

Optimization of the Sugarcane Value Chain for the Mayabeque Distillery

Optimización de la cadena de valor de la caña de azúcar para la destilería de Mayabeque

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ABSTRACT: The value chain extends beyond the initial value of a product, increasing with the quality of its byproducts. In this sense, the sugar sector displays a value chain based on its raw material of great global significance, allowing sugar companies to increase profits from these resources. The situation at the "Héctor Molina Riaño" Distillery UEB (Bakery Industry Unit) has led to the development of research aimed at making improvements in the integrated management of the alcohol value chain in this entity. A documentary analysis was conducted on the topic addressed, a diagnosis of the production entity was performed, a SWOT matrix was applied, and, based on the presentation of an Ishikawa diagram, 10 problems were identified, for which 10 actions were proposed. Of the proposed actions, 80% were resolved in the short term, and 50% of them were resolved within 8 months. A technological framework for the production of alcohol and spirits was proposed for application in the distillery. Five categories for primary actions and four categories for supporting actions were identified, based on Porter's proposal, which was used as a reference for this work.

Keywords: alcohol, agricultural production, swot matrix.

RESUMEN: La cadena de valor se extiende más allá del valor inicial de un producto, incrementándose con la calidad de sus subproductos. En este sentido el sector azucarero muestra una cadena de valor a partir de su materia prima de gran realce a nivel mundial, permitiendo aumentar ganancias para las empresas azucareras a partir de estos, la situación que se presenta en la UEB Destilería "Héctor Molina Riaño" ha permitido desarrollar una investigación que tiene como objetivo realizar mejoras en la gestión integrada a la cadena de valor del alcohol en esta entidad. Se realizó un análisis documental sobre el tema abordado, un diagnóstico de la entidad productiva, se aplicó una matriz DAFO y a partir de la presentación de un diagrama de Ishikawa se relacionaron 10 problemas, a los que se les propusieron 10 acciones. De las acciones propuestas el 80 % se solucionaron a corto plazo y de ellas el 50% se resolvieron en un tiempo de 8 meses. Se propuso un esquema tecnológico para la producción de alcohol y aguardiente para aplicar en la destilería. Se relacionaron cinco categorías para las acciones primarias y cuatro categorías para las acciones de apoyo según la propuesta de Porter que se empleó referencia para este trabajo.

Palabras clave: producción de alcohol, diagrama de Ishikawa, matriz DAFO.

INTRODUCTION

Increasing competition in the business sector requires companies to improve their competitiveness in order to succeed in the market. (Bak et al., 2020). Competition within the market is everything related to demanding buyers eager for satisfaction and sellers focused on generating income and maximizing profits, where the relationship between the two is the key to market competition (Gutiérrez, 2016). The interaction between both, demand (customers) and supply (sellers), results in the determination of prices for the products and services

offered by a company, allowing it to establish strategies to withstand competition and be profitable within the market in which it operates or participates; that is, a competitive company (Calle et al., 2020).

Among the keys to success for business competitiveness are the use of improvements not only in the service and products offered to customers, but also in the company itself, seeking measures to increase the value of its products, reduce costs, and increase profits, all to ensure its profitability. Knowing everything that generates value in its products determines points of economic loss and offers financial possibilities and strengths,

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which is vitally important for a company to grow and become more profitable and efficient (Gutiérrez & Reyes, 2003).

These advantages are applicable if all aspects of production that generate value for the company, known as the value chain, are properly controlled (Quimis et al., 2022). Currently, there are many analytical tools that support this business activity; one of the most comprehensive and well-known is Michael Porter's value (Riquelme, 2020).

In Cuba, as for the business world, it is vitally important to understand or identify the value chain of primary production, as it will determine all aspects that influence the productive growth of the institution or business, making it more profitable.

Cuba's current situation with the economy and infrastructure of state-owned enterprises suggests increasing efforts to minimize any negative impact on its production or services, in order to promote economic improvement for the country and the institutions in question.

One of the sectors most affected by the economic situation is the sugar industry, causing a significant decline. From being the world leader in sugar and derivatives production, it now ranks 22nd in the ranking of sugar-producing countries. In 2023, it produced approximately 1,211,100 tons of raw sugar. However, although it is not among the top ten producers, it remains a relevant player in the sugar industry (Tecnica Na, 2023).

This, in turn, has led to situations in the production of sugar derivatives, where product quality is sometimes not as expected, due to many factors such as a lack of inputs, raw materials, poor strategic planning, among others (Chávez-García & Haro-Sosa, 2020). Therefore, it is important for those responsible for the production of sugarcane derivatives to maintain a strong focus on the continuous improvement of production processes to achieve sustainability in the economy of the state and the country. Success will only be achieved through solid strategic planning and mastery of the key aspects that add value to the production of derivatives.

From the tropical plantations of Brazil and Thailand to the vast fields of India and the United States, countries around the world are dedicated to the cultivation and processing of sugarcane and sugar beets (Arana-Bravo, 2021).

This industry not only meets the ever-increasing demand for sugar in various sectors, including food and beverages, but also provides employment opportunities and contributes to the economies of many nations (Hochrein et al., 2015). Sugarcane is not only the source of the sweet grain; it is one of the most versatile plants in the world, allowing for the production of different derivative products (Torres & Zunino, 2019). From sugar to ethanol, sugarcane is used in a wide variety of industries, ranging from food to energy.

Sugarcane byproducts include sugar, molasses, cane syrup, rum, ethanol, bagasse, panela, alcohol, yeast, citric acid, and processed sugarcane for cleaning products such as soaps and detergents (Arana-Bravo, 2021).

Everything related to the production of sugarcane and its derivatives is of interest, as competition for customer satisfaction, product quality, production efficiency, and the revenue generated influence their profitability. The competitiveness analyzed from the managerial perspective, is the action that develops and it impels to the companies to be better and more profitable. Knowing all the parameters that give or they generate value in the company, it is the essence of a competitive company (Lara-Manjarrez & Sánchez-Gutiérrez, 2021). For all him before exposed you dearrolla like objective: to carry out improvements in the administration integrated to the chain of value of the alcohol at the "Héctor Molina Riaño" Distillery UEB.

MATERIALS AND METHODS

The research focused on analyzing the value chain at the "Héctor Molina Riaño" Distillery UEB (Beauty and Beverage Industry) to increase production quality and business competitiveness. To this end, the methodology employed was both qualitative and quantitative, and included two stages.

The first consisted of a literature review related to the value chain. To this end, a qualitative study was conducted, based on Michael Porter's book, Competitive Advantage: Creating and Sustaining, as it is considered a benchmark for the theory under evaluation (Porter, 2008). This study also drew on information from the qualitative methodology of the systemic literature review proposed by Hochrein et al. (2015). The second involved an adaptation of the nine-link analysis tool proposed by González et al. (2018), which included specific aspects related to the sugar sector. It is important to highlight that the basic tool used in this study is considered valid for application in any productive sector; only modifications in approach are required.

In addition, for the research, an analysis and characterization of the sugarcane (*Saccharum officinarum* L.) value chain was conducted, based on the proposal made by Porter (1985).

Figure 1 shows Porter (1985) graphic representation.

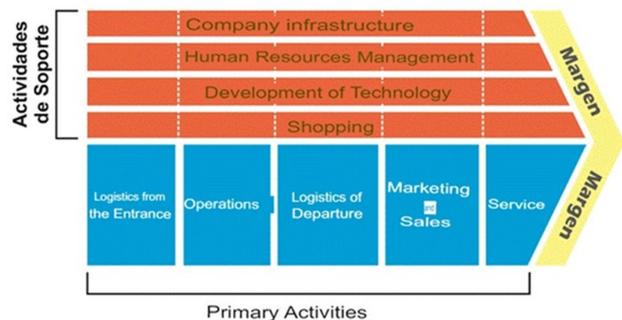


Figure 1. Graphic representation by porter (1985)

A SWOT analysis was also used to identify the entity's strengths, weaknesses, opportunities, and threats (SWOT). An Ishikawa diagram was developed to identify the problem. This diagram is very similar to a fish skeleton. The head represents the problem or effect, and the spine with its bones represents the causes. These causes are subdivided into six main categories, also known as the 3Ms, 5Ms, or 6Ms of quality. In this research, the 3Ms were used: Raw Material, Machinery and Equipment, Measurement.

Description of the Alcohol Technological Process

The image shows a flowchart for the production of alcohol (ethanol) from fermentation (blended), followed by distillation and purification. The path of the main flows can be seen: steam, alcohol, water, and non-condensable gases.

Figure 2 shows the flowchart of the alcohol production process.

Preparation of the Batter

- Batter: Fermented mixture (probably molasses or spirit juice, 22 m³/h at 80°C), which is the raw material.
- Degasser: Removes unwanted gases before entering the wine heater.

Initial heating

- Wine heater: The batter is heated with steam (exact pressure not noted here).
- Steam exchanges heat to raise the temperature of the batter, optimizing alcohol separation.

Distillation

- Kettle: Container where distillation begins. Heated with direct steam (5 psi, 105°C). The internal mixture is partially vaporized.
- Stripper: The generated steam (3.5 psi, 90 °C) is separated to remove impurities.
- The steam (rich in alcohol) passes to the following equipment. The residue can be returned to the process.

Condensation and Purification

- Primary Condenser: Condenses the vapor, separating alcohol and water; some is sent as reflux to the process, improving alcohol concentration.
- Secondary Condenser: Separates again, allowing the escape of non-condensable gases and overhead (light products, such as methanol and unwanted compounds, 150 L/h).
- Reflux is managed to recycle liquids and fine-tune the concentration.

Cooling and Product Collection

- Cooling Water: The condensed alcohol (80 °C) passes through a heat exchanger with refrigerant, cooling it.
- Alcohol Outlet: The final alcohol exits at 2,000 L/h, already cooled and purified.
- Beating: The residue is recirculated or disposed of as vinasse (byproduct).

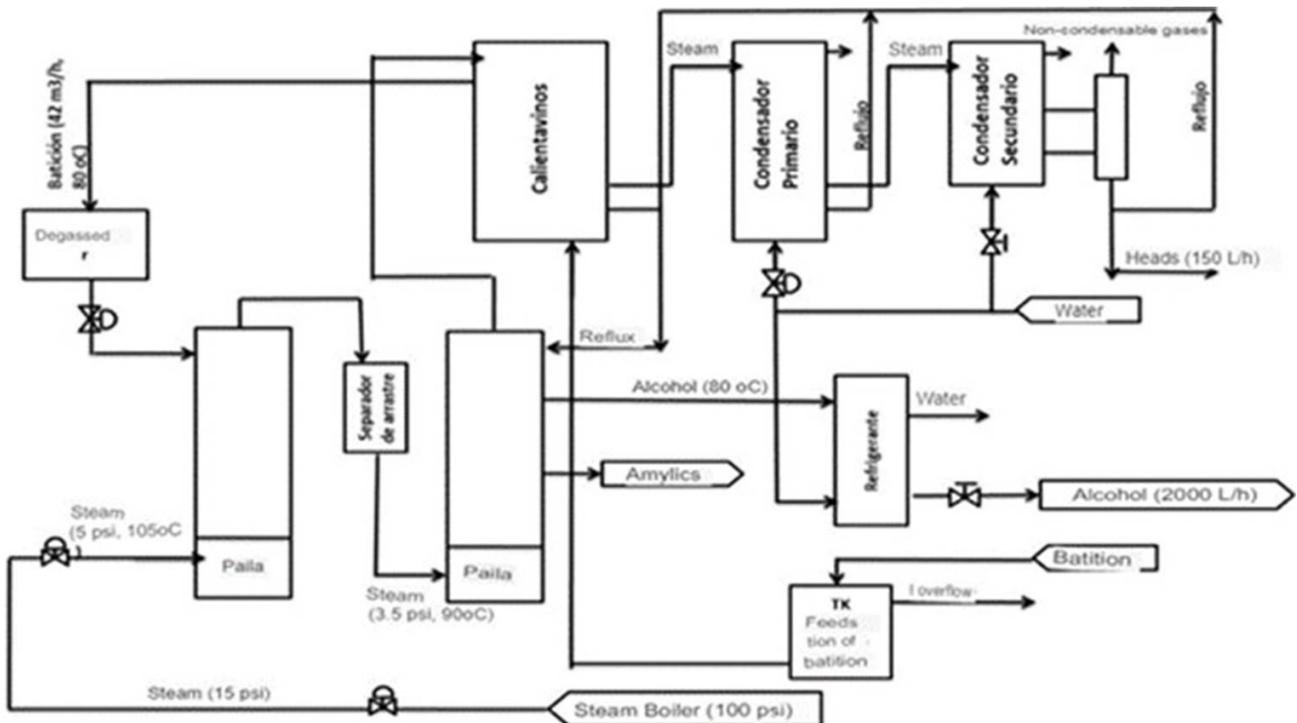


Figure 2. Flowchart of the alcohol production process. Source: Prepared by the authors.

Control and Inputs

- Boiler steam (100 psi): Provides all the steam for heating and distillation, distributed through valves to different points (kettle, wine heater, etc.).
- Water: Used in condensers and to cool the final alcohol.
- Feed tank: Feed tank controls the supply of the beating process.

Products and Byproducts

- Alcohol: Main product, 2000 L/h at the outlet.
- Overhead: Light byproducts, 150 L/h.
- Non-condensable gases: Eliminated in the final stage.
- Stillage or beating process: Process residue, generally reused or treated for disposal.

It is observed that:

The process performs fractional distillation (reflux and condensers in series), increasing the purity of the alcohol.

The use of different steam pressures and temperatures makes the process energy efficient.

Closed and controlled system, with internal recycling (reflux, beating process, and steam recirculation). The image represents the industrial process of ethyl alcohol production through fermentation and distillation, highlighting how the raw material (beating) is heated, distilled, purified, and cooled, allowing for the production of high-purity alcohol, while byproducts and waste are separated.

Competitive advantage is not a product of chance; it is built through hard work and perseverance. This implies constant monitoring of the environment that allows for a proper analysis and diagnosis of both the internal and external environment. This makes it possible to identify the company's true strengths and weaknesses, as well as the real opportunities and threats present in the market.

With this in mind, strategic options can be designed to build a differentiating and lasting competitive advantage. This approach is consistent with that proposed by Calle et al. (2020), who used this methodology to establish work strategies to resolve the most pressing difficulties in a productive entity with characteristics similar to those analyzed in this research.

The Héctor Molina Riaño Distillery (UEB) has experienced deficiencies in the production of sugarcane alcohol, which has impacted the productive and economic stability of the entity. This has caused the sugarcane alcohol value chain to be affected by the instability of production. These aspects have been:

- Deficient supply of raw materials (molasses)
- Obsolete or missing equipment in laboratories
- Lack of automation in the absolute alcohol production process (used in medicine, cosmetics, industry, and fuel)
- Deficiency in the spirit distillation column (incorrect design).

Knowing this, a SWOT analysis can provide insight into the distillery's strengths, weaknesses, threats, and opportunities for improved production performance. This tool is essential for current and future decision-making, as it provides a framework for understanding what is being done well and anything that represents a current or potential challenge. It helped identify which internal and external factors affect the distillery's operations.

The internal factors identified-strengths and weaknesses-are:

- Human resources: team, volunteers, board of directors.
- Physical resources: equipment.
- Finances: sources of income.
- Activities and processes: programs.

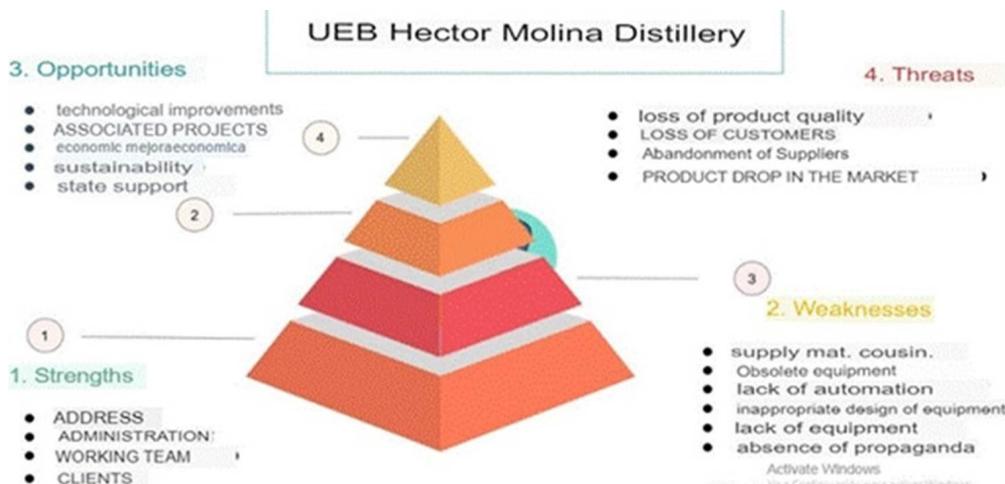


Figure 3. Graphical representation of the results of the SWOT matrix at the UEB. Source: Prepared by the authors

Based on the difficulties encountered, it was found that alcohol production at the "Héctor Molina Riaño" Distillery UEB exhibits deficiencies such as:

- Laboratory equipment for cell counting.
- Failure to receive raw materials.
- Design problems with the spirit distillation column.
- Lack of business marketing (although this does not influence production, it has a significant impact on customer acquisition and sales).

To represent this series of deficiencies and how they affect production, an Ishikawa diagram is presented in Figure 4. This diagram, also known as a cause-and-effect diagram, is based on the premise that every problem has a cause: something wrong with a process.

The analysis identifies three critical axes in the distillery's production delays: 1) Technical deficiencies (a design error in the distillation column that generates intermittent operations), 2) Logistics inefficiency (extensive raw material transfer with high fuel consumption), and 3) Analytical limitations (lack of a spectrophotometer and microscope that affect quality control). These interdependent causes create a negative cycle where technical failures increase operational losses (≈15% production capacity, 8-10% batch rejection) and high costs (30% excess fuel); according to established industry standards. The proposed solution integrates equipment redesign with CFD simulations, logistics optimization using GIS systems, and laboratory modernization to break this systemic loop.

RESULTS AND DISCUSSION

Value chain analysis in the studied entity

At the "Héctor Molina" Distillery, part of the AZCUBA Business Group, there is a production line for sugarcane derivatives, producing alcohol, rum, cattle feed, spirits, and organic fertilizer LEBAME (Source: Héctor Molina Distillery). The first step is to define the primary and secondary activities that influence the process before implementing the Porter model. This model allows for the analysis of the activities that add value to the final product and the identification of opportunities for improvement and competitive advantage.

The primary activities were divided into five categories; although one of them was not implemented, its implementation is suggested. They are described below:

The value chain is divided into two large groups of activities:

a) Primary Activities: These are those directly related to the physical creation of the product, its sale, and after-sales service. These include: Inbound Logistics: This is where the necessary inputs are managed, in this case, raw materials for alcohol production.

It is mentioned that there are six suppliers, facilitating the acquisition of raw materials, but if one is far away, the supply may be affected.

Operations: Transformation of raw materials into finished products (alcohol and byproducts).

It involves maintenance and operation of equipment, intervention of operators, and periodic maintenance.

External Logistics: Storage of the final product (alcohol) and transportation to customers. This is also where sales collections are managed.

Marketing and Sales: Efforts to sell the product. It indicates sales strategies, advertising, offers, and distribution methods/routes, but it also clarifies that these are not implemented (a point for improvement).

Post-Sales Services: Seeks to ensure customer satisfaction by evaluating the product after the sale.

b) Support Activities: These are activities that support the primary activities, increasing their efficiency and effectiveness. Mentioned here:

Company infrastructure: planning, production and resources control, application of standards, financial control, and strategy design.

Human Resources Management: small staff, training of new employees, payment control, and workforce management.

Technological Development: technological innovations and equipment improvements. However, limitations are mentioned here: the need to transform the distillation column, lack of laboratory equipment, and lack of alcohol analysis.

Supply (Purchase of Raw Materials): The purchase of raw materials is highlighted in bold, essential in the alcohol industry as a cornerstone of the production chain.

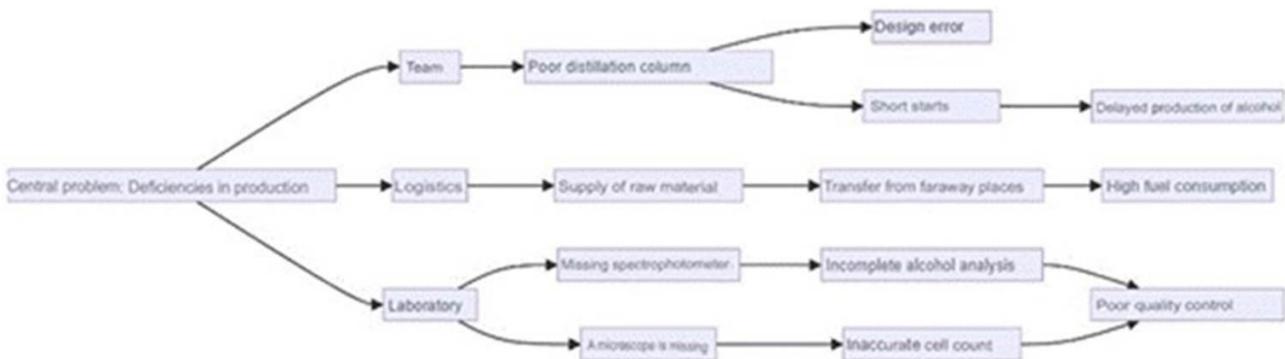


Figure 4. Ishikawa diagram at the Héctor Molina Riaño distillery UEB. Source: prepared by the authors

Margin: This is the profit added by the company throughout the value chain, that is, the difference between the total value perceived by the customer and the total cost of performing the value-added activities.

Applying Porter (1985) graphical representation, the entity would be as shown in figure 5.

The proposal is to analyze the value chain to identify sources of competitive advantage and efficiency.

In this image, the alcohol BEU:

- Integrates all stages: from the purchase of raw materials to after-sales service.
- Has potential weaknesses: vulnerable inbound logistics, technological and laboratory limitations, unimplemented marketing, and the need for ongoing training.
- Relies on secondary activities to support core operations (planning, control, training, innovation).
- The objective is to achieve a margin, that is, value generated above cost, through continuous improvement in all its activities.

Action plan design

To develop the entity's action plan, the opinions of specialists and operators were taken into account, based on the experience and their proposals. The action plan took into account that the time frames are defined as: short-term, from 6 months to 1.5 years; medium-term, from 1.5 to 3 years; and long-term, from 3.5 to 5 years. Since this is a sector that requires inputs that are not dependent on the entity in question, the latter would be the responsibility of country-level executives, as these actions would be considered impossible for the entity's management to implement.

Based on this representation, an action plan was established, which is presented in Table 1.

Based on the problem/action plan analysis, it was decided, in conjunction with the entity's management and with the influence of the government, that the proposed short-term actions would be achieved in a shorter period. Therefore, the problems listed below could be resolved within an 8-month period, with 50% of those identified being considered resolved.

Achievements achieved by completing 50% of the proposed actions:

Molecular sieve automation: Molecular sieve automation was implemented to obtain absolute alcohol. This technology was based on the absorption of water by zeolite beds. The process involves dehydrating the hydrated alcohol using molecular sieves, which eliminated impurities and produced a highly pure product.

Use of combined raw materials: To increase ethanol production, the distillery used combined raw materials, such as filter juice and honey, a strategy that allowed the distillery to operate for more days. According to the literature, grains such as corn, barley, and wheat can also be used as raw material sources, as these grains contain starch, which is converted into fermentable sugars.

Energy modeling and simulation: An energy modeling, simulation, and analysis study was conducted at the Héctor Molina distillery. Six alternatives for energy and environmental improvements were evaluated to optimize its operation. Chemical and microbiological characterization of distillery-related products was achieved, such as:

Saccharomyces cerevisiae cream: contains enzymes, peptides, amino acids, organic acids, and B vitamins, with results indicating that the values are adequate for use in the production of symbiotic additives such as PROBIOLEV®.

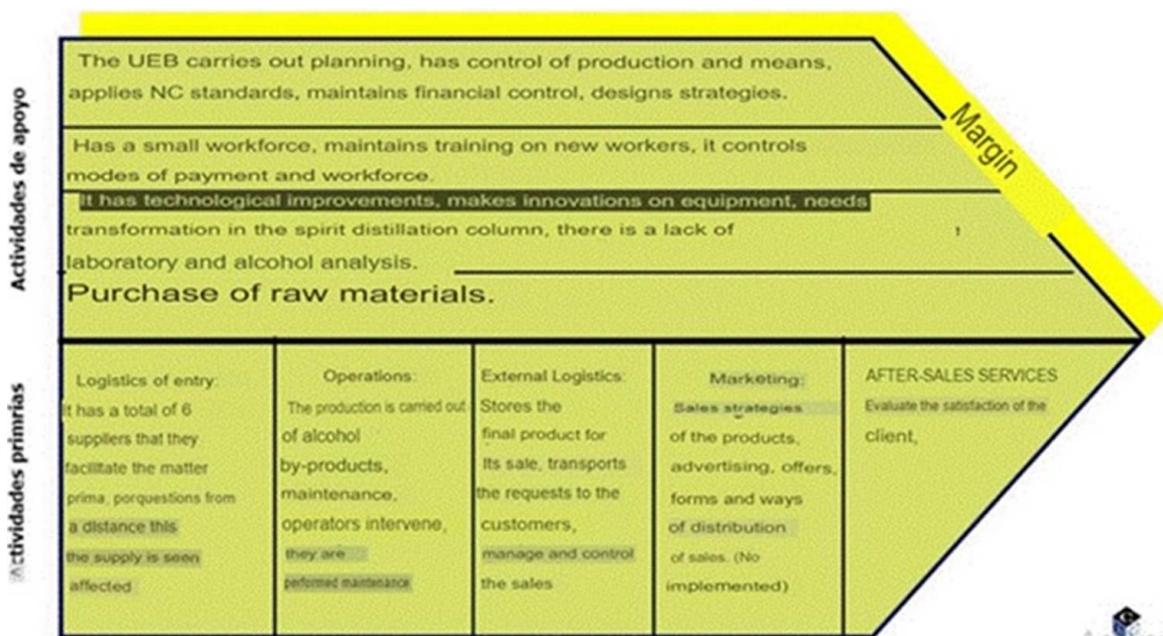


Figure 5. Graphic representation of the alcohol value chain in the UEB according to porter (1985). Source: prepared by the authors

Table 1. Proposed action plan for the UEB

Problem detected	Action	Manager	Term
Supply of raw materials	Attract suppliers closer to the UEB to guarantee uninterrupted supply	Management, Administration, Production Manager	Long
Obsolete equipment	Renew older equipment	Management, Technical Manager	Long
Lack of automation	Implement technological innovation projects (Molecular Sieves)	Management, AZCUBA	Short
Inappropriate equipment design	Restructure the distillation column design	Management, Production Manager, Technical Manager	Short
Lack of equipment	Supply laboratories through partnerships with recognized entities	Management, Administrative Management	Short
Lack of advertising	Create a media and social media outreach program	Management, Administration, Production Manager	Short
Loss of product quality	Verify the use of the most appropriate raw materials for production	Management, Logistics	Short
Loss of customers	Fulfill contracts/orders + conduct customer satisfaction assessments	Management, Logistics	Short
Supplier abandonment	Establish feedback with suppliers to strengthen ties	Management, Production Manager, Economics	Short

Source: own elaboration

Vinasses: are another byproduct of sugarcane distillation. In this case, the vinasses resulting from the production of ethanol and spirits from final molasses at the distillery were studied. Their chemical, physical, and microbiological parameters were analyzed to assess their quality.

The analysis reveals that 55% of the losses arise from interactions between the three axes (equipment, logistics, and laboratory), not from isolated failures. The phased implementation of the proposed plan could recover 92% of production capacity in 24 months, with an estimated ROI of 217%, considering:

- Reduction in technical downtime (from 22 to 4 days/year)
- Optimization of logistics costs (-38%)
- Reduction in quality rejections (from 10% to 1.2%)

This model not only resolves the identified deficiencies but also lays the foundation for circular and resilient production, aligned with SDGs 9 (Industry) and 12 (Responsible Production).

CONCLUSIONS

- The study conducted using the analysis methodology proposed by Porter (1985) and several other authors allowed for a review of the situation within the value chain at the “Héctor Molina Riaño” Distillery UEB. It also shows that competitiveness in the technological production of alcohol is achieved through strategic synergies: operational optimization through automation 4.0, the adoption of circular biorefineries to utilize byproducts, and the use of predictive artificial intelligence in fermentation processes.

- The value chain of the “Héctor Molina Riaño” Distillery UEB is characterized according to Porter's (1985) methodology, and problems were identified between the (equipment-logistics-laboratory) components. The interaction between technical, logistical, and quality control failures creates a systemic risk scenario that requires integrated interventions.
- An action plan consisting of 10 tasks was proposed, 80% of which were expected to be completed in a short period of time. 50% of these tasks were completed in less time (eight months).

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