Production and Characterization of Valhalla Craft Beer in Style Porter Added with Rapadura and Mate Herb

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Craft beer production involves several critical phases, including mashing, boiling, fermentation, and carbonation. The increasing popularity of craft beer in recent decades has revolutionized the global beverage market. This article delves into the history, production methods, and physical-chemical analyses essential for ensuring product quality. Each stage described in this article is based on specific literature, and rigorous laboratory analysis is employed to certify the excellence of the final product. An outstanding characteristic of artisanal beer is its emphasis on quality, authentic flavor, and traditional production techniques. Analyses indicate that craft beers establish a more intimate connection with local cultures and brewing traditions besides offering diversified and complex flavors. This trend suggests a promising future for artisan producers, highlighting the importance of sustainability and innovation in the sector.
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Craft beers stand out from their industrial counterparts due to their meticulous brewing process. The smaller scale of production allows for the use of higher-quality raw materials and the inclusion of regional ingredients, resulting in a drink with an intense and unique flavor profile. Unlike industrial beers, craft beer production follows a longer process, ensuring that fermentation and maturation periods are fully respected without using accelerants.

A significant distinction between craft and industrial beers lies in the malt composition. While industrial beers typically contain 60% malt and 40% other cereals to reduce production costs, craft beers prioritize a higher proportion of malt. This emphasis on malt enhances the beer's flavor and aroma complexities, catering to the preferences of a discerning consumer base [1].

Porter is renowned for its deep, dark color and originates in 18th-century Britain. Interestingly, its name stems from the English port workers who, seeking a richer and more robust beverage, blended various types of beers. However, as manufacturing techniques evolved and roasted malt was introduced, this blending practice gradually fell out of favor. Its medium body, well-balanced bitterness, and low foaming properties characterize Porter. It is distinguished by aromas reminiscent of coffee and chocolate, attributed to its malt composition. The histories of Porter and Stout are closely intertwined; in 19th-century England, more robust and drier beers began to be labeled as stouts. Although initially distinct, the differences between Porter and Stout have become more subtle over time.Nevertheless, the Porter style has experienced a revival. It has branched out into contemporary variations such as Imperial Porter (the standard version), Baltic Porter (a more prosperous and creamier variant), American Porter (noted for its higher hop content), and robust Imperial Porter, featuring a more pronounced alcohol profile and prominent hops [2].

Materials and Methods

The formulation of craft beer containing yerba mate and rapadura was defined using the BeerSmith® software for assistance. The production process followed a specific protocol visually represented in Figure 1 for better understanding. Essential ingredients such as malts, yeasts, and hops were sourced from a reliable supplier, Bahia Malte,

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in Salvador/BA. Specifically, the 1st generation Safale American yeast was utilized, with a 50.28 cells/mL concentration. According to Sleiman and colleagues (2010), first-generation yeasts are those used for the first time, meaning they have not yet been utilized in the wort fermentation process. These yeasts can be reused for this purpose up to six consecutive times.

Local ingredients were procured for the Porter-type craft beer, including yerba mate (Ilex paraguariensis) from Salvador/BA and rapadura from Barreiras/BA. The selected hop variety was Northern Brewer, renowned for its aromatic properties and moderate bitterness potential. However, it is worth noting that it can be substituted with another hop variety, Perle, originally from Germany and introduced in 1934. Perle has a high content of alpha acids and Cohumulone, which are responsible for the bitterness and aroma in beer, with the latter ranging from 27 to 32%. Hops were added during the final wort-boil stage to impart the beer's distinctive aroma.

The malts chosen for this production were Swaen©Ale, GoldSwaer©Red, GoldSwaen©Munich Dark, and BlackSwaen© Chocolate B, all obtained from Bahia Malte, a reputable supplier of inputs for craft brewers in Salvador/BA.

Cleaning of Equipment

Equipment cleaning is a crucial step before starting the brewing process to ensure product quality and minimize the risk of contamination. The equipment was meticulously cleaned using a specific protocol. Initially, it was washed with water at 75°C and detergent to remove dirt or residues. This was followed by cleaning with a 70% alcohol solution to disinfect the surfaces and kill any remaining microbes.

As illustrated in Figure 2, specialized cleaning agents were employed for the heat exchanger. These included detergent, sodium bicarbonate, and a hydrochloric acid solution to thoroughly clean and sanitize the heat exchanger. These cleaning agents help remove stubborn residues, mineral deposits, and microbial contaminants that can affect the quality and safety of the final product. It is important to note that thorough equipment cleaning is essential in the brewing industry to maintain hygiene standards, prevent cross-contamination, and ensure the consistency and quality of the brewed beer [3].

Used Equipment

Figure 3 illustrates the equipment used to produce Valhalla beer: a cauldron for boiling the malt, pipes for transporting fluids, a pump, and a heat exchanger.

Preparation of Craft Beer Added with Yerba Mate and Rapadura

During the production of Valhalla beer, the process begins with grinding the malt and infusing it into 15 liters of mineral water. This step, known

Figure 1. Simulation in BeerSmith® Software.

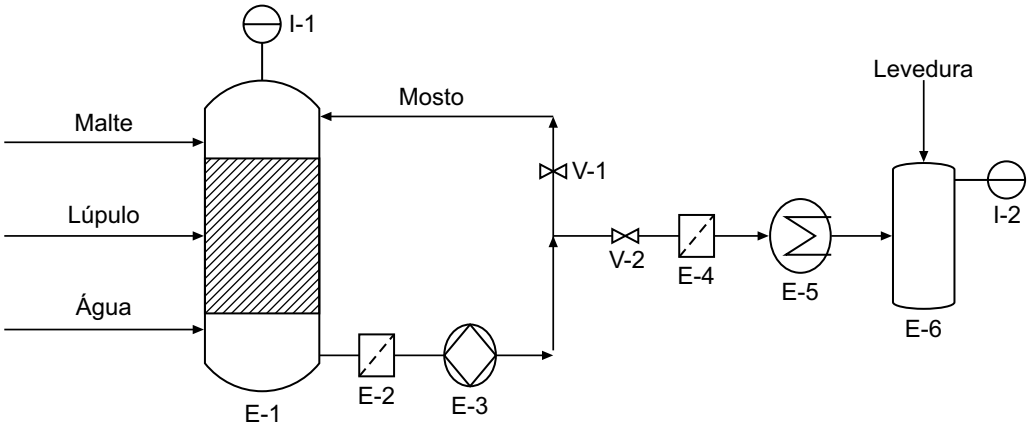
Amt kg	Name	Type	#	%/IBU
2.50 kg	Swaen©Ale (7.1 EBC)	Grain	2	73.5 %
1.0 pkg	Safale American (DCL/Fermentis #US-05) [50.28 mL]	Yeast	7	-
15.50 g	Northern Brewer [8.50 %] - Boil 35.0 min	Hop	6	22.9 IBUs
0.70 kg	GoldSwaen©Red (50.0 EBC)	Grain	3	20.6 %
0.10 kg	GoldSwaen©Munich Dark (145.2 EBC)	Grain	5	2.9 %
10.50 l	Dias D'Avila	Water	1	-
0.10 kg	BlackSwaen©Chocolate B (900.3 EBC)	Grain	4	2.9 %

Figure 2. Team members cleaning the heat exchanger.

Figure 3. Enlarged image of the production process.

as malting, involves converting barley into malted barley, typically at a temperature of 70°C. To efficiently extract sugar from the malt, the grains are washed repeatedly using 3 liters of water. Subsequently, the malt is removed, and the wort is boiled for an hour with the addition of hops. After 45 minutes of boiling, yerba mate and brown sugar, previously diluted in 1 liter of water, are added to the wort. Once the boil is complete, it is crucial to cool the wort rapidly. This is achieved using a heat exchanger (Figure 4), to bring the wort to the ideal fermentation temperature range of 16-22°C. Elevated temperatures can compromise the yeast's viability, making cooling essential. After cooling, the wort is filtered to remove residual solids, and yeast is added to initiate fermentation. This fermentation process involves complex chemical and biochemical reactions and requires precise control. Upon completion of maturation and fermentation, the beer is ready for bottling. For every 600 mL of beer, 5 g of sugar is added before bottling to induce carbonation. In total, 45 bottles of 350 mL were

Figure 4. Valhalla beer production process flowchart.



Caption - Flowchart for the production of Valhalla Beer		
Equipments	**Name**	**Descriptive**
E-1	Reactor	Performing stages of mashing and wort boiling
E-2	Filter	Filtration of the wort for reflux with the pump
E-3	Pump	Conveying the wort to the reflux system or the heat exchanger
E-4	Filter	Filtration of the wort for the fermentation stage
E-5	Heat exchanger	Cooling the wort for the fermentation stage
E-6	Tank	storage tank
I-1	Temperature indicator	Indicator to maintain temperature
I-2	Temperature indicator	Indicator to maintain temperature
V-1	Valves	Valve for wort reflux in the reactor
V-2	Valves	Valve for cooling the wort in the geat exchaner

produced, resulting in 16 liters of beer. The process outlined here serves as the basis for the industrial-scale production of Valhalla beer, adapted from the steps used in experimental production.

Results and Discussion

The craft beer's processing yield was within expected parameters, reaching 84.3%. However, a 15.7% loss was attributed to residual sludge at the bottom of the fermenter and maturator, typically discarded during the process. The recipe's initial volume was 19 liters, but after preparation, it was reduced to 16.017 liters. In the experimental production of beer with yerba mate and brown sugar, the initial wort showed 19.8° Brix, a density of 1.077, and a pH of 5.68. After boiling, the final extract had 24.0° Brix, a density of 1.093, and a pH of 4.54.

Carbonation was found to be satisfactory, as indicated by carbon dioxide microbubbles. This characteristic enhanced the yerba mate's pungency, complementing the hops' balance. The Northern Brewer hops contributed a distinct aroma and bitterness to the product.

The 24° Brix value signifies the concentration of sugars in the must, which is crucial for fermentation and conversion into alcohol, heat, and carbon dioxide until all fermentable substrates are consumed. It is typical to observe a reduction in Brix value as fermentation progresses (Table 1) [4].

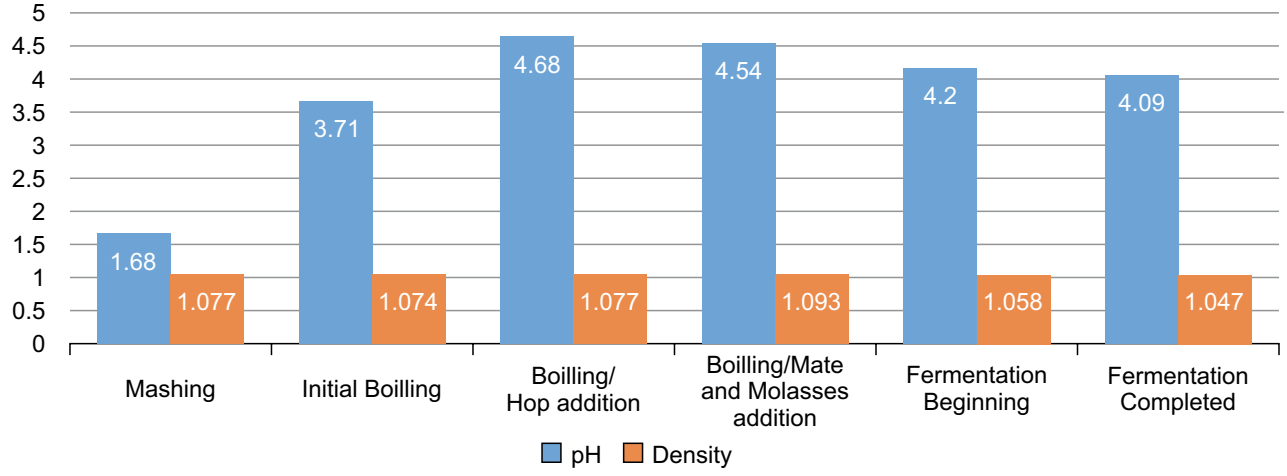
During the boiling process, where starch is extracted from the malt until complete fermentation, the Brix value is reduced from 24° Bx to 12.1 °Bx. This reduction is due to yeast consuming sugars and converting them into alcohol.

Figure 5 presents the pH and density analysis from the start of the manufacturing process to the conclusion of fermentation. The initial pH, recorded as 4.02, complies with the recommended

Table 1. Brix degree values during the process.

Process	Degress Brix (°Bx)
Mashing	19.8 °Bx
Boiling	19.2 °Bx
Boiling/Adding of hops	19.8 °Bx
Boiling addition of malt and molasses	24.0 °Bx
Fermentation/Beginning	15.2 °Bx
Fermentation/Complete	12.1 °Bx

Figure 5. Monitoring of pH and density analyses.



values in the literature for this beer style [5]. Due to biochemical reactions during fermentation, the pH decreased to 0.007. Borzani and colleagues (1983) note that this reduction correlates with the formation of 44 organic acids, including acetic acid, succinic acid, and lactic acid [5]. This value meets the established standards for the beverage [6].

The alcohol content is a crucial characteristic of beer influenced by fermentation. It is during this process that the alcohol level is determined. Therefore, categorizing beer based on its alcohol content is essential (Table 2). The final alcohol content of the beer produced was 8.3% (v/v), which is considered high but consistent with expectations for Porter-type beers. According to Brazilian legislation, beers can contain up to 45% adjuncts relative to their malt content [7]. Thus, all samples are classified as beers regarding adjunct and alcohol content.

The increase in °Bx (Table 3) at the end of the carbonation process, where our final product is obtained, is due to adding an average of 5 g of sugar

Table 2. Analysis of Brix, pH, and Density in the last stages.

	Brix Degree (°Bx)	pH	Density
Maturation	11.9°	4.16	1.044
Final Product	13.6°	4.16	1.042

Table 3. Colorimetric assessment.

	L*	a*	b*
Color	20.86 + -0.01	3.50 + -0.02	3.79 + 0.06
Coefficient of Variation	0.05%	0.44%	1.68%
Confidence Interval	20.86 + -0.02	3.50 + -0.05	3.79 + 0.15

L* represents luminosity, ranging from 0 (completely black) to 100 (completely white). The result falls between 20.84 and 20.88, indicating low luminosity, characteristic of dark beer, specifically Porter-type beer. The positive a* value enhances the coloring from the rapadura additive, which is reddish in an aqueous medium. Additionally, the positive b* value indicates a yellowish color, resulting from the chromatic mixture of red and yellow, resembling dark orange or caramel, consistent with the color of our beer (Figure 6).

Figure 6. Beer coloring.

per 600 mL of beer during bottling. This addition enables the production of CO_2, as the yeast produces CO_2 retained in the bottle. Statistical calculations were performed for each variable, including mean, standard deviation, coefficient of variation, and a 95% confidence interval (Table 3).

Conclusion

Hence, the history of beer is intertwined with human evolution and has always been associated with pleasure, gatherings, celebrations, and more. It is noteworthy that the global market remains predominantly controlled by significant corporations. However, the surging demand for craft beers is exponential, driven by their enhanced palatability and the opportunity for unique recipe additions that complement the chosen beer style. Valhalla beer, infused with mate tea and brown sugar, epitomizes a typical craft beer that aligns with the theoretical Porter style, validated through laboratory-based physical-chemical analyses that substantiated the initial hypothesis. Despite a relatively high yield (84.3%), minor losses during the fermentation process did not impact the final outcome. This underscores that artisanal production does not equate to compromised quality.

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