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Non Alcoholic Beers: Review and Methods

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Article Info

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Abstract

The market for nonalcoholic and low-alcohol beer has grown significantly in recent years and is expected to continue to grow. This is primarily due to health concerns, workplace or road safety concerns, and strict social regulations. There are also countries where alcohol consumption is strictly prohibited by law. Consumers in such situations are willing to consume products that are as close to the traditional types as possible from a sensory standpoint (especially flavor characteristics). Non-alcoholic beer has an artificial and dull flavor, as well as poor body and foaming properties. Biological methods focus on the limited production of ethanol during fermentation, whereas dealcoholization methods focus on gentle and selective ways to remove ethanol from normal strength beers without compromising the taste. In recent years, research into the use of yeasts from the non-Saccharomyces sector has gained attraction, with the potential to introduce new flavors to these beers without using any specialized equipment.

Keywords: Beer; Brewing; Alcohol; Non-alcoholic; Low alcoholic; Dealcoholization.

Introduction

Beer is one of the oldest fermented beverages a popular drink and the most widely consumed alcoholic beverage in the world. It is a nutritive, digestive, soothing, and sedative tonic or beverage. Beer is consumed as a refreshing drink [1]. The brewing process involves several steps: starting from the malting of barley, followed by milling of malted grains, then mashing (addition of water), lautering (wort separation), boiling of wort, cooling of that wort and yeast addition, fermentation, maturation, filtration, and packaging. 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. Beer also gains interest due to the potential medical benefits and antioxidants. Studies suggest 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. Moderate beer consumption can have positive health benefits, but the negative consequences of its alcohol and energy content outweigh them [2].

However, innovations in brewing could enhance the bioactive compounds in beer while reducing its alcohol and energy content through a variety of methods, such as new ingredients, brewing processes, and different types of fermentation. In recent years, beer manufacturers have developed products that are lower in alcohol content. These beers are growing in popularity throughout the world. To create these types of beers, brewers use different ingredients and technologies as well as produce them using a different brewing process [3].

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. The brewing industry is different in other countries, where laws are less strict and brewers have more flexibility. Other grains are used, such as wheat, rice, rye, oats, maize (corn), unmalted barley, and to a lesser extent sorghum, millet, cassava etc. [4].

Thus, other carbohydrate sources (adjuncts) like cereal grains (malted and unmalted) are the most widely used. Barley malt is usually used along with wheat and oat due to their foam stability and bitterness. Before hops were introduced, other bitter herbs, spices, and flowers were added to spread different sensory profiles. Also from ancient times, different fruits were used in brewing as sources of fermentation and also as flavoring ingredients [5].

While developing new beers, brewers must keep up with consumer interests and needs. Brewers have responded to these demands by making continuous improvements and attempting to reduce the amount of alcohol in their products while maintaining other qualities. Consumers are looking for products that are as close to traditional types as possible in terms of sensory characteristics, particularly when it comes to flavor characteristics [6].

Regular or traditional beer is an alcoholic beverage made by saccharification of starch and fermentation of the sugar that results in good quality. The alcohol content, bitterness, pH, turbidity, color, and, most importantly, the flavor of beers can all vary. Beers are classified primarily by their visual appearance (color and turbidity) as well as the fermentation process [5].

Fruits, wine, or honey are inoculated in the wort of beer due to their natural yeast sources. Perhaps as a result of the global trend toward a healthier lifestyle and higher product quality, the market for specialty beers has evolved significantly in the last decade, offering additional product traits such as improved functionality, new flavors, and tastes. These enhancements went beyond the use of hops, which are still important to the brewing industry because they contribute significantly to beer's sensory properties. Recently, microbreweries have devoted themselves to the creation of unique beers, utilizing fruits, honey, herbs, and spices to enhance the aroma and provide flavors and colors not found in grains [7].

Currently, a wide range of beers are available, the majority of which fall into one of two categories: Ale has a high (or top) fermentation, while lager has a low (or bottom) fermentation. Nowadays, a special category, Non-alcoholic beer includes low-alcohol beers (<2.5 percent v/v) and alcohol-free beers (≤1% v/v). Low-alcohol beer, also known as "low alcoholic beer," "lower-alcohol beer," "low-point beer," "alcohol-reduced beer," and "light beer," is defined differently in different countries and the alcohol by volume limits vary. This limit is no more than 0.5 percent v/v in Germany, the United States, and China; in Spain, the maximum value is 1 percent v/v alcohol; and in France, it is 1.2 percent v/v alcohol. Non-alcoholic beers which contain less than 0.5 percent v/v alcohol and provide some of the main bioactive components of traditional beers are an alternative to other non-alcoholic beverages in Islamic countries such as Saudi Arabia and the United Arab Emirates, where alcohol consumption is prohibited by law [8].

Craft beers, particularly traditional ales and lagers, which are distinctively flavored, have seen a global rise in consumer interest over the last decade. These beers are also unpasteurized, unfiltered, and without added nitrogen or carbon dioxide pressure and produced locally in small quantities. Breweries can be categorized into three different types: brewpubs, microbreweries, and regional craft breweries. Brewpubs are restaurants that produce beer for their customers to drink on the premises but also distribute it regionally. Microbreweries are typically smaller-scale breweries that focus on unique flavors and quality instead of quantity. Regional craft breweries usually have a larger production process than brewpubs or microbreweries but still distribute most of their products locally [9].

The production of low alcohol content beers has had different reasons throughout the centuries. For example, during World Wars I and II, there was a shortage of raw materials, which led to brewers producing low-alcohol beers. Prohibition in the United States from 1919 to 1933 also increased production of these types of beers [10].

In Europe, market share for low-strength alcohol and alcohol-free beer has increased in recent years, whereas in the United States, after a growth period from 2007 to 2012, market share has remained stagnant. Each country's legislation on beer classification varies, and there is no European-wide regulation on reduced-alcohol-content beer [22]. Sales of low-alcohol beers have not met optimistic expectations, and this market has long been a mere drop in the sea of overall beer production. However, this segment is growing rapidly worldwide. In the last five years, average sales of low-alcohol beers in Europe have climbed by 50%. Spain is now the largest consumer of these beers in the Europe, with 9.5% of all beer sales in that market being alcohol-free. Germany, meanwhile, falls behind at 4% and 5%. The most significant reasons for the annual increase in alcohol-free beer sales in EU countries are the legislative interventions restricting alcohol consumption and the increasing awareness of consumers about moderate beer drinking benefits [10].

Currently, the craft beer market is experiencing a boom in non-alcoholic and low alcohol beers. Consumers are demanding drinks that offer the same sensory appeal as alcoholic beverages but do not have alcohol content. The popularity of this segment has also been influenced by new technology that allows producers to brew these types of beers without compromising their taste and quality.

Non-Alcoholic Beers: alcohol-free (NB) and low-alcohol beers (LB)

Breweries wanted to increase the variety of their products in the late twentieth century. They did this by designing new non-alcoholic beer products that they could sell in countries with high competition and providing consumers with a new product that they can drink before or during daily activities.

The impact of sensory properties such as color, foam, flavor and aroma, mouthfeel, and aftertaste on a consumer's perception of non-alcoholic beer quality is usually associated with a complex combination of expectations. Some of these sensory perceptions are beyond the brewer's control, but beer flavor and aroma control are the most important of those directly influenced by the brewing and packaging processes. The appearance and flavor profile of each beer variety are two factors that must meet consumer demands. Impurities can alter the appearance of beer, causing increased turbidity and lowering the product's quality [10].

In the beer market, various factors influence consumption habits. Bitterness level, alcohol content, packaging volume, design, ease of transportation and storage all play a role in influencing consumers' consumption patterns. Non-alcoholic beer is on the rise because it avoids the drawbacks associated with high alcohol content.

Alcohol consumption is the third most harmful health risk factor in the world. That also have serious social consequences, and when considering the potential health benefits of beer, novel brewing techniques and yeasts should be considered that can help to moderate or minimize alcohol content while preserving flavor and potential health benefits.

For those in the alcohol industry, developing beverages that attract consumers is a challenge. New beer products can provide benefits (such as different colors, antioxidants, etc.), which may attract new customers. Consumers are willing to pay more for specialty beers, which typically have a lower alcohol content than other beers or wine.

Non-alcoholic beer consumers seek a product that most closely resembles regular beer, but the dealcoholization process gives these beers a different taste and overall sensory characteristics. This is sometimes reflected in modest consumer acceptance. Low alcoholic beers produced by limited fermentation are often characterized by an off-flavor and sweet taste, which are not common traits of beer [11].

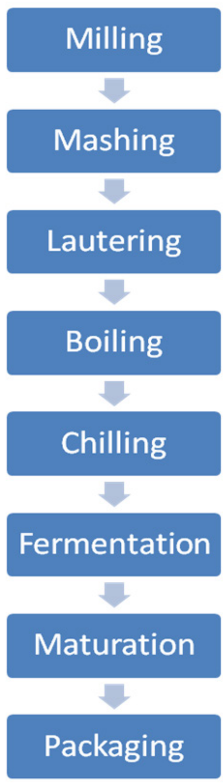
The slight shift away from beer-like flavours and toward a fruitier flavour, on the other hand, may prove beneficial in terms of consumer acceptance. Because compounds that impart taste can be directly sensed through the tongue, that is also an important factor in beverage selection. The aroma, on the other hand, refers to any volatile compound that emerges from the beverage. Alcohols, phenols, esters, carbonyl compounds, and organic and fatty acids are the main flavour components. Bellut and Arendt [12] reviewed marketing and labelling issues and concluded that product labelling is a powerful tool for creating specific sensory expectations that can influence a consumer's choice.

Microbreweries rarely have a laboratory for quality control of their beer. The NB's taste profile is difficult to maintain while removing the alcohol. Beer is subject to chemical reactions from the moment it leaves the manufacturing facility, and given large brewing producers entering the global beer market, this poses an increased risk for product quality.

Brewing: Beer production

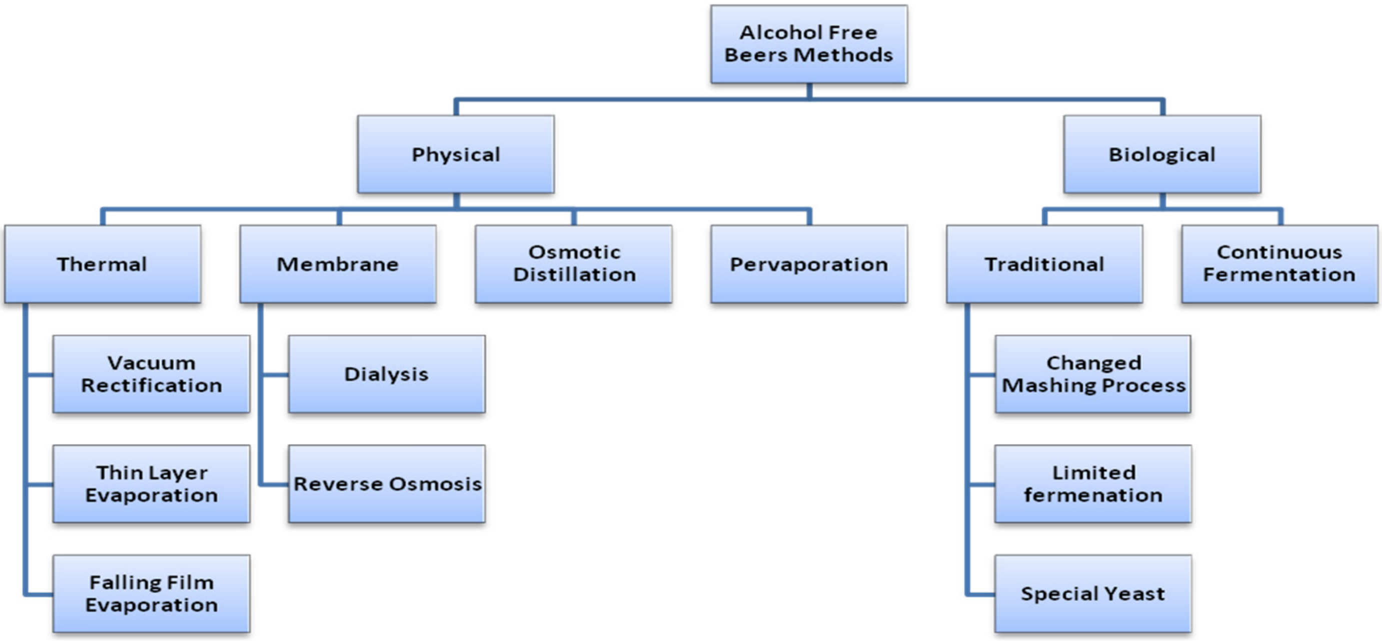
Brewing is a large-scale, complex process in which water, grains, and hops transform into beer, with the help of yeast. The wide variety of beer is primarily due to the various conditions (temperature, grain type, etc.) established during the various stages of production. Barley malt (processed barley) is responsible for the body of the beer. Malt can be partially replaced with starch-rich adjuncts like rice, corn, or wheat. Firstly, malt is milled and milling is usually 80% coarse but that also depends on the type of equipment used for brewing.

After that mashing is done where milled malt is mixed with brewing water, that is known as mash, then slurry of barley malt and brewing wateris heated at various temperatures (depending on the beer style and grains used) around 60°C where the malt enzymes, mainly amylases but also proteases acticates and that degrade starch and proteins respectively, leading to a mixture of sugars and peptides or amino acids. This starch-to-sugar conversion is stopped by applying heat. Then through Lautering mash is filtered and after filtration, the sugar solution is known as wort is transferred to the boiling kettle, where wort is boiled for 60-80mins with the addition of hops (*Humulus lupulus* L.). After cooling and removal of spent hops, hopped wort is transfeered to the fermentation vessels and yeast is added under aeration for growth. During the anaerobic phase yeast cells convert sugars to ethanol and carbon dioxide. Fermentation usually takes one week and then beers need a maturation or lagering period of several weeks at about 0°C, during which the unwanted components are slowly decomposed. Only after the content has decreased below critical values can beer be packaged. For prolonged conservation beers may be pasteurized. Special beers often require a slow (several months) second fermentation, usually in oak kegs, to generate sour flavours. [19].



Brewing Techniques for NBs and LBs

In recent decades, the methods for obtaining NB or LB have evolved rapidly in tandem with rising market demand, fueled by restrictive alcohol consumption policies in the EU and growing awareness of the benefits of moderate beer consumption. In general, NB or LB beer production processes can be divided into two categories: physical and biological processes.Thermal treatments or membrane separations can be used in physical processes.



A. Thermal treatments

Falling film evaporation, continuous vacuum rectification, and thin layer evaporation are post-fermentation techniques that use thermal treatments to remove all or part of the alcohol (ethanol) from the original beer.

a.Vacuum rectification

The steps in the technique are as follows: The filtered beer is pre-heated in a heat exchanger, the volatile compounds and CO2 are stripped in a vacuum degasser, and the alcohol is released from the beer at 42–48°C in a vacuum column, recovering the aroma components from CO2 by spraying them with dealcoholized beer or water and redirecting them into dealcoholized beer. This method can produce 4–200 hL of alcohol-free beer per hour with an ABV of less than 0.05 percent. Furthermore, the alcohol vapours obtained as a by-product can be used directly in the production of vinegar by acetification [8].

b. Thin layer evaporation

The centrifugal thin layer evaporator (Centritherm system) works in a vacuum at low temperatures (35–60°C) and pressures ranging from 60 to 200 mbar. The beverage is fed into the evaporator via a feed tube and injection nozzles, which distribute it to the hollow rotating cone's underside. The beer is instantly spread across the entire heating surface by centrifugal force in an extremely thin layer (approximately 0.1 mm). In less than a second, the beer travels across the heating surface. The de-alcoholized beer collects at the cones' outer edges before exiting the evaporator through a stationary product tube. The beer vapours rise through the cone's centre and into an exhaust pipe, where they are transferred to an external condenser. When a rectifying column is coupled to the evaporator, the Centritherm evaporators are designed with 1-12 hollow cones, which correspond to NB production capacities of 0.5 to 100 hL/h, respectively, allowing the production of beer with an alcohol content below 0.05 percent v/v [8]. The high energy costs of this process, as well as the use of an evaporator, are disadvantages.

c. Falling film evaporation

The beer is pre-boiled in an even thin film under vacuum conditions, then entered the heating tubes through a distribution device in the evaporator's head, flowed downward at boiling temperature using gravity and co-current vapour flow, and was partially evaporated. Per pass, the process takes only a few seconds. The alcohol-rich vapours are separated from the de-alcoholized beer concentrate by a vapour separator, which is then condensed in a condenser. This technology is widely available due to the evaporator's low maintenance requirements, as there are no moving parts and no wear, and its high efficiency. The heating steam supply and the evaporation temperature adjustable by the vacuum pump-control are the main process parameters controlling the dealcoholization degree in the falling film evaporator [13].

B. Membrane separation processes

Nanofiltration, reverse osmosis, osmotic distillation, dialysis, and pervaporation are all membrane separation processes. They have some competitive advantages over other physical NB production processes, such as mild operating temperatures, low energy consumption, little or no need for enhancing agents, and lower operating costs [14], but they still require additional equipment not found in standard industrial plants.

a. Dialysis

A semipermeable membrane separates beer and dialysate (aqueous solution) in the dialysis process in which flow is counter current and the exchange of substances occurring practically only through diffusion. The compound exchange degree is determined by the contact time and the concentration gradient across the membrane. Despite its resemblance to the RO, the dialysis method does not require a concentration stage, post-carbonation of the NBs, or a high-pressure pump, resulting in lower operational costs [15].

b.Reverse osmosis

When the transmembrane pressure substantially exceeds the osmotic pressure of beer, the reverse osmosis (RO) process allows ethanol and water to pass through the membrane selectively. The process is divided into three stages: the concentration phase, during which the permeate, which consists of alcohol, water, CO2, and aromatic substances, is removed from the beer, increasing the alcohol concentration to the desired level; the diafiltration phase, during which demineralized water quantitatively replaces the permeate previously removed; and the make-up phase, during which demineralized water refills the retentate to the initial volume of beer, lowering the alcohol content even further. Carbonation of the final product is required due to the removal of RO and CO2 during the process [13].

Large molecules, such as aromatic compounds, will mostly remain on the retentate side of the membrane, according to Catarino et al. [16], even when using low temperature and high pressure. According to research, reverse osmosis is not cost-effective for the production of beer with an alcohol content of less than 0.45%.

C. Osmotic distillation

When compared to RO or distillation, osmotic distillation is a beer dealcoholization process carried out at low pressure and temperature with little interaction between the membrane and the permeate and retentate, resulting in a method having high energy efficiency. The disadvantage of the process is that it loses the volatile CO2 compounds, necessitating additional investment in a recovery unit. Because the component with the highest partial pressure suffers the highest permeation rate of the membrane, the selectivity of the process is determined by the equilibrium between the liquid and vapour concentration in the system [17].

D. Pervaporation

At low temperatures, the pervaporation process uses selective semipermeable membranes to separate alcohol through diffusion in its gas phase. Alcohol molecules are displaced by the difference in chemical potential of the separated fluids and permeate the membrane in the direction of the highest alcoholic concentration to the lowest. Pervaporation technology can also be used to extract and concentrate volatile aroma compounds from beer by adjusting the temperature and suitability of the membrane constituent and then adding them to the final NBs. Other methods, such as nanofiltration, absorption on hydrophobic zeolites, supercritical CO2 extraction, and freeze concentration, have been studied, but without current technological advancements and craft beer NB appliances [11].

Biological processes

The biological methods of NB production based on limited alcohol formation can be classified based on the production equipment required, such as traditional brewery equipment (changed mashing process, arrested or limited fermentation process, cold contact process, and use of special yeast) or special equipment (use of special yeast) (continuous limited fermentation). Clearly, the technologies that are most exploited by beer crafters and large-scale industrials are those that do not require additional investments, as many strategies are used in combination, while the continuous immobilized cell process is a promising but niche technology.

Changed mashing process

The potential alcohol content in beer is determined by the fermentative potential of the wort, which is accounted for by fermentable sugars. By altering the mashing process, the profile of wort sugars can be altered, limiting the formation of alcohol even more. To make a low-alcohol beer, the wort fermentability must be around 25–30% [8].

Thus, strategies such as [1] inactivation of the-amylase enzyme, which is sensitive to a higher mashing temperature (>75_C); [2] cold water malt extraction to obtain wort with some fermentable sugars; [3] reducing the fermentable extract/unfermentable extract ratio by adding other grains such as maize or rice to barley; and [4] re-mashing of spent grains to produce a second extract with very small amount of fermentable sugars can be used to produce (a) Extrusion cooking of the spent grains prior to the second extraction and (b) acidic hydrolysis of spent grain to yield a secondary wort with a significant content of non-fermentable pentoses; [5] use of barley varieties with-amylase deficient with wide variations in b-amylase thermostability [11]. These processes will result in more nonfermentable sugar residue in the wort, which will result in an unpleasant sweetness in the NBs, a higher risk of microbial contamination, and a wort-like flavour. Mixed corrective measures are required for successful beer production, including vigorous wort boiling to reduce aldehyde levels, wort acidification, limited fermentation, and colour and bitterness adjustments.

Limited fermentation process

This is probably the most common method for making NB and LB. Arrested or limited fermentation processes aim to maintain a low ethanol content by removing yeast after a partial fermentation (stopped fermentation through filtration or centrifugation) or creating conditions that inhibit yeast activity (limited fermentation through rapid cooling to 0°C, pasteurization), while also limiting or disabling the wort-like flavour impression. These production methods use the same equipment as traditional breweries, but they necessitate precise and rapid analytical control. The disadvantages of these methods stem from the fact that a short fermentation time and insufficient wort-to-beer conversion may result in a final product lacking in aromatic compounds but with a strong wort flavor. According to studies, an initial gravity of 4.0 to 7.5 wt% is optimal for both arrested and limited fermentation processes, and brewing at a high gravity (20 wt%) enhances the formation of higher alcohols and esters. More sensorial corrections of volatiles can be achieved by: [1] fermenting at a higher temperature; [2] inhibiting wort oxygen content, which significantly increases ester formation by ale yeasts; or [3] adding flavourings (e.g., isoamyl acetate) to cover the "defects" [11].

Special yeast

This method of NB production is associated with two different approaches: one based on strain selection and the other on brewing yeast genetic modifications. Specific Saccharomyces and Saccharomycodes strains are uNBle to ferment maltose; however, the main sugars in the wort can be fermented, resulting in a lower ethanol content but a high residual extract content and a high proportion of glycerol and sugar alcohols. Because it requires oxygenation of beer to consume ethanol under aerobic conditions and has negative effects on flavour and colloidal stability, Zygosaccharomyces rouxii has limited application for NBs [11]. S. ludwigii produces better NBs than S. ludwigii, with sweet notes from the high residual maltose and maltotriose. It is unable to ferment the latter, like Saccharomyces cerevisiae, and produces liveliness and fullness in beer, as well as higher alcohol and ester formation, with barely perceptible off-flavor. Because the genetic approach is not widely accepted by consumers, craft brewers will not take the risk of implementing it in their breweries.

Continuous fermentation

Yeasts are attached to a carrier material, such as diethylaminoethyl cellulose (DEAE-C), calcium alginate, calcium pectate, or sintered glass, in this process. The carrier material and yeast are combined in a reactor, where the wort flows, resulting in higher biomass concentration and faster wort transformation. Although investment is required in immobilisation support, low temperatures (2–4°C) for limiting yeast growth and metabolism, and anaerobic conditions for preventing an oxidation phenomenon responsible for off flavour development, this process could generate advantages in a brewery, including lower capital, production, and manpower costs [8].

Different immobilisation technologies exist, according to Montanari et al. [13], but they are adapted to regular beers and are unlikely to be used in craft breweries due to the difficulty in controlling the process parameters (e.g., temperature, dissolved oxygen concentration) for producing NBs. Both alcoholic and non-alcoholic beers have residual fermentable sugars that are easily spoilt by bacteria. Good production hygiene is critical for beverage microbiological stability and safety, but craft brewers have a variety of physical and biological solutions at their disposal to ensure this [11].

Traditional non-thermal preservation techniques include high-pressure processing, hydrodynamic cavitation, ionising irradiation, pulsed high-voltage electric field, and ultraviolet irradiation treatments, as well as emerging non-thermal preservation techniques like high-pressure processing, hydrodynamic cavitation, ionising irradiation, pulsed high-voltage electric field, and ultraviolet irradiation treatments. Preservation with natural antimicrobials obtained from herbs, spices, and their derived essential oils and extracts, or bio-acidification of wort with selected microbes showing good antimicrobial properties, are two biological techniques commonly used to obtain more "natural" products [18].

Research studies

Senkarcinova et al. [20], studied the growth characteristics of probiotic yeast in the presence of wort sugars and ethanol and iso-α-bitter acids were quantified. On glucose (0.44 ± 0.03 1/h at 30 °C), there was highest specific growth rate (μ) of probiotic yeast observed while on maltose and maltotriose it was lowered by 34 and 89%, respectively. Ethanol (5% v/v) and iso-α-bitter acids (50 IBU) decreased μ on glucose (30 °C) by 20 and 23%, respectively. Affects of fermentation on the formation of esters and higher alcohols were identified by Response surface methodology.

Riu-Aumatel et al., [23] compared the volatile profile of low-alcohol and alcohol-free beers with alcoholic beers. Headspace solid-phase microextraction coupled to gas chromatography-mass spectrometry (HS-SPME–GC-MS) was used to analyze qualitative and quantitative differences. In alcoholic beers, fermentation compounds as esters (isoamyl acetate, ethyl hexanoate), alcohols (1-octanol, decanol, isobutanol, isoamyl alcohol) and fatty acids (hexanoic and octanoic acid) were observed in higher quantities. Whereas in low-alcohol beers, compounds like pyrazines and furanes, and volatile compounds such as linalool, β-humulene and α-terpineol were observed that are derived from malt and the essential oil of hops,respectively. Benzaldehyde, acetylpyrrole, furfural and 2-furanmethanol were also observed in free-alcohol beers.

Alcohol-free beers produced by limited fermentation often suffer from a lack of volatile compounds, this can be improved by yeast selection and optimization of fermentation conditions. Puerari et al., [21] demonstrated the yeast selection by comparing traditional lager yeast with selected *cachaça* yeast strains. Response surface methodology was used to enhance the formation of the flavour-active volatile compounds by optimization of the fermentation conditions (original wort extract, fermentation temperature, pitching rate).

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