16

Cachaça and Rum

A.B.P. Medeiros*, M.E. de Matos, A. de Pinho Monteiro,
J.C. de Carvalho, C.R. Soccol

FEDERAL UNIVERSITY OF PARANA, CURITIBA, BRAZIL

16.1 Cachaça

Cachaça is the typical and exclusive denomination of a sugarcane spirit produced in Brazil, with alcohol content between 38% and 48% (v/v) at 20°C, obtained from the distillation of fermented sugarcane juice [1].

Brazilian sugarcane spirits are very appreciated for their characteristic aroma and flavor that can still be improved by aging in wooden casks. The Brazilian Ministry of Agriculture, Livestock, and Supply (MAPA) published a normative instruction, which reiterates the definition of cachaça and sugarcane spirits and set new ratings for the aged product [2]. A legal distinction between cachaça and sugarcane spirit is primarily in the must that originates the beverage. Cachaça should be exclusively produced from fermented sugarcane juice must.

Normative Instruction 13/2005 sets forth the standards of identity and quality of the sugarcane spirit and cachaça, specifically mentioning the following: alcohol content and total sugars, volatile acidity in acetic acid, higher alcohols (expressed as the sum of *n*-propyl alcohol, isobutyl alcohol, and isoamyl alcohol), furfural, hydroxymethylfurfural, aldehydes, and total esters in ethyl acetate (Table 16.1). The coefficient of congeners includes the sum of volatile acidity, esters, aldehydes, furfural, hydroxymethylfurfural, and higher alcohols. The standards also require control over contaminants such as ethyl carbamate, acrolein, sec-butyl alcohol, *n*-butyl alcohol, lead, arsenic, copper, and methanol [2]. These established standards with their respective limits are intended to moderate the influence of each of these components in protecting public health and the quality of the beverage; it does not mean, therefore, that the spirits that comply with these standards should be considered a product with higher sensory quality. Brazilian legislation allows the addition of sugar in cachaça up to 6 g/L of sucrose. After this limit, the label of the product must describe a sweetened beverage.

*Corresponding Author.

Current Developments in Biotechnology and Bioengineering: Food and Beverages Industry
http://dx.doi.org/10.1016/B978-0-444-63666-9.00016-9

Table 16.1 Maximum Limits of Compounds and Contaminants Established by Brazilian Law for Sugarcane Spirit and Cachaça

Compound	Limit (mg/100 mL of Anhydrous Alcohol)
Volatile acidity	150
Esters, in ethyl acetate	200
Aldehydes, in acetaldehyde	30
Furfural and hydroxymethylfurfural	5
Total higher alcohols: Isoamyl, isobutyl, and 1-propanol	360
Coefficient of congeners	200–650
Methanol	25
Copper[a]	0.5
Ethyl carbamate [a]	0.015
Acrolein	5
Sec-butyl alcohol	10
n-Butyl alcohol	3

[a]Expressed as mg/100 mL of beverage.

Adapted from BRASIL, Ministério da Agricultura, Pecuária e Abastecimento, 2005. Instrução Normativa n. 13, de 29 de junho de 2005. Diário Oficial da União. Brasilia, 30 junho de 2005; A.R. Alcarde, Cachaça: Ciência, Tecnologia e Arte. Ed. Edgard Blücher Ltda. São Paulo, 2014, 96 p.

16.1.1 History

The history of cachaça is intertwined with the history of Brazil. It was the first distilled spirit in Latin America, discovered between the years of 1534 and 1549, from the cane sugar production process in the mills in São Vicente, São Paulo. The broth “forgotten” in pots of fermented molasses from one day to the next originated the spirits.

The name “cachaça” may have originated from the term “cagaça,” as the lees of residual sugarcane juice from sugar production was called. Parallel to the production of sugar, the drink production was enhanced and highlighted economically and socially at that time in colonial Brazil. Cachaça was seen as a threat to Portuguese interests, because “bagaceira”—a wine spirit of Portuguese origin—started to be consumed on a smaller scale. It became a factor and symbol of the Brazilian people’s resistance against Portuguese domination, culminating in the independence of Brazil [3].

Currently, about 1.7 billion liters of cachaça are produced in Brazil, of which approximately 75% is produced by industrial manufacturing and 25% by artisanal manufacturers [4]. The distinction between the beverage produced industrially and artisanal cachaça is basically in the form of distillation, being industrially obtained from continuous distillation in stainless column or, in the case of artisanal cachaça, copper alembic. Other procedures differentiate artisanal cachaça from industrial cachaça in terms of its sensory and chemical characteristics. Artisanal cachaças are produced in small distilleries, which are usually family-run businesses [5].

Cachaça is the fourth highest produced beverage among the local spirits categories in the world, behind baijiu, vodka, and soju [3]. There are over 40,000 producers of cachaça

(4000 brand names). The Brazilian states with the highest production of cachaça are São Paulo (44%), Pernambuco (12%), Ceará (12%), Minas Gerais (8%), and Paraíba (8%) [6,7]. The state of Minas Gerais is notable for its large production of artisanal or stilled cachaças. In Brazil, it is estimated that around 70% of cachaça is consumed as a pure beverage, but it can be consumed as cocktails like “caipirinha” [8].

16.1.2 Sugarcane

To obtain a high-quality cachaça, care begins at the planting of sugarcane, from the selection of seedlings; fertilization and soil choice can interfere with the desired characteristics of the product produced.

The sugarcane (*Saccharum* spp.) is a perennial grass with a cylindrical stem that reaches about 3 m high and consists of 75% water and 25% organic matter. The stem is responsible for storage of the sucrose; the extraction of sugarcane juice is primarily used for the production of sugar from cane [8]. Typical of tropical climates, sugarcane in Brazil is cultivated from October to March in the southeast and from June to November in the northeast, being an available product practically all year [9]. The chemical composition of sugarcane culms is showed in Table 16.2.

For the cultivation of sugarcane it is ideal to have a hot and rainy season, followed by a cooler and drier one. Under high rainfall and luminosity levels, as well as high temperatures, the budding, tillering, and plant growth are stimulated. In dry soil times and low temperatures, there is a certain physiological rest and, consequently, the accumulation of sucrose in the stem, thereby achieving ripening. It is important to know the behavior of each variety as to sucrose accumulation through the maturity curve. With this information, one can set the initial and final terms of the quality of the raw material to be processed.

Table 16.2 Chemical Composition of Sugarcane Culms

Component	Concentration (g/100 g)
Water	65–75
Sugar	12–18
Sucrose	11–18
Glucose	0.2–1.0
Fructose	0–0.6
Fibers	7.0–17.0
Cellulose	5.0–6.5
Hemicellulose	1.8–2.3
Lignin	1.5–2.5
Nitrogen compounds	0.3–0.6
Lipids (waxes and fats)	0.15–0.25
Organic acids	0.1–0.15
Pectic substances and gums	1.5–0.25
Ash	0.3–0.8

Adapted from V.V. Toledo, C.V. Gancho, Verdes Canaviais. third ed., São Paulo, Moderna (Ed.), 1996 80 p.

16.1.3 Production Process

The production process of cachaça starts with grinding the sugarcane, separating the juice from the bagasse. This broth is sieved, decanted to remove fine solids, and, if necessary, diluted to adjust the soluble solids content (°Brix). In this step, the sugarcane juice is now called must and will be fermented by the action of yeasts. The fermented must or wine is then distilled and separated into three fractions: tail, head, and heart. This last fraction will result in the cachaça, which will be later stored or aged in wooden barrels (Fig. 16.1).

16.1.3.1 Sugarcane Reception and Grinding

It is recommended to discharge and wash the harvested cane on a suspended table, properly fitted with ropes or chains to facilitate discharge; this basic hygiene procedure is one of the requirements to prevent contamination and degradation due to contact with the ground. The maximum time between receiving and grinding should be 24 h to avoid the loss of cane quality owing to deterioration and formation of higher alcohols.

To obtain a juice rich in sugars and to separate the solid fraction, sugarcane culms are processed in mill-type cylindrical compressors. The efficiency of the milling is measured as the amount of extracted sucrose per amount of processed sugarcane per unit of time [10]. A large amount of sugar produced in the field is lost through the various operating phases until the final product. The low performance of the extraction set contributes to the high losses. The extraction conditions should be improved, because the amount of alcohol produced is directly related to the amount of extracted sugarcane juice.

16.1.3.2 Preparation of Must

It is essential that the sugarcane juice pass through a fine mesh sieve. The construction material should be stainless steel because it is inert to the composition of the juice and the design should facilitate cleaning and sanitizing. After this filtering, the juice is sent to a settling tank where impurities like earth and fine residues are separated. In the settling tank, total soluble solids are adjusted to 14–16°Brix. Above 16°Brix is necessary to dilute the sugarcane juice for the smooth progress of the fermentation process. Undiluted fermentation will be incomplete, be slower, and have formation of undesired compounds in the final product [11].

16.1.3.3 Alcoholic Fermentation

Fermentation is the critical point in the cachaça manufacturing process. Important aroma compounds that characterize the beverage are formed at this stage.

The process is initially characterized by the propagation phase of the yeast cells in the presence of oxygen followed by alcoholic fermentation, particularly where there is the formation of ethanol. In this step, other by-products such as carbon dioxide and other metabolites (glycerol, aldehydes, esters, and organic acids) are also coproduced, as well as materials for biomass production and products for yeast survival and adaptation to the environment.

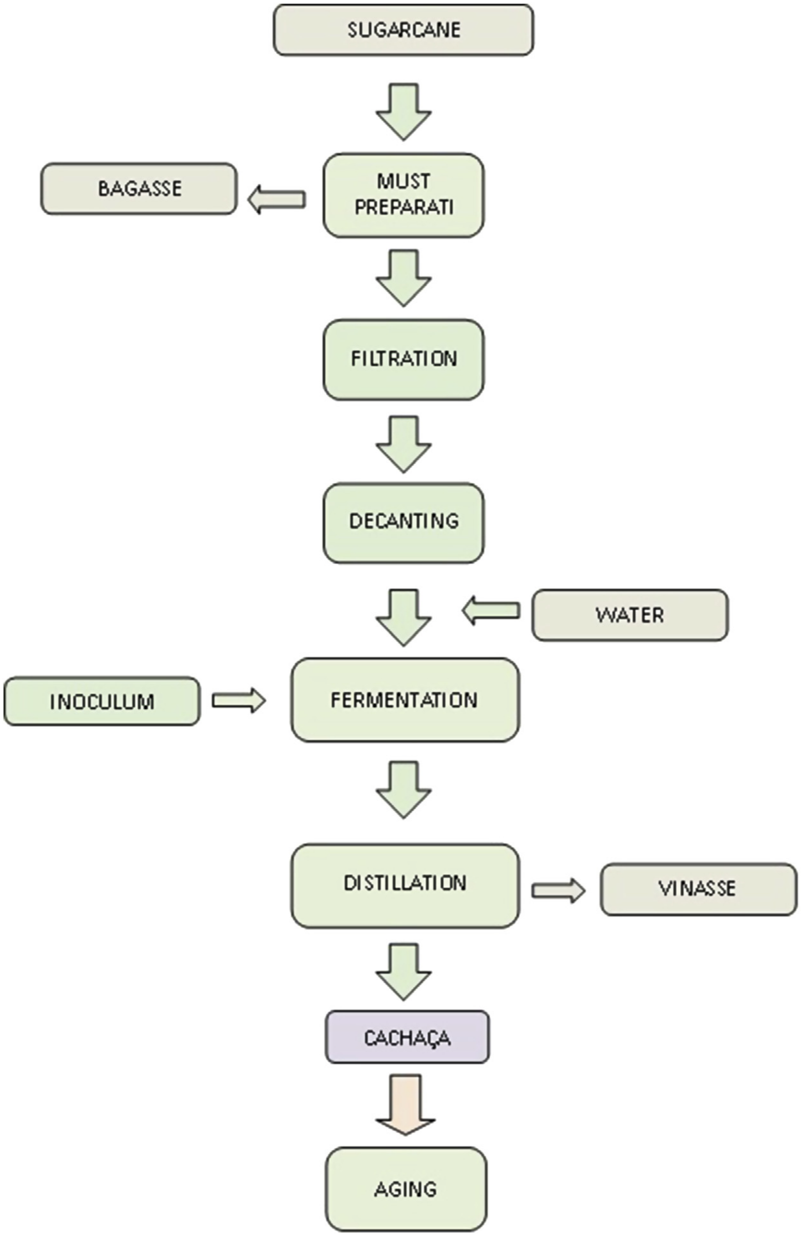

FIGURE 16.1 Flowchart of the cachaça production process.

Among a group of more than 250 compounds, the "bouquet" of the beverage is given by the so-called congeners [12]. The presence of congeners in balanced proportions differentiates cachaça from a fermented hydroalcoholic mixture.

The fermentation system used by most small stills occurs in simple batch or fed-batch, to avoid osmotic stress to the yeast cells.

The fermentation begins with the introduction of the inoculum on the substrate. In this phase, the incubation is under optimal growth conditions. In the fermentation process, nothing is added to the system, except oxygen necessary in the initial phase for the formation of the microbial biomass. Antifoam and acidic or basic solutions for pH adjustment must be added if required. There is a correlation between the acidity of the wine and the yeast growth rate. It is considered that the growth of the yeast is good in the pH range between 5.0 and 6.0, and for the production of ethanol, the optimum pH is 4.5. The sugarcane juice has a pH of 5.5 [9]. Acidification is required prior to inoculation to promote fermentation and prevent growth of contaminating bacteria. The optimum temperature is controlled between 28 and 32°C. In the case of a fed-batch system, the addition of nutrients or substrate is progressive in small concentrations throughout the fermentation. The production of spirits in large scale is done in a continuous fermentation system. The sterile nutrient solution is continuously fed with an equivalent amount of a mixture of fermented substrate, nutrients, and microbes out of the bioreactor. Higher yields are obtained and there are fewer operational problems. The fermentation ends when carbon dioxide is reduced significantly and the cells are allowed to settle at the bottom of the tank. Fermentation occurs for around 24 h. Large producers may use cell recycle centrifuging of the fermented must [3].

16.1.4 Inoculum

The cachaça can be produced with native yeast (homemade yeast), that is, it uses yeasts naturally present in the environment. Small producers prepare the inoculum from a paste composed of rice bran, cornmeal, cracker, lemon juice, or sour orange [7]. The addition of diluted sugarcane juice in 24-h intervals is performed. The process is repeated until the inoculum is equivalent to 20% of the volume of the must to be fermented in the vat. Although it is a common practice, it has the inconveniences of the presence of contaminating microorganisms and a long period required to achieve the desired volume.

The use of selected yeast strains avoids fluctuations in the quality of the beverage and contributes to a faster process startup. Compared to spontaneous fermentation, there is a lower risk of contamination, a rapid and uniform rate of fermentation, a lower competition for essential nutrients, a higher yield, and a lower level of residual sugars [13]. Generally, *Saccharomyces cerevisiae* strains are isolated and selected from fermentation processes. Regarding producing yeast alcohol, different strains of *S. cerevisiae* can be found in higher abundance in fermentations for the production of cachaça. These yeasts are characterized by high alcohol yield and tolerance to high concentrations of ethanol [14,15]. In addition, yeast selection involves morphological and physiological aspects to be considered, such as quick and complete fermentation of the sugarcane juice; low requirement of vitamins, fatty acids, and oxygen; relative resistance to low pH; flocculation characteristics; production of the “killer” factor; tolerance to high osmotic pressure; the production of aroma components (organic acids, esters); and the nonproduction of acetic acid.

Preparation of the inoculum with selected yeasts starts with the propagation of cells from a pure laboratory culture. Initially, the strain is preinoculated in small volumes of sugarcane juice at 5°Brix, enriched, and sterile. The volume of inoculum is increased to 400 mL at 7°Brix, until it reaches 10% of the volume of the vat. These stages should be well controlled to remain aseptic and sanitary.

According to Schawn et al. [16], the microbiota of traditional sugarcane fermentation processes is complex. A variety of yeasts can be found, such as *S. cerevisiae*, *Kluyveromyces marxianus*, *Pichia heimii*, *Pichia subpelliculosa*, *Debaryomyces hansenii*, and *Hanseniaspora uvarum*. Among the bacteria, lactic and acetic acid bacteria and several bacteria belonging to the Enterobacteriaceae family are also present during the fermentation. The community of bacteria in the cachaça fermentation process includes lactic acid bacteria as the main group found during fermentation. The species *Lactococcus lactis*, *Lactobacillus plantarum*, and *Lactobacillus fermentum* were abundantly identified. *Lactococcus lactis* was frequently found in sugarcane fermentations as a contaminant during cachaça and other alcoholic fermentation [17].

This complex mixture of yeast and bacteria species produces metabolites and volatile compounds that contribute to the unique characteristics of the taste and odor of artisanal cachaça [18].

The influence of non-*Saccharomyces* yeasts on the final quality of alcoholic beverages has been investigated, including wine [19] and mezcal [20]. *Kluyveromyces marxianus* and *S. cerevisiae* were compared in the agave fermentation process for tequila production. A better organoleptic quality of tequila was observed when *K. marxianus* was used as biocatalyzer [21]. *Dekkera bruxellensis* can produce aroma compounds and easily adapts to fermentation conditions; thus, it is a yeast strain with potential industrial application in the production of cachaça. Its capacity to produce fusel alcohols was derived from aromatic and branched-chain amino acids [22].

The interactions of *S. cerevisiae* and non-*Saccharomyces* species on beverage quality have also been studied. *Lactococcus lactis* and *S. cerevisiae* in coculture were evaluated by Carvalho et al. [17] during sugarcane fermentation for cachaça production and led to an increase in the acidity of the beverage. The use of bacteria did not affect the yeast activity and improved the cachaça aroma. In the sensory analysis the attributes appearance, aroma, taste, and overall quality were evaluated. The aroma acceptance was higher than 80%.

16.1.5 Distillation

All substances of interest formed during the fermentation process need to be separated; for this reason, distillation is considered extremely important to obtain a cachaça with the highest quality. Cachaça is distilled in pot stills or in continuous columns. However, the beverage obtained by still distillation has a better chemical composition and higher congener content than those coming from continuous distillation [3]. Distillation columns are used by medium and large producers. A large number of plates allows greater control over the amount of congeners in the distillate and also higher alcohol yield.

Initially the columns were used only for the production of fuel ethanol. They had to undergo several adaptations for the production of cachaça because the distillate was obtained with high alcohol content, but was poor in secondary components. The first stills were created by the Arabs in the middle of the 7th century and they introduced the technique to Europe to obtain drinks with higher alcohol content. The name "spirit" comes from the nomenclature associated with alchemy, which was extracted by distilling the essence, the soul, the spirit of the fruit or herb that composed the must [10]. Cachaça has been traditionally distilled in copper stills, which gives a better quality beverage than those produced with other types of materials such as stainless steel. Copper has the ability to catalyze certain chemical reactions in the distillation process, which involve volatile components of the wine, contributing to the elimination of unpleasant smells during the distillation [23]. The wine distilled in stainless steel stills may contain higher concentrations of sulfur compounds from the fermentation. However, copper can move into the beverage by the drag of metal via alcoholic vapors, stimulated by the acidity of the distillate, and thus contaminate the final product. Therefore, copper is present in the distilled liquid originating from the still when there is oxidation of metallic copper on the inner wall of the still.

Wine containing from 7% to 12% (v/v) ethanol is subjected to temperatures between 92.6 and 95.9°C. The separation of the fractions occurs based on the boiling point of substances. The first fraction is separated under a boiling point higher than ethanol, methanol, aldehydes (acetaldehyde), and esters (methyl and ethyl acetate). This fraction, called the head, has an alcohol content below 60 GL and corresponds to 1–5% of the initial volume of wine. The fraction of interest for the final product corresponds to the fraction obtained at the intermediate boiling point. The heart fraction has 60–40 GL and 80% of the volume of wine. The tail is the fraction with 38–14 GL, with about 15% of the volume of wine. The head and tail fractions must be separated as they present compounds that depreciate the quality of the beverage (Fig. 16.2).

16.1.5.1 Double Distillation

According to Bruno [24] the bidistillation of cachaça was introduced in Brazil in 1991, aiming to reduce the ethyl carbamate content in cachaça and spirits from sugarcane fermentation. The bidistillation process of cachaça is applicable to distillation in copper stills and aims to improve and standardize the quality of the beverage. Two successive distilled fractions are obtained (Fig. 16.3). At first, the distillate obtained from wine is collected without separation of fractions. This distillate is called phlegm and contains about 21% ethanol. In the second distillation, three fractions are separated: head, heart (65% ethanol), and tail.

16.1.6 Storage and Aging

The storage or "rest" of cachaça should take place in an inert container (stainless steel or glass), which does not confer odor and flavor to the beverage and does not allow

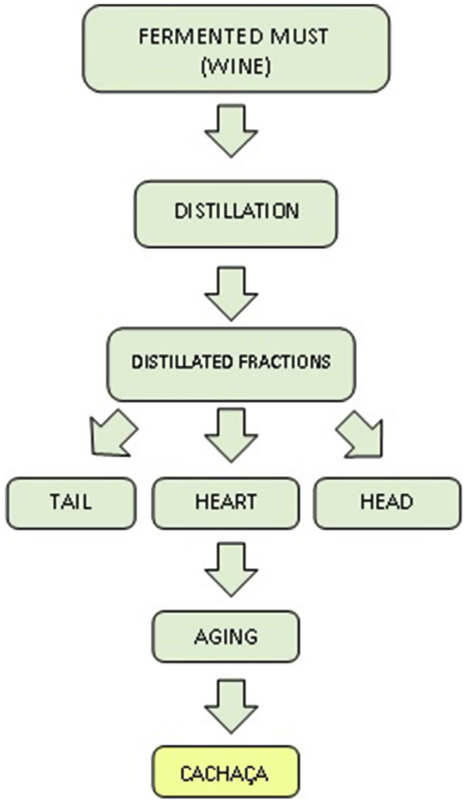

FIGURE 16.2 Flowchart of the distillation process of cachaça.

FIGURE 16.3 Schematic diagram of double-distilled cachaça.

contamination. In contrast, aging aims to improve the sensory aspect and assign characteristics that add value.

Aging consists of storing the cachaça in wooden casks with a maximum capacity of 700 L for a certain time. This complex process produces changes in the chemical composition, aroma, flavor, and color of the beverage [25]. Several chemical reactions are associated with aging and maturation of cachaça and depend on several factors, including the type of wood used and the maturation time course of the initial distillate quality. The cask volume is also important and influences the relation of wood to liquid. Reactions are based on the decomposition of macromolecules of wood (lignin, cellulose, and hemicellulose) and they are added to the beverage in addition to the extraction of secondary wood compounds. Furthermore, numerous compounds are formed during reactions between the compounds of the wood with the original components of the distillate and between the secondary compounds of the distillation that may also be incorporated into the beverage [26]. Brazilian legislation classifies cachaça into three types: aged cachaça, premium cachaça, and extra premium cachaça. The difference among types is related to the time of storage and shelf life. Aged and premium cachaça have an aging period of at least 1 year. Aged cachaça may have up to 50% nonaged cachaça using a blend process. Premium cachaça has 100% aged cachaça. Extra premium cachaça has a minimum aging period of 3 years and cannot contain nonaged cachaça [1].

Although the most traditional wood used in Brazil to age alcoholic beverages is oak, other woods are often employed to age cachaça, especially balm and native Brazilian woods [27]. Each type of wood gives peculiar compounds to the beverage. However, some woods only increase the acidity of the cachaça and do not interfere with its color or taste. Detailed knowledge of the chemical and sensory composition of cachaça, as well as the maturation time, constitute important factors in controlling beverage quality and evaluation of changes that may contribute to the improvement of production processes. This knowledge can contribute to the production process especially for small producers and artisan industries.

The use of various native woods in the construction of casks for aging cachaça has contributed to the characterization and improvement of the quality of cachaça as a genuine Brazilian product. Native woods such as cabreúva or bálsamo (balm), jequitibá, amburana, ipe, aribibá, pau-brasil, and more than 20 different species are cataloged [28].

The influence of various types of Brazilian wood on the profile of volatile compounds of aged sugarcane spirits was investigated by Bortoletto and Alcarde [26]. Ten different wooden casks were constructed, namely, amendoim (*Pterogyne nitens*), araruva (*Centrolobium tomentosum*), cabreúva (*Myrocarpus frondosus*), cerejeira (*Amburana cearensis*), grápia (*Apuleia leiocarpa*), ipê roxo (*Tabebuia heptaphylla*), jequitibá (*Cariniana estrellensis*), jequitibá rosa (*Cariniana legalis*), oak (*Quercus sessilis*), and pereira (*Platycyamus regnellii*). Among these types of Brazilian woods, jequitibá rosa showed high potential for aging because of the contents of the vanillic acid and vanillin in the aged cachaça. Because of the congeners found in the aged spirit, the authors also found cerejeira, grápia, and cabreúva as potential woods for the maturation process.

The aging time gives some sensory aspects easily identified in the beverage. There is a decrease in pH and the concentrations of methanol and ethanol, whereas there is an increase in color and the concentrations of ethyl acetate, acetaldehyde, acetone, and phenolic compounds [29]. A young cachaça presents transparent as any spirit. After a few months of storage it acquires a vanilla tone. With 1–2 years, its odor is typically characteristic of the wood used and a more pronounced tone. In 3 years of aging in wood casks, the smell of the cachaça becomes harmonious. It is no longer easy to distinguish the contributions of fermentation or wood, owing to the association between the components of these steps [3].

16.2 Rum

Rum is a distilled spirit made from sugarcane and born in the Caribbean, acquiring great historic and gastronomic value due to its character. Produced by many nations of Spanish, French, English, and Dutch origin, it presents a unique flavor and aroma that made it known for its versatility when used in cocktails, counting many different recipes with rum in their composition. Rum production accounts for the fourth position in the spirits market (Table 16.3).

16.2.1 History

Even though sugarcane has been cultivated for more than 2000 years and has Asiatic origins, rum is the first spirit from sugarcane to present historical relevancy. With the introduction of sugarcane cuttings by Cristopher Columbus in the island of Hispaniola (Dominican Republic), the first crops of sugarcane were grown in the Caribbean [30].

The colonization of other islands by the French, Dutch, and English for the sugar industry made this spirit one of the symbols of the Caribbean.

With the growing business of the sugar industry in the West Indies colonies a spirit made from sugarcane would soon appear. The first report belongs to the Portuguese, who produced sugar, molasses, and some kind of spirit from the juice of sugarcane in regions of Pernambuco and Bahia in Brazil [31].

Molasses is a by-product of the refining of sugar and needed to be dissolved in water to be fermented in order to be distilled in low-technology pot stills to produce what would become known as rum today.

The first samples of rum had a low quality and did not have the same prestige as they have today. Many slave masters offered this spirit to their slaves to make them more "easygoing" for an easier handling. Rum was so consumed as well by the poorest section of the population and pirates [30].

Rum has some of its fame due to pirates who consumed this spirit in the 17th and 18th centuries. Rum was not only consumed by them, but also used as a trade currency for commodities of that time, like cotton, tobacco, gunpowder, guns, and even slaves [31].

Table 16.3 Global Growth of Individual Spirits Chart

Spirit/Quantity[a]	Year 2000	Year 2010
Rum	101,757	142,291
Vodka	395,668	495,218
Shochu/soju	189,184	236,440
Scotch whisky	74,233	84,330
Cane	131,903	115,451

[a]Values in millions of 9-L cases.

Adapted from F.P. Pacult, The Rum Authority. Available at: http://www.therumauthority.com/wp-content/uploads/2015/04/TheRumAuthorityManual.pdf, (accessed May 2015).

The origin of the word rum is not very clear, explained by many different stories; but there are two versions that are widely accepted. The first would be that it derives from the word "saccharum," which means sugar in Latin, and the second one comes from a report from the island of Barbados of a "rumbullion" spirit, know as well as a kill-devil, for the bad quality of the spirit. The word would be abbreviated and become "rum" [30,31].

16.2.2 Definition

Rum (rhum in French or ron in Spanish) is defined by the WIRPA (West Indies Rum & Spirits Producers Association, Inc.) as any spirit made from fermentable sugar from sugarcane with a maximum alcohol content of 96% v/v. It can be made entirely from molasses, sugarcane syrup, or sugarcane juice. It is a common practice for French-based cultures to use only the sugarcane juice; this rum is known as agricole, and corresponds to only 3% of the worldwide production, whereas the rum made from molasses corresponds to 97% [31].

Rum made from sugarcane juice presents an earthy, grassy, and sometimes mineral flavor, whereas that from molasses can have some floral and spicy notes balanced with hints of sweetness [32].

Bottled rum should have at least 35.4% v/v alcohol; rum may have some spices and caramel additions, in addition to the blending for building the desired character of the spirit. For lower alcohol concentrations the spirit should called "aguardiente" [31].

16.2.3 Legislation

Rum, rhum, or ron has different legislation for each producer country, so it can vary a lot, but in general rum is accepted as an spirit with an alcohol content of at least 35.4% at 20°C, made from molasses or sugarcane juice, fermented and then distilled. It can be aged in wood casks or in tanks with the addition of wood chips [1].

The addition of sugar is accepted until at most 6 g/L; the use of caramel for coloration and activated charcoal for decoloration is accepted for color correction.

The congeners (fermentation by-products) cannot be below 40 mg/L or over 500 mg/L in anhydrous alcohol [1].

Rum can be classified according to BRASIL [1] into:

Light rum: Congeners concentration below 200 mg/L in alcohol
Heavy rum: Congeners concentration between 200 and 500 mg/L and made exclusively from molasses
Aged rum: Any kind of rum that has been aged for a period of at least 2 years

16.2.4 Production

Rum production follows the same basic steps as many other distilled spirits, i.e., fermentation, distillation, and wood aging. Some details about must preparation, fermentation, and aging will differ a bit from other spirits but follow the same principles (Fig. 16.4).

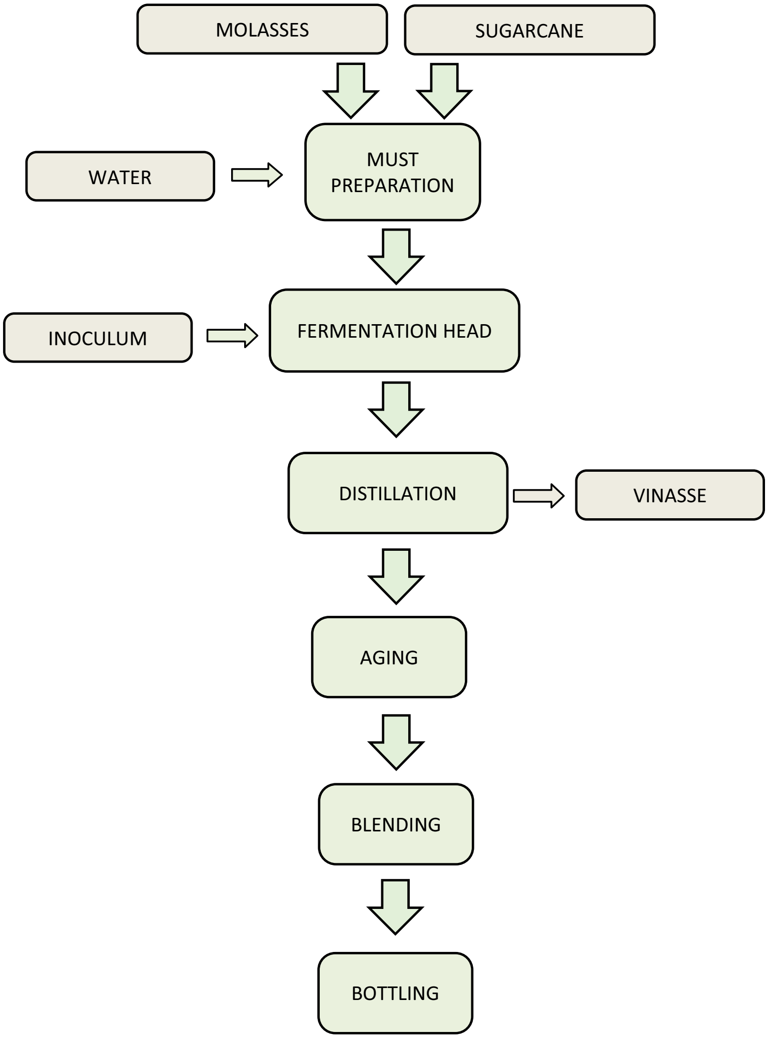

FIGURE 16.4 Flowchart for rum production.

16.2.4.1 Must Preparation

The must used for the fermentation can be made with the dissolution of molasses in water, the fresh juice extracted from sugarcane, or a mixture of both. Most rums are made of molasses, a by-product of the sugar industry, which is very viscous and dark in coloration. Some exceptions, like rhum agricole, are made exclusively out of sugarcane juice, a tradition among French-based cultures.

The sweet must has an average sugar concentration of 17–24°Brix and pH level range of 4.8–5.0 and can have some nutrients like salts added to the mix. The must can be pasteurized before inoculation for a better microbiological stability, limiting the growth of bacteria that could spoil the fermentation or produce off-flavors [31,32].

Molasses contains 55% fermentable sugars in its composition, of which approximately 35% is sucrose and 20% is a mix of glucose and fructose. Easy storage and low prices make it a great raw material [32].

One of the first process in the sugar refining process is pressing the sugarcane to obtain a sweet juice. The juice is hazy, with a yellowish color and very sweet taste, with a sugar content ranging from 10% to 15% w/v. The juice has a low microbiological stability and can be fermented quickly by airborne bacteria and yeast, so storing the juice is not a common practice [32].

16.2.4.2 Fermentation

The aim of fermentation for the production of rum is to have a high sugar conversion rate to ethanol and congeners, which are by-products that impart flavor and aroma to the spirit, like organic acids, aldehydes, esters, and alcohols. All compounds should be in balance to obtain high-quality rum.

Fermentation generally takes 20–26 h for light rums, whereas the spontaneous process can last 2–4 days or even 1–3 weeks for heavier rums. The optimal temperature range for most yeast strains is 31–32°C; however, the cost of a temperature control system makes this unfeasible, so the fermentation occurs at room temperature. Some tropical yeast strains present a high alcohol yield at temperatures of 34–36°C; there are even reports on strains with high alcohol production at temperatures as high as 40°C [30,33,34].

The fermented must has an alcohol concentration varying from 5% to 10% according to the yeast strain, sugar concentration, temperature, and fermentation time.

When fermentation ends, it is a common practice to let the fermented must sit for periods of 6–12 h to decant the solids and dead yeast cells for a better distillation [30].

In general, fermentation takes place in a batch process because of the flexibility it offers, allowing one to obtain rum with different characteristics using the same equipment.

Rum can be classified according to two types of fermentation (Table 16.4):

- Light rum

  The fermented must is known for a low content of congeners and high ethanol production. Generally, using *Saccharomyces* strains achieves a higher yield of ethanol production and high productivity [33].

- Heavy rum

  Fermentation is characterized by high amounts of sugar, producing a fermented must that contains a high concentration of congeners and lower ethanol content owing to the fermentation conditions. Most fermentations are done with *Schizosaccharomyces* strains or sometimes happen by spontaneous fermentation or inducing bacterial inoculation. The symbiotic fermentation of bacteria and yeasts produces many congeners desired for the rum character [34].

In many English culture-based islands there is the addition of a liquid called "dunder" to the fermenting must. Dunder is a by-product of distillation; it is the fraction that

Table 16.4 Volatile Compounds Content, Must Fermentation, and Microbial Flora of Various Rums

	Light-Flavor Rum	Heavy-Flavor Rum	Industrial Rhum	Rhum Agricole
Raw material	Molasses	Molasses	Molasses	Sugarcane juice
Volatile compounds[a]	>225	>800 (esters >500)	>225	>225
Fermentation	Pure	Mixed	Mixed	Mixed
Microbial flora	*Saccharomyces*	Bacteria, *Schizosaccharomyces*	Bacteria, *Saccharomyces*	Bacteria, *Saccharomyces*

[a]Values in g/hL of pure alcohol.

Adapted from L. Fahrasmane, B. Ganou-Parfait, Microbial flora of rum fermentation media, Journal of Applied Microbiology 84 (1998) 921–928.

remains in the pot still and is composed of sugars, dead yeast cells, and solids dissolved in water. This solution is fermented by inoculation of wild bacteria before it can be added to another fermentation. The fermented dunder increases the congener production and fermentation velocity through bacterial action [30,31,33,34].

16.2.4.3 Distillation

For years rum fermentation was carried out in a very rustic way and most of the spirits made in copper or wooden pot stills. At least a double distillation is needed for a spirit to acquire the desired quality and a concentration of approximately 76% v/v ethanol [30].

Industrially continuous columns distillation is done to ensure a better control of the process and a better spirit. It is possible to achieve an alcohol content of 95% v/v through this kind of distillation and it corresponds to a huge slice of the rum made in the world, whereas the batch pot-still distillation is attributed to smaller craft producers [31].

16.2.4.4 Aging

After distillation, the spirit is aged in wood casks, generally American oak used for bourbon or Tennessee whiskey production, although there are some French islands where they prefer casks used for cognac for maturation [30].

Most casks are charred before the addition of the spirit to produce different flavor notes through cellulose and lignin degradation by the heat, in addition to the reduction of off-flavors by the active char layer formed [26,35].

Owing to the porous nature of the wood, many different compounds are extracted and it permits the evaporation of the spirit over time [36].

Tropical temperatures are responsible for a quick maturation of the rum compared to a whisky aged in Scotland or Ireland. The evaporation rates in the tropics can be as high as 10–12% per year, whereas in cold climates like Scotland the rate is only 2–4% per year [30].

Oxidative reactions, condensations, esterifications, and the extraction of aromatic aldehydes, tannins, and lignin-related substances will give the aged rum character and color [26,30,35].

16.2.4.5 Blending

The possibility of producing different quality rums offers to the distillery the use of blending to obtain a certain flavor or quality. For example, a 3-year-old aged heavy-flavor rum can be mixed with a light-flavored rum to produce a drink that meets the organoleptic standards of a desired brand [37,38].

Some rum can be treated with the addition of sugar, spices, and caramel for the desired color and flavor [30−32].

16.3 Conclusions and Perspectives

Although cachaça and rum have many similarities with respect to raw material, process, and origins, slight modifications in the overall process can produce great differences in organoleptic properties, flavor and aroma, function of the congeners, and the type of wood used, as well as how wood is used, charred barrels or wood chips in the maturation tank, for example.

Quality control and assurance are the biggest issues that small producers face and have to work with to provide a better product and avoid great variability in flavor in the final product. Most small producers work with low tech equipment and have little technical knowledge of all the factors that influence the process for a better product, such as sugarcane cultivation, fermentation control, distillation, and maturation.

The market for both products has a steady growth with no major fluctuations. While rum is a product already well established worldwide, the exportation of high-quality aged cachaça is beginning to be significant. Cachaça has become recognized for its quality and fine flavor characteristics and not only as a simple sugarcane spirit used for the preparation of "caipirinha."

References

[1] BRASIL, Decreto n. 6.871, de 4 de Junho de 2009. Regulamenta a Lei nº 8.918, de 14 de julho de 1994, que dispõe sobre a padronização, a classificação, o registro, a inspeção, a produção e a fiscalização de bebidas, 2009.

[2] BRASIL, Ministério da Agricultura, Pecuária e Abastecimento, 2005. Instrução Normativa n. 13, de 29 de junho de 2005, Diário Oficial da União, Brasilia, 30 junho de 2005.

[3] A.R. Alcarde, Cachaça: Ciência, Tecnologia e Arte. Ed., Edgard Blücher Ltda, São Paulo, 2014, 96 p.

[4] M. Capobiango, E.S. Oliveira, Z.L. Cardeal, Evaluation of methods used for the analysis of volatile organic compounds of sugarcane (cachaça) and fruit spirits, Food Analytical Methods 6 (2013) 978−988.

[5] C.R. Oliveira, H.A.A. Maia Garíglio, M.S.P. Alvarenga, M.M. Ribeiro, Cachaça de Alambique - Manual de Boas Práticas Ambientais e de Produção, SEMAD/FEAM, Belo Horizonte, 2005.

[6] IBRAC, Instituto Brasileiro da Cachaça. Available at: http://www.ibraccachacas.org/, 2008 (accessed June 2015).

[7] EMBRAPA H.R. Sakai. Available at: http://www.agencia.cnptia.embrapa.br/gestor/cana-de-acucar/arvore/CONT000fioglob502wyiv80z4s473agi63ul.html, 2010 (accessed June 2015).

[8] J.R. Miranda, História da cana-de-açucar, Campinas, Ed. Komedi, 2008, 167 p.

[9] V.V. Toledo, C.V. Gancho, Verdes Canaviais, third ed., Ed. Moderna, São Paulo, 1996, 80 p.

[10] W.G. Venturi Filho, Tecnologia de bebidas: matéria-prima, processamento, BPF/APPCC, legislação e mercado, Edgard Blucher, São Paulo, 2005, 550 p.

[11] C.R. Peixoto, R.G. Rosa, C.N. Silva, B.T. Santos, T.L. Engelmann, Miniprojeto para ensino de química geral experimental baseado na fermentação do caldo de cana-de-açucar, Química Nova 35 (2012) 1686–1691.

[12] E.A. Nonato, F. Carazza, C.R. Carvalho, Z.L. Cardeal, A headspace solid-phase microextraction method for the determination of some secondary compounds of Brazilian sugarcane spirits by gas chromatography, Journal of Agriculture Food Chemistry 49 (2001) 3533–3539.

[13] C.R. Campos, C.F. Silva, D.R. Dias, L.C. Basso, H.V. Amorin, R.F. Schwan, Features of *Saccharomyces cerevisiae* as a culture starter for the production of distilled sugarcane beverage cachaça in Brazil, Journal of Applied Microbiology 108 (2010) 1871–1879.

[14] P.B. Morais, C.A. Rosa, V.R. Linardi, Characterization and succession of yeast populations associated with spontaneous fermentations during the production of Brazilian sugar cane aguardente, World Journal of Microbiology and Biotechnology 13 (1997) 241–243.

[15] P.H.A. Silva, J.O. Santos, L.D. Araújo, F.C. Faria, A.F. Pereira, V.A. Oliveira, M.A. Vicente, R.L. Brandão, Chromatographic evaluation of volatile compounds in Brazilian sugar cane spirits produced with yeasts from different locations, Food Science and Technology 29 (2009).

[16] R.F. Schawn, A.T. Mendonça, J.J. Santos Junior, V. Rodrigues, A.E. Wheals, Microbiology and physiology of cachaça (aguardente) fermentations, Antonie Van Leeuwenhoek 79 (2001) 89–96.

[17] F.P. Carvalho, W.F. Duarte, D.R. Dias, R.H. Piccoli, R.F. Schwan, Interaction of *Saccharomyces cerevisiae* and *Lactococcus lactis* in the fermentation and quality of artisanal cachaça, Acta Scientiarium 37 (2015) 51–60.

[18] W.F. Duarte, J.C. Amorim, R.F. Schwan, The effects of co-culturing non-*Saccharomyces* yeasts with *S. cerevisiae* on the sugar cane spirit (cachaça) fermentation process, Antonie van Leeuwenhoek 103 (2013) 175–194.

[19] F. Viana, S. Genovés, S. Vallés, P. Manzanares, Rational selection of non-*Saccharomyces* wine yeast for mixed starters based on ester formation and enological traits, Food Microbiology 25 (2008) 778–785.

[20] G. Hernández-Carbajal, O.M. Rutiaga-Quiñones, A. Pérez-Silva, G. Saucedo-Castañeda, A. Medeiros, C.R. Soccol, N.O. Soto-Cruz, Screening of native yeast from *Agave duranguensis* fermentation for isoamyl acetate production, Brazilian Archives of Biology and Technology 56 (2013) 357–363.

[21] A.L. Alvarez, A.L.D. Pérez, C.S. Aguirre, L.M. Rodríguez, J.C. García, Ethanol yield and volatile compound content in fermentation of agave must by *Kluyveromyces marxianus* UMPe-1 comparing with *Saccharomyces cerevisiae* baker's yeast used in tequila production, Journal of Bioscience and Bioengineering 113 (2012) 614–618.

[22] D.C. Parente, E.E. Vidal, F.C.B. Leite, W.B. Pita, M.A. Morais Jr., Production of sensory compounds by means of the yeast *Dekkera bruxelensis* in different nitrogen sources with the prospect of producing cachaça, Yeast 32 (2015) 77–87.

[23] R.F. Nascimento, D.R. Cardoso, B.S. Lima Neto, D.W. Franco, Influencia do material do alambique na composição química das aguardentes de cana-de-açucar, Química Nova 21 (1998) 735–739.

[24] S.N.F. Bruno, Distillation of Brazilian sugar cane spirits (cachaças), in: Dr. S. Zereshki (Ed.), Distillation - Advances from Modeling to Applications, InTech. Available at: http://www.intechopen.com/books/distillation-advances-from-modeling-to-applications/-cacha-adistillation-systems-, 2012.

[25] F.W.B. Aquino, S. Rodrigues, R.F. Nascimento, A.R.S. Casimiro, Simultaneous determination of aging markers in sugarcane spirits, Food Chemistry 98 (2006) 569–574.

[26] A.M. Bortoletto, A.R. Alcarde, Congeners in sugar cane spirits aged in casks of different woods, Food Chemistry 139 (2013) 695–701.

[27] J.B. Faria, D.W. Franco, J.R. Piggott, The quality challenge: cachaça for export in the 21st century, in: Distilled Spirits: Tradition and Innovation, Nottingham University Press, Nottingham, UK, 2004.

[28] F. Jannuzzi, Expedição Mapa da cachaça - As madeiras para envelhecer cachaça. Available at: http://www.mapadacachaca.com.br/artigos/expedicao-mapa-da-cachaca-madeiras/, 2013 (accessed June 2015).

[29] W.D. Isique, H.M.A.B. Cardello, J.B. Faria, The aging effect on sulfur contents of "Cachaças" samples distilled in copper and stainless steel alembics, Alimentos e Nutriçao 12 (2001) 33–44.

[30] F.P. Pacult, The Rum Authority. Available at: http://www.therumauthority.com/wp-content/uploads/2015/04/TheRumAuthorityManual.pdf, (accessed May 2015).

[31] R. Harris, D.H. West, Carobbean rum: its manufacture and quality, in: M.A. Godshall, CaMA (Eds.), Chemistry and Processing of Sugarbeet and Sugarcane, Elsevier Science Publishers, Amsterdam, 1988, pp. 313–339.

[32] J.E. Murtagh, Feedstocks, fermentation and distillation for production of heavy and light rums, in: The Alcohol Textbook: A Reference for the Beverages, Fuel and Industrial Alcohol Industries, Elsevier Science B.V., Amsterdam, 2003, pp. 243–255.

[33] G.H. Fleet, V. Green, The microbiology and biotechnology of rum production, in: G.M. Walkers, P.S. Hughes (Eds.), Worldwide Distilled Spirits Conference, New Horizons: Energy, Environment and Enlightenment, Nottingham University Press, Nottingham, 2010, pp. 87–94.

[34] L. Fahrasmane, B. Ganou-Parfait, Microbial flora of rum fermentation media, Journal of Applied Microbiology 84 (1998) 921–928.

[35] J.R. Mosedale, J.L. Puech, Wood maturation of distilled beverages, Trends in Food Science & Technology 9 (1998) 95–101.

[36] J.A. Pino, S. Tolle, R. Gök, P. Winterhalter, Characterisation of odour-active compounds in aged rum, Food Chemistry 132 (2012) 1436–1441.

[37] J.A. Pino, Characterization of rum using solid-phase microextraction with gas chromatography-mass spectrometry, Food Chemistry 104 (2007) 421–428.

[38] E.L. Regalado, S. Tolle, J.A. Pino, P. Winterhalter, R. Menendez, A.R. Morales, J.L. Rodríguez, Isolation and identification of phenolic compounds from rum aged in oak barrels by high-speed countercurrent chromatography/high-performance liquid chromatography-diode array detection-eletrospray ionization mass spectrometry and screening for antioxidant, Journal of Chromatography A (2011) 7358–7364.