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Perspectives of the HACCP System in the Alembic Cachaça Certification

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SUMMARY: Cachaça is the name of a Brazilian beverage produced by distillation of fermented sugarcane juice. It is called "alembic cachaça" when produced in an agricultural environment, through fermentation of fresh sugarcane juice and distillation by batches in copper stills. Due to the peculiarities of the process and the dedication of hundreds of producers, this drink achieved improved and highly differentiated sensory quality; conquering new markets and winning important prizes in national and international competitions. In this context, there is a growing search both for resources to prevent fraud in marketing and for certificates that attest to the safety of consumers' health, especially HACCP. In this review article, we highlight the points already achieved in the standardization of the production process and introduce others that still require appropriate standardization, related to the control of pesticides in the sugarcane field, the safety of the wood used in the storage barrels and the certification of the production process. It is also proposed to review the limit of Brazilian legislation for the ethyl carbamate content.

KEYWORDS: Alembic cachaça, Ethyl carbamate, HACCP, Pesticides, Wood barrels.

1. INTRODUCTION

Cachaça is the typical and exclusive denomination of sugarcane brandy produced in Brazil, with an alcohol content of 38.0 to 48.0% vol., obtained by distillation of the fermented must of sugarcane juice. The beverage can be referred to as "alembic cachaça", as long as it is produced from fresh sugarcane juice and distilled by batches in copper stills (MAPA, 2022). The raw material is harvested, collected, transported and stored with hygienic care; before milling, it can be sanitized by applying a jet of fresh, potable water, but the application of heat and/or chemicals to exterminate the natural microbiota that accompanies the cane culms is not permitted. Object of multiple government actions and technical advances, alembic cachaça has found a marked appreciation in the domestic market, in addition to special receptivity in the international trade. Many trademarks have been awarded in sensory evaluation competitions, both in Brazil and abroad. In addition, they stand out for their care in the adoption of nice bottles and labels. In this context, producers of alembic cachaça have been dealing with an increase in the risks of fraud. On the other hand, they point out the need for instruments for certification of origin and food safety as a way to consolidate themselves in the international market (Barbosa and Rosa, 2003; Bortoletto, 2018).

Conceived as an instrument for the promotion of food safety in industrialized products, HACCP ("the analysis of hazards and critical control points") is designed to monitor and control all risks of contamination or deterioration (physical, chemical and/or biological) throughout the production process. It was created in the United States in the 1960s to ensure the absence of food poisoning risks for astronauts on their space missions (Pearson and Dutson, 1995). Since then, the vertiginous growth in food industrialization has given rise to questions regarding the food security of the entire population. In the 1970s, the FDA (Food and Drug Administration) determined the implementation of the HACCP system in the low-acid canned food industries, considering the risks of contamination by toxins from the bacterium *Clostridium botulinum.* Subsequently, attention turned to the dangers of industrializing meat, poultry, eggs, and seafood (FAO/WHO, 2006). In the 1980s and 1990s, after revisions and readjustments, the system was introduced in Europe by the WHO (World Health Organization) and in the United States by the USDA (United States Department of Agriculture). At the beginning of the 21st century, the United Kingdom enacted the application of HACCP to all food establishments (EC, 2004).

In Brazil, ANVISA (National Health Agency) has implemented ordinances and resolutions related to the adoption of standardized procedures in the manufacture of food and beverages in general. Still at the end of the twentieth century, the Ministry of Agriculture determined the implementation of HACCP (Portuguese acronym corresponding to HACCP) in all industries of animal products, based on guidelines of the WHO and the Codex Alimentarius (MAPA, 1998). To date, the requirements and controls remain restricted to foods of animal origin.

The objective of this article is, based on the HACCP guidelines, to present data and considerations that can contribute to the assertiveness for advances in the certification of origin, fraud prevention and safety of alembic cachaça for consumers.

2. METHODOLOGY

A survey of publications related to HACCP/HACCP in the production of food in general and alcoholic beverages (Google Scholar, Scielo, Science.gov, PubMed and FSTA) was carried out. The review was supplemented by data referring to direct experience with hundreds of producers,through LABM (2023).

3. PRINCIPLES AND REQUIREMENTS

With the sharp growth of international trade, the expectation is that an international consensus will evolve on tolerance limits for secondary components and contaminants of food in general. However, to date, each country has the autonomy to establish its quality and safety benchmarks. The same is true, of course, in the field of distilled spirits It is true that, in recent decades, the international leadership of the CAC (Codex Alimentarius Certification) created by FAO/WHO has grown (Pang et al., 2017). However, given the diversity of raw materials and procedures employed, there will always be a need to distinguish between secondary compounds that necessarily come from the raw material and fermentative metabolism and the others, whose occurrence points to contamination due to hygienic failures (Dearfield et al, 2014)

Before applying for certifications of excellence with international coverage, each producer must have internal certification within the scope of good manufacturing practices, as recommended in the Brazilian legislation, which, to a large extent, is in tune with the CAC references (ANVISA, 1997, 2005). In fact, the Brazilian standards are already established in the scope of the definition of criteria and, especially in the state of Minas Gerais, of the routine inspection of alembic cachaça factories, according to the step-by-step summarized below.

4. GENERAL ORGANIZATION

The factory must have an organizational chart describing the duties of each of the team members. The floor plan of the productive sector and its surroundings must demonstrate the existence of a logical chain of activities, without the occurrence of a cross flow of materials and people. The facilities must include facilities and safety both for the hygienic procedures to be applied to the floors, walls and ceiling (slight inclination of the floors, distance between drains, final disposal of wastewater) and for the mobility and comfort of the workers, including items such as ventilation, lighting and spaces for operation and maintenance activities of the equipment and accessories. All food and beverage companies must prove the adoption of standardized procedures, the definition of which may, in many cases, be under the responsibility of the productive sector itself, with reference to the guidelines of the CAC-WHO (MAPA, 1998; ANVISA, 2002).

The good practice manuals are mandatory and specific for each production unit, containing a description of the procedures and routines to be applied at each stage and recorded in specific forms.

Every food and beverage plant must prove:

- Adequacy of the water supply and its periodic quality control (for the various purposes).
- Routine application of procedures for the prevention of insects and rodents, with a record of the resources and products used, form of application and traceable record of the procedures applied.
- Training of the team in the field of essential health care, as well as resources and procedures for personal hygiene.
- Effective protocol for handling complaints, ensuring ease of access by customers and consumers and the promptness/traceability of internal referrals.

5. SPECIFIC REQUIREMENTS

The manufacture of alembic cachaça requires routine and peculiar controls in each of the stages of the production process, as summarized in Figure 1.

It is important to highlight that, although inserted in an agricultural environment, often constituting a patrimony of family succession,

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all Alembic Cachaça factories need to maintain a link with a professional with academic and/or technical training, duly qualified to guide the procedures of:

- Selection and harvesting of sugarcane (healthy and at the optimal point of ripeness).
- Transport and storage of sugarcane, restricting the time of exposure to the sun and contact with the soil, to prevent contamination by undesirable microorganisms.
- Cleaning and sanitization of all equipment.
- Cleaning and preparation of sugar cane for milling.
- Milling and preparation of the juice.
- Propagation or reinvigoration of the yeast.
- Handling of appropriate distillers (stills) equipped with resources to control the heating rate of the wort, the reflux of vapors and the collection of the distillate.
- Cutting of the head, heart and tail fractions, and only the central fraction (heart) is destined to the production of cachaça. The others (head and tail) can be sent for the production of ethanol fuel in a specific distiller.
- Accumulation of several successive batches of freshly distilled cachaça in large steel or wood barrels, from which samples are extracted for analysis of identity and quality parameters (in accredited laboratories).

In Minas Gerais, the Brazilian state that holds the largest production of alembic cachaça, the inspection is the responsibility of the IMA (Minas Gerais Institute of Agriculture). Producers need to keep a file of laboratory analyses of all batches, proving compliance with the parameters of current legislation (Table 1).

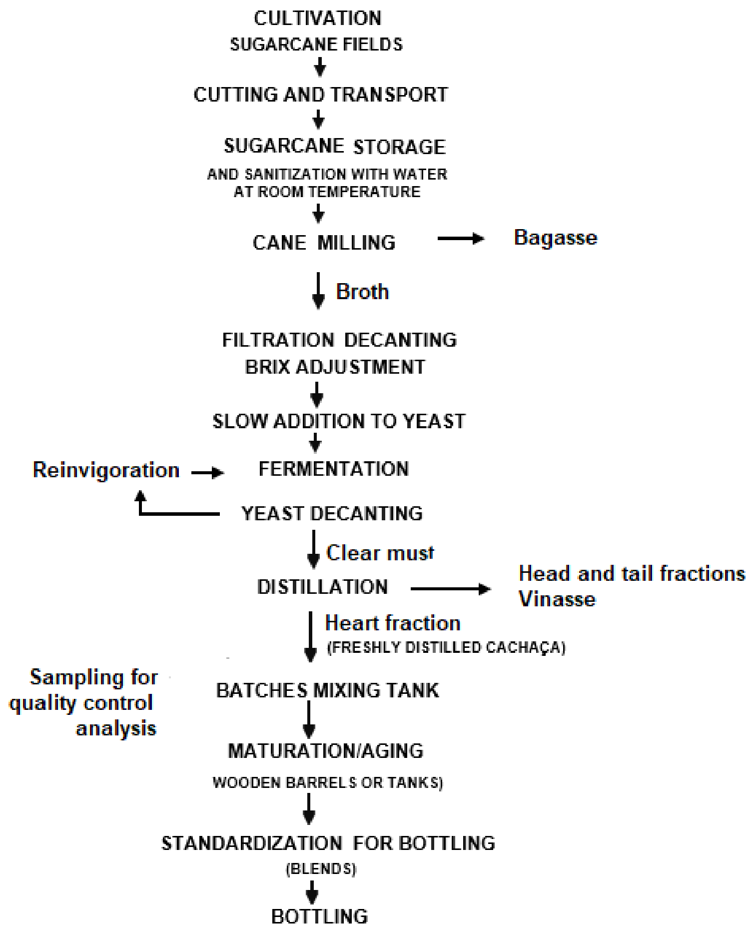

Figure 1 – Flowchart of the production of alembic cachaça (Maia and Campelo, 2006)

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In this context, the search for HACCP certification signals an opportunity to affirm the specificities and expand international recognition regarding the quality and safety of "alembic cachaça" – including its differentiation from industrial or generic cachaça. In principle, the prospect of certification would be practically immediate, as the standardized procedures are already in place and approved by the inspection bodies. However, there is a difference to be overcome in terms of the degree of detail of the records: the HACCP system establishes that each point that requires control is classified as low, medium or high probability of contamination, in order to justify periodicities and routines to be adopted in each case. For all points, you need to define quantitative values for the "critical tolerance limits". In the production of alembic cachaça, although indispensable, several controls are traditionally linked to subjective references, such as the cleaning of the sugarcane, the effectiveness of the sedimentation of impurities in the juice, the demand for nutrients to reinvigorate the yeast, among others. Thus, it is essential to have the understanding of the certifying bodies in order to make the requirements of quantitative controls more flexible. In fact, the EU (European Union) itself has pointed out and defended the application of differentiated criteria, both reducing the points and the control requirements (EU, 2004; Almeida et al., 2005). In the production of alembic cachaça, several precautions are traditionally adopted and recognized as essential for the producer to achieve excellence in the quality of the final product. In its absence, the flaws will be evidenced not only by sensory depreciation but also by the physicochemical analysis of the identity and quality parameters, which includes both the references related to the identity of the beverage (for which there are minimum and maximum limits) and the markers of contamination that may result from hygienic failures during the process (Table 1).

Table 1 – Parameters of the Brazilian legislation for alembic cachaça (MAPA, 2022).

Marker	Parameter/Unit	Minimum	Maximum
Beverage identity	Alcohol content, % v/v - 20°C	38,0	48,0
	Volatile acidity, in acetic acid, in mg/100 mL ethanol	-	150
	Ethyl acetate, in mg/100 mL de ethanol	-	200
	Acetaldehyde, in mg/100 mL ethanol	-	30
	Furfural + Hydroxymethylfurfural, in mg/100 mL of ethanol	-	5
	Alcohols: n-propyl + isobutyl + isoamyl, in mg/100 mL ethanol	-	360
	Sum of congeners, in mg/100 mL of ethanol	200	650
	Total sugars, for cachaça, in g/L (expressed as glucose)	-	6
	Phenolic compounds (cachaça stored in wood)	Presença	
Contamination (process failures)	Methyl alcohol (methanol), in mg/100 mL ethanol		20
	Ethyl carbamate, in µg/L		210
	Acrolein, in mg/100 mL of ethanol		5
	Sec-butanol, in mg/100 mL ethanol		10
	n-butanol, in mg/100 mL ethanol		3
	Copper, in mg/L		5,0

6. CRITICAL POINTS

Through laboratory analysis (mandatory for each batch to be sold) it is possible to point out failures in compliance with any of the parameters in Table 1 during the production process. The only exception is ethyl carbamate (item 6.3). In many cases, there are safe procedures that allow you to make the necessary corrections. However, the producer committed to quality will always be aware of the appropriate procedures that allow avoiding the need for corrections at the end of the process. In particular, any correction requires new procedures and new laboratory analyses. Thus, within the scope of identity and quality parameters, it is understood that controls throughout the process are necessary and important, but they are not indispensable to attest to consumer safety.

On the other hand, there are topics that have not yet been fully regulated or included in the Brazilian legislation for cachaça and that may constitute the real obstacles to international certification. Finally, the "really critical" points.

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6.1) PESTICIDES

Widely used in agricultural activity in general, pesticides are also widespread in sugarcane plantations (Sanches et al., 2003). The term encompasses hundreds of substances (pesticides, pesticides, insecticides, fungicides and herbicides) that are intended to exterminate undesirable organisms in the crop. In Brazil, most of the cultivation is destined for the production of fuel alcohol and industrial cachaça. The management of sugarcane plantations has been investigated in the context of the living conditions and health risks of sugarcane plantations and adjacent communities (Moraes, 2007; Novaes and Alves, 2007; Oliveira et al., 2010; Verçoza, 2012; Fialho et al, 2018; Rodrigues, 2020; Barreto, 2021). But there is a great scarcity of studies on the risks of contamination of beverages produced from sugarcane, such as garapa (sugarcane juice) and cachaça.

The diversity of chemical structures applied to Brazilian sugarcane plantations can be illustrated by the work of Armas et al (2005), who identified the application of 39 different commercial products, several of them corresponding to mixtures of various active ingredients. In terms of toxicity, 36% were classified as extreme or largely toxic and 38.5% as moderately toxic. Only 26.5% were assessed as having low toxicity. The half-life ranged from 24 to 1320 days, raising questions about the risks of dragging into watercourses. These data allow us to question the risks of pesticide occurrence in sugarcane-derived beverages, such as garapa (fresh juice) and cachaça (fermented and distilled juice). In fact, although small, there are risks. In Japan, Inoue et al (2010) researched 249 pesticides used in rice and barley crops regarding their occurrence in sochu (distilled beverage from these raw materials). In the beverage, the authors reported the presence of 12% of the pesticides analyzed. And they pointed out that, in common, the pesticides transferred to the sochu had high vapor pressure (above 1 mPa) and low molecular weight (below 350).

Cabras et al. (1997) investigated the fate of 13 pesticides (eight fungicides and five insecticides) found in grape fermentation musts. Among the pesticides studied, only residues of fenthion and vinclozoline were found in the distilled spirits, corresponding to 13% and 5%, respectively, of the contents contained in the musts. Shin et al. (2019) fermented rice previously contaminated with five pesticides (terbufos, fenthion, iprobenfos, flutolanil and ethoprophos) and analyzed their contents in the distilled beverage in a continuous column. The authors detected traces of some pesticides in the distillate, in the order of 50 µg/L, a fact that they evaluated as due to the high vapor pressure (especially ethoprophos) and the high level of contamination (flutonyl, terbufos and fenthion). These studies illustrate the possibility of selecting appropriate pesticides for application in sugarcane fields for the production of beverages - both in terms of the degree of toxicity to humans and the physicochemical properties - in order to ensure their absence in alembic cachaça - as well as distilled beverages in general.

6.2) WOODS

Brazil has a great diversity of native woods (Lorenzi, 2008), whose alcoholic extracts are recognized as suitable for therapeutic purposes (ANVISA, undated; MS, 2016). Numerous species are used in the making of barrels for storing cachaça, giving it a peculiar color, odor, and flavor (Maia, 2021). This diversity is traditionally valued and praised by the producers of alembic cachaça who, in addition to using barrels of various types of wood, have the support of specialists (master-blenders) to develop and improve mixtures of various woods, giving rise to an instigating diversity of aromas and flavors in the final drink. It is well known that the odors and flavors, in addition to the color incorporated into cachaça, result from the incorporation of phenolic compounds that are extracted from the wood (Maia, 2021). In fact, Brazilian legislation requires proof of the "presence" of phenolic compounds in the analysis of cachaças stored in wood (Table 1). Although endowed with nutraceutical properties (especially due to their antioxidant action) and even therapeutic (with a wide range of applications attributed to each class of phenolic compounds), the presence of these compounds requires certain controls and tolerance limits – especially taking into account limits related to drug and/or potentially toxic functions, associated with the ingestion of higher amounts (Pang et al., 2017).

By way of illustration, coumarin is known to be the main phenolic incorporated into cachaça stored in amburana tones (Maia et al., 2023a,b). It is an o-hydroxycinnamic acid lactone widely used for culinary purposes, due to its sensory properties, and which also has a consolidated history of drug applications. (Hassan et al., 2016). However, at the end of the late twentieth century, it was demonstrated that its continued ingestion could cause damage to the livers of sensitive people. Subsequently, it has been shown that even sensitive people are free from adverse effects at doses up to 6 mg/kg/day (Garg et al., 2020; Rad et al., 2021). However, since 1999, the EU has proposed the value of 0.1 mg/kg/day as the daily limit for safe consumption (EU, 1999, 2004, 2008) of coumarin. It also defined the limit of 10 ppm coumarin in distilled beverages (EU, 2008), recently adopted by ANVISA (2022).

Maia et al. (2023 a,b) pointed out an average coumarin content of found the content was shown that cachaça stored in shades of 18.7±7.0 mg/L. It can be noted that this non-compliance does not necessarily signal the existence of risk to the consumer In fact, similar evaluations can be made with respect to other parameters already established for distilled spirits around the world (Pang et al., 2017). However, the Pact for the Effective Protection of Public Health stipulates that, if there is no compliance with the established standards, the products cannot be marketed.

6.3) ETHYL CARBAMATE

Brazilian legislation sets a limit of 210 µg/L for the EC (ethyl carbamate) content in cachaça (MAPA, 2022). At the international level, most countries do not include this parameter in the monitoring of foods and distilled beverages (Ryu et al, 2015). In countries that already monitor EC, higher thresholds are found (Ryu et al, 2015; Lim and Lee, 2011), such as 400 µg/L in the Czech Republic, 800 µg/L in Germany and up to 1000 µg/L in France and Switzerland, which are applied to fruit spirits.

In 2007, the EU carried out a risk assessment to set a limit on ethyl carbamate in spirits (EU, 2007). Subsequently, it endorsed the limit of 1000 µg/L in stone fruit distillates (the most susceptible to the formation of ethyl carbamate), from which the distillate must be subjected to redistillation. (EU, 2010). However, the benchmark has not been converted into a requirement.

According to IARC (2010), in the consumption doses of distilled beverages, the carcinogenic potential of alcohol (ethanol) is much higher than that of ethyl carbamate. It is known that EC can result from factors related to plant physiology (raw material) and metabolism of fermentation yeasts (Zimmerli and Schlatter, 1991; Taky et al. 1992; Orduna et al., 2000; Galinaro and Franco, 2011). However, there are still no standardized procedures for its effective control. In fact, most of the cachaças analyzed soon after distillation have EC content below 210 µg/L (LABM, 2023). However, there is evidence that EC content may increase during storage in casks and even in the bottled beverage (Weber and Sharypov, 2009; Baffa, 2011; Xue et al., 2015; Du et al., 2018; Silva et al. 2019). In addition, there are seasonal fluctuations in EC content, for the origin of which traceability parameters do not yet exist.

In our view, therefore, Brazilian legislation should increase the tolerance limit to 1000 µg/L. In fact, the limit of 400 µg/L would already allow the vast majority of stored and bottled alembic cachaças to be included (Maia, 2022)

6.4) CERTIFICATION OF ORIGIN

The growing appreciation of alembic cachaça has accentuated the need for parameters that allow certifying its origin, differentiating it from generic cachaça and industrial cachaça. Having benchmarks to deal with fraud risks is important for the safety of both consumers and producers. It is, therefore, a "critical demand" to be urgently regulated. Certainly, several criteria can be introduced with the advancement of research. However, it has already been demonstrated that the specific analysis of the "ethyl lactate" ester is perfectly feasible and does not add cost to the analytical procedures chosen (Maia et al., 2020, 2021).

Being produced from fresh sugarcane juice and not subjected to antibacterial treatments, alembic cachaça contains ethyl lactate. In the fermentation stage, the lactic acid bacteria that naturally accompany the broth secrete lactic acid; during distillation, part of this acid reacts with ethanol to form ethyl lactate.

In addition to being widely disseminated in nature, including in the human body, lactic acid bacteria are safe (GRAS) and do not transmit diseases (Sobrun et al., 2012). They do not secrete toxic compounds, unlike pathogenic bacteria, such as those of the genera *Escherichia*, *Enterobacter*, *Klebsiella*, *Salmonella or Clostridium*, which, in the rural environment, can result from contamination of sugarcane with the soil of corrals, feces, sewage and animals (Coldea et al, 2017; Edwards et al, 1989, Lloret et al, 2002, Maarse, 191, Bintsis, 2010, Pardo and Ferrer, 2022). Lactic bacteria are traditionally applied in the production of wines and some beers, precisely to enrich the aroma and soften the flavor (Bauer and Dicks, 2004; Bintsis, 2018). Indeed in alcoholic fermentation, lactic acid bacteria can only be referred to as contaminants when the process is intended to maximize the conversion of sugar into ethanol, as happens in the production of fuel alcohol (Ventura, 2007). In this case, lactic acid bacteria actually cause yield loss by converting a fraction of the sugar into lactic acid.

7. CONCLUSION

Notwithstanding the undeniable advances that have led to great appreciation of alembic cachaça in the national and international markets, the demand for HACCP certification (or similar) still faces certain obstacles. Within the scope of certifying entities, it is necessary to accept and recognize the subjective nature of various control points, dispensing with the need for tedious and tedious records: possible contamination, if it occurs, will be identified and quantified in the laboratory analysis intended for the approval of the batch. Under Brazilian law, there is a need to:

- Introduce chemical parameters related to the characterization of the wood used in the beverage storage barrels.
- Introduce criteria for the selection of pesticides that can be applied to sugarcane plantations and their surroundings.
- Introduce parameters for the certification of alembic cachaça, reducing the risk of fraud.
- Increase the limit for EC content in cachaça (both generic and still) until the procedures for prevention and control are standardized.

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