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Quality control of small and large-scale brewed beers

Controle de qualidade de cervejas pequenas e em larga escala

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ABSTRACT
Beer is one of the oldest and most consumed beverages in the world. It is the industry that has more excellent representation in the alcoholic beverage sector, contributing significantly to the global economy. There has been a recent boom in demand for small-scale brewed beers (called craft beer), people have sought variety in flavor, aroma and unique beer characteristics. Microbreweries are companies that aim at productions on a small-scale and with a differentiated product, of high sensorial quality and defined styles. The beer of microbreweries is more full-bodied, with a remarkable aroma and flavor. The producers are engaged in proposing novelties, surpassing expectations, achieving perfection, and producing the product with art. Marketing connects these two worlds and uses the sensory, affective relationship to drive that market. Considering the current market requirement and the importance of effective quality control, this work evaluated the quality of American IPA, small and large-scale brewed beers, by assessing the reproducibility of physical-chemical and sensory analysis. Through physical-chemical tests, the craft beer produced in the present work was compared to the large-scale brewed beers, the market-leading, and a beer recently introduced to the market with innovative/bold proposals. To conclude the comparative analyzes, a sensorial analysis was carried out to determine the acceptability and the preference scale of the beers. No significant differences were perceived by the beer consumers comparing the three evaluated products, showed the high quality of the craft beverage developed in the present work.

Keywords: craft beer, quality control, sensorial analysis

RESUMO
A cerveja é uma das bebidas mais antigas e consumidas no mundo. É a indústria que tem uma representação mais excelente no setor de bebidas alcoólicas, contribuindo significativamente para a economia global. Houve um boom recente na demanda por cervejas fabricadas em pequena escala (chamadas de cerveja artesanal), as pessoas buscaram variedade em sabor, aroma e características únicas da cerveja. Microcervejarias são empresas que visam produções em pequena escala e com produtos diferenciados, de alta qualidade sensorial e estilos definidos. A cerveja das microcervejarias é mais encorpada, com um aroma e sabor marcantes. Os produtores estão empenhados em propor novidades, superando expectativas, alcançando a perfeição e produzindo o produto com arte. O marketing conecta esses dois mundos e usa o relacionamento afetivo sensorial para impulsionar esse mercado. Considerando a atual exigência do mercado e a importância de um controle eficaz da qualidade, este trabalho avaliou a qualidade do IPA americano, cervejas pequenas e de larga escala, avaliando a reprodutibilidade das análises físico-químicas e sensoriais. Por meio de testes físico-químicos, a cerveja artesanal produzida no presente trabalho foi comparada às cervejas fabricadas em larga escala, as líderes de mercado, e uma cerveja recentemente introduzida no mercado com propostas inovadoras / ousadas. Para concluir as análises comparativas, foi realizada uma análise sensorial para determinar a aceitabilidade e a escala de preferência das cervejas. Nenhuma diferença significativa foi percebida pelos consumidores de cerveja, comparando os três produtos avaliados, mostrou a alta qualidade da bebida artesanal desenvolvida no presente trabalho.

Palavras chaves: cerveja artesanal, controle de qualidade, análise sensorial

1 INTRODUCTION

Beer is the beverage obtained by the alcoholic fermentation of the brewing must (sugared liquid) from malt barley and drinking water, as a result of yeast, with the addition of hops. Part

of the barley malt may be replaced by brewing adjuncts, whose use is limited to a maximum quantity. Brewing adjuncts are considered to be beer barley and other cereals suitable for human consumption, either malted or non-malted, as well as starches and sugars of plant origin (Bertuzzi et al., 2020).

Fermentation is an ancient process of modifying food employing microorganisms. It is used to preserve food, preventing the development of pathogens and contaminants (Braga et al., 2012; Rios et al., 2019; Lima et al., 2018; Martinez et al., 2019; Machado et al., 2015; Burck et al., 2019; Sampaolesi et al., 2019). According to the Union of Beer Industries (SINDICERV), the most consumed beers in Brazil are the lightest, like the Pilsen type. The breweries can be classified into large companies, which produce the most consumed popular beers and aim at large sales volumes, operating in almost all national territory. Small companies, in turn, have a proposal to provide high-quality beers with a greater variety of styles and serve in regional markets, are known as craft breweries or microbreweries (Gonzalez Viejo et al., 2019).

Both small and large-scale breweries are of crucial importance in the Brazilian economy, with investments close to R$ 20 billion between 2011 and 2014, 1.6% of Brazilian GDP, R$ 27 billion in salaries, and R$ 21 billion in taxes and fees per year (CERVBrasil, 2018).

Microbreweries represent a small market share compared to large beer producers. Still, they are gaining great economic importance in the Brazilian scenario, representing 8% of the national market in 2012, 11% in 2014, with a projection for 20% in 2020 (SEBRAE, 2017). The craft beer market grows every year above the average of the famous beer market and has been winning over consumers, entrepreneurs, and investors.

In this context, this work aims to assess the quality of artisanal beers by carrying out microbiological, physical-chemical and sensory analysis, considering that the growing market will be accompanied by higher demands on the quality of the products currently available.

2 MATERIAL AND METHODS

2.1 SAMPLES

Three beer samples were evaluated in the present work, one craft beer (produced by the authors) and two large-scale brewed beers. The homebrew beer sample was produced by adjusting the brewing recipe to 20 L of American IPA from the Brew Head Shop. Commercial samples were also evaluated and were denominated as samples 2 and 3. Both were obtained from a standard market located in the city of São Paulo. The physical-chemical analysis procedures were carried out in triplicates, and the three beers were identified as: sample 1 (craft

beer), sample 2 (large-scale brewed beer recently inserted in the market, with an innovative/bold proposal), and sample 3 (large-scale brewed beer and known as the market leader).

2.2 MICROBIOLOGICAL QUALITY

For the microbiological safety analysis, the craft beer samples were stored in sterile packaging and kept refrigerated for 48 h until the analyzes were performed, while the commercial beers were kept as indicated in the label. The microbiological evaluation consisted of investigating coliforms at 45 °C/g, mold, and yeast count, besides a standard aerobic count. The analysis of coliforms at 45 °C and *E. coli* was performed using the quick Petrifilm® (3M) methodology, following the manufacturer's instructions and recommendations. Quantitative research of molds and yeasts (potato-dextrose agar acidified with tartaric acid at 25 ºC) was carried out for five days. In addition, standard aerobic counts were performed using standard agar for counting at 35 ºC for 48 h. All analyses were performed in triplicates (Fai et al., 2011; Moraes et al., 2016).

2.3 DETERMINATION OF RELATIVE DENSITY

The relative density was obtained through pycnometry for all the beer samples (AOAC, 2005). The pycnometer was washed, rinsed with ethanol, then with ether, and dried naturally. The empty pycnometer was weighed, then it was filled with distilled water at 20 °C and weighed again. To determine the relative density, the experiment was carried out in triplicates, and the relative density was obtained through Equation 1.

$$Relative\ Density\ = \frac{[(M\text{pycnometer}+Msample)-(M\text{pycnometer})]}{[(M\text{pycnometer}+\text{Mwater})-(M\text{pycnometer})]} \quad (1)$$

Where Mpycnometer is mass of the empty pycnometer (g); Msample is the mass of the sample (g), and Mwater is mass of the water (g).

2.4 DETERMINATION OF ACIDITY

To determine the titratable acidity (Instituto Adolfo Lutz, 2005), 10 mL of each sample was pipetted and transferred to a 125 mL Erlenmeyer flask with 50 mL of water,

Then, two drops of the phenolphthalein solution were added and subsequently titrated with 0.1 M sodium hydroxide solution. To determine the acidity, the experiment was done in triplicates, and the total acidity was obtained using Equation 2.

$$\text{Acidity } (\%) = \frac{(VolumeNaOH * n * 100)}{V} \quad (2)$$

Where n is NaOH normality value (0.009), and V is the volume of the sample (mL).

2.5 DETERMINATION OF ALCOHOL GRADE

The relative density measurements determined the alcoholic grade in the three beers. The ABV scale, from English alcohol by volume, indicates the alcoholic content of the beverage in a volumetric percentage. The calculation of the ABV scale is shown in Equation 3.

$$ABV(\%) = (IG - FG) * 131.25 \quad (3)$$

Where IG corresponds to the initial density measure, and FG corresponds to the final density.

2.6 SENSORY ANALYSIS

The sensory analysis shows the acceptance of the evaluated product, guiding studies, research, and improvements. This kind of analysis reflects non-acceptance results as well, for example, in the study by Villanueva et al. (2005), in which beer was produced with nettle and sage instead of hops, and the results showed beer to be unacceptable to most consumers.

This step was performed at the Laboratory of Food Sensory Analysis (UNIFESP - Baixada Santista). The evaluators were recruited via internal advertisements and via the internet (in a social network group). All participants signed and received a copy of the Informed Consent Form and were informed of the objectives of the study, in addition to being attested that they were over 18 years old, that they had a habit of consuming beer and that they had no allergies or intolerance to any of the components of the formulations. The tasters evaluated the acceptability of the appearance, color, aroma, texture, flavor and global acceptance of the beers on a semi-structured 10 cm hedonic hybrid scale (0 = intensely disliked, 5 = neither liked/disliked, 10 = I liked it) [10]. In the sensory analysis session, the three samples were served monadically and in balanced presentation order. The evaluators received beer samples (portions of 25-30 mL; product temperature between 2 and 7 °C) encoded with random three-digit numbers in disposable 50 mL polystyrene cups. Participants evaluated samples in individual booths at the Laboratory of Food Sensory Analysis and were instructed to drink water between samples to minimize residual effects.

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3 RESULTS AND DISCUSSION

Table 1 presents the results of the microbiological quality of the evaluated beers. All tests were performed in triplicates, and the results are expressed in CFU/mL, and all samples were safe for consumption, so it was possible to proceed with the sensory analysis step.

The data from the physical chemical analyzes were presented as the mean and standard error. For comparison of means, the data were subjected to analysis of variance (ANOVA) and Tukey's test. The STATISTICA 13.0 software was used for data processing. The summary of the analysis results can be seen in Table 2. Different letters in the same column represent different values for each one, since p> 0.05 in the analysis of variance.

Table 1. Microbiological quality of the evaluated beers

Sample	Standard aerobic count	Coliforms at 45° C and *E. coli*	Molds and yeasts
Craft beer	< 3.0 x 10^2 CFU/mL	Undetectable	< 100 CFU/mL
Innovative	< 3.0 x 10^2 CFU/mL	Undetectable	< 100 CFU/mL
Leader	< 3.0 x 10^2 CFU/mL	Undetectable	< 100 CFU/mL

The relative density was determined from Equation 1, considering the mass of pycnometer as 42.894 g and weight of the water plus pycnometer as 158.694 g. The data was calculated using the average of the three tests and shown in Table 2. Following the Brazilian Health Regulatory Agency (ANVISA) standard values for beer, all beers presented data of relative density within the range. Total acidity was obtained employing Equation 2, using the average of the three tests for the volume of NaOH, and the data were shown in Table 2. The color of the beer made it challenging to visualize the turning point of the titration of the samples, so the high percentage of acidity may not show the real acidity of the analyzed beers. When comparing density, it can be concluded that the craft beer is statistically different from the leader and equal to innovative, but the innovative and the leader are statistically equivalent to each other.

According to the ANVISA standard values for beer, all beers evaluated presented acidity data outside the established range (maximum amount is 0.3%). Some beers show a high acidity index when contaminated by microorganisms. However, the microbiological analysis test did not show any contamination evidence in any sample.

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Table 2. The relative density of the evaluated beers

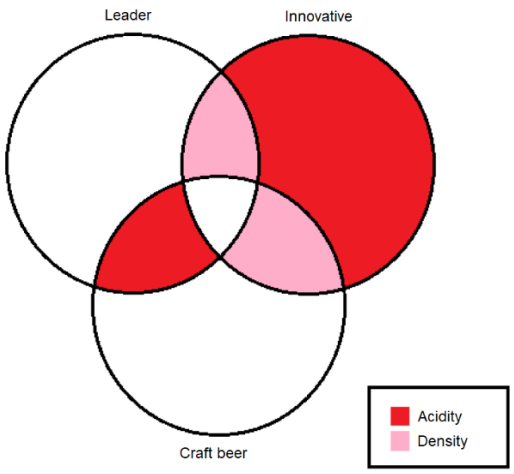
Sample	Relative Density	Acidity (%)	Alcohol by volume – ABV (%)
Craft beer	1.017 ± 0.002	0.42 ± 0.011	6.3
Innovative	1.011 ± 0.001	0.41 ± 0.013	4.7
Leader	1.015 ± 0.002	0.55 ± 0.025	7.0

Figure 1 shows the relation among the evaluated beers considering the acidity and density results. The market-leading beer was the one with the highest acidity index. It can be concluded that this was not a categorical indicator for the quality of the beer since all are outside the range provided by ANVISA. What is worth noting is that there is a balance between acidity and bitterness on the palate, and even considering the American IPA type from the non-traditional American school, one can understand how harmonious the high acidity index combined with the bitterness of the beer.

Analyzing the acidity, the craft beer is statistically equal to the lead beer and statistically different from the innovative beer. In contrast, the leader and the innovative beer are statistically different from each other.

To determine the alcoholic strength of craft beer, the initial density (IG) was measured before fermentation, obtaining the IG value of 1.065 and the final density measurement (FG) after fermentation, obtaining an FG of 1.017. Using Equation 3, the alcohol content calculated was 6.3% (ABV) of the produced beer. The alcoholic percentage of craft beer was compared with the rate described on the market beer label, as shown in Table 2.

Figure 1. Venn diagram of the acidity and density analyze



Considering that high-content beers are in the range of 4.5% to 7% ABV, all beers analyzed are in the high-alcohol range, characteristic of American IPA [4]. By examining the

alcohol content, it can be seen that the beer itself has an alcohol content closer to the market leader than innovative beer. Therefore, craft beer can be considered statistically equal to the market's leading beer in acidity and statistically equal to innovative beer when compared to density, as can be seen in Figure 2.

The sensory analysis was carried out with a sample space of 62 individuals, 51 female tasters and 11 male tasters, 85% of participants are between 18 and 30 years old and 15% over 30 years old. The results of the analysis were compiled, and the averages and standard deviations of the assigned scores can be seen in Table 3.

Table 3. Averages and standard deviation of the scores attributed in the sensory analysis

Samples	Appearance	Aroma	Color	Flavor	Texture	Global
Craft beer	8.46 ± 1.66	7.86 ± 2.21	8.16 ± 2.00	7.06 ± 2.76	8.11 ± 1.85	7.46 ± 2.41
Innovative	8.23 ± 1.70	7.62 ± 2.45	8.02 ± 1.96	6.67 ± 2.49	7.80 ± 1.93	7.04 ± 2.24
Leader	7.90 ± 1.79	7.94 ± 2.64	7.73 ± 1.97	6.65 ± 2.81	7.87 ± 2.08	6.98 ± 2.49
Average	8.20 ± 0.23	7.81 ± 0.14	7.97 ± 0.18	6.79 ± 0.19	7.93 ± 0.13	7.16 ± 0.21

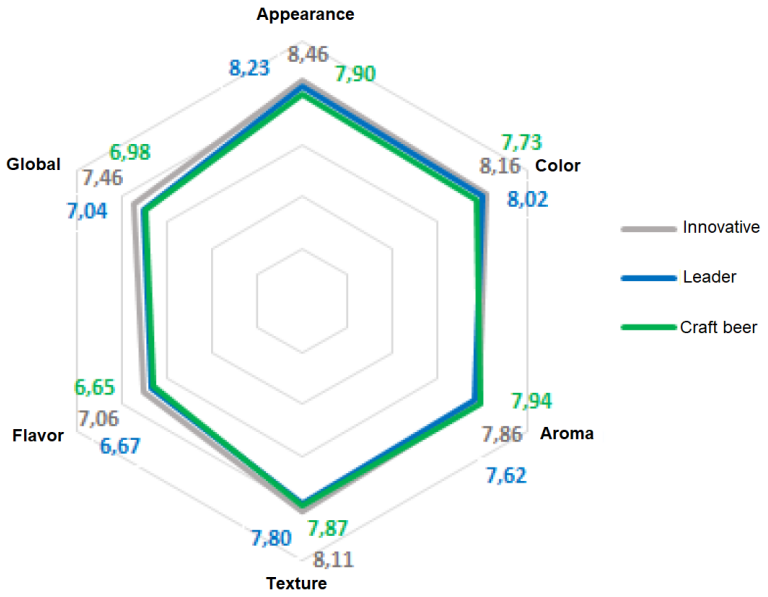
From the sensory analysis, it was observed that the samples did not show significant statistical differences in any of the evaluated attributes. The appearance, color, and texture obtained the highest acceptability, while the flavor had the lowest. There was no significant difference in acceptance between the formulations evaluated. For the item's appearance, color, flavor, texture, and global aspect, the beer preferred by the evaluators was innovative beer. In addition, the perceptions from the color undoubtedly influence the real experience of tasting, however, few studies are arguing this. The reason may be due to the difficulties of conducting consistent studies, also to the rapid transition of the liquid after served in the glass (van Doorn et al., 2019). In terms of aroma, the craft beer was chosen by the participants in the analysis.

As already mentioned in the present work, the most consumed beers in Brazil are the lightest and lightest of the Pilsen type. The best global average was innovative beer, which reflects that innovative beer brings with it more accepted characteristics in Brazil, such as lightness and lighter color. It can, therefore, be concluded that the innovative proposal to bring this proximity to popular taste without leaving aside the aroma, body, and flavor of American IPA is, without a doubt, promising in the Brazilian market.

In addition, the results are positive for craft beer, since it has averages very close to the innovative beer and the market's leading beer, thus adding value to the beer, with an emphasis on aroma, which was preferred over the others. Figure 3 illustrates the proximity of the beer averages. So, with this pairing and acceptability, it is possible to prove the reproducibility of

American IPA, and it is also possible to conclude that the brewed beer has excellent chances of obtaining space in the market.

Figure 3. Sensory attributes studied and respective averages assigned



4 CONCLUSION

Through the comparative qualitative analyzes, it can be concluded that the results for the craft beer and for the standard market beers were satisfactory, obeying the American IPA beer standards and demonstrating that the final process parameters and adjustments proposed by the beer manufactured in-house are satisfactorily adjusted on an artisanal scale. The analyzes also pointed out that craft beer can be considered statistically equal to the market's leading beer in acidity and statistically equal to innovative beer when comparing density. By analyzing the alcohol content, it was observed that the beer itself has an alcohol content closer to the market leader.

Regarding the sensorial analysis, the three beer formulations (craft, innovative, and leader) did not present statistically significant differences in any of the evaluated attributes. For the parameters appearance, color, flavor, texture, and global aspect, the beer preferred by the evaluators was innovative beer. In terms of aroma, the craft beer was chosen by the participants in the analysis.

The craft beer showed similar averages in the compared items, adding value to the beer, proving the reproducibility of the American IPA type, reflecting the quality and providing a positive return to the search for constant revenue improvements and adjustments considering the process variables. Furthermore, it can also be concluded that the brewed beer has excellent

chances of gaining space in the market when compared to the leading and innovative/bold beers, which are also produced by hand, but with strict process control.

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