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Fertilization of *Physalis peruviana* and its influence on beer quality with two yeast strains

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Fertilización de *Physalis peruviana* y su influencia en la calidad de la cerveza con dos cepas de levadura

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ABSTRACT

Keywords:
Blonde ale
Cape gooseberry
Craft beer
Nutrition
Sensory evaluation

Cape gooseberry (*Physalis peruviana*) is a fruit native to the Andean region that possesses organoleptic and nutritional properties, making it a potential candidate to produce craft beer. However, there is a knowledge gap in terms of fertilization practices and their effect on the quality of the fruit and its final product. In this sense, the present study aims to evaluate the effect of different nutrition strategies on the agronomic characteristics of cape gooseberry and to determine how the combination with two strains of *Saccharomyces* yeast influences the quality of the Blonde Ale type craft beer. For this purpose, weekly treatments of complete chemical fertilization and commercial organic products were applied and compared with a control treatment without fertilization. Agronomic variables of the fruit (weight, diameter, firmness, soluble solids, and acidity), physicochemical and sensory parameters of the beer (pH, alcohol content, color, and acceptability) were evaluated. The results showed that complete chemical fertilization produced higher-yielding, firmer, and sweeter fruit. The beers brewed showed physicochemical stability but differed significantly in sensory quality depending on the yeast used. The combination of complete fertilization with the S-04 strain resulted in higher acceptability, due to the balance between sweetness and fruity notes, while the K-97 strain resulted in a beer that was less appreciated, especially due to its turbidity and acidity. In conclusion, chemical fertilization optimizes the quality of the fruit and, when combined with a suitable strain, will substantially improve the properties of the craft beer.

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RESUMEN

Palabras clave:
Blonde ale
Uchuva
Cerveza artesanal
Nutrición
Evaluación sensorial

La uchuva (*Physalis peruviana*) es una fruta originaria de la región andina que posee propiedades organolépticas y nutricionales, haciéndola potencial para la elaboración de cerveza artesanal. Sin embargo, existe un vacío de conocimiento en términos de prácticas de fertilización y su efecto sobre la calidad del fruto y su producto final. En este sentido, el presente estudio se plantea evaluar el efecto de diferentes estrategias de nutrición sobre las características agronómicas de la uchuva y determinar cómo la combinación con dos cepas de levadura *Saccharomyces* influye en la calidad de la cerveza artesanal tipo Blonde Ale. Para esto se aplicaron semanalmente tratamientos de fertilización química completa y productos orgánicos comerciales y se compararon con un tratamiento control sin fertilización. Se evaluaron variables agronómicas del fruto (peso, diámetro, firmeza, sólidos solubles y acidez), parámetros fisicoquímicos y sensoriales de la cerveza (pH, grado alcohólico, color y aceptabilidad). Los resultados evidenciaron que la fertilización química completa produjo frutos de mayor rendimiento, más firmes y dulces. Las cervezas elaboradas presentaron estabilidad fisicoquímica, pero difirieron significativamente en la calidad sensorial en dependencia de la levadura utilizada. Respecto a la combinación de fertilización completa con la cepa S-04, se obtuvo mayor aceptabilidad, a razón del equilibrio entre dulzor y notas afrutadas, mientras que con la cepa K-97 resultó en una cerveza menos valorada, especialmente por su turbidez y acidez. Concluyendo así que la fertilización química optimiza la calidad del fruto y, al combinarla con una cepa adecuada, mejora sustancialmente las propiedades de la cerveza artesanal.

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Physalis peruviana is an Andean fruit belonging to the Solanaceae. Its importance lies in its potential for food and nutraceutical purposes (Diniz et al. 2020). The species has been gaining prominence in the market, as its fruits are sold fresh or used in the food and medicinal industries (Barroso et al. 2022; Guiné et al. 2020). This makes it an excellent alternative source of income (Barroso et al. 2022; Silva et al. 2021), which has been substantially researched in terms of training systems (de Freitas et al. 2023), fertilizations (Brito et al. 2022), and post-harvest quality of fruit (Hayati et al. 2023) and production costs (Bendlin et al. 2016).

Other similar studies, Paucar-Menacho et al. (2024), who optimized an ale-type beer with the incorporation of cane malt and *P. peruviana*, achieved improved physicochemical, sensory, and nutritional properties, with high consumer acceptance. Mejía-Bustamante et al. (2022) evaluated an alcoholic beverage from *P. peruviana* and *Solanum betaceum* with Ale and Lager yeasts, resulting in a higher preference for the Ale blends and providing a basis for exploiting the potential of the crop. Fernandes et al. (2019) report using *Physalis* for vinegar production by fermentation of fruit, which shows antioxidant effects and antimicrobial potential. Similarly, Rinaldi et al. (2022) incorporated cape gooseberry into fruity beers by freeze-drying to ensure a constant supply of pulp. And so, there are different studies related to the fortification of fermented beverages (beer, yoghurt, fermented milk drinks, vinegars, and functional beverages). The background information presented suggests that it is an important crop thanks to its organoleptic characteristics; however, the lack of knowledge can be complemented with this type of study, which allows for substantial improvements in production based on good fertilization. Furthermore, this study is expected to raise the profile of the crop in Ecuador, considering that both research and production of *P. peruviana* are limited in the country (de Freitas et al. 2023; Diniz et al. 2020).

Against this background, the present study aims to evaluate the effect of fertilization on cape gooseberry, focusing on the quality of a craft beer-type beverage with two yeast strains, as a strategy for optimizing agronomic management and promoting value-added processing. This study explores the influence of technical management on the products derived from the crop.

MATERIALS AND METHODS

The experiment had two parts: the first was oriented to cultivation, and the second was oriented to brewing. For the first part, two-month-old, cultivated plants were used, to which three types of nutrition were applied; a completely randomized block design (RCBD) was applied with eight replications and a total of 24 experimental units. In the second stage, craft beer was made with the harvested fruit from each treatment, and two yeast strains were added, considering one fermentation barrel for each combination of nutrition and yeast, with a total of 6 treatments for the processing stage.

Nutrition

For the first treatment of nutrition, a soil analysis was made (Table 1), which detected deficiencies of phosphorus, boron, zinc, and sulfur. To correct these deficiencies, potassium nitrate, ammonium sulfate, and magnesium sulfate were applied, adapted to the alkaline pH=8.08. The doses were 8.02, 9.92, and 1.65 kg ha^{-1}, respectively, diluted in water, applying 200 mL per plant. Calcium was not used due to its high level in the soil. A second treatment was applied, with an organic product containing humic and fulvic acids, in a solution of 8 mL $L^{-1,}$ applying 210 mL per plant. In addition, a control treatment without fertilization was used. The frequency of application was weekly, together with irrigations according to crop needs.

Fruit characterization

Yield variables were evaluated every 15 days for three months after entry into production. All fruits from each plant were considered, and the variables to be evaluated were fruit number, estimated yield (total weight of fruit per plant), and average weight per fruit. In addition, variables such as diameter (with calibrator), firmness (with penetrometer), Brix degrees (with refractometer), pH (with potentiometer), and titratable acidity (by titration with NaOH) were measured in 15 fruits per treatment and per replication.

Brewing

Specific inputs were selected to produce a blonde ale. The malts and wheat were milled and underwent a simple mash at 60 °C for 90 minutes to obtain the wort. The grain was then washed, and the wort was boiled for 60 minutes with the addition of hops. The wort was then cooled to 20 °C, while fermentation was carried out with *Saccharomyces*

Table 1. Soil chemical properties and cation exchange capacity (CEC).

Chemical analysis			Cation Exchange Capacity analysis		
Parameter	**Unit**	**Value**	**Parameter**	**Unit**	**Value**
pH	-	8.08	K	meq 100 g^{-1}	1.01
N	ppm	16	Ca	meq 100 g^{-1}	56.2
pH	ppm	15.4	Mg	meq 100 g^{-1}	3.3
S	ppm	5.7	Na	meq 100 g^{-1}	0.57
B	pm	0.59	Σ Bases	meq 100 g^{-1}	61.1
K	meq 100 g^{-1}	0.85	Base saturation	%	Saturated
Ca	meq 100 g^{-1}	43.99	Cation Exchange Capacity	meq 100 g^{-1}	19.4
Mg	meq 100 g^{-1}	3.23			
Zn	ppm	1.5			
Cu	ppm	6.2			
Fe	ppm	27			
Mn	ppm	6.8			
Ca/Mg	ppm	13.61			
Mg/K	ppm	3.81			
Ca+Mg/K	ppm	55.61			
Σ Bases	meq 100 g^{-1}	48.07			
Organic matter	%	0.85			

yeast of the Fermentis brand, using strains S04 and K97 (strain S04 is characterized by high flocculation and fast fermentation. The K97 strain, on the other hand, has a slower fermentation and less flocculation, providing floral aromas and a slight acid touch, typical of German styles such as Kölsch) at a dose of 3.6 g; here, the cape gooseberry pasteurized from nutrition treatments was added in an amount of 5% of the wort and fermented for 7 days. After fermentation, the beer was clarified at low temperature, carbonated, and matured for 5 days before bottling.

Craft beer physicochemical analysis

In carbonated samples at 20 °C, the properties of the beer were measured and analyzed by measuring pH using a potentiometer; besides, with a refractometer, the alcohol content (ABV) was measured by the difference in initial and final densities of the wort; a colorimeter was used for brightness and hue on Lab color space; total dissolved solids (TDS) were measured with a potentiometer; and titratable acidity was determined by titration with 0.1 N NaOH, adjusting to a pH=8.1 in degassed samples.

Craft beer tasting

Three certified tasters evaluated the beers obtained with a blind tasting methodology according to qualitative parameters following established formats, considering appearance (clarity, foam, and color), aroma (malt, hops, and yeast), and flavor (intensity, aftertaste, balance, and palate). These tests have a rating scale of 10 points, with higher scores indicating better organoleptic characteristics according to the experts.

Statistical analysis

InfoStat and the R project were used, applying ANOVA for quantitative variables, verifying normality with the Shapiro-Wilks test, and homogeneity of variances with the Levene test at 95%. Frequency tables were also used for qualitative variables.

RESULTS AND DISCUSSION

For the first stage of the assay, related to the cultivation and nutrition of cape gooseberry, significant differences are evident in some productive variables, as indicated in Figure 1.

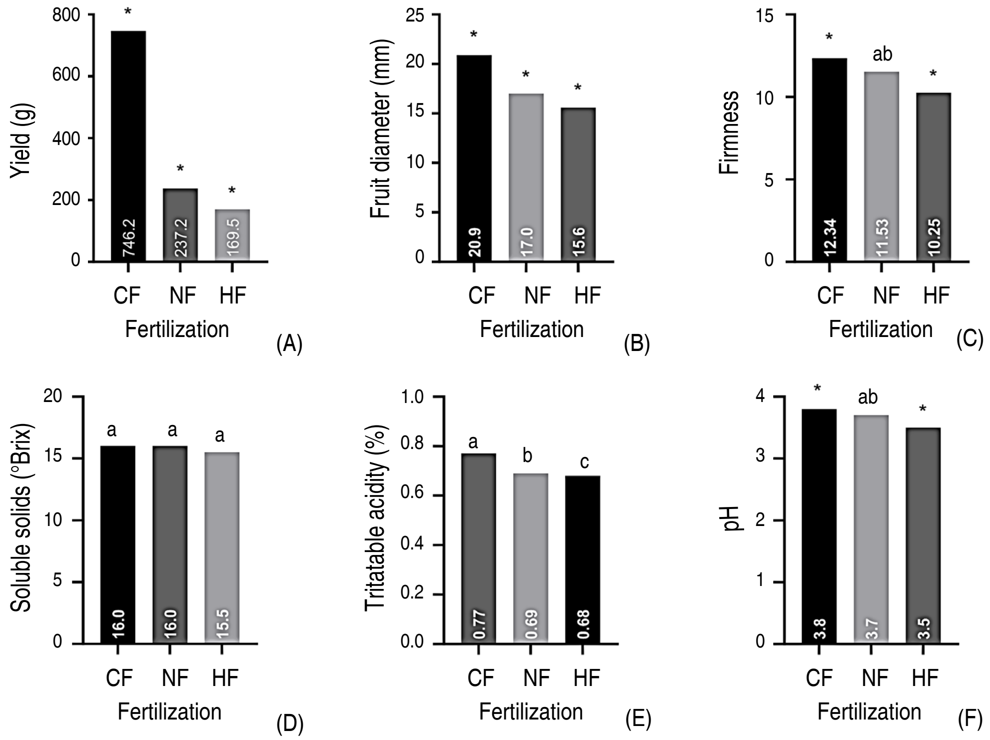

Figure 1. Fruit variables in relation to fertilization. A) Yield, B) Fruit diameter, C) Firmness, D) Soluble solids content, E) Titratable acidity, and F) pH. Note: T0= No fertilization; T1= Humic and fulvic acids fertilization; T2= Chemical fertilization. (*) for $P<0.05$. Chemical fertilization (CF), No fertilization (NF) and Humic and fulvic acids (HF).

According to Figure 1, complete chemical fertilization produced the best performance across most evaluated parameters, with yield being particularly notable (746.2 g). Similarly, Syropoulou et al. (2022) reported the highest yield (7.51 t ha^{-1}) under inorganic fertilization, followed by organic fertilization (6.89 t ha^{-1}), while the lowest yield (3.69 t ha^{-1}) was observed in untreated plots. This increase was attributed to higher nitrogen content in fertilizer. Fruit diameter under chemical fertilization (20.9 mm) was similar to the values reported by Muniz et al. (2014). However, organic fertilization produced the largest diameter (21.14 mm), surpassing inorganic fertilization (19.98 mm). In contrast, Ariati et al. (2017) observed greater fruit diameters with inorganic fertilization (18.75 mm) compared with organic fertilization (18.30 mm). Bilalis et al. (2018) determined that this parameter is strongly influenced by factors in cultivar genetics. For firmness, values between 10.25 and 12.34 N were reported; the highest value was for chemical fertilization, a result that can be related to that obtained by Álvarez-Herrera et al. (2022), who found no significant differences between fertilization with chemical elements versus a control, only an increase of 1.6%. However, it is important to mention that calcium-based fertilization can help to maintain the integrity of the cell membrane (Bhatla et al. 2018), which could contribute to the post-harvesting of this crop. A pH=3.8, whose variation will depend on the temperature to which the fruit is exposed, according to Casaubon-Garcín et al. (2018). The cape gooseberry pH ranged between 3.38 and 3.60 at 20 °C, presenting a hydrogen potential qualified as acid; in this study, when applying chemical fertilization versus the application of humic and fulvic acids, a significant difference was observed, measuring a pH of 3.77 and 3.53 in the fruit, respectively, only the latter being within the range mentioned by the authors. This significantly exceeded the treatments with humic and fulvic acids and the control, which presented lower values in these variables. As for titratable acidity, control obtained the highest percentage (0.77%), followed by humic and fulvic acids (0.69%) and complete chemical fertilization (0.68%). Similarly, Pedó et al. (2018)

obtained similar titratable acidity in *P. peruviana* plants under all fertilization intervals used. In addition, Lima et al. (2009) and Lanchero et al. (2007) found similar results and mentioned that titratable acidity is related to physiological ripening processes. As for the soluble solids content, no significant differences were observed among treatments, with similar values between 15.5 and 16.0, in this sense, the combination of treatments could be tested, for example, in the study of Ávila et al. (2006), who evaluated fertilization with bacterial strains in combination with different concentrations of chemical fertilization, an absolute control and one with CF. With respect to soluble solids, it was found that the combination of strains with 50% chemical fertilization increased Brix (11%) with respect to the treatment with 100% chemical fertilization. For the second stage, on the brewing of craft beer, concerning the addition of two yeast strains, the results are presented in Table 2.

Table 2. Characteristics of the craft beer according to the yeast strains used.

Strain	pH	Titratable acidity (%)	Total dissolved solids (ppm)	Alcohol content (%)
K-97	4.19*	0.16*	1.011	5.7
S-04	4.16*	0.14*	1.006	5.7

(*) for $P<0.05$.

The results indicate that the pH of strain K-97 is slightly higher than that of strain S-04 (4.16) with a statistically significant difference. Likewise, the Ecuadorian technical standard INEN 2262 establishes that the accepted pH value for beers ranges from 3.5 to 5.0 (INEN 2013). Total dissolved solids ranged between 990 and 1,020 ppm, being slightly higher in the treatments with chemical fertilization and humic and fulvic acids compared to the controls. Castorena-García et al. (2020) mentioned that the addition of natural sugar for brewing increases the initial total soluble solids, which favors the anaerobic metabolism of the yeasts used; tested in the present trial, since the brix degrees allowed us to determine that the *P. peruviana* used had a sweet flavor, and when comparing the treatments used for each strain, no significant differences were found in terms of TDS. The alcohol content was constant in all cases (5.7%). Castorena-García et al. (2020) mention that a fermentation exposed to 7 to 13 °C results in a "Lager" type beer, and between 16 to 23 °C it will be an "Ale" type beer, which is consistent with the type of beer obtained in this research. The titratable acidity presented small variations, with values between 0.14 and 0.16%, being slightly higher in the K-97 strain; however, in a study conducted by Sánchez et al. (2019), it was demonstrated that, when fermenting beer from sorghum, an average total acidity value of 4.26% was recorded in the Tínima beer, where the authors mention that this is probably due to the predominant fermentative action of lactic acid bacteria, mainly *Lactobacillus fermentum*, *Lactobacillus buchneri* and/or *Lactobacillus divergens* as a normal and typical occurrence during the fermentation stage of beer from this grain. This was not evident, actually, since the S-04 and K-97 strains belonging to the *Saccharomyces cerevisiae* yeast that were used presented more specific characteristics that were more adapted to the requirements for brewing beer from cape gooseberry.

According to Figure 2, shows that the treatments Chemical Fertilization (S04) and Humic and Fulvic Acids (S04) obtained the highest scores in the tasting, 7.7/10, these would be attributed to their superior qualitative characteristics, such as: transparent appearance, fruity flavor, with a licorice malt aroma, with medium aftertaste, compared to the K-97 strain yeast, which presents a long-lasting aftertaste, with cereal and citric hop aroma. Amaya and Diaz (2019) mentioned that, in their research, the beer fermented with the Candida tropicalis strain presented an odor and flavor like green apple, with a sensation of dryness in the mouth and fruity notes, obtaining an outstanding rating of fifty points (45-50). In contrast, the fermented with *Saccharomyces* reached 35/50 points, classified as very good (30-37), standing out for its low incidence of defects and acceptable, although not excellent, commercial quality. The chemical fertilization treatment (K94) had the lowest score, 5.7/10. The other treatments, including the controls and other treatments with humic acids, obtained intermediate scores between 6.0/10 and 6.7/10, suggesting that the results vary according to the type of treatment and its specific condition (S04 or K97).

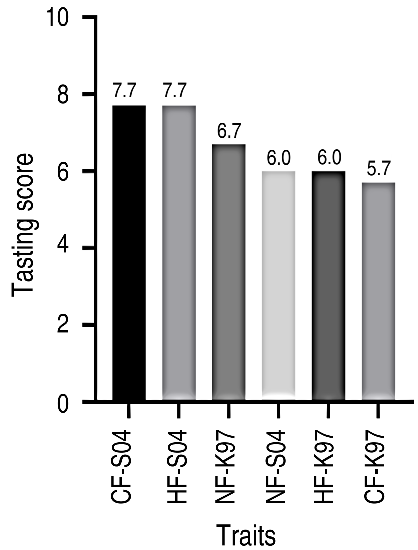

Figure 2. Final score of the tasting of the fermented *P. peruviana* beverage according to the treatments applied. NF-S04= No fertilization with strain S04; NF-K97= No fertilization with strain K97; HF-S04= Humic and fulvic acid fertilization with strain S04; HF-K97= Humic and fulvic acid fertilization with strain K97; CF-S04= Chemical fertilization with strain S04; CF-K97= Chemical fertilization with strain K97.

Table 3 shows that pH varied slightly among treatments, with the highest value in Chemical Fertilization (S-04) of 4.22 and the lowest in humic and fulvic acids (K-97) of 4.13. According to the Ecuadorian technical standard INEN 2262 (INEN 2013), the accepted pH range for beers is 3.5 to 5.0. In this investigation, the six samples studied presented pH values between 4.13 and 4.22, complying with the stipulations of national legislation. In addition, Kunze (2006) suggests that a pH below 4.4 contributes to a more refined taste in beer and improves the biological stability of the intestinal microflora. Total dissolved solids (ppm) were higher in the treatments with Humic and Fulvic Acids (S-04) and chemical fertilization (K-97), whereas the lowest values were recorded in the control treatment. In this regard, Castorena-García et al. (2020) reported that the addition of natural sugars during the winemaking process increases the initial total solids, thereby enhancing the anaerobic metabolism of the yeasts involved. Alcohol levels remained constant at 5.7% for all treatments, while titratable acidity varied, being lower in control (S-04, 0.141%) and higher in humic and fulvic acids (K-97, 0.16 %). According to Castorena-García et al. (2020), an exposed fermentation of 7 to 13 °C results in a "Lager" type beer, and between 16 and 23 °C it will be an "Ale" type beer, which is consistent with the type of beer obtained in this research Chaparro (2021) mentions that alcohol degrees may also vary due to incomplete extraction of sugars from the malt. This indicates that the treatments mainly affect dissolved solids and titratable acidity, with minor variations in pH.

Table 3. Organoleptic characteristics of craft beer using two types of yeasts.

Fertilization	Strain	pH	Total dissolved solids (ppm)	Alcohol content (%)	Titrable acidity (%)
NF	S-04	4.19	1,003	5.7	0.141
NF	K-97	4.16	990	5.7	0.161
HF	S-04	4.16	1,020	5.7	0.146
HF	K-97	4.13	1,010	5.7	0.163
CF	S-04	4.22	1,010	5.7	0.154
CF	K-97	4.19	1,020	5.7	0.156

(*) for *P*<0.05. **NF:** No fertilization**, HF:** Humic and Fulvic Acids fertilization, and CF: Chemical fertilization.

In Table 4, results for color show differences in color coordinates among treatments. No fertilization-K97 treatment presents the highest value of luminosity (L=45*) and greater intensity in a* and b* (15 and 53, respectively), with a lighter shade (#945F00). In contrast, humic and fulvic acid-K97 treatment has the lowest luminosity (L=33*) and lower values in b*, which generates a darker and more opaque color (#6D4703). Chemical fertilization-S04 showed a balance with L=43* and lower intensity in a* (5), obtaining a more neutral and clear tone (#806101). Regarding this, Delgado and Salame (2015) mentioned that the coloration of the beer depends on the malts used: base malts give a light yellow color, while colored malts, depending on the kilning temperature, produce darker colors. In this study, the light-yellow base malt influenced the final color of the beer, which matched the expected color. Additionally, Ferreyra (2014) explains that beer color is formed by chemical reactions such as the Maillard reaction (or browning), caramelization, and oxidation.

Table 4. CIE L*a*b* color coordinates in the fermented beverage according to the type of fertilization and strain used.

Fertilization	Strain	Color coordinates			Visualization	Code
		L*	a*	b*		
NF	S04	38	11	46		#795100
NF	K97	45	15	53		#945F00
HF	S04	39	10	47		#7B5300
HF	K97	33	11	42		#6D4703
CF	S04	43	5	50		#806101
CF	K97	35	11	44		#724B00

NF: No fertilization, HF: Humic and Fulvic Acids fertilization, and CF: Chemical fertilization.

Table 5 results show differences in appearance, foam, and flavor among treatments. In appearance, treatments NF-S04, HF-S04, CF-S04, and CF-K97 stand out for being completely transparent (100%), while NF-K97 and HF-K97 present up to 33.3% turbidity. Foam was predominantly poor in NF and HF-K97, while HF-S04 and CF-S04 achieved 100% correct foam. In terms of flavor, treatments HF-S04 and CF-S04, CF-K97 showed a stable balance (66.7-100%), while HF-K97 showed higher bitterness intensity (33.3%). Finally, long-lasting aftertaste was observed more in NF-S04, NF-K97, and HF-S04, with up to 66.7%, indicating that treatment and

Table 5. Results of the characteristics evaluated during the tasting.

Descriptor	Characteristic	Traits					
		NF-S04	NF-K97	HF-S04	HF-K97	CF-S04	CF-K97
Appearance- Clarity (%)	Transparent	8.3	30.0	11.7	40.0	8.3	37.0
	Opaque	0.0	0.0	0.0	0.0	0.0	0.0
	Murky	0.0	0.0	0.0	0.0	0.0	0.0
Appearance-Foam (%)	Poor	21.7	0.0	22.5	41.7	15.0	31.7
	Correct	0.0	50.0	0.0	0.0	0.0	0.0
	Persistent	0.0	0.0	0.0	0.0	0.0	0.0
Flavor-Intensity (%)	Light	40.0	46.7	45.0	46.7	48.3	3.67
	Medium	0.0	0.0	0.0	0.0	0.0	0.0
	Intense	0.0	0.0	0.0	0.0	0.0	0.0
Flavor-Balance (%)	Malty	0.0	0.0	25.0	0.0	27.7	0.0
	Balanced	56.7	51.7	0.0	56.7	0.0	50.0
	Bitter	0.0	0.0	0.0	0.0	0.0	0.0
Flavor-Aftertaste (%)	Short	0.0	0.0	45.0	0.0	46.7	0.0
	Medium	55.0	56.7	0.0	53.3	0.0	55.0
	Durable	0.0	0.0	0.0	0.0	0.0	0.0

NF-S04= No fertilization with strain S04; **NF-K97=** No fertilization with strain K97; **HF-S04=** Humic and fulvic acid fertilization with strain S04; **HF-K97=** Humic and fulvic acid fertilization with strain K97; **CF-S04=** Chemical fertilization with strain S04; **CF-K97=** Chemical fertilization with strain K97.

strain influence flavor clarity, balance, and persistence. Regarding this, Garrido (2014) mentions that, in terms of appearance, beers can be found between dark and cloudy (due to the presence of yeast in suspension), slightly opaque (if the crude has not undergone filtration), clear and clean (after exhaustive filtration), or completely crystalline (when subjected to ultrafiltration). Multiple gradations exist within this spectrum. Foam can be characterized by attributes such as texture and persistence, ranging from frothy, dense, and compact to creamy or short-lived. Likewise, these sensory perceptions are further refined by a wide array of characteristic flavors.

CONCLUSION

The best nutritional strategy for yield optimization and craft beer quality improvements was chemical, based on crop requirements and soil analysis. This mode of management ensured adequate nutrient availability, reflected in better agronomic performance and higher fruit quality, compared to treatments with humic and fulvic acids or no fertilization. In terms of brewing, the application of the S04 strain generated a beverage with more balanced acidity and greater sensory acceptance than that made with the K97 strain, demonstrating the influence of yeast selection on the organoleptic profile of the final product. Overall, the results highlight the importance of integrating precise nutritional management together with proper strain selection to improve both raw material and final product quality in craft brewing. Future research should focus on evaluating the interaction between crop nutrition and different yeast strains to develop sustainable strategies to boost productivity and improve the sensory quality of products made from these raw materials.

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CONFLICT OF INTERESTS

The authors assure that there are no relevant conflicts of interest related to the conduct of the study, the interpretation of the results, or the publication of this manuscript.

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