PRODUCTION AND CHARACTERIZATION OF STILL-DISTILLED RUM

PRODUÇÃO E CARACTERIZAÇÃO DE RUM DESTILADO EM ALAMBIQUE

PRODUCCIÓN Y CARACTERIZACIÓN DEL RON DESTILADO EN ALGO

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ABSTRACT

The global rum market was valued at US$15 billion in 2020 and is projected to reach US$21.5 billion in 2025 at a compound annual growth rate of 5.5% during the period. This growth expectation is due to the global increase in demand for high-quality, intensely flavored rum (Market Data Forecast, 2020). The rum market in Brazil follows the global trend, registering significant growth in consumption in recent years, driven by a public seeking products with more sophisticated and differentiated flavor profiles (Businesscoot, 2020). Thus, rum distilled in copper stills stands out for its fuller-bodied and more complex flavor compared to rum produced in distillation columns, achieving a prominent position in the market. This scenario motivated this study, which aimed to investigate the production and characterization of rum distilled in copper stills, in accordance with current Brazilian legislation. The raw material used was sugarcane molasses. Fermentation was carried out in a fed-batch system using CA-11 yeast, a commercial strain of Saccharomyces cerevisiae. The resulting wine was distilled in a copper still, and rum was produced by diluting the heart fraction of the distillate to 40 ºGL. Physicochemical analyses confirmed that the rum produced meets the requirements established by legislation, demonstrating adequate parameters that guarantee its conformity and quality. Furthermore, the product obtained presented a visual aspect, aroma, and flavor characteristic of excellent beverages, demonstrating that the processes adopted were effective in obtaining a well-crafted distillate.

Keywords: Rum. Molasses. Copper Still.

RESUMO

O mercado global de rum foi avaliado em US$ 15 bilhões em 2020, e deverá atingir US$ 21,5 bilhões em 2025 a uma taxa de crescimento anual composta de 5,5% durante o período. Esta expectativa de crescimento é devido ao aumento global da demanda por rum de alta qualidade e sabor intenso (Market Data Forecast, 2020). O mercado de rum no Brasil acompanha a tendência global, registrando um expressivo crescimento no consumo nos últimos anos, impulsionado por um público que busca produtos com perfis de sabor mais sofisticados e diferenciados (Businesscoot, 2020). Desse modo, o rum destilado em

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alambique de cobre destaca-se por seu sabor mais encorpado e complexo em comparação ao rum produzido em colunas de destilação, conquistando uma posição de destaque no mercado. Esse cenário motivou a realização deste estudo, que teve como objetivo estudar a produção e caracterização do rum destilado em alambique de cobre, em conformidade com a legislação brasileira vigente. A matéria prima utilizada foi o melaço de cana. A fermentação foi realizada em sistema de batelada alimentada utilizando a levedura CA-11, uma cepa comercial da *Saccharomyces cerevisae*. O vinho resultante foi destilado em alambique de cobre e o rum foi produzido diluindo-se a fração coração do destilado a 40 ºGL. As análises físico-químicas realizadas comprovaram que o rum produzido atende aos requisitos estabelecidos pela legislação, evidenciando parâmetros adequados que garantem sua conformidade e qualidade. Além disso, o produto obtido apresentou aspecto visual, aroma e sabor característicos de bebidas de excelência, demonstrando que os processos adotados foram eficazes na obtenção de um destilado bem elaborado.

Palavras-chave: Rum. Melaço. Alambique de Cobre.

RESUMEN

El mercado mundial del ron se valoró en 15.000 millones de dólares en 2020 y se proyecta que alcance los 21.500 millones de dólares en 2025, con una tasa de crecimiento anual compuesta del 5,5% durante el período. Esta expectativa de crecimiento se debe al aumento global de la demanda de ron de alta calidad y sabor intenso (Market Data Forecast, 2020). El mercado del ron en Brasil sigue la tendencia global, registrando un crecimiento significativo en el consumo en los últimos años, impulsado por un público que busca productos con perfiles de sabor más sofisticados y diferenciados (Businesscoot, 2020). Así, el ron destilado en alambiques de cobre destaca por su sabor más completo y complejo en comparación con el ron producido en columnas de destilación, alcanzando una posición prominente en el mercado. Este escenario motivó el presente estudio, que tuvo como objetivo investigar la producción y caracterización del ron destilado en alambiques de cobre, de acuerdo con la legislación brasileña vigente. La materia prima utilizada fue melaza de caña de azúcar. La fermentación se realizó en un sistema de lotes alimentados utilizando levadura CA-11, una cepa comercial de Saccharomyces cerevisiae. El vino resultante se destiló en un alambique de cobre, y el ron se produjo diluyendo la fracción central del destilado a 40 °G. Los análisis fisicoquímicos confirmaron que el ron producido cumple con los requisitos establecidos por la legislación, demostrando parámetros adecuados que garantizan su conformidad y calidad. Además, el producto obtenido presentó un aspecto visual, aroma y sabor característicos de bebidas excelentes, demostrando que los procesos adoptados fueron efectivos para obtener un destilado de alta calidad.

Palabras clave: Ron. Melaza. Alambique de Cobre.

1 INTRODUCTION

1.1 CONCEPTS AND DEFINITIONS

Rum is an alcoholic distillate obtained from sugar cane. It is produced in several subtropical regions of the world, where sugarcane is grown. Although the most well-known rums are from Caribbean countries, rum is also produced in Australia, Fiji, India, Indonesia, Mauritius, Réunion, Sri Lanka, and other countries (Buglass, 2011).

The etymological origin of the word "rum" is uncertain. Some authors suggest that the term derives from "*Saccharum*", the genus of sugarcane (*Saccharum officinarum* L.). Another possibility is that it originates from the word "*rumbustion*", British slang for "great turmoil or uproar". A more likely origin is "*rumbullion*," a term used to describe a beverage boiled from sugarcane stalks. However, both terms were first reported at about the same time as the emergence of the word "rum", which makes it difficult to reach a consensus on its origin (Liberman, 2010).

Rum is a beverage whose definition and classification are very diverse, varying according to the country or region of the world in which it is produced. Regarding the raw material, its manufacture can be made from sugarcane juice, molasses from the sugar industries or a combination of these. In Brazil, rum is produced from molasses. In the French overseas territories, there are specific distinctions: rum is called "agricultural" when produced from sugarcane juice and "industrial" when made with molasses (Fernández, 2016).

Similarly, the criteria used to classify rum as "white", "golden", "dark", "light", "heavy", etc. vary depending on the place of manufacture. These classifications are directly related to the distillation method, the aging time and the color of the product, which can result either from aging in wooden barrels or from the addition of dyes, or even from a combination of both (Murtagh, 2003).

1.2 THE RUM MANUFACTURING PROCESS

The manufacture of rum comprises the stages of clarifying the molasses, making the must, fermentation, distillation and finally the storage of the product.

Clarification aims to remove gums, waxes and colloidal substances present in molasses, which interfere with the fermentation and distillation stages. This process is carried out with the use of flocculation agents, at a pH between 5.0 and 5.5, at 80 ºC, followed by filtration or centrifugation. The clarified molasses is then diluted to a ºBrix of 14-16, which is the ideal sugar concentration range for the fermentation stage. Fermentation wort is made from clarified and diluted molasses, supplemented with nutrients such as ammonium sulfate, vitamins, minerals, cornmeal, and rice bran, among others (Mangwanda, 2021).

From the fermentation stage, the production of rum follows a process similar to that of other beverages derived from sugarcane, brandy and cachaça. Fermentation is carried out with the use of the yeast *Saccharomyces cerevisiae*, which converts the sugars present in the must into ethanol, resulting in a sugarcane wine. Several other compounds are formed in smaller amounts, such as organic acids, methanol, esters, aldehydes, and higher alcohols. Such compounds contribute to the formation of the aroma and flavor of the drink.

After fermentation, the wine is then distilled, obtaining rum. Distillation can be carried out discontinuously, using copper stills, or continuously, by means of distillation columns. Generally, small producers opt for stills, while medium and large distilleries use columns.

In distillation in pot stills, the distillate is collected and separated into three distinct fractions. The first fraction is called the "head", which corresponds to the first condensed vapors and contains high concentrations of alcohol, usually above 60% (v/v). The volume of this fraction represents 1.0% to 2.0% of the volume of the wine, or approximately 10% of the total volume distilled. Next, the fraction called "heart" is distilled, which corresponds to an average of 16% of the volume of the wine, or 80% of the total volume distilled. This is the fraction that will give rise to rum. Finally, the fraction called "tail" or "weak water" is distilled, which corresponds to approximately 3.0% of the total volume of the wine, or 10% of the volume of the distillate. The "head" and "tail" fractions should not be used in the rum production process, as they present undesirable compounds that depreciate the quality of the product. However, these fractions can be mixed and distilled again in a column for the manufacture of fuel alcohol (Souza *et al*., 2013).

In column distillation of rum, there is no sequential separation of the distillate into fractions. The feeding of wine to the column, the separation of the more volatile components, such as methanol, and less volatile, such as higher alcohols, and the removal of the distillate happen simultaneously and throughout the process.

The product obtained in the distillation stage is diluted until it reaches the alcohol concentration determined by the manufacturer. After this adjustment, the liquid can be subjected to maturation, being stored for a period of 2 to 4 months in inert containers, such as stainless steel, or it can go on to the aging process, where it remains for at least one year in wooden barrels, acquiring unique characteristics of flavor and aroma.

1.3 BRAZILIAN LEGISLATION: STANDARDS OF IDENTITY AND QUALITY OF RUM

In Brazil, the standards of identity and quality of rum are established by Decree No. 6,871, of June 4, 2009. According to this legislation, rum is defined as a beverage with an alcohol content of thirty-five to fifty-four percent by volume, at twenty degrees Celsius, obtained from the simple alcoholic distillate of molasses, or from the mixture of distillates of sugar cane juice and molasses, aged totally or partially in an oak or equivalent wood container, conserving its peculiar sensory characteristics. The product can be added sugars up to a maximum amount of six grams per liter and the use of caramel for color correction is allowed. The coefficient of congeners, which is the sum of the concentration of the substances formed during the manufacturing process, cannot be less than forty or more than five hundred milligrams per hundred milliliters of anhydrous alcohol.

Rum may be called:

I. Light rum or light rum when the coefficient of congeners of the beverage is less than two hundred milligrams per hundred milliliters in anhydrous alcohol;
II. Heavy rum or heavy rum when the coefficient of congeners of the beverage is two hundred to five hundred milligrams per hundred milliliters in anhydrous alcohol, obtained exclusively from molasses; e
III. Aged rum or old rum is a beverage that has been aged, in its entirety, for a minimum period of two years.

1.4 MARKET AND CONSUMER TRENDS

Rum is the second most consumed distilled beverage in the world, with 1.6 billion liters per year, second only to vodka, with 4.5 billion liters (Market Data Forecast, 2020).

Depending on the country where it is produced, rum can be obtained from sugarcane juice, molasses or a mixture of these, in addition to having a diversity of classifications regarding color, flavor and aging time. As for the distillation method, rum falls into two categories: alembic rum, when distilled in copper stills, and column rum, when distilled in distillation columns (Fernández, 2016). Copper pot still distillation provides a drink with a more intense aroma and flavor, while column distillation provides a drink with a milder aroma and flavor.

The global rum market was valued at $15 billion in 2020, and is expected to reach $21.5 billion by 2025 at a compound annual growth rate of 5.5% during the period. This growth expectation is due to the global increase in demand for high-quality, intense-tasting rum (Market Data Forecast, 2020). The increase in rum consumption is already consolidated in several countries around the world. India and the United States record strong growth in the premium rum market (Grand View Research, 2023). Other markets, such as China, Japan, the Philippines, and Australia are also expected to have a significant impact on the market growth due to the large consumer base and demand for quality rum, with a fuller taste (Market Data Forecast, 2020).

The rum market in Brazil is in line with the global trend, with a notorious increase in consumption in recent years. This increase is due to a growing group of consumers who are looking for products in a higher category, with a striking and differentiated flavor profile (Businesscoot, 2020). In this context, alembic rum, because it has a richer flavour than rum produced using distillation columns, is expected to occupy a prominent position in the market.

The growing consumer interest in alembic rum and the low supply of this product in the domestic market represent an opportunity to generate revenue for small and medium-sized producers of cachaça and brandy throughout the country, who use distillation in copper stills in the manufacture of their products. The equipment already installed and the experience acquired in the manufacture of cachaça and brandy greatly favor the production of alembic rum by these producers.

Another important factor is that the manufacture of rum can contribute to optimizing the operation and use of the productive capacity of a mill that already produces cachaça and/or brandy. Sugar cane, the raw material for cachaça and brandy, deteriorates quickly and cannot be stored. Therefore, the production of these beverages occurs only during the sugarcane harvest period, underusing the machinery and increasing maintenance costs. The manufacture of rum, in addition to increasing the company's product portfolio and revenue, allows the mill to operate practically all year round, since molasses, the raw material for rum, can be stored for long periods. In this way, it is possible to produce cachaça during the harvest, and rum in the sugarcane off-season.

Therefore, the study of rum manufacturing, in addition to contributing to technical and scientific knowledge, also values the economy and sustainable development of sugarcane-producing regions. The synergy between rum, cachaça and brandy optimizes production and increases the economic sustainability of the mills, which adds even more value to this study.

2 METHODOLOGY

2.1 RAW MATERIAL

The raw material used for the manufacture of rum was molasses, whose physicochemical characterization was carried out through the analysis of Brix, Pol, Purity and Total Reducing Sugars (ART), according to the methodology described by Caldas (2012).

2.2 FERMENTATION MUST

The must consisted of eight liters of molasses diluted to 16º Brix and supplemented with forty grams (5g/L) of corn meal. To minimize bacterial contamination during fermentation, the pH was adjusted to values between 4.0 and 4.5 by adding citric acid.

2.3 YEAST

For the preparation of the yeast, the selected yeast CA11, a commercial strain of *Saccharomyces cerevisae, was used*.

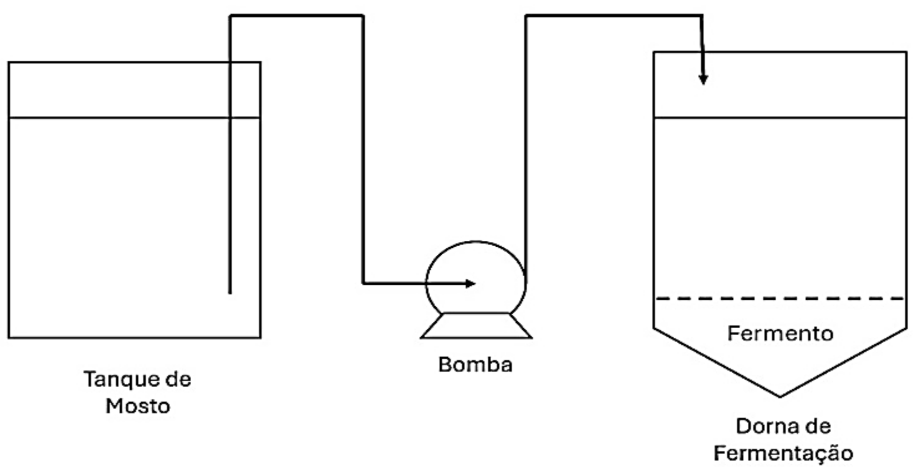
Initially, eight grams of the yeast were hydrated in 250 mL of water for 15 minutes. Subsequently, 250 mL of diluted molasses was added and supplemented, as specified in item 2.2. Once the Brix of this mixture was halved, an additional 500 mL of molasses was incorporated. When the Brix of the new mixture reached 4%, the yeast was transferred to the fermentation vat.

2.4 FERMENTATION

Fermentation was conducted in a fed-batch system, as illustrated in Figure 1.

Figure 1

Fed batch fermentation scheme



Source: Authored by the author.

The process began with the introduction of the yeast into the vat, which was then filled with the fermentation wort, prepared as described in item 2.3. The peristaltic pump was configured to fill the vessel in a period of five hours, a time commonly adopted in distilleries. After the end of filling, the pump was turned off, and the fermentation evolution was monitored by measuring the Brix of the fermentation medium, at twelve-hour intervals, using a Brix saccharimeter. Fermentation was considered complete when the Brix of the must remained constant between two consecutive measurements.

2.5 DISTILLATION

The distillation was carried out in a copper still with a useful volume of eight liters, heated over direct heat and equipped with a dephlegmator (Figure 2). The separation of the head, heart and tail fractions was carried out according to the estimated volume of the distillate, calculated according to the methodology reported by Chaves (2007):

$$V_{dest} = V_{vinho} * (Brix_{mosto} - 2)/100 \qquad (1)$$

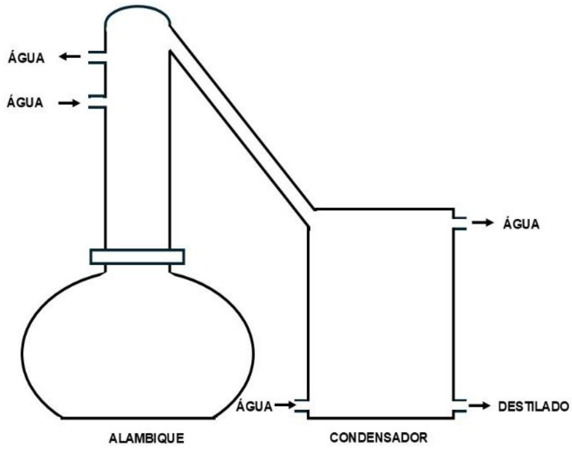
Where:

V_{dest} = Estimated volume of distillate, in liters;
V_{vinho} = Volume of wine (fermented must), in liters;
$Brix_{mosto}$ = Concentration of soluble solids of the wort, before fermentation.

According to this method, the head and tail fractions each correspond to ten percent and the heart fraction to eighty percent of the estimated volume of the distillate.

Figure 2

Copper still equipped with dephlegmator and condenser



Source: Authored by the author.

2.6 ADJUSTMENT OF ALCOHOL CONTENT

According to current legislation, rum can have an alcohol content ranging from 35 to 54 ºGL. In this project, it was decided to produce a drink with 40 ºGL, as this is a very common value in rums available on the market.

To obtain the rum with the desired alcohol content, the heart fraction of the distillate was diluted with a volume of water calculated by the solution dilutions equation (Brown et al., 2005), as described below:

$$C_1 * V_1 = C_2 * V_2 \quad (2)$$

Where:

C1 = Alcohol content of the heart fraction;
V1 = Volume of the heart fraction;
C2 = Alcohol content of the rum;
V2 = Volume of rum with alcohol content C2.

2.7 REVIEWS

The quality control of the rum produced was carried out according to the standards of identity and quality established in Normative Instruction No. 15/2011, of MAPA. Analyses were performed to determine the alcohol content and concentrations of volatile acidity, aldehydes, higher alcohols, esters, furfural, methanol and the congener coefficient. The alcohol content (% by volume) was initially determined by measuring the density of the sample, using a pycnometer. Next, the relative density at 20°C was converted into alcohol content, using a conversion table, according to the official method of the Adolfo Lutz Institute (2008).

The other analytical parameters were determined using a Shimadzu gas chromatograph, model QP-201O Pro, with flame ionization detector (GC-FID), Stabilwax-DA capillary column and automatic injection system of 1.0 microliter sample.

3 RESULTS AND DISCUSSION

3.1 MOLASSES

The result of the molasses quality control analyses is shown in Table 1. The results of all parameters are within the characteristic ranges of molasses considered to be of good quality (Mangwanda, 2021).

The origin of the molasses exerts a significant influence on the quality of the rum. This was proven in experiments that used beet molasses in the production of the drink, demonstrating that it was not possible to obtain the same aroma profile present in rum made from sugarcane molasses (Arroyo, 1948). Fresh sugarcane molasses, with low viscosity and high total sugar content, such as the one used in this study, is ideal for the production of rum, providing superior quality aromas and flavors (Delevante, 2004).

Table 1

Molasses quality control parameters

Parameter	(%) w/m
Brix	77,5
Pol	44,34
ART	63,55
Purity	57,21

Source: Authored by the author.

3.2 MUST PREPARATION AND FERMENTATION

To obtain the wort at the desired Brix concentration, 1,500 mL of molasses were diluted in 6.5 L of water. These proportions were calculated through a mass balance, using as calculation bases the Brix of molasses (Table 1) and the volume and Brix intended for the must. After dilution of molasses and supplementation with forty grams of cornmeal, eight liters of must with a concentration of 16 ºBrix and an initial pH of 5.64 were obtained. To reduce the growth of contaminating bacteria, citric acid was gradually incorporated until the pH of the wort was adjusted to the range of 4.0 to 4.5. At the end of the addition of 10 grams of citric acid, the pH was stabilized at 4.38 and therefore considered suitable for fermentation.

Fermentation was carried out in a fed-batch system, as illustrated in Figure 1. Initially, a liter of yeast was placed in the vat. Then, the pump was turned on, and the fermentation time began to count. The pump flow was programmed to add the eight liters of wort to the vessel over a five-hour period. The evolution of fermentation was followed by measuring the concentration of sugars in the fermentation medium, at twelve-hour intervals, using a Brix saccharimeter. The results are presented in Table 2.

Table 2

Concentration of sugars as a function of fermentation time

Fermentation time (h)	Brix (%)
0	16
12	14,5
24	12
36	9
48	6
60	3
72	3

Source: Authored by the author.

Alcoholic fermentation is considered complete when all of the fermentable sugar is consumed, resulting in a Brix value of zero. However, molasses may contain different proportions of non-fermentable sugars, those that are not metabolized by yeast. As a consequence, at the end of the fermentation of these molasses, the Brix will not reach zero. Thus, the process is considered to be finished when the value of the Brix remains stable for an extended period. In this study, as no reduction in Brix was observed between 60 and 72 hours, fermentation was considered finished after 60 hours, and the resulting wine went to the distillation stage.

3.3 DISTILLATION AND ADJUSTMENT OF ALCOHOL CONTENT

The distillation process has a significant impact on the characteristics of the rum and can be carried out in copper stills or distillation columns. The first method results in a more aromatic drink with a pronounced flavor, while the second produces a rum with a lower concentration of congeners, giving it a milder aroma and flavor. Both systems have variations, both in equipment and in the mode of operation. In this study, aiming at the production of a more full-bodied rum and in line with the global consumption trend, it was decided to distill in a copper still.

Initially, the estimated volume of the distillate was calculated, according to the methodology described in item 2.5:

$$V_{dest} = V_{vinho} * (Brix_{mosto} - 2)/100 \quad (3)$$

$$V_{dest} = 8{,}0 * \frac{(16-2)}{100} = 1{,}12 \text{ litros ou } 1220 \text{ mL} \quad (4)$$

According to this method, the "head" and "tail" fractions correspond to 10% each, while the "heart" fraction represents 80% of the volume of the distillate. Therefore, during the distillation process, the first 122 mL collected were classified as the "head" fraction and discarded. Then, the subsequent 976 mL were considered as the "heart" fraction and properly stored. Distillation was interrupted after this step, since the "tail" fraction had no applicability in this study.

The alcohol content of the "heart" fraction was measured with a Gay-Lussac alcoholmeter, and the result was 45 ºGL. To obtain rum with an alcohol content of 40 ºGL, the heart fraction was diluted with a volume of water calculated by the solution dilutions equation (Brown *et al*., 2005), as described in item 2.6. Starting from 976 mL of a heart fraction with an alcohol content of 45 ºGl, 122 mL of water were added, thus obtaining 1098 mL of rum at 40 ºGL.

3.4 PHYSICOCHEMICAL ANALYSES

Table 3 presents the results of the physicochemical analyses of the rum produced in this study. The values obtained for all the parameters analyzed are within the limits established by the Brazilian legislation.

Table 3

Analytical parameters of rum

Parameter	Value	Minimum threshold	Maximum limit
Alcohol content, in %, in v/v, at 20 ºC	39,1	35	54
Volatile acidity, in acetic acid, in mg/100 mL of anhydrous alcohol	10,6	-	150
Superior alcohol (sum of n-propyl alcohol, isobutyl alcohol and iso amyl alcohol), in mg/100 mL of anhydrous alcohol	96,2	-	260
Aldehydes, in acetic aldehyde, in mg/100 mL anhydrous alcohol	17,6	-	20
Esters, in ethyl acetate, in mg/100 mL anhydrous alcohol	25,4	-	200
Sum of furfural and hydroxymethylfurfural, in mg/100 mL of anhydrous alcohol	-	-	5
Congener coefficient, in mg/100 mL of anhydrous alcohol	149,8	40	500

Methyl alcohol, in mg/100 mL anhydrous alcohol	3,04	-	200

Source: Decree No. 6,871/2009, I.N. Map No. 15/2011

4 CONCLUSION

The methodology used in this study allowed a detailed analysis of the production and characterization of rum distilled in copper stills, in accordance with the current Brazilian legislation. The characterization of the molasses used provided essential information about its composition and quality, ensuring its suitability to be used as raw material.

The physicochemical analyses carried out proved that the rum produced meets the requirements established by the legislation, evidencing adequate parameters that guarantee its compliance and quality. In addition, the product obtained presented a visual aspect, aroma and flavor characteristic of excellent beverages, demonstrating that the processes adopted were effective in obtaining a well-prepared distillate.

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