IOSR Journal of Research & Method in Education (IOSR-JRME)
e-ISSN: 2320–7388, p- ISSN: 2320-737x Volume 14, Issue 5 Ser. 6 (Sept. – Oct. 2024), 05-13
www.iosrjournals.org

Brewing Bioprocess: A Practical View Of Product Analysis And Development Using Brazilian Hops

Pedro Prates Valério; Margarete Aparecida Pereira, Alef Alves Dos Santos; Jefferson Silveira Brandão; Fernando Brandão Barcelos
Federal University Of Minas Gerais (UFMG); Trivento Educação; Uaimii Brewer; Minas Gerais School Of Sommelier; Una University Center

Abstract:
This study focuses on the practical application of bioprocesses in brewing, aiming to enhance student learning through hands-on engagement with real-world industry practices. In collaboration with the "Mundo Hop" farm, which provided high-quality national hops, and the active participation of a master brewer, students gained valuable practical experience in beer production. The project involved the brewing of beer using locally sourced raw materials, followed by comprehensive data collection, analysis, and evaluation of sensory attributes and biochemical transformations. The educational methodology employed a combination of traditional lectures, flipped classrooms, peer instruction, and immersive laboratory activities. This approach aimed to bridge the gap between academic theory and industry practices, fostering critical thinking and problem-solving skills among students. By engaging in the entire brewing process—from ingredient selection to fermentation and sensory analysis—students not only applied theoretical knowledge but also developed practical skills relevant to the brewing industry. The results indicate a significant increase in student engagement and understanding of the brewing process, demonstrating the effectiveness of combining academic learning with industry collaboration. The insights gained from this study underscore the importance of such partnerships in brewing education, highlighting how experiential learning can prepare students for future careers in the brewing sector. This methodology serves as a valuable model for enhancing educational outcomes in brewing sciences and strengthening the connection between academia and industry.
Keywords: *Bioprocesses, Biochemistry, Brazilian Hops, Education..*

Date of Submission: 17-10-2024 Date of Acceptance: 27-10-2024

I. Introduction

According to Decree No. 6,871, from 2009, beer is defined as the beverage resulting from the fermentation of malted barley wort or malt extract, using brewer's yeast. During the production process, the wort is boiled and hops or hop extract is added, with a portion of the malted barley or malt extract being partially replaced by brewing adjuncts (BRAZIL, 2009). Although this definition simplifies the beer production process, Young and Lewis (2002) argue that if beer were invented today, its complex process might even be considered an inappropriate technology.

Despite the remarkable technological advancements distinguishing ancient breweries from modern high-tech facilities, the traditional beer-making process remains unchanged. This process is characterized by precise time and temperature intervals, which play crucial roles in the activation, deactivation, and denaturation of enzymes responsible for malting, starch release from malt, aroma and flavor development during hopping, as well as alcohol and carbon dioxide production during fermentation. Understanding the brewing process requires mastery of fundamental scientific concepts, such as proteins, enzymes, pH, conductivity, and heat transfer, among others (YOUNG; LEWIS, 2001; PIRES; BRÁNYIK, 2015).

Given this complexity, the brewing process can be presented as a multidisciplinary tool to explore and discuss concepts in biochemistry, thermodynamics, analytical chemistry, unit operations, and quality control, contributing to the development of skills and competencies as defined by the National Curriculum Guidelines (DCNs) for engineering undergraduate programs.

The National Curriculum Guidelines (DCNs) for engineering undergraduate programs establish graduates' expected profile and competencies, including the ability to recognize users' needs and formulate, analyze, and solve engineering problems creatively. To develop these competencies, Opinion No. 1 of 2019 by the National Education Council (CNE) and the Higher Education Chamber (CES) emphasizes the importance of teaching and learning practices that promote dynamism and autonomy, including active methodologies, problem-solving of real-world issues, and the integration of interdisciplinary knowledge (BRAZIL, 2019a; BRAZIL, 2019b).

In this study, a curriculum approach centered on components related to the educational path in Chemical Engineering was developed, emphasizing Bioprocesses and Beer Production, highlighting the value of using domestic raw materials and the integration of theory and practice in product analysis and development. To optimize the learning of bioprocesses, a diversified methodology was adopted, including lectures, flipped classrooms, peer learning, practical laboratory activities, project development, case studies, and real-world problem-solving.

Additionally, a closer connection between academia and the world of employability was fostered by bringing into the laboratory a previously characterized national hop, provided by a local farm, and by having the presence and on-site supervision of a master brewer from a partner industry, as well as a specialist in the cultivation and production of domestic raw materials. Along with the production process, methodologies for collecting, analyzing, and discussing sensory data related to the finished product were incorporated.

II. Bibliographic Review

Professional Profile in the 21st Century and Its Relation to the Brazilian´s National Curricular Guidelines for Undergraduate Engineering Programs"

Education in the information society not only facilitates access to knowledge-based training but also must promote the development of essential skills such as the ability to select and process information, autonomy, decision-making, versatility, and flexibility (FLECHA; TORTAJADA, 2009). In this context, it is also necessary to highlight the importance of learners developing metacognition and self-regulation, with a focus on the awareness of "learning to learn."

To meet the demands of the current and future employability landscape, it is worth noting that the World Economic Forum (WEF) emphasizes the need to build educational systems with curricula adapted to the 21st century, along with the consistent delivery of widely accessible instruction. This provides a solid foundation for a lifetime of adaptation and the development of new skills, in line with the expectation of pursuing and accessing lifelong learning.

Thus, the training of future professionals requires attention to changes in the labor market by establishing flexible curricula that integrate the needs of employers with the necessary technical-scientific and socio-emotional training required to solve problems. Table 1 presents the top 15 skills projected for 2025.

The New National Curriculum Guidelines for engineering courses are being implemented in Brazil in response to new market demands, aiming to modernize engineering programs. These guidelines emphasize competency-based education, the adoption of innovative methodologies, the promotion of institutional policies focused on innovation, the strengthening of learning process management, the intensification of partnerships with different organizations, and the enhancement of faculty development (BRASIL, 2019a).

Pedagogical Applications: General Elucidation on the Beer Manufacturing Process

General Aspects of the Process:

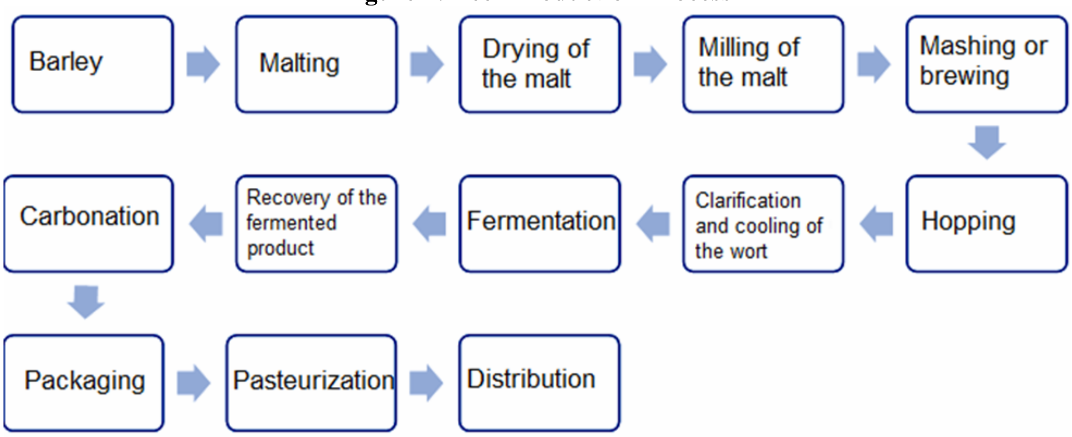
In more general terms, the beer production process begins with the selection of high-quality raw materials aligned with the purpose of the process, aiming to achieve the desired product. Among the initial phases, following this essential selection and definition, the extraction and breakdown of carbohydrates from malted grains—usually barley—can be highlighted to obtain a solution rich in sugars, including fermentable sugars, known as wort. In addition to sugars, the wort contains the nutrients necessary for the anaerobic growth of yeast (BASTOS, 2010; VENTURINI-FILHO, 2011; D'AVILA et al., 2012).

The stages following wort production involve principles of heat exchange, the addition (various hopping methodologies, among other potentials), separation (e.g., filtration and whirlpool), and clarification, with physical, chemical, and biochemical changes that complement the relevance of enzymatic stages, fermentation, among others. To elucidate, a specific section on hops is presented later, highlighting some of its particularities relevant to this study.

Moving forward with a more generalized view, especially emphasizing the yeast activation and growth stage, the simpler sugars present in the wort are then available for microbial consumption, enabling the alcoholic fermentation stage, which results in the production of alcohol, CO2, and aromatic metabolic by-products (WILLAERT, 2007; D'AVILA et al., 2012).

Figure 1 illustrates some of the main stages of the beer transformation and production process, from malting to distribution.

Figure 1: Beer Production Process



Source: Harrison; Nummer, 2000; Young; Lewis, 2001; Willaert, 2007

Preliminary Stage for Obtaining Wort: Malting and Milling of Grains

For a comprehensive understanding, it is crucial to highlight the significant modifications that occur during the malting process of barley, resulting in the activation of biochemical and enzymatic physiology. During barley malting, the grain undergoes controlled germination, stimulating the development of endogenous enzymes. These enzymes act on substrates such as starch, proteins, lipids, and other grain components. Malting requires strict control, with direct and potential impacts on grain quality. In this context, the structure of malt is often similar to that of the grain's endosperm, preserving nutrient reserves, including sugars and starches, which are essential for the fermentation stage (HARRISON; NUMMER, 2000; KOK et al., 2018).

At the beginning of the malting process, barley grains are submerged in water at a temperature between 10°C and 15°C, enabling germination at temperatures between 15°C and 20°C for a period of 3 to 7 days. After this period, the germinated seed is dried under controlled temperature and time conditions to preserve the nutrients necessary for fermentation. From an operational standpoint, the ideal stage to stop germination is when maximum modification of the endosperm occurs with minimal consumption of the available nutrients (HARRISON; NUMMER, 2000; PIRES; BRÁNYIK, 2015; KOK et al., 2018).

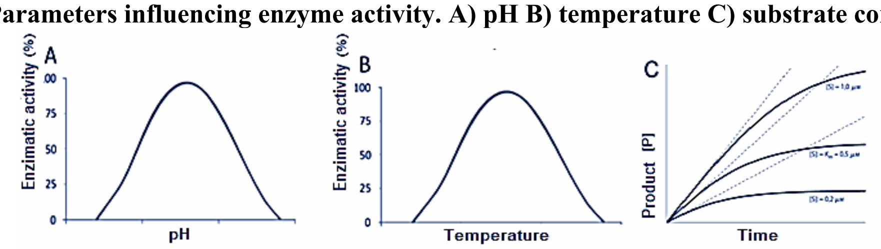
Regarding the malting process, its execution highlights two main objectives: Controlled particle size reduction with maximum uniformity. The adequacy and uniformity of particles aim to increase the surface area for enzyme activity. On one hand, the finer the particles, the better the breakdown of malt into fermentable sugars and assimilable nitrogen compounds. However, it is important to note that malt grain milling, whether in roller or hammer mills, should be performed to preserve as much of the malt husk as possible. Preserving the malt husk is essential to facilitate wort separation and clarification, and to minimize the extraction of tannins and other undesirable components during mashing (LEWIS; YOUNG, 2001; PIRES; BRÁNYIK, 2015; KOK et al., 2018).

The milled product, also known as grist, is then mixed with water and heated during mashing. This process allows the starch granules to gelatinize and become more accessible to the endogenous malt enzymes, activated during the malting stage, including α-amylase, β-amylase, α-glucosidase, dextrinase, among others (KOK et al., 2018; HORNINK, 2022).

Enzymatic Actions: A General Overview

During the enzymatic control stage, considering that the starch granules have been gelatinized and the enzymes are naturally present, it is crucial to control temperature, pH, and the concentration of extracted substrates. Altering these parameters can change the reaction rate, directly impacting the final quality and characteristics of the products. Figure 2 illustrates some of the key parameters that influence enzymatic activity (MONTEIRO; SILVA, 2000; NELSON; COX, 2014).

Figure 2: Parameters influencing enzyme activity. A) pH B) temperature C) substrate concentration



Source: MONTEIRO; SILVA, 2000; NELSON; COX, 2014

The effects caused by temperature variation in the wort are detailed in Table 2. Lower temperatures (35–40 °C) allow for extensive degradation of β-glucans, promoting wort separation and beer clarification. Proteolytic degradation begins at around 45 °C and continues until approximately 55 °C when the maximum activity of proteolytic enzymes occurs. In general, resting periods above 60 °C are the most critical for mashing. In this temperature range, most of the extract is dissolved, and about 80% of the fermentable sugars are produced, considering enzymatic hydrolysis that also includes α and β-amylases, as well as limit-dextrinase, with secondary action from other amylolytics. Between 70 and 72 °C, the formation of glycoproteins occurs, which are important for the foam stability of the beer. The mash-out usually takes place above 72 °C, involving enzymatic inactivation (FIX, 1999; LEWIS; YOUNG, 2001).

When the conversion of starch is complete, the wort is separated from the spent grains; however, a residual extract may remain that needs to be recovered to achieve maximum efficiency. To remove this residue, the grains can be washed (sprayed) with hot water (FIX, 1999). After separating the residual solids, the sugary liquid is boiled with hops, possibly applying different methodologies and techniques of hopping.

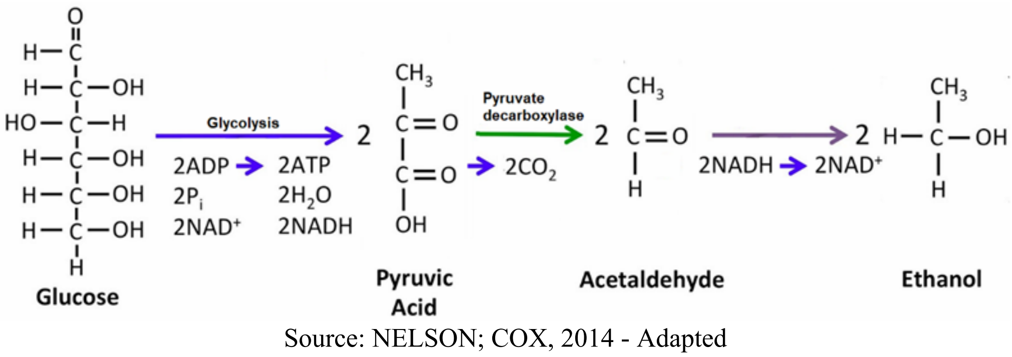
In general, the entire process takes about 90 to 120 minutes. Therefore, the boiling process of the wort involves processes that include: the inactivation of enzymes, sterilization, precipitation of proteins, evaporation of water and undesirable volatiles, isomerization of α-acids from hops, and even the formation of flavor compounds through the Maillard reaction. After the precipitation of proteins, the wort is cooled and aerated before the yeast inoculation stage to start the fermentation process (DURELLO; SILVA; BOGUSZ JUNIOR, 2019; FIX, 1999; PIRES; BRÁNYIK, 2015).

Alcoholic Fermentation: An Objective Approach

The slowest stage of the process tends to be the fermentation phase. During this phase, yeast cells, whether Lager or Ale, already activated and free in suspension (such as S. cerevisiae, S. uvarum, and S. pastorianus), ferment the wort in batch-operated reactors without agitation, maintaining the temperature efficiently controlled to avoid variations greater than 1 to 2 °C. The growth and multiplication of these organisms are closely linked to the metabolic processes that produce ethanol, carbon dioxide, and other metabolic products such as esters (ethyl acetate, isoamyl acetate, n-propyl acetate), acids (acetic, propionic), and higher alcohols (1-propanol, 2-methyl-1-propanol, 2-methyl-1-butanol, and 3-methyl-1-butanol), which contribute to the flavor of the different variations of final products (LEWIS; YOUNG, 2001; REBELLO, 2009).

Biochemically, as described by NELSON and COX (2014), yeasts and other microorganisms ferment glucose into ethanol and CO2 to obtain energy through ATP formation. For a better understanding, ethanol, and CO2 are metabolites of ethanolic fermentation, and the general equation is described in the following Equation 1.

Typically, the fermentation process is divided into two stages: the primary fermentation, responsible for the formation of ethanol, producing a "green beer," followed by a slower process at lower temperatures and with smaller amounts of yeast. This second stage is called secondary fermentation. Finally, the beer may be matured to develop its sensory characteristics, including what can popularly be defined as rounding out its sensory traits (LEWIS; YOUNG, 2001).



Source: NELSON; COX, 2014 - Adapted

Given the processes described above, the brewing process offers various opportunities for the application and development of pedagogical activities aimed at training professionals capable of meeting the demand presented in regional and national contexts, considering the contemporary job market and the rapidly growing brewing industry.

Brazil is the third-largest producer in the world, with 15.4 billion liters, and has 1,549 establishments registered with the Ministry of Agriculture, Livestock, and Supply (MAPA), showing a 12% increase in 2021 (BRASIL, 2022; Sindicerv, 2023). These pedagogical activities aim to develop competencies, skills, and attitudes to empower learners to evaluate results, enzymatic processes, the composition and structure of present enzymes, drying curves of the produced malt, monitoring of fermentation, and quality and sensory analysis of the final product.

Quality of Raw Materials: Focus on National Hops

In the national landscape, the topic of hops is gaining prominence. Until the mid-2010s, the idea of producing beer with Brazilian hops seemed unattainable. However, in 2016, the first harvest of Cascade hops was recorded on Brazilian soil (ALMEIDA; CONTO, 2024).

For a long time, various studies indicated that this plant only thrived in climates adverse to Brazil, such as cooler temperatures and long exposures to sunlight. However, as noted by Almeida and Conto (2024), it is evident that hops are adapting to the Brazilian climate, as demonstrated by the continuous improvement of their physicochemical properties with each new harvest, including increased alpha acids and essential oils.

In beer production, certain characteristics of hops stand out, directly influencing the sensory properties of the beverage. According to Hieronymus (2020), alpha acids undergo isomerization when in contact with wort at temperatures of 82 °C and above. This process results in the conversion of alpha acids into iso-alpha acids, which are responsible for the bitterness of beer. It is worth noting that the higher the wort temperature, the greater the conversion rate of alpha acids (HIERONYMUS, 2020).

On the other hand, essential oils are the main agents responsible for the aroma and flavor of beer. Therefore, practices such as late hopping additions to the beer wort are employed to extract these oils. Considering that essential oils are volatile, their evaporation occurs at higher temperatures during the addition to the wort. Late additions can be made at different points in production, such as at the end of boiling, during the whirlpool, or even during fermentation and maturation phases using the dry-hopping technique. Thus, it is observed that Brazilian hops are fully compatible with beer production techniques and are deliberately explored to enhance the physicochemical characteristics of the plant. In this context, the development and production of recipes for various styles become viable, as well as the exploration of a variety of experiences related to the bitterness, flavor, and aroma of beer (MARQUES et al., 2023).

III. Methodology

Pedagogical Strategies and the Evaluation Process

The accelerated production and distribution of knowledge require individuals to remain constantly informed and updated (lifelong learning) and to be capable of acting in uncertain scenarios by absorbing and proposing innovative solutions. In this context, we adopted Kolb's idea: Knowledge is generated through the transformation of experience (ENAP, 2015). Thus, the learning strategies were based on flipped classrooms, peer instruction, laboratory classes, project development, case studies, and real problem-solving—providing a form for recording student perceptions, enabling a more precise understanding of their experiences.

The evaluation process focused on the progressive monitoring of the brewery project proposal and on proposed process improvements based on the biochemical reactions present in the production.

Development and Elaboration of Content

Table 3 presents part of the developed and already applied syllabus, highlighting the target audience, objectives, skills, and competencies associated with it.

Beer Production: The use of Brazilian Raw Material (Hops)

The practical application of the concepts described in the Curriculum Plan, which includes the developed content, generating topics, understanding, and performance goals, was enhanced in the effective production of a beer product, specifically in the Cream Ale style. This style, of American origin, was attributed to the late 19th century as a variation of the Pilsner style. It is noteworthy that the hops used in production were supplied by the "Mundo Hop" farm and are of the Triumph variety, which is typically grown in Brazil. During the production process, we had the on-site presence of a master brewer, a professional from a partner industry, as well as a specialist in the cultivation and production of national raw materials.

Sensory Evaluation

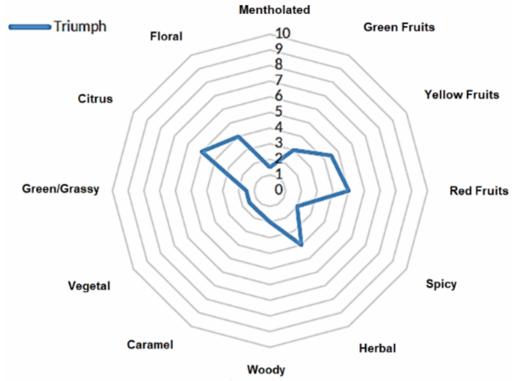
According to the definition by the Brazilian Association of Technical Standards (ABNT), sensory analysis can be understood as the scientific discipline used to evoke, analyze, measure, and interpret the reactions to the characteristics of foods and materials as perceived by the senses: smell, sight, touch, taste, and hearing (ABNT, 1993). The applied sensory methodology combined descriptive tests, which elucidate the main points of difference between the studied products and their intensities, and affective tests, which aim to determine whether the product is accepted or preferred by the consumer (HEYMANN; EBELLER, 2017).

IV. Results

Pelletized National Hops: Main Physicochemical Characteristics

The national hops of the Triumph variety (planted in Matheus Leme, MG), from the 05/2023 harvest, were supplied by the partner farm "Mundo Hop." The aroma of the hops in their natural, pelletized state was evaluated from macerated pellets through olfactory sensory evaluation using the Hand-Rub method - Barth-Haas/Haas. The perception scale, in a radar chart, can be seen in Figure 3.

Figure 3: Aroma perception scale in spider chart – Triumph Hops



Source: the authors

In its primary composition, the following quantitative values can be highlighted: Total alpha acids (%) = 7.52 ±0.02; Total beta acids (%) = 3.05 ±0.14; Total essential oils (mL/100g) = 0.77 ±0.05; Moisture (%) = 12.08 ±0.04.

It is worth noting that the essential oils in hops are responsible for the aroma of beer. Due to the volatility of these oils, the aim is to add them closer to the end of the boiling process to enhance their aromatic presence in the final products. The resins are divided into alpha acids (α-acids) and beta acids (β-acids).

Regarding the total essential oil composition in the hops used, the following percentage of the main compounds is mentioned: Alpha-pinene 0.59%, Beta-pinene 0.52%, Myrcene 52.29%, D-limonene 0.52%, Linalool 0.49%, Citronellol 0.30%, Geranyl acetate 0.64%, Trans-caryophyllene 6.76%, Alpha-humulene 21.79%, Trans-farnesene 0.63%, Phytol 1.66%, Alpha-terpineol n.d., Geraniol n.d., Others 13.80%.

Sensory Results: Final Product

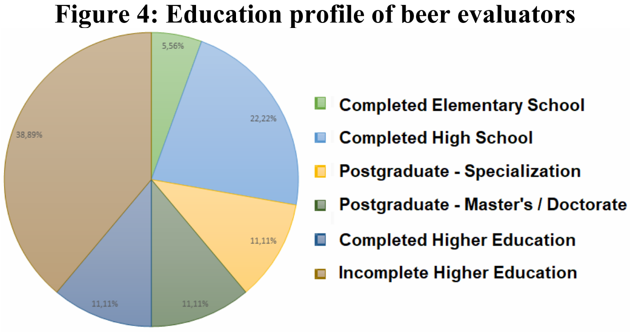
The produced beer was evaluated by 18 people, with 56% male and 44% female, representing different educational backgrounds, as shown in Figure 4.

The highest percentage of individuals with incomplete higher education is due to the participation of engineering students invited to take part in the evaluation process.

The sensory evaluation is presented in Figure 5 (a, b, c, d). Respondents were instructed on each of the concepts, which are detailed in the caption of each figure.

The aroma evaluation of the beer is of utmost importance, as aroma is one of the main factors contributing to the sensory experience and the overall perception of the drink's quality. Aroma is the consumer's first contact with the product, which can create either a positive or negative expectation. This parameter was evaluated on a scale from 0 to 12. From scores the distribution that can be observed, the values ranged from 7 to 12, with an average of 10.5 and a standard deviation of 1.4. Some evaluators noted fruity aromas, while others either did not perceive the aroma or identified the aroma of the hops used.

Figure 4: Education profile of beer evaluators



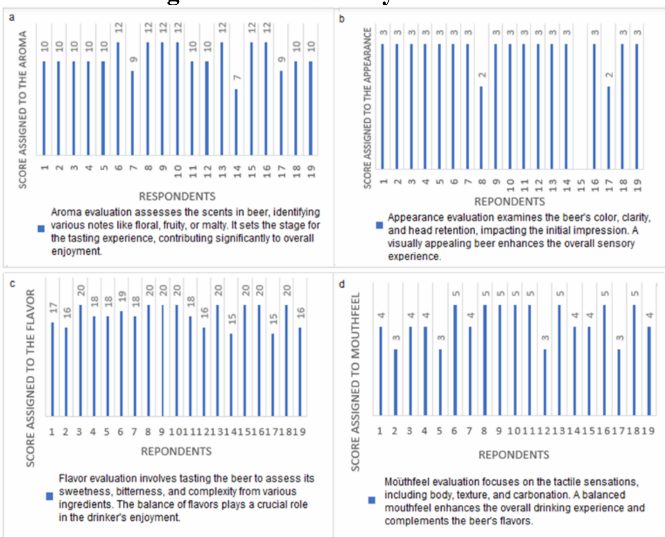
Source: the authors

The appearance of the beer is evaluated based on color, clarity, foam color, foam texture, and foam retention time. It is not merely an aesthetic aspect but an indicator of the beer's quality and the production process.

The appearance was scored between 0 and 3 points. As shown in Figure 5, 16 evaluators (84%) assigned a score of 3 for appearance, while the others did not evaluate or assigned a score of 2. The average score for this parameter was 2.9, with a standard deviation of 0.3. Evaluators noted the presence of turbidity, which may be due to issues in the filtration process or the removal of the trub. The foam was assessed as stable. Despite the observed turbidity, the presence of suspended materials did not affect the beer's flavor and mouthfeel, as shown.

The flavor of the beer is one of the most complex and essential aspects of sensory evaluation and involves an interaction of ingredients (malt, hops, yeast, and additives such as fruits and honey), manufacturing processes, and storage conditions. The flavor can be broken down into several components that contribute to the overall tasting experience. The flavor was evaluated on a scale from 0 to 20, with an average score of 18.2 and a standard deviation of 1.9. The beer was rated as sweet with a slight bitterness.

Figure 5: The Sensory Evaluation

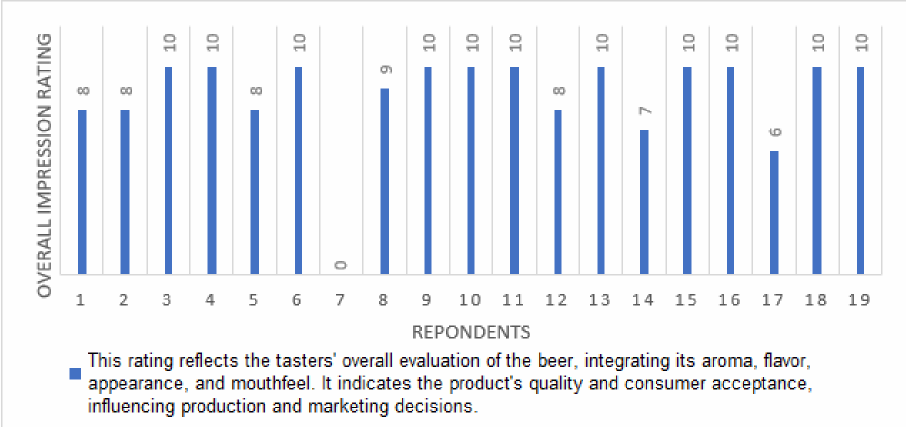


Source: the authors

Mouthfeel is an essential component in the sensory evaluation of beer and refers to how the beer physically interacts with the mouth and tongue. Mouthfeel includes various characteristics that collectively contribute to the overall tasting experience. Here are the main aspects of mouthfeel in beer: carbonation, body, astringency, among others. This parameter was evaluated on a scale from 0 to 5, with an average score of 4.2 and a standard deviation of 0.8. The mouthfeel was described by some evaluators as light and velvety. However, one evaluator judged the creaminess as excessive and tiring.

The overall impression was evaluated on a scale from 0 to 10, reflected by Figure 6. The results indicate an excellent overall impression, with an average score of 9.1 and a standard deviation of 1.3. Evaluators described the beer as refreshing, with pleasant aromas and flavors.

Figure 6: General impression



Source: the authors

V. Conclusions

The development of the proposal, based on the curricular components related to the educational path in Chemical Engineering, focusing on Bioprocesses and Beer Production, using national raw materials such as hops, allowed for an integration of theory and practice, culminating in the creation of a concrete product. The methodological convergence, which included lectures, flipped classroom sessions, peer instructions, laboratory classes, project development, case studies, and solving real problems, was perceived by the students as a facilitator of learning. This study promoted integration between the university and the workforce, with the presence and on-site guidance of a master brewer from a partner industry, as well as a specialist in the cultivation and use of national raw materials. The collection, analysis, and discussion of sensory data related to the beer produced as a finished product allowed for quantitative insights into the organoleptic characteristics associated with the quality of the final product produced by the students, using national hops and understanding the biochemical transformations involved.

The teaching strategy employed enabled project development, with direct student involvement, allowing for questioning at different stages and tasks. This significantly increased engagement in the classes and reflected in the meaningfulness of learning for all involved. It is important to note that, with an increasingly demanding job market, the development of skills and competencies for future chemical engineers has become a challenge for educational institutions.

In this context, the implementation of teaching strategies aimed at mobilizing knowledge, increasing engagement, and intentionality should involve the use of real, tangible, and applicable industrial processes in schools. The production of beer, using exclusively national raw materials, emerges as a suggestion for future projects. This approach not only stimulates the expansion of an increasingly integrated production chain but also contributes to strengthening the agronomic and industrial culture of the country.

References

[1] Abnt, Associação Brasileira De Normas Técnicas. Análise Sensorial Dos Alimentos E Bebidas. Terminologia – Nbr 12806. São Paulo: Abnt, 1993

[2] Almeida, Aline Da Rosa; Conto, Leilane Costa De. Lúpulo No Brasil: Uma Cultura Promissora Em Ascensão. Food Science Today, Florianópolis, V. 3, N. 1, P. 1-6, Jan. 2024.

[3] Bastos, R. G. Tecnologia Das Fermentações: Fundamentos De Bioprocessos. São Paulo: Fscar. 2010.

[4] Brasil A. Conselho Nacional De Educação/Câmara De Educação Superior. Parecer 01/2019: Diretrizes Curriculares Nacionais Do Curso De Graduação Em Engenharia. Brasília, 2019. 41 P.

[5] Brasil B. Resolução Nº 2, De 24 De Abril De 2019. Institui As Diretrizes Curriculares Nacionais Do Curso De Graduação Em Engenharia. Diretrizes Curriculares Nacionais Do Curso De Graduação Em Engenharia.. Brasília, Df, 24 Abr. 2019. P. 1-6.

[6] Brasil. Dispõe Sobre A Padronização, A Classificação, O Registro, A Inspeção, A Produção E A Fiscalização De Bebidas. Decreto 6871. Brasília.

[7] Brasil. Ministério Da Agricultura, Pecuária E Abastecimento. Anuário Da Cerveja 2021. Brasília: Mapa, 2022. 36 P.

[8] Centro Federal De Educação Tecnológica De Minas Gerais. Comparação Entre As Diretrizes Novas E Antigas Dos Cursos De Engenharia. 2019.

[9] D'avila, Roseane Et Al. Adjuntos Utilizados Para Produção De Cerveja: Características E Aplicações. Estudos Tecnológicos Em Engenharia, [S.L.], V. 8, N. 2, P. 60-68, 31 Dez. 2012. Unisinos - Universidade Do Vale Do Rio Dos Sinos. Http://Dx.Doi.Org/10.4013/Ete.2012.82.03.

[10] Durello, Renato; Silva, Lucas; Bogusz Junior, Stanislau. Química Do Lúpulo. Química Nova, [S.L.], P. 900-919, Ago. 2019. Sociedade Brasileira De Quimica (Sbq). Http://Dx.Doi.Org/10.21577/0100-4042.20170412.

[11] Flecha, Rámon; Tortajada, Iolanda. Desafios E Saídas Na Entrada Do Século Xxi. In: Imbernon, Franscisco (Org.). A Educação No Século Xxi: Os Desafios Do Futuro Imediato. Porto Alegre: Artmed, 2008. Cap. 1. P. 21-36.

[12] Fix, George. Principles Of Brewing Science: A Study Of Serious Brewing Issue. 2. Ed. Usa: Brewers Publications, 1999. 250 P.

[13] Harrison, Mark A.; Nummer, Brian. Bee/Brewing. In: Lederberg, Joshua (Ed.). Encyclopedia Of Microbiology. 2. Ed. Londres: Academic Press, 2000. P. 412-422.

[14] Heymann. H.; Ebeler, E. S. Sensory And Instrumental Evaluation Of Alcoholic Beverages. 1 Ed., Cambridge: Academic Press, 2017. 280 P.
[15] Hieronymus, Stan. Lúpulo: Guia Prático Para O Aroma, Amargor E Cultivo De Lúpulos. 2. Ed. Belo Horizonte: Editora Krater, 2020.
[16] Hornink, Gabriel Gerber. Princípios Da Produção Cervejeira E As Enzimas Na Mosturação. Alfenas: Unifal, 2022. 96 P.
[17] Kok, Yee Jiun , Et Al. Brewing With Malted Barley Or Raw Barley: What Makes The Difference In The Processes? Applied Microbiology And Biotechnology, [S.L.], V. 103, N. 3, P. 1059-1067, 4 Dez. 2018. Springer Science And Business Media Llc. Http://Dx.Doi.Org/10.1007/S00253-018-9537-9.
[18] Marques, Samuel P. D.; Trevisana, Maria T. S.; Owena, Robert W.; Silva, Ana M. A.; Nascimento, Francisco M. G.; Lima, Francisca S. S.; Lima, Thales C.; Brito, Edy S. De; Magalhães, Hilton C. R; Silva, Francisco L. F. Da. Avaliação Quantitativa De Ácidos Amargos, Xanthohumol E Óleos Essenciais Presentes Em Flores De Diferentes Cultivares De Humulus Lupulus L. Produzidas Na Região Nordeste Do Brasil. Química Nova, São Paulo, V. 47, N. 2, P. 1-12, Ago. 2023.
[19] Monteiro, Valdirene Neves; Silva, Roberto Do Nascimento. Aplicações Industriais Da Biotecnologia Enzimática. Revista Processos Químicos, [S.L.], V. 3, N. 5, P. 9-23, 2 Jan. 2009. Revistas Processos Quimicos. Http://Dx.Doi.Org/10.19142/Rpq.V3i5.83.
[20] Nelson, David L.; Cox, Michael. Princípios De Bioquímica De Lehninger. 6. Ed. Porto Alegra: Artemed, 2014. 1250 P.
[21] Pires, Eduardo; Brányik, Tomáš. Biochemistry Of Beer Fermentation. New York: Springer, 2015. 80 P. (Springerbriefs In Biochemistry And Molecular Biology)
[22] Rebello, F. D. F. P. Produção De Cerveja. Revista Agrogeoambiental, [S. L.], V. 1, N. 3, 2009. Doi: 10.18406/2316-1817v1n32009224
[23] Sindicerv. Sindicato Nacional Da Indústria Da Cerveja. O Setor Em Números. 2023. Disponível Em: Https://Www.Sindicerv.Com.Br/O-Setor-Em-Numeros/. Acesso Em: 04 Abr. 2023.
[24] Venturini-Filho, W. G. Indústria De Bebidas: Inovação, Gestão E Produção. São Paulo: Blucher, 2011.
[25] Young, Tom W.; Lewis, M. J. Brewing. Kluwer Academic/Plenum Publishers, 2001.
[26] Willaert, Ronnie. The Beer Brewing Process:: Wort Production And Beer Fermentation. In: Hui, Y. H. Et Al (Ed.). Handbook Of Food Products Manufacturing. Hoboken: John Wiley & Sons, Inc., 2007. Cap. 20.
[27] World Economic Forum. Education, Skills, And Learning. Disponível Em: Https://Intelligence.Weforum.Org/Topics/A1gb0000000lpffeao. Acesso Em: 20 Abr. 2023.
[28] World Economic Forum. The Future Of Jobs Report 2020. World Economic Forum, 2020. 163 P.

Tables

Table 1 – Key Skills for 2025

Analytical Thinking and Innovation	Resilience, Stress Tolerance, and Flexibility
Active Learning and Learning Strategies	Service Orientation
Reasoning, Problem Solving, and Ideation	Leadership and Social Influence
Complex Problem Solving	Systems Analysis and Evaluation
Emotional Intelligence	Technology Use, Monitoring, and Control
Critical Thinking and Analysis	Persuasion and Negotiation
Problem Solving and User Experience	Technology Design and Programming
Creativity, Originality, and Initiative	

Source: The Future of Jobs Report (WEF, 2020)

Table 2: Modification of the wort during rest at various temperatures

Temperature (°C)	**Effect promoted in the temperature range**
30-40	Liquefaction of grains and activity of β-glucanase
45-55	Activity of β-glucanase
47-52	Activity of proteinase and peptidase
60-65	The activity of β-amylase leads to maltose production
65-72	Activity of α-amylase leading to hydrolysis of starch to dextrins
70-72	Formation of glycoproteins leading to stability and texture qualities of beer foam

Source: Fix, 1999

Table 3 – Curriculum Content, Target Audience, Objectives, Skills, and Competencies

Curriculum Content	*Bioprocesses and Bioreactors* *Microbiological Concepts and Sterilization and Substrates* *Fermentation Processes and Kinetic Fundamentals; Cellular and Population Growth* *Introduction to Brewing: History and Context; Beer and Brazilian Legislation* *Raw Materials and Ingredients: Malt, Hops, Water, Yeast, Adjuncts* *Stages of Beer Production: Mashing, Filtration, Hopping, Boiling, Trub Precipitation, Cooling, Inoculation, Fermentation, Maturation, Filtration, Carbonation, Packaging, Conditioning* *Brewing Technology: Sterilization and Pasteurization* *Industrial Equipment and Layouts* *Beer Production and Practical Applications: Group Production* *Quality Control: Physico-chemical and Sensory Analyses*
Target Audience	Undergraduate and graduate students in chemical and food engineering, as well as related fields and professionals
General Objectives	To develop competencies, skills, and attitudes aimed at enabling the formulation of solutions by analyzing and evaluating methods and tools related to beer production processes.
Specific Objectives	To be able to examine and experiment with sequential stages and unit processes, relating and applying knowledge linked to beer production, including the selection of inputs and adapted

	calculations; to be capable of identifying and applying technical and scientific fundamentals, formulating creative solutions for the brewing industry; to develop skills and competencies related to the application of technologies, considering modifications of state, energy, or composition.
Skills and Competencies	To Apply mathematical, scientific, technological, and instrumental knowledge in the relevant context; Design and conduct experiments, interpret results, conceive and analyze products and processes; Plan and supervise stages and operations, considering systems and projects; Identify and formulate solutions to engineering problems using tools and techniques; Communicate effectively in written, oral, and graphic forms while working in multidisciplinary teams; Assess the impact of engineering activities on social and environmental contexts; Understand and apply professional ethics and responsibility; Evaluate the economic feasibility of engineering projects; Maintain a proactive attitude toward continuous professional development.

Source: The Authors