisitions seem to reduce the number of major brewing firms, the total production in volume is not affected. This tendency provides an opportunity to the merged breweries to take advantage over the microbreweries in terms of economical scale and increased market share. Despite the macrobrewers dominance, worldwide craft beer numbers are increasing at a rapid rate [28].

4. New tendencies: is the glass half-full or half-empty for brewers?

The last two decades brewing landscape continues to rise in number of micro and craft breweries almost everywhere in the world. As it is shown below (**Table 1**), in the last decade, from 2008 to 2017, the number of craft breweries significantly

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Europe	1755	2123	2407	2670	3094	3616	N/A	N/A	N/A	N/A
Czech Republic[1]	57	51	65	90	20	207[8]	238	202	350	402
France[1]	N/A	263	322	373	293	504	566	690	850	1000
Germany[1]	594	628	646	659	665	668	677	723	738	824
The Netherlands	N/A	N/A	115[2]	N/A	N/A	N/A	222	380[2]	434[3]	N/A
Poland	79[5]	89[5]	107[5]	133[5]	164[5]	212[5]	263[5]	308[5]	N/A	N/A
Spain	21	27	46	70	114	203	314	409	465	502
The UK	671	694	778	898	1250	1440	1414	1828	2198	2378
America										
The USA	1321[7]	1596[7]	1754[7]	2016[7]	2420[7]	2898[7]	3739[7]	4544[7]	5424[7]	6266[7]
Canada	N/A	N/A	277[9]	N/A	N/A	N/A	N/A	610[9]	612[3]	N/A
Africa										
South Africa	22[6]	22[6]	27[6]	34[6]	54[6]	63[6]	N/A	N/A	N/A	N/A
Asia										
Japan	N/A	N/A	208[2]	N/A	N/A	N/A	N/A	222[2]	N/A	N/A
Oceania										
Australia	N/A	N/A	172[2]	N/A	N/A	N/A	N/A	358[2]	410[2]	N/A
New Zealand	N/A	N/A	62[4]	59[4]	65[4]	79[4]	98[4]	111[4]	130[4]	N/A

[1] *[29].*
[2] *[24, 26].*
[3] *[29].*
[4] *[30].*
[5] *[31].*
[6] *[32].*
[7] *[27].*
[8] *[29].*
[9] *[33].*

Table 1.
Microbrewery expansion in the last decade sample countries by continent.

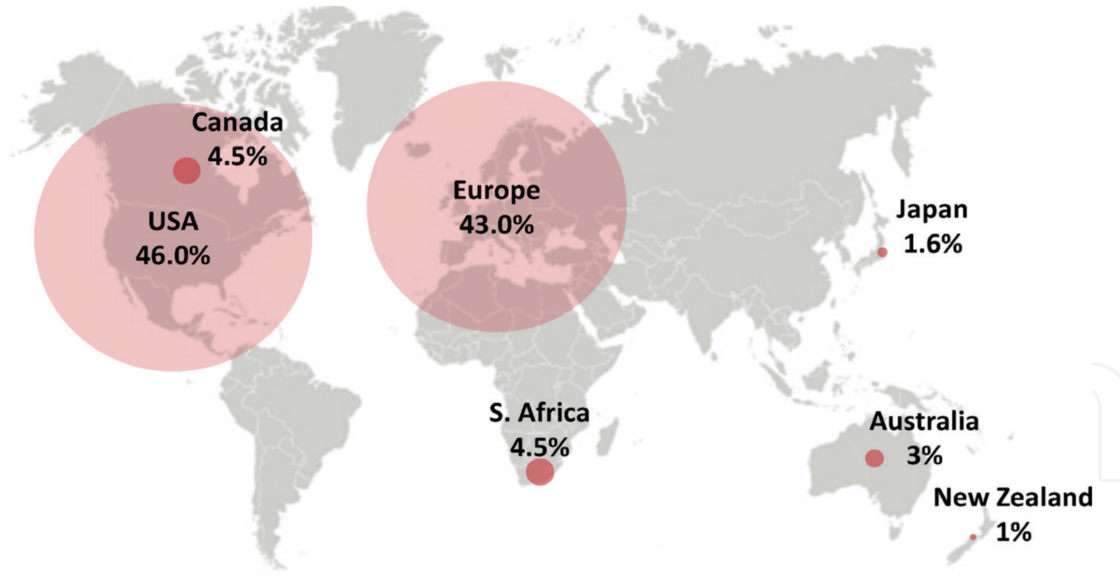

Figure 1.
Percentage of craft beer producers (2013–2017).

increased globally. In fact it passed from 671 to 2378 in the UK (traditionally beer-producing and beer-drinking country), and from 1321 to 6266 in the USA, an increase of 354 and 474% respectively, within the same period (not traditional beer producer country). This increase in number of craft breweries and production volume run up to an increase in compound annual growth rate (CAGR) within the sector. Craft brewing continues to take market share away from the largest brewing companies. According to Brewers Association report (the U.S. beer sales volume growth 2017, National beer sales and production statistical data), the overall U.S. beer volume sales were down 1% in 2017, whereas craft brewer sales continued to grow at a rate of 5% by volume, reaching 12.7% of the U.S. beer market by volume. Craft production grew the most for microbreweries. Retail dollar sales of craft increased 8%, up to $26.0 billion, and now account for more than 23% of the $111.4 billion U.S. beer market [27]. Percentage of craft beer producers (2013–2017) can be seen in **Figure 1**.

There are various factors, which favored this increase in overall craft beer consumption. These factors include per capita income growth, the availability of alternatives toward the production of successful and high levels of quality beers, increased health concerns, and the emergence of new government regulations that affects directly the sustainability issue and consistency and innovation among many others.

5. Craft and special beers: classification

A single beer style, lager beer, has long been the main dominant beer in the world market. However, a worldwide change in trend for the last decade has been registered due to the growing interest in craft and specialized beer [34]. A significant growth in the number of breweries, the variety of styles and the total volume of production had been observed in previous years [35].

But the reasons for the growth are multiple: first, increase in the demand for high more flavorful and stronger beers [34, 36]. This is particularly important in the case of American consumers, often not satisfied with the dominant in the market American pale lagers. An increase in flavors (malted barley, chestnut, honey flavored) and a more readily quality perceived are the main factors to choose craft beer instead of commercial beer between habitual beer drinkers [37]. Second, exclusivity and "unique drinking experiences" are also highly rated by craft beer consumers [34, 38]. Finally, even though traditional brands of beer are closely linked to very specific places [39], craft beer is part of a broader neolocalism movement in which people are demanding goods and services that have a connection with the local community [36].

Taking into account that all beer types evolve from the combination and relationships among ingredients, processing, packaging, marketing and culture, it is therefore necessary to establish some criteria to establish differences between special and craft beers.

This section analyzes the main criteria for classifying beers as special or craft beers (**Figure 2**).

The first element taken into account is the production output of beer per year (**criterion 1**). Craft beer are characterized by small production output and their "small," "independent," and "traditional" character. These characteristics are compatible with others which have been traditionally used to classify beer styles and now they are assuming new importance and making possible to enrich traditional beer brewing: we refer to type of fermentation and yeast strain selection (**criterion 2**). Here, we will look at non-*Saccharomyces* brewing yeasts which require special attention [40, 41]. While malted barley remains the main source of sugars for fermentation in the production of beer, the ingredients can be changed based on the region and preference of the consumer. Innovative ingredients in wort production can be used as a valuable source of variation in craft beer production (**criterion 3**) The two last criteria are relatively recent and novel and are related with the development of special beers in the perspective on health and nutrition (**criterion 4**) and with the use of emerging technologies in brewing (**criterion 5**).

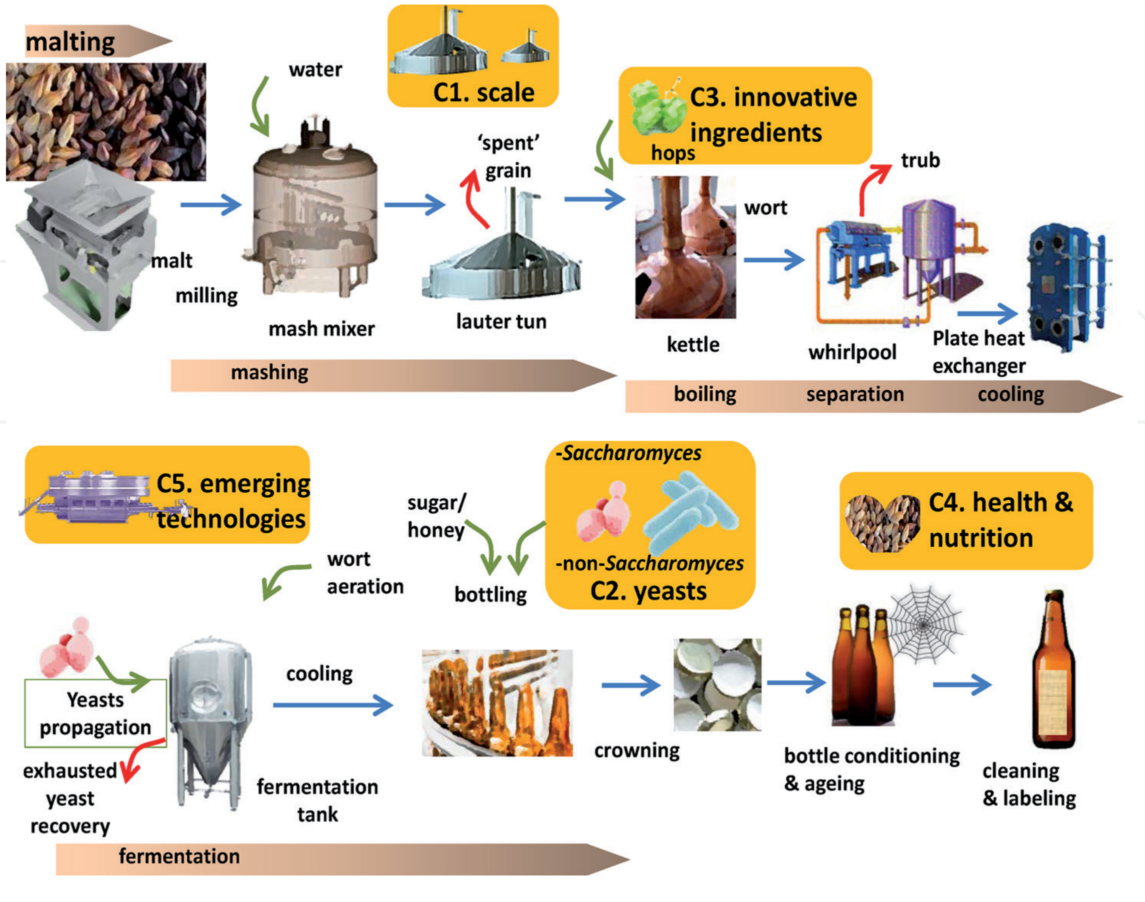

Figure 2.
Main criteria to classify craft and special beers.

5.1 Production output of beer per year (scope of craft beer)

The annual beer production allows distinguishing between *larger breweries mass-producing beer* (annual production capacity of up to 6 million barrels) and *craft beers* or "small" scale breweries (less than 6 million barrels; where 1 BBL = 339 12 oz bottles of beer or 235 half-liter bottles of beer) [26, 42].

According to Kleban and Nickerson [42], small scale beers have different considerations:

- Minimum production quantity: **Nanobreweries**.
- The place of sale of beer: production is sold outside (Microbreweries) or on the same floor of production (**Brewpub**).
- Brewing companies that outsource their production to other already established breweries (**Contract Brewing Company**).
- Over 50% or more of their volume production focuses on all-malt beers and/or their malt flagship (**Regional Craft Brewery**).

The American craft brewing industry assumes that in addition to low volume production, further requirements are expected by the craft beers [36]. They are *independent* in that and not more than 25% of the business is owned by another member of the alcohol industry who is not a craft brewer. *Traditional ingredients* (water, malt, hops, yeast) must also be used in the brewing process although *innovation* in terms of reinterpreting historic beer styles or developing new styles is a hallmark of the industry.

5.2 Selection of the yeast strain and type of fermentation

The main brewing classification criterion particularly relies on the selection of the yeast strain and type of fermentation [35, 41]. Two types of brewing yeast were originally classified based on their flocculation behavior during fermentation.

Beers are classified into two large groups according to the yeast strain and type of fermentation: Ale beers and Lager beers. **Ale yeasts or top-fermenting yeasts**, which are *Saccharomyces cerevisiae* strains, rise up to the surface of the vessel with the escaping carbon dioxide gas bubbles and become entangled in the fermentation head, facilitating their collection by skimming.

Ale yeast fermentation temperature ranges between 15 and 20°C. **Lager yeast or bottom-fermenting yeast** does not rise and becomes entrapped in the foam but settles out at the end of the fermentation. Lager worts often ferment at lower temperatures (8–14°C) than ale yeasts and are therefore much slower.

Ale beers represent only a small percentage of the total beer consumption. They are very common in Britain, Germany, Canada's eastern provinces, the United States and, last but not least, Belgium. Until the sixteenth century, ale was the main type of beer in Europe [43].

Standard/ordinary bitter (Britain), English pale ale (Britain), Mild (Britain), Brown Porter (Britain), Robust Porter (Britain), Dry stout (Ireland), Sweet stout (Britain), Kölsch (Germany, Cologne), Lambic (Belgium), Rauchbier (Germany) and Weizen/Weissbier (Germany) are some examples of ale beer types.

Lager beer is the dominant style in almost all countries and represents more than 90% of the beer produced worldwide [43].

Some principal Lager beer types are: German Pilsner (Pils) (Germany), Bohemian Pilsener (Czech Republic), Classic American Pilsner (United States), Vienna Lager (Austria), Oktoberfest/Märzen (Germany), Dark American Lager (United States), Munich Dunkel (Germany), Schwarzbier (Black Beer) (Germany), Maibock/Helles Bock (Germany), Traditional Bock (Germany), Doppelbock (Germany), Eisbock (Germany).

In all beers cited, the flavor-active compounds such as acids, alcohols, aldehydes, ketones and esters are produced by yeast during fermentation. Although there are many strains of brewing yeast (*Saccharomyces cerevisiae*) for beer production, the choice of suitable yeasts to produce desirable tastes and flavors in beer is very important and significant.

5.2.1 Use of non-Saccharomyces

Several non-*Saccharomyces* yeasts can be used successfully in the making of craft beers with interesting possibilities. Yeasts such as *Lachancea thermotolerans*, *Torulaspora delbrueckii*, *Hanseniaspora vineae* and *Schizosaccharomyces pombe* can help to modulate acidity, aroma, mouthfeel or even color [41, 44]. As the final alcoholic degree in beers is lower than in wines, and normally ranging between 4 and 8% vol, the use of medium fermentative power non-*Saccharomyces* species is possible because most of these yeasts are able to ferment reaching this ethanol level.

Lachancea thermotolerans is trending yeast in fermented beverages because of its ability to ferment until 4–9% vol producing high amounts of lactic acid from sugars. Therefore, it can be used to decrease pH of beverages [45–47]. Moreover, interesting effects in beer aroma can be reached by the production of fruity esters [48]. The use of *L. thermotolerans* has been also described in beer technology [49, 50]. In the brewing of craft beers, *L. thermotolerans* can be used not only in the primary fermentation of the wort but also during the second fermentation in bottle to produce the suitable foam and CO_2 pressure. However, the most interesting application is in the production of sour beers because of the natural biological acidification during wort fermentation [46]. Moreover, even when the early use of *L. thermotolerans* has been proposed in winemaking in which the use of suitable species of these yeasts can produce pH reductions of 0.5 pH units [47] and the use in beer technology is even more effective due to the lower buffer effect in beer compared with wine. In our lab, we reached pH reductions of 1 pH unit [51]. The sensory effect of this acidity is described as a citric acidity without dairy hints because of the low production of acetoin and diacetyl [47]; moreover, the volatile acidity produced by *L. thermotolerans* is very low compared to volatile acidity produced by selected *S. cerevisiae*.

Torulaspora delbrueckii is another versatile yeast suitable for beer production. It has a medium fermentative power and improves the formation of fruity esters in addition to a low production of volatile acidity. These characteristics make it a good yeast for the initial fermentation of the must and the subsequent in bottle [50]. Also it is possible the use of this yeast sequentially or in mixed cultures with *S. cerevisiae* [52] or *S. pombe* [53]. It has been described as yeast able to decrease volatile acidity during fermentation. The ability to ferment sugars easily reaching 7–9% vol makes it interesting also for secondary bottle fermentation [52]. The production of 2-phenylethyl acetate, a floral ester with positive floral aroma, is increased during fermentation with *T. delbrueckii*; moreover, high amounts of 3-ethoxy propanol are formed by this species [52]. The release of polysaccharides is also improved by the fermentation with *T. delbrueckii* affecting mouthfeel and structure [54].

Hanseniaspora vineae is an apiculate yeast able to produce fresh and complex fermentation, increasing fruity aroma and producing full bodied structure [55]. It is possible to find strains with fermentative power close to 9% vol, which facilitate its use not only for primary fermentation but also for bottle fermentation. Moreover, it is a persistent yeast that can be found until the end of the alcoholic fermentation in wines and therefore also in beers because of the lower alcoholic degree. During the fermentation with *H. vineae*, an increase in the concentration of acetyl esters, benzenoids, and sesquiterpenes [56, 57], and a decrease in the contents of alcohols and acids occurs. Intense either β-glucosidase or β-xylosidase activities has been described in some strains of *H. vineae* increasing the levels of hotrienol and 2,6-dimethyl-3,7-octadien-2,6-diol during fermentation [58]. It is especially noticeable the production of 2-phenylethyl acetate by *H. vineae* [55], compared with other *Hanseniaspora/Kloeckera* species.

Schizosaccharomyces pombe is a fission yeast able to produce maloalcoholic fermentation, and some strains can reach 13–15% vol of ethanol during fermentation [59, 60]. The peculiar metabolism of *S. pombe* produces an intense degradation of malic acid together with a significant release of pyruvate in the fermentative media [60]. *S. pombe* is especially resistant to some common preservatives such as sulfur dioxide, actidione, benzoic acid, and dimethyl dicarbonate [59, 61]. The main drawback of this yeast is the high production of volatile acidity. Concerning its structure this species has a peculiar and dense 2-layer cell wall. The autolysis produces the release of high amount of polysaccharides during maturation improving the mouth feel of beers [62]. This property can be especially interesting to produce full-bodied and soft bottle-aged beers. Moreover, we have observed intense bottle fermentation with good foam properties. The aromatic profile in beers is fruity and fresh when this is yeast is used specially in bottle fermentation.

5.3 Innovative ingredients

Raw material in wort production and parameters in production lead to produce an unlimited number of beer types. It might be argued that *beer is a horizontally differentiated product*. [35]. In fact, beers are quite similar in most respects but small differences in their composition can greatly affect both appearance and flavor [63].

We are going to examine each one of the raw materials separately.

5.3.1 Water

Water is quantitatively the main ingredient of beers; it forms more than 90% and often even more than 94% of the final product. The chemical composition of water has a determinant effect on beer properties and contributes significantly to the final beer flavor. The balance of minerals in brewing water will affect the flavor character and flavor perception of malt, hops, and by-products of fermentation. It may also influence the performance of yeast, which in turn influences the flavor, aroma, and mouthfeel of beer.

Chemical composition of water of the localities where famous beer styles were originated are very different in approximate ionic concentrations (in ppm). The chemical composition of water of Pilzen, Munich, Dortmund or Vienna is typical between Lager examples. Burton-on-Trent, Dublin or Edinburgh are typical between ale examples.

5.3.2 Malt

Malted barley is the main source for fermentable sugars used by yeasts in the traditional brewing of beers [64].

Depending on the conditions (time and temperature), pale or amber-colored or even dark malts are obtained; the color being due to caramelization of sugars and to Maillard-type reactions [65]. The variety of barely and the malting process influences the type and quality of beer [66]. **To elaborate craft beer, the right malt** is a **key factor** because craft beers include high proportion of adjuncts and enzymatic activity of malt has to ensure adequate hydrolysis of all the starch present in the wort.

5.3.3 Adjuncts

Malted barley is the main source for fermentable sugars used by yeasts in the traditional brewing, Other grains, malted or not, have been included to provide fermentable carbohydrates to the wort in addition to those from malt [63]. In former times, most cereals were used for malting, emmer, oats, spelt wheat, bread wheat were widely used and, in Estonia, rye was used up until the nineteenth century [67]. Outside Europe, millet, rice, maize and tuber plants have been, and are still, commonly used.

Bogdan and Kordialik-Bogacka [64] estimate that 85–90% of beer worldwide is now produced with adjuncts. Traditionally they had been used because they lead to reduce the cost of raw materials. When adjuncts are selected as unmalted grains, they present the added advantage of improved sustainability, by reducing reliance on the malting process [68] and its associated cost.

Craft brewing is increasing the use of adjuncts [68] because they lead to create a unique beer **flavor/aroma** [69]. **Figure 3** shows the influence of different concentrations of roasted malt addition on sensory properties of beer.

Appropriately chosen adjuncts can contribute to light or dark colors, improved colloidal or foam stability and prolongation beer shelf-life [64]. The flavor profile can also be changed by altering the sugar and amino acid spectra in wort.

5.3.4 Hops

Hops (*Humulus lupulus* L.) are almost exclusively consumed by the brewing industry. Although hops are only a minority ingredient, they have significant impact on the sensory properties of beer [65]. It contributes not only to bitter flavor but also with the particular character of the selected hop variety [66].

This is mainly due to its particular chemical composition in: the hops resins, the hop oil and hop polyphenols [70].

Figure 3.
Effect of roasted barley addition on beer sensory properties.

In the closing years of the twentieth century, the hop became an icon of the "craft beer revolution" that swept across the United States. The "hopped up" vats created more flavorful and aromatic beers, making them more akin to European specialty varieties than anything seen in United States markets since before prohibition. The hops also became an effective marketing tool [39] from a nutritional and health point of view. It had recently come to light the effect antiviral and anti-HIV of xanthohumol, a phenylated flavonoid isolated from hops [66].

5.4 Perspective on health and nutrition

This section also includes a part on special or craft beers, which meet the **new consumer requirements** related with health and nutrition. In this context, it should include categories such as [66] light or low-calorie beers, low alcohol or non-alcohol beers, gluten free beers and functional beers.

5.4.1 Light beers

Light beer is a relatively new product on the market. Light beers contain at least one-third less calories than conventional beers [71]. However, these products are not widely accepted in Europe compared to North America and Australasia because of their lack of fullness in the taste and low bitterness compared with conventional beer. **Enhanced hop character and addition of a low level of priming syrup** have been proposed to the production of a low-calorie beer with a well-balanced and full beer flavor [38].

From a nutritional point of view [71], light beer contains less carbohydrate than regular beer, low alcohol beer or non-alcoholic beer. Surprisingly, light beer presents more calorie supply than such beers. This may be explained considering that light beer has a significant amount of alcohol (3%) providing a high calorie value.

5.4.2 Low alcohol beers

Low-alcohol beer is a beer with very low- or no-alcohol content. The alcohol by volume (ABV) limits depends on laws in different countries. In recent years, there has been an **increased market share for low alcohol beers**. This is mainly due to health and safety reasons and increasingly strict social regulations [72]. The alcohol-free beers also claim beneficial effects of healthy beer components with a simultaneous effect of the lower energy intake and complete absence of negative impacts of alcohol consumption.

According to Blanco et al. [73], the dealcoholization processes that are commonly used to reduce the alcohol content in beer have negative consequences to beer flavor. Several processes (physical and biological) have been developed for the production of low-alcohol or alcohol-free beer [74]. The physical processes include thermal and membrane processes such as thin-layer evaporation; falling film vacuum evaporation; continuous vacuum rectification; reverse osmosis; and dialysis. The biological processes include cold contact process (CCP); arrested fermentation; and use of special yeasts (*S. ludwigii*).

Overall, the taste defects in alcohol-free beer are mainly attributed to loss of aromatic esters, insufficient aldehydes, reduction or loss of different alcohols, and an indeterminate change in any of its compounds during the dealcoholization process or as a consequence of incomplete fermentation [73].

5.4.3 Gluten free

The market segment for gluten free (GF) products continues to grow rapidly and gluten free beers are a niche market with **increasing demand** [75, 76].

Beer is considered unsuitable for people suffering from gluten intolerance, but with some modification and removal of proteins which occur during traditional beer processing. The majority of the precipitated protein remains in the spent grain after the lautering process and only a small proportion of gluten passes from malt to sweet wort. A study conducted by [77], in twenty-eight commercial beers, found that 10 of the tested beers contained less than 20 ppm gluten.

There are different alternatives for the reduction of gluten levels below the legislative gluten-free threshold (≤20 ppm) (EC No. 41/2009, 2009), on a daily basis, including precipitation and enzymatic hydrolysis. Deglutinization treatments by enzymatic process were proposed by Fanari et al. [78].

Furthermore, gluten free beers can be produced **using gluten free cereals and pseudocereals**. Currently only sorghum, rice, maize, millet, and buckwheat appear to be successful GF beer ingredients, while others have only shown adjunct possibilities. Among cereals, Teff is gaining a lot of popularity in GF beer production. **Teff** grain nutrients are promising and it is also an excellent GF alternative for people with celiac disease and other gluten allergy. Though the α- and β-amylase activities of teff malt are lower than that of barley, it has sufficient level of enzyme activities to be used as a raw material for malting [79] and GF beer production. Mayer et al. [80] has also prepared a GF beer from **all-rice malt** with sufficient endogenous enzyme activity for degradation of the rice components.

A third approach is the production of yeast fermented beverages based on fermentable sugars/syrups [75]. The search for new gluten-free brewing materials is still in its infancy and researchers in this field of study are continuously researching on the malting, mashing, fermentation conditions [78].

5.4.4 Functional beer

There is also scope for positioning low-calorie beers as a source of good carbohydrates, such as the soluble fiber and prebiotics derived from the β-linked glucans and arabinoxylans in the cereal walls [81]. Because these carbohydrates are neither metabolized by the brewing yeast nor they do not contribute toward calorie count but exert health benefits. Prebiotics are dominantly oligosaccharides that are nondigestible to human being but selectively stimulate growth and activity of beneficial bacteria (probiotics) in the human gastrointestinal tract.

Further, β-glucans could enhance stress tolerance of intestinal lactobacilli, which may have a positive impact on survival of probiotics. Nonetheless, high molecular weight b-linked glucan materials may have a negative impact on filtration efficiency and optimization of a filtration process will be required.

Probiotics are not limited to bacteria, and there is a well-known probiotic yeast strain of *S. cerevisiae* var. *boulardii*. A novel unfiltered and unpasteurized probiotic beer could be produced by fermenting wort with a probiotic strain of *S. cerevisiae*. A new category of functional beer could be the specialty beer of the future, given the rising consumer recognition and acceptance of probiotics [38].

5.5 Use of new technologies

Emerging technologies as high hydrostatic pressure (HHP) and ultra-high pressure homogenization (UHPH) open new possibilities in beer production. Both technologies are considered as cold techniques allowing the control of microorganisms in beverages [82]. Even when some temperature increasing is produced that can be quantified in 2–3°C/100 MPa in HHP [83] by compression adiabatic heat and until 100°C but just for 0.2 s in UHPH because of intense shear forces and impact [84]. The use of HHP is able to eliminate yeasts at pressures of 400 MPa-10 min but Gram-positive bacteria needs 600 MPa-10 min and spores remain unaffected even with these pressures [85]. Also it has the drawback of being a discontinuous technology. UHPH is now currently highly developed being a fast technology with a good industrial scale-up with equipment that are working at a flow of 10,000 l/h (https://www.ypsicon.com/). Moreover, UHPH is a continuous technology and able to produce sterilization due to the extreme impacts and shear forces produced when the fluid pumped at 300 MPa cross the depressurization valve [84]. In beer production theoretically is possible to pump the beer at 300 MPa and release the pressure until 4 bar, later is possible to make a sterile iso-barometric bottling. The intense de-polymerization produced by UHPH can also disaggregate colloidal particles improving the beer structure and stability. Potentially it is possible to produce the mechanically lysis of the yeasts formed during fermentation increasing the amount of small size polysaccharides.

Other interesting technology that can be quite useful in beer production and sterilization is pulsed light (PL). This technology produces high energy light during a very short time (few μs) with a strong capacity to inactivate microorganisms and spores allowing sterilization [85]. The light is applied by flash lamps with a range spectra of 160–2600 nm with an intensity 105 folds the sunlight intensity at the seaside level. Power peak can reach 35 MW. PL technology is also a cold technology being a gentle process with sensory quality of beverages. This technique can be applied continuously during beer processing previously to packaging. It is also possible to use this technology to sterilize bottles or packages.

The use of these new technologies opens new possibilities in the processing and preservation of beer. UHPH and PL can be applied in a continuous way being efficient and easily implemented at industrial scale. Both sterilization technologies have a gentle repercussion in sensory quality of beverages.

6. Future trends

The development of new craft and special beers will be focused in the improvement on sensory properties and differentiation. Moreover, health care connotations are essential and should be supported by traditional processes but improved with both new biotechnologies and emerging processes.

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References

[1] Hayden B, Canuel N, Shanse J. What was brewing in the Natufian? An archaeological assessment of brewing technology in the Epipaleolithic. Journal of Archaeological Method and Theory. 2012;**20**(1):102-150. DOI: 10.1007/s10816-011-9127-y

[2] Dineley M, Dineley G. Neolithic ale: Barley as a source of malt sugars for fermentation. In: Fairbairn AS, editor. Plants in Neolithic Britain and Beyond. Oxford: Oxbow; 2000. pp. 137-154

[3] Cabras I, Higgins DM. Beer, brewing, and business history. Business History. 2016;**58**:609-624

[4] McGovern P, Zhang J, Tang J, Zhang Z, Hall G, Moreau R, et al. Fermented beverages of pre- and proto-historic China. Proceedings of the National Academy of Sciences of the United States of America. 2004;**101**(51):17593-17599

[5] Meussdoerffer FG. A comprehensive history of beer brewing. In: Esslinger HM, editor. Handbook of Brewing. Weinheim: Wiley-VCH Verlag GmbH & Co.; 2009. pp. 1-42

[6] Bai J, Huang J, Rozelle S, Boswell M. Beer battles in China: The struggle over the World's largest beer market. In: Swinnen JFM, editor. The Economics of Beer. Oxford: Oxford University Press; 2011. pp. 267-286

[7] Jiajing W, Li L, Terry B, Linjie Y, Yuanqing L, Fulai X. Revealing a 5,000-y-old beer recipe in China. Proceedings of the National Academy of Sciences of the United States of America. 2016;**113**(23):6444-6448

[8] Hardwick WA. History and antecedents of brewing. In: Hardwick WA, editor. Handbook of Brewing. New York: Marcel Dekker; 1994. pp. 37-52

[9] Cortacero-Ramirez S, De Castro MHB, Segura-Carretero A, Cruces-Blanco C, Fernandez-Gutierrez A. Analysis of beer components by capillary electrophoretic methods. Trends in Analytical Chemistry. 2003;**22**(7):440-455

[10] Michel C. L'alimentation au Proche-Orient ancien: Les sources et leur exploitation. Dialogues d'Histoire Ancienne. 2012;**7**:17-45

[11] Maksoud SA, Hadidi MN, Amer WN. Beer from the early dynasties (3500-3400 cal. B.C.) of Upper Egypt, detected by archaeochemical methods. Vegetation History and Archaeobotany. 1994;**3**(4):219-224

[12] Nelson M. The barbarian's Beverage: A History of Beer in Ancient Europe. London/New York: Routledge; 2005. DOI: 10.4324/9780203309124. Available from: https://scholar.uwindsor.ca/llcpub/26

[13] Poelmans E, Swinnen JFM. From monasteries to multinationals (and back): A historical review of the beer economy. The Journal of Wine Economics. 2011;**6**(2):196-216

[14] Moore J. Pre-Hispanic beer in coastal Peru: Technology and social context of prehistoric production. American Anthropologist. 1989;**91**(3):682-695

[15] Burger RL, Van Der Merwe NJ. Maize and the origin of Highland Chavín civilization: An isotopic perspective. American Anthropologist. 1990;**92**(1):85-95

[16] Hastorf CA, Johannessen S. Pre-Hispanic political change and the role of maize in the Central Andes of Peru. American Anthropologist. 1993;**95**(1):115-138

[17] Liua L, Wanga J, Rosenbergb D, Zhaoc H, Lengyeld G, Nadel D. Fermented beverage and food storage in 13,000 y-old stone mortars at Raqefet cave, Israel: Investigating Natufian ritual feasting. Journal of Archaeological Science: Reports. 2018;**21**:783-793

[18] Perruchinia E, Glatza C, Haldb MM, Casanac J, Toneyd JL. Revealing invisible brews: A new approach to the chemical identification of ancient beer. Journal of Archaeological Science. 2018;**100**:176-190

[19] Howard PH. Too big to ale? Globalization and consolidation in the beer industry. In: Patterson MW, Pullen NH, editors. The Geography of Beer: Regions, Environment, and Society. Dordrecht, The Netherlands: Springer; 2014; pp. 155-165

[20] Sewell SL. The spatial diffusion of beer from its Sumerian origins to today. In: Patterson M, Hoalst-Pullen N, editors. The Geography of Beer: Regions, Environment, and Society. Dordrecht: Springer; 2014. pp. 23-29. https://doi.org/10.1007/978-94-007-7787-3_3

[21] Elzinga K, Tremblay C, Tremblay V. Craft beer in the United States: History, numbers, and geography. The Journal of Wine Economics. Dordrecht, Springer; 2015;**10**(3):242-274. DOI: 10.1017/jwe.2015.22

[22] Garavaglia C. Birth and Diffusion of Craft Breweries in Italy. In: Garavaglia C, Swinnen J, editors. Economic Perspectives on Craft Beer: A Revolution in the Global Beer Industry. London: Palgrave Macmillan; 2017

[23] van Dijk M, Kroezen J, Slob B. From Pilsner Desert to craft beer oasis: The rise of craft brewing in the Netherlands. In: Economic Perspectives on Craft Beer. Cham, Switzerland: Palgrave McMillan; 2017. pp. 259-293. DOI: 10.1007/978-3-319-58235-1_10. ISBN: 978-3-319-58235-1

[24] Sammartino A. Craft brewing in Australia, 1979-2015. In: Garavaglia C, Swinnen J, editors. Economic Perspectives on Craft Beer: A Revolution in the Global Beer Industry. London/New York: Palgrave Macmillan; 2018. pp. 397-423

[25] Depenbusch L, Ehrich M, Pfizenmaier U. Craft Beer in Germany–New Entries in a Challenging Beer Market. In: Garavaglia C, Swinnen J, editors. Economic Perspectives on Craft Beer: A Revolution in the Global Beer Industry. London, New York: Palgrave Macmillan; 2018

[26] Garavaglia C, Swinnen J. The craft beer revolution: An international perspective. Choices. 2017;**32**(3):1-8. Available from: http://www.choicesmagazine.org/choices-magazine/theme-articles/global-craft-beer-renaissance/the-craft-beer-revolution-an-international-perspective

[27] Brewers Association. 2019. Retrieved from: https://www.brewersassociation.org/statistics/ [Accessed: April 1, 2019]

[28] Bamforth C, Cabras I. Interesting times: Changes for brewing. In: Cabras I, Higgins D, Preece D, editors. Brewing, Beer and Pubs: A Global Perspective. London: Palgrave Macmillan; 2016. pp. 13-33

[29] The Brewers of Europe. Beer Statistics—2018 and Previous Years. 2018. Retrieved from: https://brewersofeurope.org/site/index.php [Accessed: April 1, 2019]

[30] Australia and New Zealand Banking Group Limited (ANZ). New Zealand craft beer industry insights: ANZ industry reports. 2017. Available from: https://comms.anz.co.nz/businsights/

article/report.html?industry=Craft%20 Beer [accessed: April 1, 2018]

[31] Tripes S, Dvořák J. Strategic forces in the Czech brewing industry from 1990-2015. Acta Oeconomica Pragensia. 2017;**3**:3-38

[32] Rogerson CM, Collins KGE. Developing beer tourism in South Africa: International perspectives. African Journal of Hospitality, Tourism and Leisure. 2015;**4**(1):1-15

[33] Beer Canada. *2015 Industry Trends*. 2016. Available from: http://www.beercanada.com/sites/default/files/2015_industry_trends_final.pdf

[34] Gómez-Corona C, Lelievre-Desmas M, Buendía HBE, Chollet S, Valentin D. Craft beer representation amongst men in two different cultures. Food Quality and Preference. 2016;**53**:19-28

[35] Clemons EK, Gao GG, Hitt LM. When online reviews meet hyperdifferentiation: A study of the craft beer industry. Journal of Management Information Systems. 2006;**23**(2):149-171

[36] Reid N, McLaughlin RB, Moore MS. From yellow fizz to big biz: American craft beer comes of age. Focus on Geography. 2014;**57**(3):114-125

[37] Smith S, Farrish J, McCarroll M, Huseman E. Examining the craft brew industry: Identifying research needs. International Journal of Hospitality Beverage Management. 2017;**1**(1):3

[38] Yeo HQ, Liu SQ. An overview of selected specialty beers: Developments, challenges and prospects. International Journal of Food Science & Technology. 2014;**49**(7):1607-1618

[39] Kopp P. The global hop: An agricultural overview of the brewer's gold. In: Patterson M, Hoalst-Pullen N, editors. The Geography of Beer. Dordrecht: Springer; 2014

[40] Tataridis P, Kanelis A, Logotetis S, Nerancis E. Use of non-*Saccharomyces Torulaspora delbrueckii* yeast strains in winemaking and brewing. Zbornik Matice Srpske za Prirodne Nauke. 2013;**124**:415-426

[41] Callejo MJ, González C, Morata A. Use of non-*Saccharomyces* yeasts in bottle fermentation of aged beers. In: Kanauchi M, editor. Brewing Technology. Rijeka, Croatia: IntechOpen; 2017. DOI: 10.5772/intechopen.68793. Available from: https://www.intechopen.com/books/brewing-technology/use-of-non-saccharomyces-yeasts-in-bottle-fermentation-of-aged-beers

[42] Kleban J, Nickerson I. To brew, or not to brew-that is the question: An analysis of competitive forces in the craft brew industry. Journal of the International Academy for Case Studies. 2012;**18**(3):59

[43] Pavsler A, Buiatti S. Non-lager beer. In: Beer in Health and Disease Prevention. London, United Kingdom: Academic Press; 2009. pp. 17-30

[44] Budroni M, Zara G, Ciani M, Comitini F. *Saccharomyces* and non-*Saccharomyces* starter yeasts. In: Kanauchi M, editor. Brewing Technology. Rijeka, Croatia: IntechOpen; 2017. DOI: 10.5772/intechopen.68792. Available from: https://www.intechopen.com/books/brewing-technology/saccharomyces-and-non-saccharomyces-starter-yeasts

[45] Gobbi M, Comitini F, Domizio P, Romani C, Lencioni L, Mannazzu I, et al. *Lachancea thermotolerans* and *Saccharomyces cerevisiae* in simultaneous and sequential co-fermentation: A strategy to enhance acidity and improve the overall quality of wine. Food Microbiology. 2013;**33**:271-281. DOI: 10.1016/j.fm.2012.10.004

[46] Morata A, Loira I, Tesfaye W, Bañuelos MA, González C, Suárez Lepe JA. *Lachancea thermotoleran*s applications in wine technology. Fermentation. 2018;**4**:53. DOI: 10.3390/fermentation4030053

[47] Morata A, Bañuelos MA, Vaquero C, Loira I, Cuerda R, Palomero F, et al. *Lachancea thermotolerans* as a tool to improve pH in red wines from warm regions. European Food Research and Technology. 2019;**245**:885-894. DOI: 10.1007/s00217-019-03229-9

[48] Escott C, Morata A, Ricardo-da-Silva JM, Callejo MJ, González MC, Suarez-Lepe JA. Effect of *Lachancea thermotolerans* on the formation of polymeric pigments during sequential fermentation with *Schizosaccharomyces pombe* and *Saccharomyces cerevisiae*. Molecules. 2018;**23**:2353. DOI: 10.3390/molecules23092353

[49] Domizio P, House JF, Joseph CML, Bisson LF, Bamforth CW. *Lachancea thermotolerans* as an alternative yeast for the production of beer. Journal of the Institute of Brewing. 2016;**122**:599-604. DOI: 10.1002/jib.362

[50] Callejo MJ, García Navas JJ, Alba R, Escott C, Loira I, González MC, et al. Wort fermentation and beer conditioning with selected non-*Saccharomyces* yeasts in craft beers. European Food Research and Technology. 2019;**245**:1229-1238. DOI: 10.1007/s00217-019-03244-w

[51] Vanooteghem M. Impact of non-*Saccharomyces* fermentations on the flavour profile of craft beer [MS thesis]. Madrid, Spain: Technical University of Madrid; 2019

[52] Loira I, Vejarano R, Bañuelos MA, Morata A, Tesfaye W, Uthurry C, et al. Influence of sequential fermentation with *Torulaspora delbrueckii* and *Saccharomyces cerevisiae* on wine quality. LWT - Food Science and Technology. 2014;**59**:915-922. DOI: 10.1016/j.lwt.2014.06.019

[53] Loira I, Morata A, Comuzzo P, Callejo MJ, González C, Calderón F, et al. Use of *Schizosaccharomyces pombe* and *Torulaspora delbrueckii* strains in mixed and sequential fermentations to improve red wine sensory quality. Food Research International. 2015;**76**:325-333. DOI: 10.1016/j.foodres.2015.06.030

[54] Comitini F, Gobbi M, Domizio P, Romani C, Lencioni L, Mannazzu I, et al. Selected non-*Saccharomyces* wine yeasts in controlled multistarter fermentations with *Saccharomyces cerevisiae*. Food Microbiology. 2011;**28**:873-882. DOI: 10.1016/j.fm.2010.12.001

[55] Martin V, Valera MJ, Medina K, Boido E, Carrau F. Oenological impact of the *Hanseniaspora/Kloeckera* yeast genus on wines—A review. Fermentation. 2018;**4**:76. DOI: 10.3390/fermentation4030076

[56] Martin V, Giorello F, Fariña L, Minteguiaga M, Salzman V, Boido E, et al. De novo synthesis of benzenoid compounds by the yeast *Hanseniaspora vineae* increases the flavor diversity of wines. Journal of Agricultural and Food Chemistry. 2016;**64**:4574-4583

[57] Martin V, Boido E, Giorello F, Mas A, Dellacassa E, Carrau F. Effect of yeast assimilable nitrogen on the synthesis of phenolic aroma compounds by *Hanseniaspora vineae* strains. Yeast. 2016;**33**:323-328

[58] López S, Mateo JJ, Maicas S. Characterisation of *Hanseniaspora* isolates with potential aroma enhancing properties in Muscat wines. South African Journal of Enology and Viticulture. 2014;**35**:292-303

[59] Suárez-Lepe JA, Palomero F, Benito S, Calderón F, Morata A.

Oenological versatility of *Schizosaccharomyces* spp. European Food Research and Technology. 2012;**235**:375-383

[60] Loira I, Morata A, Palomero F, González C, Suárez-Lepe JA. *Schizosaccharomyces pombe*: A promising biotechnology for modulating wine composition. Fermentation. 2018;**4**:70. DOI: 10.3390/fermentation4030070

[61] Escott C, Loira I, Morata A, Bañuelos MA, Suárez-Lepe JA. Wine spoilage yeasts: Control strategy. In: Morata A, Loira I, editors. Yeast-Industrial Applications. London, UK: InTech; 2017. pp. 89-116

[62] Palomero F, Morata A, Benito S, Calderón F, Suárez-Lepe JA. New genera of yeasts for over-lees aging of red wine. Food Chemistry. 2009;**112**:432-441

[63] Buiatti S. Beer composition: An overview. In: Beer in Health and Disease Prevention. London, United Kingdom: Academic Press; 2009. pp. 213-225

[64] Bogdan P, Kordialik-Bogacka E. Alternatives to malt in brewing. Trends in Food Science & Technology. 2017;**65**:1-9

[65] De Keukeleire D. Fundamentals of beer and hop chemistry. Quimica Nova. 2000;**23**(1):108-112

[66] Sohrabvandi S, Mortazavian AM, Rezaei K. Health-related aspects of beer: A review. International Journal of Food Properties. 2012;**15**(2):350-373

[67] Behre KE. The history of beer additives in Europe—A review. Vegetation History and Archaeobotany. 1999;**8**(1-2):35-48

[68] Kok YJ, Ye L, Muller J, Ow DSW, Bi X. Brewing with malted barley or raw barley: What makes the difference in the processes? Applied Microbiology and Biotechnology. 2019;**103**(3):1059-1067

[69] Schnitzenbaumer B, Arendt EK. Brewing with up to 40% unmalted oats (*Avena sativa*) and sorghum (*Sorghum bicolor*): A review. Journal of the Institute of Brewing. 2014;**120**(4):315-330

[70] Steenackers B, De Cooman L, De Vos D. Chemical transformations of characteristic hop secondary metabolites in relation to beer properties and the brewing process: A review. Food Chemistry. 2015;**172**:742-756

[71] Blanco CA, Caballero I, Barrios R, Rojas A. Innovations in the brewing industry: Light beer. International Journal of Food Sciences and Nutrition. 2014;**65**(6):655-660

[72] Brányik T, Silva DP, Baszczyňski M, Lehnert R, e Silva JBA. A review of methods of low alcohol and alcohol-free beer production. Journal of Food Engineering. 2012;**108**(4):493-506

[73] Blanco CA, Andrés-Iglesias C, Montero O. Low-alcohol beers: Flavor compounds, defects, and improvement strategies. Critical Reviews in Food Science and Nutrition. 2016;**56**(8):1379-1388

[74] Montanari L, Marconi O, Mayer H, Fantozzi P. Production of alcohol-free beer. In: Beer in Health and Disease Prevention. London, United Kingdom: Academic Press; 2009. pp. 61-75

[75] Hager AS, Taylor JP, Waters DM, Arendt EK. Gluten free beer—A review. Trends in Food Science & Technology. 2014;**36**(1):44-54

[76] Watson HG, Vanderputten D, Van Landschoot A, Decloedt AI. Applicability of different brewhouse technologies and gluten-minimization treatments for the production of gluten-free (barley) malt beers: Pilot-to

industrial-scale. Journal of Food Engineering. 2019;**245**:33-42

[77] Guerdrum LJ, Bamforth CW. Prolamin levels through brewing and the impact of prolyl endoproteinase. Journal of the American Society of Brewing Chemists. 2012;**70**:35-38

[78] Fanari M, Forteschi M, Sanna M, Zinellu M, Porcu MC, Pretti L. Comparison of enzymatic and precipitation treatments for gluten-free craft beers production. Innovative Food Science & Emerging Technologies. 2018;**49**:76-81

[79] Gebremariam MM, Zarnkow M, Becker T. Teff (*Eragrostis tef*) as a raw material for malting, brewing and manufacturing of gluten-free foods and beverages: A review. Journal of Food Science and Technology. 2014;**51**(11):2881-2895

[80] 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 Science and Technology. 2016;**67**:67-73

[81] Bamforth CW. Beer, carbohydrates and diet. Journal of the Institute of Brewing. 2005;**111**(3):259-264

[82] Morata A, Loira I, Vejarano R, González C, Callejo MJ, Suárez-Lepe JA. Emerging preservation technologies in grapes for winemaking. Trends in Food Science & Technology. 2017;**67**:36-43. DOI: 10.1016/j.tifs.2017.06.014

[83] Bañuelos MA, Loira I, Escott C, Del Fresno JM, Morata A, Sanz PD, et al. Grape processing by high hydrostatic pressure: Effect on use of non-*Saccharomyces* in must fermentation. Food and Bioprocess Technology. 2016;**9**:1769-1778. DOI: 10.1007/s11947-016-1760-8

[84] Loira I, Morata A, Bañuelos MA, Puig-Pujol A, Guamis B, González C, et al. Use of ultra-high pressure homogenization processing in winemaking: Control of microbial populations in grape musts and effects in sensory quality. Innovative Food Science and Emerging Technologies. 2018;**50**:50-56

[85] Morata A, Loira I, Vejarano R, Bañuelos MA, Sanz PD, Otero L, et al. Grape processing by high hydrostatic pressure: Effect on microbial populations, phenol extraction and wine quality. Food and Bioprocess Technology. 2015;**8**:277-286. DOI: 10.1007/s11947-014-1405-8