Cold Brewing Process to Produce Light Beer

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Looking for new beer production techniques, the cold extraction process showed as an alternative, which is very common in producing beverages such as coffee but needs better scientific information for application in the manufacture of beer. This technique is known as Cold Brew, which aims to extract compounds through a cold solvent, in this case, water. This work aims to prepare a beer using the Cold Brew technique to remove a smaller amount of starch, thus generating a beer with a proportionally reduced final alcohol content, obtaining a body that is made classically. For the study, three treatments were made. They consisted of a standard beer as a Control (C), a cold brew (CB), and a diluted beer (DB) with the original Extract coincident with the cold brew. The physicochemical analysis, sugar quantification by HPLC, and sensorial analysis were made to evaluate the three treatments. The curves obtained for rhamnose, fructose, and sucrose showed no significant difference between C and CB but differed from DB. The C presented an average alcohol content of 5.1 + 0.07%, while the CB and DB presented 1.60 + 0.05 and 1.53 + 0.05%, respectively. Furthermore, a sensory analysis showed that the acceptance of SB and CB beers was higher than DB. Reductions in CB were obtained in; alcohol, Density, Extract, and calories compared to SB, but they meet the expectations for a beer with such a low content of fermentable sugars. This method showed potential for the manufacture of light cherries with low alcohol content, corroborating the fact that it is not a diluted beer but an alternative method for the elaboration of different styles of new beers.

1. Introduction

Beer is the most consumed alcoholic beverage in the world, and per capita consumption has been increasing in several countries. In Brazil, the number of breweries grows yearly; the most consumed style is American Standard Lager. However, there are other offers on the market, and these numbers grow yearly (Cervbrasil, 2016; Dias; Falconi, 2018). Several ingredients are needed to produce beer, with water being the raw material in the most significant quantity, followed by malt. Malt is obtained by malting grains, mainly barley. The malted grains provide the brewing wort with several essential compounds for yeast growth, and the various enzymes that arise in the malting process provide carbohydrates, proteins and lipids in an accessible way. Other micronutrients vital to the plant are now available in the brewing wort, forming a complex of compounds after fermentation, which will give unique characteristics to the beverage (Bettenhausen et al. 2018).

There are several techniques for brewing beer, such as brazing, decoction, infusion and many others (Eaton B, 2006). The aim is to transform the starch into sugars, and for this, the grains are initially crushed so that the water can hydrate the starch, and the enzymes break them down. Thus, techniques such as cold brew, typically employed in producing cold coffee, can generate distinct characteristics in brewing. This technique is a cold extraction of compounds that will prioritise extractions of compounds other than a hot extraction, generating at the end of the process an alcoholic beverage with a content of less than 2% alcohol by volume.

With the increasing demand for alcohol-free and low-alcohol beer, there are four main processes to make a beer with low or zero alcohol: thermal process (distillation), the use of membranes (nanofiltration, reverse osmosis, dialysis), interrupted fermentation before all the sugar were converted in alcohol and diluted worst, were the worst was made with less malt and consequently less sugar. Although, according to Alcantara et al. 2016, the thermal process for alcohol removal after fermentation is very efficient when it runs under low pressure or vacuum conditions, the heat results in the produced beer being of lower quality. Processes that use membranes can control temperature and pressure, among other parameters, and these currently characterise the best low-alcohol and non-alcoholic beers. However, this process is too expensive for small and medium brewers. Interrupted fermentation and diluted worst are the most straightforward process. However, the final product is deficient in quality, and there is no stability in interrupted fermentations (because of the final sugar content).

As an alternative of these traditional methods, the Cold brew technique, or cold brazing, is an initial step in beer production, using the same concept as the technique applied to coffee. First, the grains are crushed, and the shell breaks, giving access to the starch. Next, the grains are immersed in ice water for 8 to 12 hours so that unwanted enzymatic activity does not occur (Smart, 2019). After extracting the compounds of interest (conversion of starches into sugars in reduced amounts to form alcohol and compounds responsible for the body of the beer in amounts similar to the traditional process) by Cold brew, filtration is performed to separate the liquid from the skins and remaining starch. Then mashing with heating, in the same way as other beers, allows the enzymes to break down the little starch that was left in the wort. Thus, theoretically, there is everything necessary to form the body of the beer with a shallow alcoholic potential (Kunze, 2014). Given the above, this work aims to use the Cold brew technique to manufacture a low-alcohol beer with a body similar to a traditionally produced beer, using Pilsen and Pale Ale malts with high diastatic power.

2. Material and methods

2.1 Materials

Pilsen and pale ale malts (Cooperativa Agrária, Guarapuava PR, Brazil), hop pellets Nugget and Barth Haas (Hop Breeding Company, USA) and dry yeast US-04 (Fermentis, France) were used to produce the beers. The water used in the process was obtained from the treatment network in Maringá PR, Brazil, after treatment with an activated carbon filter.

2.2 Brewing

The beers were brewed in the brewery of the Department of Food Engineering at the State University of Maringá - UEM in automatic equipment based on Arduino with control of time, temperature, agitation and production capacity of 2 litres per batch.

Three treatments were produced in triplicate of beers in volumes of 2 litres, and the beers were produced following the definitions of the Beer Judge Certification Program – BJCP, 2014.

The three treatments followed the same formulation, shown in Table 01. For all processes, the malts were initially milled in roller mills, which allowed the husks to be broken more completely, facilitating the filtration of the wort while increasing the contact area of the starch, facilitating mashing.

Table 1: Formulation of beers produced in the three treatments.

Raw material	Quantity (g)
Pilsen	300
Pale Ale	150
Hop Nugget	2
Hop halletau magnum	2
Yeast US-04	2
Water	Enough for 2 litres

Following the production of the control treatment (C) and the diluted beer (DB) following the same mashing process for the production of Cold Brew (CB), it was necessary to adapt the process due to its particularity of not using heating.

2.2.1 Brewing control (C) and diluted beers (DB)

After adding all the formulation components at 20 ºC in the equipment, the first mash was at 45 ºC for 10 minutes. In this step, several enzymes act, including phytases and proteases.

The second mash was carried out at 62 ºC for 30 minutes, in which Beta amylase primarily hydrolyses the starch forming maltose, which will be the prominent alcohol former in the fermentation.

The third mash is the temperature range that prioritises alpha-amylase activity. The brazing temperature was 68 ºC for 30 minutes, which also hydrolyses the starch but generates a wide variety of sugars that can be fermentable. These sugars generate alcohol and give body and sweetness to the beer.

In the mash-out, the temperature used was 78°C for 10 minutes. At that moment, the denaturation of the enzymes occurred, giving stability to the brewing wort.

Next, boiling began to denature proteins and hydrolyse hop oils and sterilise the beverage. Finally, hops were added at the beginning of the boil, which lasted one hour.

In the control treatment (C), after boiling, the volume of water was adjusted to 2 litres to produce conventional beer. After boiling, dilution was performed for the DB treatment to obtain the same sugar content as in the CB treatment, that is, approximately one part of wort to two parts of water.

The dilution of the beer was carried out for comparison purposes since the technique most used by the industry for the production of light beer is the reduction of the proportion of malt in relation to water, which has the same effect as the dilution that was carried out in this work to guarantee the same sugar content as the beer obtained by cold brew.

After adjustment or dilution, the wort was cooled and placed in fermenters sanitised with peracetic acid. The wort was fermented at 18 ºC until the end of fermentation when all the sugars were consumed. Thus, the fermentation time was 7 and 3 days for the control and diluted beer treatments, respectively.

2.2.2 Cold Brew (CB) beer brewing

For the Cold brew (CB) treatment, the ground malt was conditioned with ice water at 2 ºC. After the Cold brew period, the wort was stirred so that the decanted particles remained in suspension, and subsequently, the content was filtered through a sieve of stainless steel to separate larger solids such as husk and starch. The wort was washed with water until the liquid volume reached 2 litres. With the wort cold, brazing began in the automatic equipment of 2 litters with time, temperature and agitation control.

As in the treatment of diluted beer, the total consumption of sugars took 3 days, that is, 3 days of fermentation due to the lower initial sugar content in the musts of these two treatments.

2.3 Chemical physical analysis

The water used was standardised following Analytica-EBC and the procedures for handling beer samples.

The analysis of alcohol content in the beer was carried out by refractometry, extracts: original, real and apparent, initial Density, colour by spectrometry and final attenuation of the beer according to the methodology 9.4 of Analytica-EBC, 2004.

pH analyses were carried out with the aid of a ONESENSE PH2500 pH meter, and turbidity with a KR2000 - AKROM turbidimeter

2.4 Quantification of saccharides

The amount of saccharides was analysed in High-Performance Liquid Chromatograph (HPLC) model CG 480-C (Brazil) equipped with a 5 µm (125 × 4.6 mm) NH2 column, operated isocratically with a flow of 0.75 ml/min at 25° C and coupled to a Waters 410 DRI detector (coupled to an index refraction detector S:32) using mobile phase acetonitrile:deionized water, 80:20, v/v.

2.5 Sensory analysis

The acceptance of treatments (C, DB, CB) was held at the Sensory Analysis Laboratory of the Department of Food Engineering at the State University of Maringa, using the methodology used by Nakagawa et al. (2019) to determine preferences between samples. The attributes of flavour, aroma, colour, body, appearance and global acceptance were analysed. Sixty-eight untrained panellists (18 to 34 years old) received 50mL of each sample, and each sample was coded with a random three-digit number using a 9-point hedonic scale. Sensory analysis was carried out with the approval of the Research Ethics Committee of the State University of Maringa (CAAE 18718013.3.0000.0104).

2.6 Statistical analysis

All data were treated statistically from the analysis of variance (ANOVA) with subsequent analysis of the Tukey tests' means at 5 % probability and correlation test. The statistical tests were made by the software Sisvar 5.6 (Vasques et al., 2022).

3. Results and discussion

Table 2 presents the initial (1,017 – 1,047 g cm-3) and final (1,005 – 1,011 g cm-3) density values of the obtained formulations.

Table 2: Density of beers

	Initial Density (g cm^{-3})	Final Density (g cm^{-3})
C	1.047[a]±0.001	1.011 [a]±0.001
DB	1.017 [b]±0.002	1.005 [b]±0.001
CB	1.018 [b]±0.001	1.005 [b]±0.000

Equal letters in the same column represent no significant difference between the samples at the 5% level.

Due to the reduced sugar content of the DB and CB treatments, their initial densities were significantly lower than those of the C treatment, as shown in table 2, since the DB was performed the same way as the C. However, after boiling, it was diluted with water so that its initial Density matched the beers produced by CB to see if only diluting a beer would have the same levels without the work of processing the malt for 12 hours in a refrigerated environment.

To compare the amount of sugars extracted and fermented in the wort, extracts analysis were performed, and their values are compiled in table 03.

Table 3: Characteristics of the extracts in the 3 treatments

	Initial Extract (ºP)	Apparent Extract (ºP)	Real Extract (ºP)	Alcohol (V/V)	Apparent attenuation (%)	Real attenuation (%)
C	11.63 [a]±0.24	2.90 [a]±0.14	4.48 [a]±0.02	4.71 [a]±0.16	75.35 [a]±1.30	61.50 [a]±1.1
DB	4.41 [b]±0.10	1.29 [b]±0.14	1.85 [b]±0.12	1.57 [b]±0.08	70.97 [b]±1.42	58.13 [a]±2.8
CB	4.48 [b]±0.10	1.37 [b]±0.24	1.93 [b]±0.11	1.56 [b]±0.14	69.37 [b]±1.20	56.83 [a]±2.3

Equal letters in the same column represent that there was no significant difference between the samples at the 5% level.

The DB formulation was diluted in water so that the amount of soluble solids approached BC. For this reason, the initial Extract did not show a significant difference, except in the standard sample made without dilution and with all available malt. At the same time, for the beers produced by cold brew, there was no participation of malt during mashing. The apparent extract parameter is the amount of solids that the drink has considering alcohol, it is not the actual amount of solids present. The real extract parameters are the presence of all solids that are part of the beverage composition, which shows us that C had the highest number of solids compared to the other treatments (capece et al. 2018). With these data, it was possible to obtain the amounts of alcohol formed in each treatment.

The alcohol ratio in the beers showed that C presented a higher amount of alcohol after fermentation, which is expected since it has an initial amount of soluble solids. The DB and CB treatments significantly reduced them, making them a Light beer in alcohol. The results obtained from the treatments are within the expected range for fermentation with low sugar content, which is compared with the value obtained from the diluted standard (Jaeger, 2020). How much a beer manages to convert its sugars into alcohol can tell us its attenuation level, and their values are shown in table 05. These levels show us how effective our mashing was.

The attenuation levels of the standard beer are higher than the other treatments because it has the highest amount of fermentable sugars, which makes the fermentation more effective. This parameter is a critical issue to be considered in brewing production because it is a calculation point for production cost. In this regard, the values were compared from beers made by CB with DB, since it is the one that presents a comparable amount with the fermentation of Standard C beer (Francesco et al. 2018). Another comparison highlight is the energy value of beers made by cold mash. Their values are in table 04.

The total energy value in DB and CB samples did not show a significant difference. In both treatments, there was a more than 60% reduction compared to treatment C. These results corroborate the work in one more aspect for the elaboration of light beers and the reduction of alcohol. Consequently, there is a reduction of total calories in the beer (Marques et al. 2017). Other factors to be considered are fundamental characteristics for the stability and acceptability of a beer, such as the pH, colour and turbidity.

Table 4: Physical characteristics of the beers produced in the three treatments

	Energetic value (kcal)	pH	Colour (EBC)	Turbidity (NTU)
C	438,5[a]±9,5	4,57 [a]±0,04	18 [a]±3,5	26,8 [a]±5,6
DB	155,4 [b]±15,1	4,34 [a]±0,10	11,8 [a]±2,5	47,8 [b]±3,8
CB	158,3 [b]±5,3	4,53 [a]±0,05	13,4 [a]±1,2	50,8 [b]±3,4

Equal letters in the same column represent no significant difference between the samples at the 5% level.

The beers did not show significant differences in pH and colour. The turbidity in the standard beer was lower than the other beers because the long fermentation time favours the decantation of suspended particles, which makes the beer less turbid. Therefore, the turbidity results are acceptable for craft beers found in the literature (Fanari et al. 2018; Marques et al. 2017).

Beer is mostly water and alcohol, with residual sugars, but only these items do not constitute it. The balance of these sugars helps build the body of the beer. For this reason, a saccharide analysis on HPLC was performed. The areas referring to each peak were measured, and the results are shown in Table 05. For each generated peak there is a saccharide referent that can be quantified in relation to the first standard that was injected with respective times and areas. These calculated areas refer to the average values for each sugar in each treatment.

Table 5: Sugar profile

	Rhamnose (mg/L)	Fructose (mg/L)	Sucrose (mg/L)
C	155[a]±10	3[a]±1,2	10[a]±2,1
DB	70[b]±5	2[a]±1,1	2[b]±0,6
CB	77[b]±11	6[b]±1,0	9[a]±1,2

Equal letters in the same column represent no significant difference between the samples at the 5% level.

As shown in Table 6, from the sensory point of view, there were no significant differences in overall acceptance between the samples produced by treatments C and CB, with the DB treatment showing significantly lower results.

These indicate that the beer produced by cold brew, despite the lower formation of alcohol content, due to the lower initial total sugars, kept the body and its sensory characteristics closer to standard C beer, while the diluted beer had less overall assessment because it lacked taste, it tasted watery.

Table 6: Sensory acceptance of the beers produced in the three treatments

	Colour	Aroma	Flavour	Body Feeling	Alcohol Sensation	Overall assessment
C	6,7 [a]±1,8	7,3 [a]±1,9	7,0 [a]±1,2	7,0 [a]±1,7	6,9 [a]±1,8	7,3 [a]±1,2
DB	4,3 [b]±1,2	5,0 [a]±3,3	4,6 [b]±1,7	5,1 [b]±1,4	4,9 [b]±2,6	4,8 [b]±1,7
CB	6,8 [a]±2,1	6,1 [a]±3,6	6,3 [a]±2,0	6,5 [a]±2,8	6,5 [a]±2,2	6,3 [a]±1,3

Equal letters in the same column represent no significant difference between the samples at the 5% level.

The cold brew process still has the advantage that due to its residues still having a high content of unconverted starches, they were used in the later production of conventional beer and presented expected characteristics for standard beers.

4. Conclusions

Even showing expected reductions in alcohol, Density, Extract, and calories, the beer produced by cold brew presented body and acceptance characteristics comparable to conventional beer with higher alcohol content. On the other hand, when comparing cold brew with diluted beer, it was found that, despite both having similar alcoholic strengths, their body and acceptance showed significant differences, with light beer produced by dilution being watery.

Finally, it can be concluded that the cold brew proved efficient as a light beer production method to obtain a significantly lower alcohol content while maintaining the expected characteristics of a conventional beer. It is also noteworthy that its brewing residues can be used in the production process of conventional beer due to its high content of residual starches. In this way, the cold brew process proved quite viable in producing light beer.

Acknowledgements

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