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# THE EFFECT OF ADDITION OF CRANBERRY SYRUP ON THE PHYSICOCHEMICAL AND SENSORY CHARACTERISTICS OF BEER

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***Abstract***

*This study evaluates the effect of cranberry syrup addition on the quality of beer, focusing on physicochemical properties, sensory characteristics, and vitamin C content. Beer samples were produced with varying concentrations of cranberry syrup (5%, 10%, and 15%) and analyzed for pH, alcohol and vitamin C content, extract, color, and sensory profile. The results showed that increasing syrup concentration led to lower pH and alcohol content, while extract and color values increased. Sensory analysis indicated improved aroma and color, with the highest overall acceptability observed for the 10% sample. Additionally, vitamin C content increased significantly in enriched samples, confirming enhanced functional value. Although the 15% sample showed the highest vitamin C content, it presented slight sensory imbalance. Therefore, the 10% formulation was identified as optimal, offering a balance between improved quality and nutritional benefits.*

***Key words****: beer, cranberry, physicochemical properties, sensory analysis, vitamin C.*

## INTRODUCTION

Beer is one of the oldest fermented beverages known to humanity, with a history spanning several millennia and a strong cultural, economic, and technological significance worldwide. In modern times, beer production has evolved from traditional practices into a highly controlled biotechnological process, involving precise manipulation of raw materials and fermentation conditions (Tirado-Kulieva et al., 2023). Today, beer remains one of the most widely consumed alcoholic beverages globally, reflecting both its accessibility and diversity of styles (Brewers of Europe, 2024).

From a compositional perspective, beer is a complex system consisting primarily of water, carbohydrates, alcohol, proteins, and a wide range of bioactive compounds. Among these, phenolic compounds derived from malt and hops have attracted increasing attention due to their antioxidant properties and potential health benefits when consumed in moderation (Piazzon et al., 2010; De Gaetano et al., 2016). These compounds contribute not only to the nutritional value of beer but also to its sensory characteristics, including color, flavor, and stability (Lentz, 2018).

In recent years, consumer demand has shifted toward innovative and functional beverages, leading to the development of specialty beers enriched with natural ingredients such as fruits, herbs, and plant extracts. Fruit beers, in particular, have gained popularity due to their enhanced sensory appeal and potential health-promoting properties (Aredes et al., 2023). The incorporation of fruits into beer formulations can increase the content of vitamins, organic acids, and polyphenols, thereby improving both the functional value and organoleptic profile of the final product (García-Guzmán et al., 2018).

Recent studies have highlighted that the incorporation of fruit-derived ingredients into beer not only enhances its nutritional profile but also contributes to product differentiation in an increasingly competitive market. Fruit beers are often perceived by consumers as more natural and healthier alternatives compared to conventional beer, mainly due to their higher content of bioactive compounds such as polyphenols, vitamins, and organic acids (Aredes et al., 2023). In addition, these ingredients can improve oxidative stability by limiting lipid oxidation and preserving flavor compounds during storage (Piazzon et al., 2010). As a result, fruit-enriched beers are

gaining attention not only from consumers but also from researchers and producers aiming to develop innovative functional beverages.

Cranberries (*Vaccinium macrocarpon*) are especially noteworthy among fruit ingredients due to their high content of polyphenols, flavonoids, and organic acids, which exhibit strong antioxidant and antimicrobial properties.

The use of cranberry-derived products in beverages has been associated with improved oxidative stability and enhanced sensory attributes, particularly in terms of color and aroma (De Gaetano et al., 2016). These characteristics make cranberry syrup a promising additive for the development of value-added beer products.

In addition to their antioxidant potential, cranberries contain significant amounts of anthocyanins, which are responsible for their characteristic red color and contribute to the visual appeal of food and beverage products. These pigments are known to be relatively stable under acidic conditions, making them particularly suitable for incorporation into beer, which typically exhibits a pH between 3.5 and 4.5 (Oszmiański & Wojdyło, 2005). Moreover, cranberry compounds may exert antimicrobial effects, potentially influencing microbial stability during storage and extending shelf life (De Gaetano et al., 2016). Therefore, the use of cranberry syrup may offer both technological and nutritional advantages in brewing applications.

Vitamin C (ascorbic acid) is an essential bioactive compound widely recognized for its strong antioxidant properties and its role in protecting biological systems against oxidative stress. In the context of beverages, vitamin C contributes not only to nutritional value but also to product stability by reducing oxidative degradation processes. Although conventional beer contains only trace amounts of vitamin C due to processing conditions and raw material composition, the incorporation of fruit-derived ingredients can significantly enhance its ascorbic acid content (Piazzon et al., 2010; De Gaetano et al., 2016).

Cranberries are particularly rich in vitamin C and other antioxidant compounds, making them a suitable candidate for the development of functional beer products with improved health-related attributes (Oszmiański & Wojdyło, 2005; Kylli et al., 2010). Therefore, the enrichment of beer with cranberry syrup may represent an effective approach to increase its antioxidant capacity and overall functional value.

At the same time, the brewing industry continues to adapt to changing consumer preferences, focusing on sustainability, natural ingredients, and product diversification. According to recent reports, the European beer market shows a growing interest in craft and specialty beers, including those with added functional ingredients (Brewers of Europe, 2024). In Romania, similar trends have been observed, with an increasing share of innovative and non-traditional beer products gaining market attention (Asociația Berarii României, 2024).

In this context, the present study aims to evaluate the influence of cranberry syrup addition on the quality characteristics of beer. The research focuses on analyzing the physicochemical and sensory properties of the final product, with the objective of identifying optimal formulations that enhance both functional value and consumer acceptability.

## MATERIALS AND METHODS

The raw materials used for beer production were barley malt (Pilsner type), hops (pellet form, bittering and aroma varieties), brewing yeast (*Saccharomyces cerevisiae*) and potable water.

The experimental ingredient consisted of **cranberry syrup**, obtained from concentrated cranberry juice, standardized to a soluble solids content of approximately 65 °Brix.

All reagents used for physicochemical analyses were of analytical grade.

Four beer variants were produced, differing in the concentration of added cranberry syrup:

- **Control sample (C)** – without cranberry syrup;
- **Sample S1** – 5% cranberry syrup (v/v);
- **Sample S2** – 10% cranberry syrup (v/v);
- **Sample S3** – 15% cranberry syrup (v/v).

The cranberry syrup was added during the **secondary fermentation stage**, in order to preserve bioactive compounds and enhance aroma.

The beer was produced using a standard brewing process (Figure 1), consisting of the following steps:

– Milling of malt;
– Mashing – conducted at controlled temperatures (62-68°C) for enzymatic conversion;
– Filtration (lautering) – separation of wort from spent grains;
– Boiling with hops – for 60 minutes;
– Cooling of wort to fermentation temperature (~20°C);
– Primary fermentation – carried out for 5-7 days;
– Addition of cranberry syrup (according to experimental design);
– Secondary fermentation/maturation –10-14 days at 4°C;
– Filtration and bottling (Tirado-Kulieva et al., 2023).

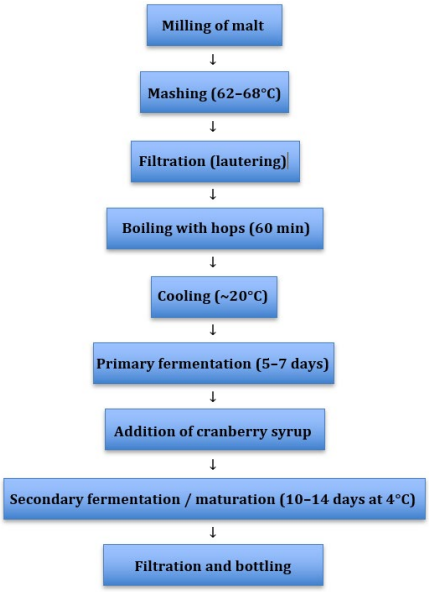


Figure 1. Technological process for obtaining beer with cranberry syrup

The obtained beer samples were analyzed for the determination of pH, alcohol and vitamin C content, extract, color and stability.

**pH determination** was conducted using a calibrated digital pH meter at 20°C. **Alcohol content (% v/v)** was determined using distillation followed by densimetric measurement. The **extract (Plato)** was measured using a refractometer. **Color** was determined spectrophotometrically and expressed in EBC units. **Stability** was evaluated through turbidity measurements and observation over a 14-day storage period at 4°C (Aredes et al., 2023).

**The determination of vitamin C content in** the beer samples was carried out using a spectrophotometric method based on the reduction of 2,6-dichlorophenolindophenol (DCPIP). Prior to analysis, the samples were filtered and appropriately diluted to ensure accurate measurement. Absorbance was recorded at a wavelength of 520 nm, and the vitamin C concentration was calculated using a calibration curve prepared with standard ascorbic acid solutions. All analyses were performed in triplicate, and results were expressed as mg/L of ascorbic acid. This method is widely used for the quantification of vitamin C in food and beverage matrices due to its reliability and sensitivity (Igual et al., 2010).

Sensory evaluation was conducted by a panel of **10 trained assessors** that evaluated the following attributes: aroma, taste, color and overall acceptability. A **9-point hedonic scale** was used (1 = extremely unpleasant, 9 = extremely pleasant) (Lentz, 2018).

All experimental determinations were carried out in triplicate, and the obtained results were expressed as mean values ± standard deviation. Statistical analysis was performed to evaluate the significance of differences between samples, using analysis of variance (ANOVA) followed by post hoc comparisons where appropriate. A significance level of $p < 0.05$ was considered statistically significant. This approach ensures the reliability and reproducibility of the results and allows for a more accurate interpretation of the influence of cranberry syrup addition on beer quality parameters (Aredes et al., 2023).

## RESULTS AND DISCUSSIONS

The physicochemical parameters of the analyzed beer samples are presented in Table 1. The results highlight the influence of cranberry syrup addition on the main quality indicators of the finished product (Aredes et al., 2023).

Different superscript letters within the same column indicate significant differences between samples ($p < 0.05$).

Statistical analysis revealed significant differences ($p < 0.05$) between the control and cranberry-enriched beer samples for all analyzed

physicochemical parameters. Increasing cranberry syrup concentration significantly decreased pH and alcohol content, while extract and color values increased significantly.

Table 1. Physicochemical characteristics of beer samples enriched with cranberry syrup (mean ± SEM, n = 3)

| Sample | pH | Alcohol (% v/v) | Extract (°P) | Color (EBC) |
|---|---|---|---|---|
| C | 4.50 ± 0.03a | 5.20 ± 0.05a | 11.5 ± 0.1d | 8.0 ± 0.2d |
| S1 | 4.30 ± 0.02b | 5.00 ± 0.04b | 11.8 ± 0.1c | 12.0 ± 0.3c |
| S2 | 4.10 ± 0.04c | 4.80 ± 0.03c | 12.2 ± 0.2b | 16.0 ± 0.4b |
| S3 | 3.90 ± 0.03d | 4.60 ± 0.05d | 12.8 ± 0.2a | 21.0 ± 0.5a |

**The pH values** of the samples decreased progressively with the increase in cranberry syrup concentration. The control sample recorded a pH of 4.5, while the sample with 15% syrup (S3) reached a pH of 3.9.

This decrease can be attributed to the presence of organic acids naturally found in cranberries, such as citric and malic acids. The reduction in pH contributes positively to microbial stability and freshness perception; however, excessively low pH values may negatively influence taste balance, leading to increased sourness (De Gaetano et al., 2016).

The decrease in pH may also influence the perception of freshness and crispness, which are desirable attributes in fruit beers. However, excessive acidity can lead to an imbalance between sweetness, bitterness, and sourness, negatively affecting overall palatability. Similar trends have been reported in other studies involving fruit-enriched beers, where optimal formulation requires careful control of acid content to maintain sensory harmony (Aredes et al., 2023).

**The alcohol content** showed a slight decreasing trend with increasing syrup concentration, from 5.2% in the control sample to 4.6% in sample S3. This variation can be explained by the dilution effect caused by syrup addition, the presence of non-fermentable sugars in cranberry syrup and by possible inhibition of yeast activity due to increased acidity. Although the decrease is moderate, it may influence the perception of body and warmth in the final product (Tirado-Kulieva et al., 2023).

**The extract values** increased proportionally with the amount of added cranberry syrup, reaching 12.8°P in sample S3. This increase is due to the contribution of soluble solids (mainly sugars and bioactive compounds) from the cranberry syrup. A higher extract content generally contributes to a fuller body and improved mouthfeel, although excessive extract may lead to a heavier sensory profile (Aredes et al., 2023).

**Color intensity** increased significantly with the addition of cranberry syrup, from 8 EBC in the control sample to 21 EBC in sample S3.

This change is directly related to the presence of anthocyanins and other pigments in cranberries. The enhanced color contributes positively to consumer appeal, especially for specialty or fruit beers, where visual characteristics are highly important (García-Guzmán et al., 2018).

The addition of cranberry syrup slightly influenced the **physical stability** of the beer. Samples with higher syrup concentrations showed a tendency toward increased turbidity during storage. This behavior may be associated with pectin content in cranberry syrup, interactions between polyphenols and proteins or incomplete clarification after fermentation.

However, no significant sedimentation or major stability defects were observed within the 14-day monitoring period (Piazzon et al., 2010).

The results of the sensory analysis are presented in Table 2.

Table 2. Sensory evaluation of beer samples enriched with cranberry syrup (mean ± SEM, n = 10)

| Sample | Aroma | Taste | Color | Overall acceptability |
|---|---|---|---|---|
| C | 6.5 ± 0.3c | 6.8 ± 0.2c | 6.0 ± 0.2d | 6.6 ± 0.3c |
| S1 | 7.5 ± 0.2b | 7.2 ± 0.3b | 7.5 ± 0.3c | 7.4 ± 0.2b |
| S2 | 8.2 ± 0.2a | 7.8 ± 0.2a | 8.3 ± 0.2b | 8.0 ± 0.2a |
| S3 | 8.5 ± 0.3a | 6.9 ± 0.3bc | 9.0 ± 0.2a | 7.2 ± 0.3b |

Different superscript letters within the same column indicate significant differences between samples ($p < 0.05$).

The sensory evaluation results showed statistically significant differences ($p < 0.05$) among samples, particularly for aroma, color, and overall acceptability. Sample S2 recorded the highest overall acceptability score, indica-

ting the best balance between fruity characteristics and traditional beer flavor.

**Aroma scores** increased significantly with cranberry syrup addition, reaching the highest value (8.5) in sample S3. The improvement is due to volatile compounds and aromatic esters present in cranberries, which contribute fruity and fresh notes. This confirms that cranberry syrup enhances the aromatic complexity of beer (Lentz, 2018).

**Taste evaluation** showed a different trend. While samples S1 and S2 recorded higher scores than the control, sample S3 showed a slight decrease. This indicates that moderate addition of cranberry syrup improves taste balance, but excessive amounts may lead to increased acidity, slight astringency, or masking of the traditional beer flavor. Thus, taste acceptability is optimized at intermediate syrup concentrations (Lentz, 2018).

**The perception of color** improved significantly with increasing syrup concentration, with S3 receiving the highest score (9.0). Panelists appreciated the intense reddish hue, which is associated with fruit beers and considered visually attractive. Color is a critical quality parameter influencing consumer perception and purchase decisions, especially in the case of specialty and craft beers. The reddish hue imparted by cranberry syrup may also create expectations regarding flavor, often associated with fruity, fresh, and slightly acidic notes. Therefore, the enhancement of color not only improves visual appeal but also contributes to the overall sensory experience by shaping consumer expectations prior to tasting (García-Guzmán et al., 2018). The highest overall acceptability score was recorded for sample S2 (8.0), followed by S1 (7.4) and S3 (7.2). Although S3 had the best aroma and color, its lower taste score affected its overall perception. This demonstrates that consumer preference depends on a balance between sensory attributes rather than a single dominant characteristic (García-Guzmán et al., 2018).

Table 3: Vitamin C content of beer samples enriched with cranberry syrup (mean ± SEM, n = 3)

| Sample | Vitamin C (mg/L) |
|---|---|
| C | 3.2 ± 0.2d |
| S1 | 18.5 ± 0.5c |
| S2 | 45.0 ± 1.1b |
| S3 | 52.3 ± 1.4a |

Different superscript letters indicate significant differences between samples ($p < 0.05$).

Vitamin C content increased significantly ($p < 0.05$) with increasing cranberry syrup concentration. The highest value was observed in sample S3, confirming the contribution of cranberry syrup to the antioxidant potential and functional value of the beer.

The results of the vitamin C analysis (Table 3) revealed a significant increase in ascorbic acid content with the addition of cranberry syrup.

The control sample showed a low vitamin C concentration (3.2 mg/L), which is typical for conventional beer, whereas the enriched samples exhibited markedly higher values, reaching up to 52.3 mg/L in sample S3. This increase can be attributed to the naturally high ascorbic acid content of cranberries, as well as the presence of phenolic compounds that are partially retained during the brewing process (Oszmiański & Wojdyło, 2005; Kylli et al., 2010).

Furthermore, these compounds contribute synergistically to the antioxidant potential of the final product, enhancing its functional properties and overall nutritional value (Piazzon et al., 2010). It is important to note that vitamin C is sensitive to processing conditions such as temperature, oxygen exposure, and light. Despite these factors, the addition of cranberry syrup during the secondary fermentation stage likely contributed to better preservation of ascorbic acid compared to earlier stages of processing. This technological approach may represent an effective strategy to retain heat-sensitive nutrients in functional beer formulations (Igual et al., 2010). However, although sample S3 recorded the highest vitamin C content, sample S2 (45.0 mg/L) appears to represent the optimal formulation when considering both nutritional benefits and sensory balance, as excessive addition may negatively influence organoleptic characteristics.

The radar chart presented in Figure 2 provides a comprehensive visualization of the overall quality characteristics of the analyzed beer samples, integrating physicochemical parameters, sensory attributes, and vitamin C content.

The graphical representation highlights the balanced profile of sample S2, which demonstrates optimal values across most

evaluated parameters, including aroma, taste, extract, and antioxidant potential. The increased values observed for color and vitamin C content in samples with higher cranberry syrup concentrations confirm the contribution of fruit-derived bioactive compounds, particularly phenolics and ascorbic acid (Piazzon et al., 2023; Oszmiański & Wojdyło, 2005).

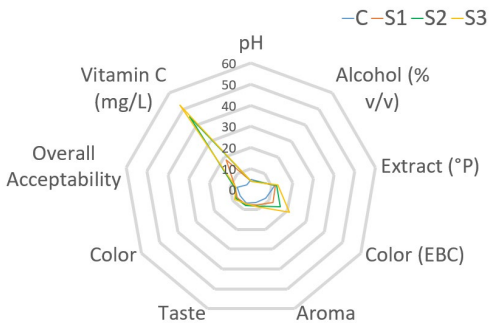


Figure 2. Radar Chart representing the overall quality characteristics of beer samples enriched with cranberry syrup

At the same time, the chart illustrates that excessive enrichment (S3) may lead to slight imbalances in sensory attributes, supporting the conclusion that moderate addition levels provide the best compromise between functional enhancement and consumer acceptability (Aredes et al., 2023). Such multivariate visualization tools are useful for identifying optimal formulations in functional beverage development.

The results confirm that the addition of cranberry syrup significantly influences both physicochemical and sensory characteristics of beer (Aredes et al., 2023; De Gaetano et al., 2016).

From a technological perspective, acidity increases with syrup addition, alcohol content slightly decreases and extract and color increase. From a sensory perspective, aroma and color are significantly improved and taste is optimized at moderate concentrations.

The optimal concentration identified in this study is 10% cranberry syrup (S2), which provides: balanced taste, enhanced aroma, attractive color and high overall acceptability. Higher concentrations (15%) lead to excessive acidity and slight sensory imbalance, despite improved visual and aromatic properties.

## CONCLUSIONS

The use of cranberry syrup as an ingredient in beer production represents a promising approach for:

- developing **functional beers** enriched with antioxidants,
- diversifying product range,
- increasing consumer appeal through natural ingredients.

These findings support the potential of cranberry syrup as a value-added component in the brewing industry, especially in the segment of specialty and craft beers.

The incorporation of cranberry syrup into beer formulation proved to be an effective strategy for increasing vitamin C content and enhancing the functional value of the final product. The results demonstrated that enriched samples contained significantly higher levels of ascorbic acid compared to conventional beer, confirming the contribution of cranberry-derived compounds.

In addition to improving antioxidant potential, the presence of vitamin C may also contribute to product stability by limiting oxidative reactions (Piazzon et al., 2010; De Gaetano et al., 2016).

From an industrial perspective, the use of fruit-based ingredients such as cranberry syrup aligns with current trends in sustainable and innovative food production. The valorization of fruit-derived products can contribute to the development of high-value beverages while meeting consumer demand for natural and functional ingredients. Furthermore, the diversification of beer assortments through such formulations may provide competitive advantages for small-scale and craft breweries (Brewers of Europe, 2024; Asociația Berarii României, 2024).

Overall, the findings support the use of cranberry syrup as a natural ingredient for the development of innovative beer products with added nutritional benefits, provided that optimal concentrations are selected to maintain sensory acceptability.

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