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FOOD TECHNOLOGY

Production and characterization of craft beers with different additions of native fruits and agro-industrial residues: a review

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ABSTRACT: There is a growing demand for authentic products that provide sensory characteristics combined with health benefits that current studies have focused on. This review addressed the technological aspects involved in producing craft beers and the use of various fruits in developing new products with higher added value. The information was collected by researching scientific databases such as Scopus, websites, and the CAPES catalog of Theses and Dissertations. Thus, this study sought to obtain more information to promote discussion about the possibilities of adding various fruits in developing beers with a strong cultural appeal, high nutritional and marketing value, and that can also be categorized as a functional food.
Key words: development, beverages, regional fruits, innovation, process.

Produção e caracterização de cervejas artesanais com diferentes adições de frutas nativas e resíduos agroindustriais: uma revisão

RESUMO: Existe uma crescente demanda por produtos autênticos, que forneçam características sensoriais combinadas com benefícios para a saúde que tem sido o foco dos estudos atuais. Nesta revisão, são abordados os aspectos tecnológicos envolvidos com a produção de cervejas artesanais e o uso de frutas diversas, no desenvolvimento de novos produtos com maior valor agregado. Para coleta de informações foram realizadas pesquisas em bases de dados científicos da Scopus, em sites e no catálogo de Teses e Dissertações da Capes. Desta forma, este estudo buscou trazer informações para promover a discussão sobre as possibilidades que a adição de frutas diversas, principalmente nativas, podem oferecer no desenvolvimento de cervejas com forte apelo cultural, alto valor nutricional e mercadológico, podendo ainda ser categorizadas como um alimento funcional.
Palavras-chave: desenvolvimento, bebidas, frutos regionais, inovação, processo.

INTRODUCTION

In the world, 180,332523 tons of beer are produced per year, and the People's Republic of China is the largest beer producer in the world with 38,927200 tons of production per year. The United States of America comes in second with an annual production of 21460700 tons, while Brazil is the third largest beer producer with 14,137900 tons of production per year (KIRIN BEER UNIVERSITY REPORT, 2019).

Craft beers are among the most produced beverages in Brazil, and craft beer production has been seen as a great investment opportunity. The beer market grew 91% between 2014 and 2017, and 186 breweries were opened in 2017. In 2020, Brazil reached 1383 breweries registered with the Ministry of Agriculture, Livestock, and Supply (MAPA), a 14.4% increase compared to the previous year according to the Anuário da Cerveja 2020 (BRASIL, 2020). Craft beer has gained a prominent position in the beer market, given the emergence of various beer styles with new flavors, aromas, and modified brewing processes to satisfy consumers (SANNA & PRETTI, 2015). Enriching beer with fruits has been attracting the attention of researchers, as it not only adds new flavors but also increases the content of bioactive substances and oxidative stability (DUCRUET et al., 2017).

Native fruits have high nutritional value, characteristic flavor and aromas, bioactive compounds

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with antioxidant properties, and health appeal (REIS & SCHMIELE, 2019). These fruits have been used for centuries as food by traditional peoples, although the effects of their addition as raw material in developing new products have been little explored. What is more, there is a growing demand for authentic products that provide sensory characteristics combined with health benefits, which has been the focus of recent research (NUNES FILHO et al., 2021). These trends have forced the food industry to adapt to these novel market segments and seek new formulations and innovative food products linked to the conscious and sustainable destination of their waste.

Given this scenario, this review explored the primary publications related to craft beer production added with various fruits and suggest the addition of native fruits and agro-industrial residues to develop new products based on technical and nutritional characteristics.

METHODOLOGY

The survey of articles was based on the search for documents according to certain terms in scientific databases (Science Direct, Web of Science, Scopus, Scielo - Scientific Electronic Library Online, and the CAPES journal portal) and the CAPES Theses and Dissertations catalog. The most relevant studies were selected by refining the information according to the publications in the last decade (2011-2021) and the articles selected from the most significant number of researches based on the central theme of this study.

DISCUSSION

Definition, composition, and classification of beers in Brazil

Brazilian legislation defines beer as "[...] the beverage obtained by the alcoholic fermentation of the brewer's wort from barley malt and drinking water by the action of yeast and with the addition of hops." Part of the barley malt can be replaced by brewing adjuncts, whose use cannot exceed 45% regarding the primitive extract (wort extract). The beer can be called Pilsen, Export, Lager Dortmunder, München, Bock, Malzbier, Ale, Stout, Porter, Weissbier, Altbier, and internationally recognized denominations may be created and based on the characteristics of the original product (BRASIL, 2009).

Craft beer is basically composed of four main ingredients: water, malt, hops, and yeast. After fermentation, alcohol and CO_2 are formed. In some beer styles, other products with more complex aromas and flavors, most often with hints of fruit and spices, are formed as yeast by-products. We also have the aroma and flavors coming from the raw materials, mainly malt and hops.

Water is the main ingredient in craft beer production. Therefore, in general, water for craft beer production must be in accordance with Brazilian legislation (Ministry of Health Ordinance no. 2.914/2011) and not pose health risks (BRASIL, 2011). Depending on the style, the water needs to be adjusted for its mineral content, pH, or alkalinity, contributing desirable characteristics to the final product (Table 1).

Malt is the ingredient responsible for the body, that is, for most of the total solids present in the beverage. It imparts flavor, color, acts in the foaming of the product, and provides the enzymes necessary for breaking the large chains of polymers, with starches and proteins present in the ingredient itself and giving rise to the fermentable sugars and dextrins necessary for the fermentation process (MUXEL, 2016; AQUARONE et al., 2001). The proportion of malt in the beer also determines its classification, that is, it is considered pure malt beer that which has 100% of barley malt by weight, over the primitive extract, as a source of sugars. The others, called simply beer, must contain a proportion of at least 55% (BRASIL, 2019).

Hops (*Humulus lupulus* L.) are added during the boiling stage in the form of pellets or essences and are responsible for the bitter taste of beer. A small amount of hops is used in the brewing industry, usually 40-300 g of hops for every 100 L of beer produced (APRO LÚPULO, 2019). There are various types of hops with different characteristics; bitterness is the main characteristic; although, the hops added at the end of the boiling, in which there is no time for alpha-acid isomerization, giving the final product different aromas depending on what the producer seeks to incorporate into the product. In addition, hops have many essential oils such as linalool, which gives the product floral and woody aromas; and methyl decanoate, which gives the beer fruity aromas (MUXEL, 2016; AQUARONE et al., 2001).

Yeast is what defines the style of beer to be produced, and it contains the two yeast species most used in craft beer production: *Saccharomyces cerevisiae* and *Saccharomyces pastorianus*. Thus, the yeast strains were divided into two groups: those of top fermentation, which are used to produce ale beers, and those of bottom fermentation, used to produce lager beers. The lambic style is also produced from wild or endogenous yeasts present in the raw materials (LORIZZO et al., 2021; CAPECE

Table 1 - Comparison of beer water composition.

Analysis	Brewpub water	Pilsen water	Burton water	Pale ale water
Hardness, (ppm $CaCO_3$)	26	28	906	900
Alkalinity, (ppm $CaCO_3$)	40	23	236	230
Ca^{2+}, (ppm)	10	7	263	250
Mg^{2+}, (ppm)	1	3	62	60
$SO4^{2-}$, (ppm)	2	5	638	600
Cl^{-}, (ppm)	3	5	36	150

$CaCO_3$, Calcium Carbonate; Ca^{2+}, Calcium; Mg^{2+}, Magnesium; $SO4^{2-}$, Sulfate; Cl^{-}, Chloride; ppm, parts per million.
Fonte: Brewing Science and Practice, 2004.

et al., 2018). Yeasts that produce Ale-style beers work at higher temperatures, which gives the product more esters (more fruity beer), faster fermentation (greater cell reproduction), and greater formation of higher alcohols (alcoholic flavor). The yeasts that produce Lager-style beers work at lower fermentation temperatures: slower and riskier fermentation with less risk of overflow in the fermenter and less esters and higher alcohols produced (MUXEL, 2016).

According to Normative Instruction No. 65 of December 10, 2019, brewing adjuncts such as honey, plant-origin ingredients, and sources of starch and sugars suitable for human consumption may also be added. The amount added must be less than or equal to 25% of weight in relation to the primitive extract (BRASIL, 2019). As examples of adjuncts in craft beer production, we can mention the addition of fruits native to a given region; fruits that have a strong identity and characterize a biome, a people, or an entire region and/or state. These fruits can incorporate desirable flavors and aromas and bring innovations to the brewing market (e.g., other fruits) already tested and used in production and that provide flavor, aroma, and sugar (fructose); in general, berries such as cherry, blueberry, and raspberry are used.

Beers are classified according to Law no. 8,918 of July 14, 1994, which covers the standardization, classification, registration, inspection, production, and inspection of beverages. In general, beers are classified according to the type of fermentation, primitive extract, color, alcohol content, proportion of barley malt, and style (BRASIL, 2009).

Quality control in brewery products

In food science and technology, in order for a food or beverage to be approved or placed on the market, it is necessary to undergo a series of technical evaluations/validation in terms of its physical, chemical, microbiological, and sensory properties. For the physicochemical analyses of industrial and/or artisanal quality control in beers, the international methods of the European Brewers Convention (EBC) are applied, and the analytical tolerances are recognized by MAPA (BRASIL, 2019). In general, the main analyses required are: bitterness (Analytica EBC, section 9, method 9.8 – bitterness of beer IM); original beer extract determination (Analytica EBC, section 9, method 9.4 – original, real, and apparent extract and original gravity of beer); polyphenol analysis (Analytica EBC, section 9, method 9.11 – total polyphenols in beer by spectrophotometry); alcohol content analysis (% v/v); pH analysis (Analytica EBC, section 9, method 9.35 – pH of beer); vicinal diketones (Analytica EBC, section 9, method 9.24.1 – vicinal diketones in beer: spectrophotometric method); color analysis (Analytica EBC, section 9, method 9.6 – color of beer: spectrophotometric method); turbidity analysis (ASBC Methodology, Beer 27 – physical stability, method B nephelometric method); foam stability determination(Analytica EBC, section 9, method 9.42 – foam stability of beer using the NIBEM-T meter); and microbiological analysis (total bacteria count – aerobic and anaerobic bacteria and research for deteriorating bacteria) in accordance with the procedures of the EBC, ASBC, and MEBAK (ISO 17025) (BRASIL, 2019).

Characterization of native fruits for developing new products

The addition of native fruits, such as jatobá (*Hymenaea courbaril*), murici (*Byrsonima crassifolia*), mangaba (*Hancornia speciosa* Gomes), cumbaru (*Dipteryx alata* Vog.), cajá (*Spondias mombin* L.), cagaita (*Eugenia dysenterica*), and bocaiúva (*Acrocomia aculeata*) are interesting alternatives in developing products with a strong cultural appeal, high biological/nutritional value, and high added value. These fruits are present in almost all Brazilian biomes, but with great dissemination in the Cerrado, Amazon, and Pantanal biomes.

The mangaba is a small, greenish-yellow berry-type fruit. The shape of the fruit varies from ellipsoidal or rounded and has a diversified diameter between 2.5 and 6.0 cm. Its fruiting occurs between October to December, and nutritionally, the fruit has significant amounts of pro-vitamin A and vitamins B1, B2, and C and minerals such as iron, phosphorus, and calcium. The protein content is similar to most commercialized fruits (0.7 g/100 g of pulp) (REIS & SCHMIELE, 2019).

The cagaita is a spherical or flat oval fruit weighing 14-20 g on average. It has a light yellow color and a slightly acidic flavor. Its fruiting season is in September and October. The fruit is extremely aromatic and has a membranous, intensely shiny epicarp, and fleshy mesocarp and endocarp tissues. Moreover, this fruit has high dietary fiber, vitamin, and mineral concentrations, low energy value (~25 kcal in 100 g, on average), a high moisture content (95%), and considerable amounts of essential fatty acids, especially linoleic acid (n-6; ~10.5%) and linolenic acid (n-3; ~11.8%) (REIS & SCHMIELE, 2019).

The cajá fruit has several names depending on the region where it is found, including taperebá (in the Amazon) and cajazeira or cajá mirim (in southern Brazil). Its harvest varies by state and occurs between May and June in Paraíba State and from February to May in southeastern Bahia State, for example. It is a good source of vitamins (especially vitamin A) and is rich in fiber, phosphorus, iron, and calcium (CHITARRA & CHITARRA, 2005). The succulent pulp of the cajá is widely used to produce jellies, juices, ice creams, jams, liqueurs, and desserts; in fact, the yield in pulp production can reach 56% (REIS & SCHMIELE, 2019).

The murici is a small fruit (1.5-2.0 cm in diameter) of the drupe type, with a yellowish color, spherical shape, and slightly flattened. Its fruiting takes place at the end of September and may also be in mid-January to March, depending on the rainfall in the year (REIS & SCHMIEL, 2019). The rind has an astringent taste due to the presence of tannins, and the pulp is fleshy and juicy. The edible portion of the fruit has 79.46% moisture content, 1.78% lipids, 0.82% proteins, 2.02% crude fiber, 0.69% ash, and 15.23% carbohydrates (MONTEIRO et al., 2015).

The baru (or cumbaru) is a drupe-type legume with an oval and slightly flattened shape, a brown color, a smooth and shiny external integument, and has only one edible almond. Fruiting occurs between July and November (MELO et al., 2014). The fruit has elevated levels of fatty acids, mainly oleic acid (n-9) and linoleic acid (n-6), followed by palmitic acid. The almond is rich in lipids (40%), with high quantities of unsaturated fats and importance for human consumption because it reduces LDL cholesterol levels, in addition to having significant levels of α-tocopherol and γ-tocopherol (5 and 4.3% respectively), which have antioxidant action (REIS & SCHMIELE, 2019; OLIVEIRA et al., 2017).

The jatobá is found in the Amazon, the Atlantic Forest, the Pantanal, and the Cerrado biomes, occurring from Piauí to Paraná States. The fruit is ripe between July and September has a hard shell and an average of two seeds per fruit. Inside, the pulp is a yellowish-green powder with a strong odor, which is edible (CERRATINGA, 2021). In its proximate composition, jatobá-do-cerrado and jatobá-da-mata in g/100 g on a dry basis have on average: 7.60 ± 0.22 and 8.37 ± 0.12 g/100 g, lipids of 3, 03 ± 0.05 and 2.92 ± 0.11 g/100 g, ash of 4.60 ± 0.06 and 5.48 ± 0.07, soluble dietary fiber of 11.01 ± 0.50 and 9.81 ± 0.58 g/100 g, insoluble dietary fiber of 42.86 ± 0.27 and 45.79 ± 0.61 g/100 g and carbohydrates of 18.54 ± 0.55 and 20.18 ± 0.46 g/100 g, respectively (SILVA et al., 2001). The genus *Hymenaea* is recognized as a source of phenolic compounds, and research has suggested that its antioxidant activity is related to polyphenol and flavonoid presence (MIRANDA et al., 2014).

Lastly, the bocaiuva (*Acrocomia aculeata*) occurs in almost the entire Brazilian territory; although, with high density in the Cerrado regions in Mato Grosso do Sul (including the Pantanal biome), Mato Grosso, Goiás, and Minas Gerais States (URBANETZ et al., 2016). Bocaiuva fruiting occurs from September to December. The fruits are small (2.5-5.0 cm), round, and arranged in clusters of about 200 units. When ripe, the fruit drops naturally. At that moment, bocaiuva fruits present a thin and brittle rind that protects the orange pulp, which is soft and fibrous; it is also possible to consume the almond inside the fruit. Despite being small, the fruit is large from a nutritional point of view, and the fruit pulp contains an average of 51.4% moisture content, 1.96% proteins, 16.91% lipids, 10.70% sugars, and 19.03% fibers. The almond contains 15.60% moisture content, 13.97% proteins 48.82% lipids, 9.25% sugars, and 12.34% fibers (TACO, 2017). Another interesting feature of the fruit is related to the bioactive compounds and antioxidant potential, suggesting the use of the fruit in enriching and developing functional foods (DUCRUET et al., 2017).

Craft beers with different additions of fruit and agro-industrial residues

The growing demand for authentic products that provide sensory characteristics and health benefits has been the objective of recent research (NUNES FILHO et al., 2021). Beers added with fruits and/or spices have been extensively explored in recent years. The search for different flavors and aromas, health-related issues, a general desire for a healthier lifestyle, and the objective of bringing something new in relation to the original recipe has led to the emergence of various interesting studies and publications in the area of technology and craft beer production (HABSCHIED et al., 2020).

These beer styles were once categorized as “special beers,” or catch-all for beer styles, which do not fit into the conventional beer categories. Five types of specialty beers are of particular interest: low-calorie beer, low-alcohol or non-alcoholic beer, innovative flavor beer, gluten-free beer, and functional beer (HUI & SHAO-QUAN, 2014). Another interesting factor is the possibility of inserting bioactive compounds such as polyphenols (Table 2), which are phytochemicals present in high levels in different types of fruits, which may be an exciting alternative to develop high biological value products (LIU et al., 2018).

Next, we will discuss the production of craft beers added with different fruits in Brazil and the world based on the studies found. GASIŃSKI et al. (2020) added mango pulp (*Mangifera indica*) in the brewing technology and evaluated the changes that occurred in the volatile and sensory composition of the product. Beers with the addition of mango were characterized by higher polyphenol content, antioxidant activity, and volatile component concentration than the control beer. They were also rated as having better flavor and aroma than beer without the addition of fruits. Beers added with different fruits have a technological differential; although, it is not enough to simply add fruit or any other adjunct without first knowing the characteristics of the added raw material. Even fruits from the same region and the same harvest can provide significant technological differences due to several factors, such as climate, storage, transport, the point of harvest, among others.

BAIGTS-ALLENDE et al. (2021) compared the polyphenolic and amino acid profiles in commercial fruit beers and observed a variation in the total content of free amino acids and the concentrations of nineteen quantified polyphenols, with catechin and epicatechin being the most abundant compounds with variations also in the pigment content. Additionally, the authors noted that these differences are related to the beer style and the type and amount of fruit added. The lambic-style beer was the only one that showed similar trends in the principal component analysis (PCA) performed. This style uses wild yeasts, which are present in the inputs themselves; thus, there was probably a good adaptation of the yeasts regarding the conditions of the added fruit must.

CASTRO MARIN et al. (2021) focused on the chromatic, volatile, phenolic, and sensorial characterization of Italian grape ale beers obtained with the addition of grape must at different concentrations and confirmed that the addition of cv. ‘Lambrusco’ grape must enriched the beers in color, acids, phenolic compounds (up to 7 times more), and volatile compounds, adding complexity to the beers; a trained sensory panel also confirmed these results. The addition of fruit enriches and gives desirable characteristics; although, this addition must be tested safely to meet the standards of quality control and identity of brewery products (BRASIL, 2019). Several grape varieties can raise the sensory and nutritional level of brewers and; consequently, bring better characteristics to the final product. There is a trend of incursions in the brewing universe, ranging from maturation in barrels with a residual beverage to blends, which mix beer and wine, creating innovative products.

Star fruit (*Averrhoa carambola*) has been used to improve the nutritional value of craft beers. The beers were added with different fruit juice concentrations (5.0, 7.0, and 10%) and compared with the control. Results showed that the addition of star fruit juice had an insignificant effect ($P \leq 0.05$) on density, while total soluble solids increased and pH, alcohol, and carbon dioxide content decreased; a significant increase ($P \leq 0.05$) in total phenolic content and antioxidant activity was also observed. Overall, beer fortified with 10% star fruit had the highest general acceptance. The authors concluded that star fruit is a valuable fortification compound for brewing beer with high nutritional value and enhanced sensory characteristics (PAL et al., 2021).

Table 2 - The concentration of total polyphenols in beers added with fruit.

Type of beer	Main compounds Identified	Total polyphenol concentration	References
Beer + mango α-pineno, β-mirceno, terpinoleno, α-terpineol, cis-β-ocimeno, cariofileno e humuleno.	267.6 mg GAE[b]/L	GASIŃSKI et al. (2020)	
Beer + plum	Total phenolics	220.43 mg GAE/L	FANARI et al. (2020)
Beer + cherry	catechin and epicatechin	298 mg GAE/L BAIGTS - ALLENDE et al. (2021)	
Beer + persimmon	Total phenolics	714.11 mg GAE/L	CHO et al. (2018)
Beer + cherry + orange + grape + plum + raspberry + peach + damascus + apple	Myricetin; resveratrol; catechin; quercetin; chlorogenic acid; neochlorogenic acid; coumaric acid; and caffeic acid.	399 - 767 mg GAE/L	NARDINI & GARAGUSO (2020)
Beer + grape	Caftaric acid; t-coutaric acid; t- fertaric acid; dihydro-po-coumaric acid	353.69 mg GAE/L	CASTRO et al. (2021)
Beer + quince	Hydroxycinnamic acid; neochlorogenic acid; chlorogenic acid; 3,5-dicaffeoylquinic acid; 3-O -coumaroylquinic acid; 5- O -coumaroylquinic acid.	3.5 mg GAE/L	ZAPATA et al. (2019)
Beer + rice + fruit by-products	Total phenolics and flavonoids.	278.82 mg GAE/L	SRIWICHAI et al. (2021)
Beer + star fruit	Total phenolics	3. 292 mg GAE/L	PAL et al. (2021)
Beer + orange juice + lemon juice + raspberry juice + cranberry juice	Total phenolics	220.43 mg ferulic acid/L	PATRASCU et al. (2018)
Beer + omija fruit	Total phenolics and flavonoids.	606.82 mg GAE/L	DENG et al. (2020)

[a]Summary of the maximum results obtained in the studies; [b]GAE - gallic acid equivalents.

Some varieties of star fruit have strong acidity and relatively high sugar content, which would explain the observed effects on pH, Brix, and dissolved CO_2 content. Analysis of the must and characterization of the fruit would help to better explain these effects.

DENG et al. (2020) produced ale beer with high antioxidant capacity and desirable sensory characteristics from omija (*Schisandra chinensis*) fruits added at different times of the brewing process. They observed that phenolic compound concentrations were dependent on the time of omija addition and that the addition of this fruit at the beginning of the boiling conferred greater oxidative stability to the beer and resulted in higher phenolic and total flavonoid levels. The authors concluded that the addition of fruit in the artisanal brewing process improved the development of value-added beer products. The moment of fruit addition can be divided into four stages: mashing and boiling (hot stages) and fermentation and maturation (cold stages). Defining the moment of adjunct addition is crucial for the stability and insertion of the compounds to be incorporated into the final product. The advantage is more significant anthocyanin extraction and sterilization of the added adjunct during the hot stages. However, phenolic compounds of interest can be lost by the action of temperature. The time of addition depends on the researcher's planning and the objective to be achieved; there is no rule.

The effects of adding fruit puree (fresh and sterile cherry and plum puree) sterilized with ohmic treatment during the fermentation step to produce fruit craft beer were verified by FANARI et al. (2020). The authors demonstrated that an ohmic-treated fruit puree is a good option toseasonalize fruit beer production, maintain a qualitative sensory profile, and avoid the risk of spoilage. Due to the presence of alcohol and heat treatments performed during the brewing process, beer is considered a stable product. Nonetheless, researchers are concerned about finding ways to treat the adjuncts to be incorporated with greater safety and greater extraction of the compounds of interest. Thus, techniques such as "ohmic treatment" are considered "green" techniques and have been gaining notable scientific visibility as they are techniques that do not use chemical products in the treatment of samples.

Beer is a product rich in bioactive compounds due to the raw materials added (hops, malt, and adjuncts). Nevertheless, most of these compounds are lost due to the addition of adjuncts during the production process. Hence, it would be interesting to always add the fruits and other non-malted adjuncts during the cold stages of beer production (fermentation or maturation) in order to enrich the beverage with compounds of interest. In this sense, NARDINI & GARAGUSO (2020) analyzed the content of total polyphenols and flavonoids, phenolic profile, and antioxidant activity of ten fruity beers (cherry, raspberry, peach, apricot, grape, plum, orange, and apple), added during the fermentation process. Results showed that cherry beers had the highest values, followed by grape, plum, and orange beers with the highest values of antioxidant activity, total polyphenols, and flavonoid content. The authors concluded that the addition of fruit during the fermentation process considerably increased the beer's antioxidant activity and qualitatively and quantitatively improved its phenolic profile.

ZAPATA et al. (2019) added quince (*Cydonia oblonga Miller*) to improve beers' functional and sensory profile and reported that the addition of quince increased the content of total polyphenols, total hydroxycinnamic acids, the concentration of the main volatile compounds related to fruity sensory descriptors, and led to higher intensities of floral and fruity sensory attributes. The authors concluded that the quince beer presented better functional composition and sensory characteristics than the control beer. The aroma of a beer can result from the contribution of numerous compounds, each with its peculiarities; they can impart aromas of fruit, butter, rancid, spices, citrus, among others. According to BENETOLI (2019), depending on their concentration, they can be desirable or not; determining them and controlling their production can be the difference between a spectacular beer and an unpalatable one.

The addition of persimmon (*Diospyros kaki*) was performed by CHO et al. (2018), who analyzed the changes in antioxidant activity and beer quality characteristics. The total polyphenol content of the persimmon treated beer was significantly high ($P < 0.05$) compared to the control, with an increase in magnesium, potassium, and calcium composition. The general acceptance value was significantly high ($P < 0.05$), and the addition of 150 g of the fruit in 10 L of water was recommended by the authors, based on the nutritional, organoleptic, and antioxidant potentials presented in the beer. Persimmon used as an adjunct to produce craft beers reveals the significant exploratory potential related to craft beer production and the universe of possibilities in creating new recipes.

MASSAMI et al. (2018) produced a beer added with dehydrated jabuticaba (*Myrciaria cauliflora Berg*) and analyzed the physicochemical and sensory characteristics. The addition of dehydrated jabuticaba to beer (boiling, fermentation, and maturation) increased carbon dioxide, total acidity, alcohol content, original extract, and apparent extract. The tasters preferred the beer's appearance from the treatment (boiling). For aroma, flavor, and general evaluation, beers from all treatments were equally preferred. A good option for adding adjuncts can be dehydrated adjuncts due to the way they are obtained. They are microbiologically stable products and can be added more safely during the cold stages of craft beer production. In the cold stages, there is greater anthocyanin extraction, which explains the greater acceptance of color by the tasters. In this same stage, a higher phenolic compound concentration can also be observed, which in most cases directly influences the aroma and flavor of the beverage.

PATRASCU et al. (2018) evaluated different brands of beers added with fruit, namely eight beers with lemon juice, two beers with orange juice, two beers with raspberry juice, and one with cranberry juice. The authors reported that all commercial beers investigated showed good antioxidant performance and phenolic content. The sensory analysis results and the physicochemical and rheological properties indicated the good quality of the fruit beers available on the Romanian market.

Seeking to bring a new product to the market for commercial purposes, PINTO et al. (2015) developed a craft beer with acerola and pineapple and associated the increase of its functional characteristics. The authors demonstrated that using pineapple and acerola pulps as adjuncts in beer processing could be a viable alternative due to the satisfactory results in the sensory evaluation and the physicochemical characteristics of an acidic/fruity craft beer.

The effects of the clarification and filtration processes were observed in craft beers added with pitanga pulp through physicochemical characterization. The filtered beer remained close to the results of the standard beer mainly in relation to pH and presented better results in the reduction of suspended solids, thus reducing the turbidity of the beverage. The authors recommended that, in future studies, it is necessary to carry out a sensory analysis to assess the acceptance of the product (LIMA et al., 2021).

As for the addition of agro-industrial residues, SRIWICHAI et al. (2021) evaluated the physicochemical, nutritional, and sensory properties of beer produced with rice and fruit derivatives in five different formulations in the proportion of 80:20 in relation to dry malt extract:dry malt extract, rice husk powder, riceberry powder, banana peel, and coffee pulp. The results showed that the beers differed positively in all parameters analyzed, making it clear that by-products or agro-industrial by-products can be used as adjuncts in the production of beer to give flavor, color, and or a special aroma to a beer. It can also determine a style and/or promote the culture and production of a given region through craft beer production. This technique can also be an important alternative in reusing waste instead of discarding it in the environment (CUNHA et al., 2021).

Other studies used fruits, seeds, fruit juices and byproducts, and fruit extracts are often used for making special beer assortments with various flavor, taste, and aroma (SALANTA et al., 2020; RICCI et al., 2019; ADAMENKO et al., 2020; DORDEVIC, et al., 2016; BELSCAK-CVITANOVIC et al., 2017; ADENUGA et al., 2010); and lastly, CUNHA et al. (2021) developed American blond ale with fruity aromas (murici, cupuaçu, and cajá), and evaluated some quality parameters, such as density and alcohol content and ºBrix. The authors also assessed untrained consumers' acceptance of flavor and aroma attributes, and their findings revealed that the beers added with fruit had higher physicochemical parameters and scores concerning the attributes analyzed. The authors concluded that craft beer production using native fruits is an excellent opportunity to develop unique products in the market with strong cultural appeal and high nutritional value (Figure 1).

Figure 1. Process of artisanal production of beers added with native fruits.

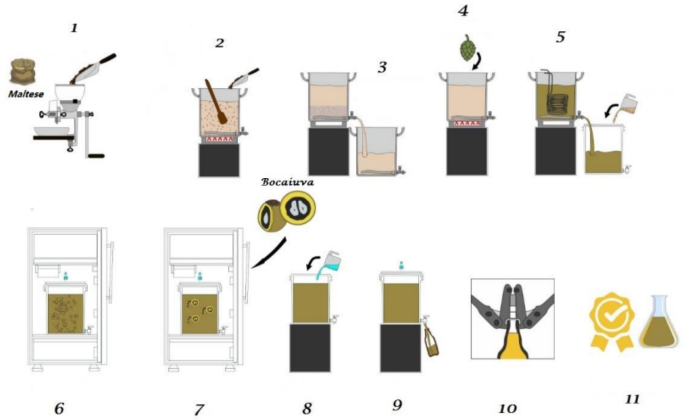

Figure 1 - Craft beer production process with added native fruits.

Legend: 1, Grind the grains; 2, Brewing; 3, Grain filtration an washing; 4, Boil; 5, Cooling and Yeast; 6, Fermentation; 7, Maturation; 8, Priming; 9, Bottling; 10 Fixing the covers; 11, Quality control.

CONCLUSION

According to our findings, beers added with various fruits can be considered more than just beverages as different physical, chemical, sensory, and nutritional parameters categorize them as functional foods due to incorporating bioactive compounds of interest for the maintenance of the organism. Moreover, we observed that the moment of fruit addition, as a brewing adjunct, during the production process (masking, boiling, fermentation, or maturation) is crucial and presents important and varied results for each objective, which is the main factor to be considered. The economic aspect can also be considered because producing beer is an excellent source of income given the low initial investment that the activity requires. Finally, the universe of research related to craft beer production added with various fruits is still little explored despite growing. Based on the reading of the manuscripts, there is a plethora of research possibilities to be explored, including the addition of native fruits such as bocaiuva (*Acrocomia aculeata*) and raising the level of discussions regarding craft beer development. With the addition of native fruits in beer production, products with a strong cultural appeal, high biological/nutritional value, and high added value can emerge.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interest to declare for carrying out this study.

AUTHORS' CONTRIBUTIONS

The main author acted in the conception and writing of the manuscript and the other authors critically reviewed the manuscript and approved the final version.

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