



Article

A Consumer Assessment of Fermented Green Coffee Beans with Common Beer/Wine Yeast Strains for Novel Flavor Properties

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Abstract: Fermentation is a critical step in the production of coffee when following standard wet processing, one of the most common methods used to remove the mucilage layer from coffee cherries. During this step, the de-pulped coffee cherries undergo fermentation with native yeast that modifies the flavor profile of the resultant coffee. This study aimed to ferment green coffee beans using commercial yeast strains from beer and wine prized for their ability to produce specific flavors, and subsequently evaluate the aroma and flavor of the coffee using coffee consumers. Four *Saccharomyces cerevisiae* strains were used: Belgian Ale, Sourvisiae, 71 B, and Tropical IPA, along with one non-*Saccharomyces*, *Toluraspora delbrueckii* (Biodiva), and a non-inoculated control sample. The green coffee beans underwent a controlled wet fermentation for 72 h, followed by roasting, grinding, and brewing. Results showed that flavor profiles varied broadly by yeast strain, suggesting that producing novel flavors in coffee through fermentation is feasible and that these flavors survive the roasting process; however, higher liking scores were still reported for the control sample compared to the fermented samples. Biodiva, a strain used in wine to produce esters and fruity flavors, resulted in coffee with highly fruity notes, and all strains were rated more floral than the control, while the sample fermented with Sourvisiae yeast used in the brewing of sour ales resulted in coffee that was both perceived as more sour and had the lowest pH, likely due to the degree of lactic acid this strain is engineered to produce. Further, there were significant color differences between the samples. In conclusion, fermenting green coffee beans with brewing and winemaking yeast strains strongly impacted the flavor and aroma of the resultant coffee; however, evaluating larger panels of strains or optimizing strain performance may yield flavor profiles more suitable for coffee.

Keywords: commercial yeast strains; sensory; coffee; flavor; fruity



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1. Introduction

As one of the most widely consumed beverages globally, coffee holds significant economic weight, cultivated in over 50 developing nations [1]. As of 2022, global coffee exports tallied up to approximately 10.88 million 60 kg bags, each averaging a price of 3.47 USD per kg [2]. Leading in coffee production are countries including Brazil, Vietnam, Colombia, and Indonesia [3]. The coffee that we relish hails primarily from two species—*Coffea canefora*, or Robusta, and *Coffea arabica*, or Arabica [4,5]. The environment where these coffee plants grow, including the altitude, temperature, and harvesting methods, can markedly influence the sensory profile of the brewed coffee [5,6]. While Robusta coffee typically imparts a distinct mouthfeel and a more bitter taste, Arabica is characterized by its heightened acidity and aromatic complexity [7].

The coffee fruit, also known as a coffee cherry, comprises multiple layers. The outermost layer, the pericarp, includes the exocarp (pulp), the mesocarp (mucilage), and the endocarp (parchment). Inside the pericarp, we find the perisperm and ultimately, the coffee seed, referred to as the endosperm [4,8]. A key step in coffee production is the natural

fermentation of the coffee cherry, a process that initiates the degradation of the mucilage [4]. This step not only facilitates the release of distinctive aroma and flavor compounds but also assists in removing the mucilage from the coffee parchment [9]. Three major coffee-processing methods exist: wet, dry, and semi-dry. The dry method, the oldest of the three, involves sun-drying and fermenting ripe coffee cherries until they reach a desired humidity level of 11–12%. This process can take anywhere from 10 to 25 days [4,10]. As the fruit ferments, it develops a sweet, smooth, and layered body. This method is widely employed in the processing of Arabica coffee, with an estimated 95% of its production utilizing this method to produce high-quality coffee [11]. In contrast, the semi-dry method separates the mesocarp and mucilage from the rest of the cherry and sun-dries the de-pulped coffee until the optimal humidity level is reached [4]. Lastly, the wet process involves removing the cherry's pulp, soaking the de-pulped coffee in water for 24–72 h, and then drying it [1,10]. In this wet fermentation, microbial activity leads to the degradation of the mucilage layer, producing metabolites and organic compounds that alter the coffee's flavor and aroma profile [12,13]. These compounds include aldehydes, acids, esters, alcohols, furans, and ketones [13,14]. Natural wet coffee fermentation involves a diverse set of microbiota, including bacterial genera such as *Lactobacillus*, *Bacillus*, *Arthrobacter*, *Acinetobacter*, and *Escherichia* [13,14], as well as yeasts including *Saccharomyces*, *Cryptococcus*, *Pichia*, and *Hanseniaspora* [13,15]. The dry method has been used since ancient times but is time consuming. Coffee producers, especially in Central and South America, have increasingly adopted the wet method, becoming more popular because it helps improve coffee quality by increasing acidity and aroma compounds developed during wet fermentation [8,16]. A disadvantage of this method is that it needs more water during the process compared to the other methods, one of the limitation of this method [16].

There has been recent discussion among coffee producers regarding the utilization of starter cultures instead of native yeast for the purpose of enhancing, accelerating, and controlling coffee fermentation [14,17]. Depending on the specific starter culture employed, the acidity of the coffee may be influenced. For instance, starter cultures containing *Erwinia*, *Klebsiella*, *Aerobacter*, *Escherichia*, and *Bacillus* can decrease the pH from 5.5–6.0 to 3.5–4.0 by producing lactic and acetic acid [18]. While coffee fermentation generally has a positive impact on coffee quality, it can also have negative consequences. Over-fermentation, exceeding the recommended fermentation duration, can negatively affect the aroma and flavor compounds. This can result in the development of an unacceptable aroma profile due to the production of chemical compounds such as propionic, butyric, and short-chain fatty acids [9,19].

Saccharomyces cerevisiae, a yeast noted for its top-fermenting behavior, plays a pivotal role in brewing ale-style beers and in the winemaking industry [20,21]. This yeast's capacity to generate volatile esters during the fermentation process is responsible for the distinct fruity and floral profiles found in these beverages [20,21]. In wine fermentation specifically, *Saccharomyces cerevisiae*, as the principal yeast, imparts characteristic wine aromas through the production of various volatile compounds, such as esters, alcohols, aldehydes, and terpenes [22]. However, *Saccharomyces cerevisiae* is not the only yeast contributing to the complexity and diversity of fermented beverages. Recent interest in the wine industry has highlighted *Torulaspora delbrueckii*, known for its slow fermentation rates and stress tolerance, often used alongside *S. cerevisiae* in mixed fermentations to modulate flavor complexity, introducing unique fruity and floral aromas [23,24]. Beyond these two, a plethora of non-*Saccharomyces* yeasts, including *Candida*, *Hanseniaspora*, *Metschnikowia*, and *Pichia* also have roles in shaping the flavor profile and complexity of beverages. These non-*Saccharomyces* yeasts, while less alcohol-tolerant, can contribute unique characteristics to the final product, thereby enhancing the sensory experience [25,26].

While traditionally associated with beer and wine production, *Saccharomyces cerevisiae* and *Torulaspora delbrueckii*, along with other yeast species, are finding broader applications, guided by academic research and industry interest. In this vein, our study inoculated green coffee beans with several commercial strains of *Saccharomyces cerevisiae* and *Torulaspora*

delbrueckii. We aimed to examine the chemical and sensory changes these yeasts might induce in resulting coffee, thereby providing a novel perspective on flavor development and offering potential innovations in coffee processing.

2. Materials and Methods

2.1. Fermentation

Green coffee beans were selected for fermentation due to the seasonality of fresh coffee cherries, and import regulations for fresh coffee fruits. We sourced green beans (*Coffea arabica*) from Primos Coffee Co., cultivated in Nicaragua (Primos Coffee Company, Jinotega, Nicaragua). After the harvesting process, the coffee cherry undergoes a transformation, becoming a green coffee bean. The primary difference between both is that the green coffee bean lacks the mucilage, pulp, and some percentage of the silverskin that the coffee cherry contains [4]. These coffee layers are rich in carbohydrates and play an important role during the fermentation process [9,27]. To simulate the fermentation process of fresh coffee cherries, we supplemented the beans with 0.48 g of glucose, following the relative ratio of fermentations reported in a previous study [28]. In a preliminary trial, we selected fourteen yeast and bacteria strains (Supplementary Tables S1 and S2). From this initial selection, we included five yeast strains in the main trial based on the resulting coffee's aroma, flavor profile, and commercial availability (see Table 1). These strains comprised two popular wine strains, one *Saccharomyces cerevisiae* strain (71 B) and one *Torulaspora delbrueckii* strain (Biodiva). Additionally, we incorporated a bioengineered *Saccharomyces cerevisiae* strain, Sourvisiae, which gained popularity in the brewing industry for its lactic acid production during fermentation. Two beer *Saccharomyces cerevisiae* strains, a Belgian Ale and a Tropical IPA strain, were also employed. During the preliminary trials, we observed that excessive water addition to the fermentation could trigger seed germination, resulting in an undesirable aroma in the resulting coffee, aligning with suggestions from previous literature [29]. To address this, we established a protocol using a yeast slurry with minimal water and a high yeast cell concentration. Specifically, we utilized 70 mL of water per 71 g of coffee beans, with an initial cell count at the inoculation of 5.94×10^{11} CFU/mL. All fermentations were conducted in triplicate, with a set of triplicates without inoculation serving as the negative control. The samples underwent a 72 h fermentation period under anaerobic conditions.

Table 1. Commercial yeasts selected for fermentation.

Strain Commercial Number	Organism	Manufacturer	Common Fermentation Product
Belgian Ale	<i>Saccharomyces cerevisiae</i>	Omega Yeast Labs (Chicago, IL, USA)	Beer
Tropical IPA	<i>Saccharomyces cerevisiae</i>	Omega Yeast Labs	Beer
Biodiva	<i>Torulaspora delbrueckii</i>	Lallemand Inc. (Montreal, QC, Canada)	Wine
71B	<i>Saccharomyces cerevisiae</i>	Lallemand Inc.	Wine
Sourvisiae	<i>Saccharomyces cerevisiae</i>	Lallemand Inc.	Beer

2.2. Coffee Drying, Roasting, Grinding, and Extraction

The fermented coffee beans plus control were dried using a commercial dehydrator for 4.5 h at 45 °C to reach the original weight of the green coffee beans, followed by roasting at a low-temperature setting (200 °C) for 7 min using a coffee roaster (FreshRoast SR500 Automatic Bean Roaster, Brandford, CT, USA). After roasting, the beans were ground to approximately 800 µm particle size with a coffee grinder (Cuisinart DBM-8P1 Supreme Grind Automatic Burr Mill, Stamford, CT, USA). Finally, the hot coffee was prepared using a standard drip coffee maker (CM1070B Black + Decker, New Britain, CT, USA), measuring 88 g of ground coffee beans for 2000 mL of water and resulting in 1700 mL of brewed coffee.

2.3. pH and Titratable Acidity

The pH was measured with a calibrated Oakton 510 (OAKTON Instruments, Vernon Hills, IL, USA) pH meter. The electrode was submerged into every sample and rinsed after the measurement. The pH electrode was submerged into 10 mL of coffee and titrated with NaOH 0.1 M, with the volume of NaOH recorded to calculate the titratable acidity.

2.4. Color Measurement

The color of the brewed coffee was measured with a Hunterlab ColorQuest XE (HunterLab, Reston, VA, USA), calibrated using white and black standards. The readings were expressed in terms of CIE LAB values for $*L$, $*a$, and $*b$. The $*L$ value measures the darkness of the sample, with values ranging from 0 to 50 indicating a dark color and values higher than 50 indicating a lighter color. The $*a$ value measures the greenness or redness of the sample color, where a positive $*a$ value indicates redness and a negative value indicates greenness. The $*b$ value measures the yellowness or blueness of the sample color, with positive values indicating yellowness and negative values indicating blueness. Each condition was replicated three times, and each replicate was measured three times for accuracy.

2.5. Sensory Analysis

The human participant procedures for this study were approved by the Cornell University Institutional Review Board. A total of 98 coffee consumers who were familiar with black coffee without any additives were prescreened, and all provided informed consent. To prescreen the panelists, participants first answered a Qualtrics survey that consisted of three questions: Do you drink coffee? Do you drink black coffee (without milk, sugar, or other additives)? How frequently do you drink black coffee (without milk, sugar, or other additives)? In order to be invited to participate in the study, people needed to answer yes to the first and second questions, and they needed to drink black coffee (without milk, sugar, or other additives) at least 3 times per week. In total, 253 people answered the survey and 98 fit the requirements and completed all parts of the survey. Of these, 58 of the participants were females and 40 were males; 8 of the participants were <20 years old; 48 of them were between the group of ages 20–29; 19 were between 30–39; 12 were between 40–49; 8 were between 50–59; and 3 were >60 years. The panelists were informed that they would participate in a sensory test involving coffee without knowing the specific research purpose. Each session lasted approximately 20–30 min. The questionnaire was created using the sensory software RedJade (Redjade Sensory Solutions, LLC, Martinez, CA, USA). Panelists were compensated for their time. Using a 100-point hedonic scale with samples rated from the “Greatest Imaginable Like” for the product (100 points) to the “Greatest Imaginable Dislike” for the product (0 points) [30]. Panelists evaluated each sample for overall liking, appearance liking, and aroma liking. They also assessed the intensity of coffee, nutty, fruity, floral, and sweet-potato aromas, as well as the tastes of sweetness, acidity, and bitterness using the generalized Labeled Magnitude Scale (gLMS), attributes determined in pre-testing by sensory experts from the lab group. Participants received a brief orientation on the gLMS, a quasi-logarithmic scale used to rate perceptions of a presumably universal set of anchors, then rating a series of varying auditory and visual imagined sensations. Whole-mouth suprathreshold taste intensity ratings were captured on the gLMS, with scale descriptors and values as follows: no sensation (0.0), barely detectable (1.4), weak (6.0), moderate (17.0), strong (34.7), very strong (52.5), and strongest imaginable sensation of any kind (100.0) [31,32]. Attributes were determined in a preliminary bench test before the main evaluation. The six samples were kept warm in insulated carafes and were served individually in 30mL pours of each sample at a temperature between 50–60 °C. To maintain anonymity, the samples were coded with three-digit blinding codes, and the order of the samples was counterbalanced. The panelists were instructed to cleanse their palate with water between each sample. At the end of the test, the panelists were asked demographic questions and questions about their coffee-related habits.

2.6. Statistical Analysis

The liking scores, coffee attributes, and the pH of the samples were analyzed with one-way repeated ANOVAs and post hoc Tukey's test or with Kruskal–Wallis test with post hoc Dunn's test depending on normality of data, using GraphPad Prism 5.0 (GraphPad Prism, San Diego, CA, USA) and XLSTAT (Addinsoft, Paris, France).

3. Results and Discussion

3.1. pH Measurement and Titratable Acidity

The pH of the coffee was measured after brewing (Figure 1), with significant differences ($p < 0.05$) between the pH of the samples depending on yeast strain. The fermented coffee samples exhibited increased pH compared to the non-inoculated control, excluding *Sourvisiae*, a lactic acid producer [33]. These results differ from the literature, stating that fermented coffee beans decrease their pH during fermentation [34], which may in fact be a strain-specific observation. During this process, polysaccharides break down into sugars, producing different compounds that modify acidity, such as alcohols and acids [35]. The fermented coffee with 71B was numerically the highest pH, while the non-inoculated sample had the second lowest pH, similar to results reported in the literature for Nicaraguan coffee [36].

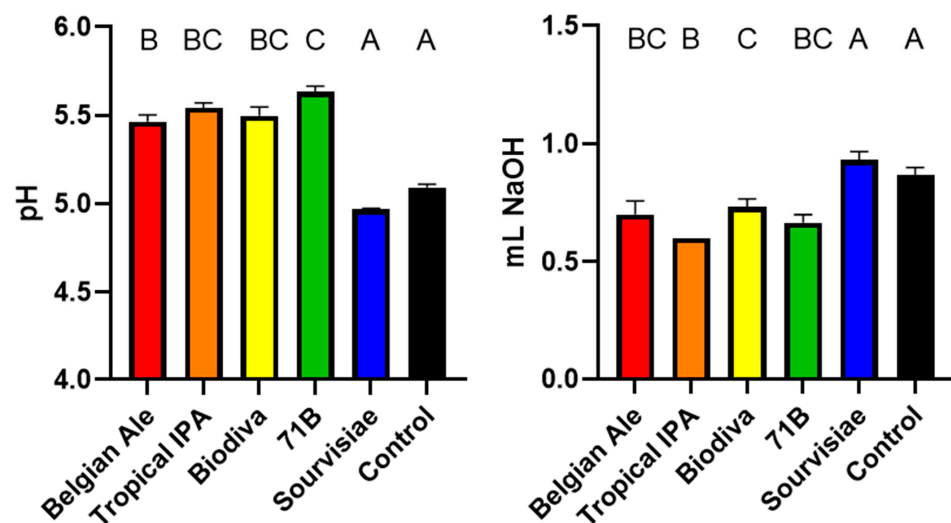


Figure 1. Samples pH and titratable acidity of roasted coffee beans. Bars with different letters indicate a significant difference ($p < 0.05$) between samples, lower case represent pH comparisons, upper case represent TA.

Given that Titratable Acidity (TA) has a higher correlation to perceived sourness than pH, we quantified TA in our coffee samples, presumably consisting primarily of chlorogenic acid, the main acid found in coffee [35]. The titratable acidity observed in our study again showed variation compared to the content reported in the literature [37]. It is important to consider that these variations can be influenced by the type of roasting method employed. When the roasting time is extended, the chlorogenic acid levels tend to decrease compared to shorter roasting durations. In our study, the samples underwent a longer (but equal between samples) roast, which may explain the lower concentration of chlorogenic acid observed. In decreasing order, the titratable acidity was *Sourvisiae* > Control > Biodiva > Belgian Ale > 71 B > Tropical IPA. On the other hand, the pH increasing order of *Sourvisiae* < Control < Belgian Ale < Biodiva < Tropical IPA < 71B. These results correlate with previous literature in which, at lower pH, the titratable acidity was higher [38].

3.2. Color Variations

A statistical difference ($p < 0.05$) between the color of the brewed coffee samples was apparent. The sample with the highest $*L$ value was Belgian Ale coffee. Fermenting the coffee beans increased the $*L$ value, excluding *Sourvisiae*, which had a lower value (20.79), indicating that the coffee sample had a darker color. In the case of the $*a$ value, the parameter increased, indicating that the fermented coffee was redder (see Figure 2). The $*b$ value of the control sample, excluding *Sourvisiae*, was lower than the fermented coffee samples (38.61), indicating that the fermented coffee was more yellow than the control. In a study by Yeager et al. (2022), they determined that on average, the $*L$ values for light-roasted coffee were between 37.52–36.42, the $*a$ value that corresponds to light-roasted was between 25.91–24.35, and the $*b$ value was between 22.05–24.10 [39]. Only the $*b$ value was completely different from the results obtained in this study, indicating that the fermented coffee has a more yellow color. The color difference may also be due to the fact that the experiment was performed with green coffee beans instead of coffee cherries, so when the bean was submerged in water, some phenolic compounds, such as chlorogenic acid, could have been extracted from the bean [40]. This could in turn affect the Maillard reaction that happens during roasting, in which chlorogenic acid plays a role in the development of melanoids [41].

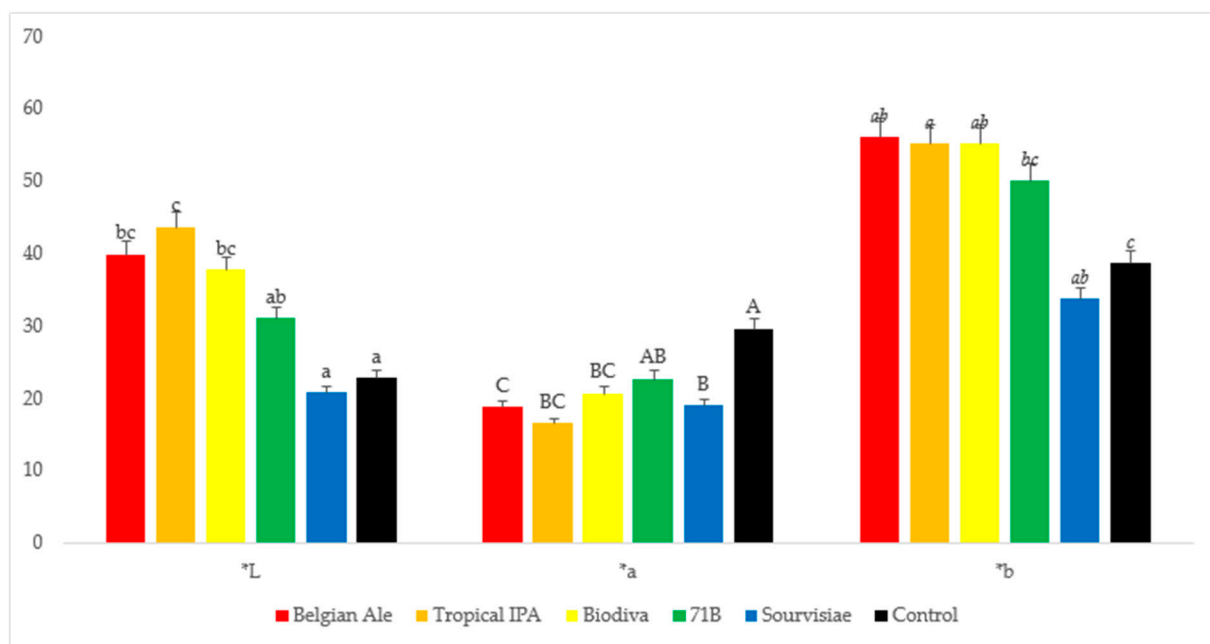


Figure 2. $*L$ $*a$ $*b$ values of inoculated and uninoculated control samples. Bars with different letters indicate a significant difference ($p < 0.05$) between samples, lower case represent $*L$ comparisons, upper case represent $*a$, italic represent $*b$. The color parameters measured in the samples include $*L$ (darkness/lightness), $*a$ (greenness/redness), and $*b$ (yellowness/blueness) For both $*a$ and $*b$, measurement of 0 represents a neutral color.

3.3. Consumer Sensory Analysis

3.3.1. Consumer Assessment of Flavor Profiles of Fermented Coffee

Saccharomyces cerevisiae and *Tolurasporea delbrueckii* are both commonly used in the beer and wine industries for fermentation, with different strains used to provide specific flavors and aromas. *Saccharomyces cerevisiae* produces various alcohols and ester groups, modifying a beverage's flavor [21]. A floral aroma is one of the descriptors often applied to fermentation with this strain. *Tolurasporea delbrueckii* has been characterized as specifically producing floral and fruity aromas [42,43]. Coffee produced in this study exhibited significantly different aroma and flavor attributes with fermentation ($p < 0.05$). The sample with

the highest score in the coffee-like attribute was, unsurprisingly, the control (the untreated sample). Each fermented sample was rated lower than 15 points on this 100-point scale. This significant difference between samples in this attribute indicates that fermenting the coffee beans with *Saccharomyces cerevisiae* and *Torulaspora delbrueckii* modified the coffee-like nature of the product in exchange for other sensory notes. *Saccharomyces cerevisiae* samples were more fruity, floral, nutty, and sweet than the control due to the flavor compounds generated during fermentation [17,34].

When considering the perceived sourness or acidity of the samples, most exhibited similar characteristics, with the exception of *Sourvisiae*. This strain notably produces lactic acid, which distinctly influences its acidity profile [33]. The uninoculated control registered the second-highest score for acidity. These results showed a correlation ($R^2 = 0.710$; $p < 0.001$) with pH and titratable acidity measurements (Figure 1), where both the uninoculated controls and the samples inoculated with *Sourvisiae* demonstrated similar patterns and displayed lower pH values. It is interesting to note that, apart from *Sourvisiae*, as expected, all the wine and beer strains worked as a tool to lower the perceived acidity as shown both in the sensory analysis and the titratable acidity measurements. This means that such a strategy could be used as a tool to lower the acidity of certain specialty coffees to fit a certain consumer group's taste. On the other hand, for those who prefer a higher acidity, utilizing *Sourvisiae*, which produces lactic acid and thus intensifies the sour flavor profile, could be an effective strategy.

Furthermore, both the uninoculated controls and *Sourvisiae* inoculated samples were perceived to have a higher degree of bitterness. One possible explanation is that the panelists may be conflating the sourness or acidity of the coffee with bitterness. Alternatively, the decreased perception in other samples could be a result of mixture suppression, induced by the abundance of distinctive fruity, floral, and nutty attributes [19]. A similar phenomenon was observed in the samples fermented with *Biodiva*. These samples showed the highest scores for floral and sweetness attributes. However, in terms of perceived acidity, they ranked second lowest, despite having a mid-range level of titratable acidity (Figures 1 and 3).

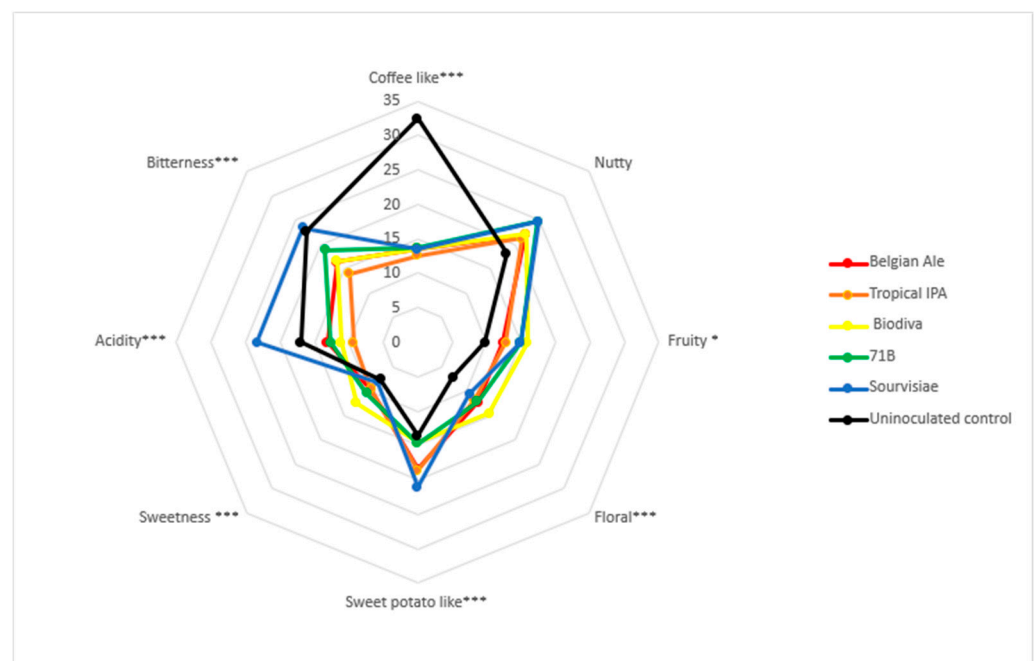


Figure 3. Radar chart of the perception of the flavor attributes evaluated by consumers. The attributes were evaluated on a scale from 0-100. Stars indicate the level of significant difference, where * indicates $p < 0.05$; *** indicated $p < 0.001$.

Even though the nutty attribute has been recognized in *Saccharomyces cerevisiae* and *Torulaspota delbrueckii* fermentations [34], nutty was the only note that did not present a significant difference in sensory testing, meaning that panelists perceived the control sample with the same nutty aroma as all others. Finally, the descriptor corresponding to the sweet-potato aroma was more predominant in the Sourvisiae and Tropical IPA samples. This aroma is a volatile compound often generated by fermentation [12]. For further research, it would be interesting to test samples with gas chromatography to determine the more predominant compounds and record how they correlate with the attributes evaluated during the sensory test.

Another point worth noting is that, in the open comments regarding “other attributes”, several panelists observed a “tea-like” quality in multiple samples fermented by wine and beer strains, likely a reflection of their floral notes. This suggests that the floral aromas produced with these strains may impart a unique characteristic that could appeal to tea consumers, potentially drawing them towards coffee. Moreover, the samples inoculated with the strains Belgian Ale, 71B, and Biodiva were distinctively noted to carry a chocolate attribute in the open comments. This observation resonates with the study by Pereira et al. (2021), which suggests that the strains *Saccharomyces cerevisiae* and *Torulaspota delbrueckii* have the potential to contribute to a chocolate flavor profile [43]. Given these intriguing results, further studies could be undertaken to explore the potential of yeast inoculation during coffee fermentations in imparting atypical but desirable aroma characteristics to coffee.

3.3.2. Overall Liking

A statistical difference was observed between the hedonic scores of overall, aroma, and appearance liking ($p < 0.05$) (Figure 4). Previous work suggested that coffee beans fermented with *P. fermentans* with sucrose supplementation were less acceptable in aroma and taste versus a control sample [18]. In this study, the uninoculated control sample obtained the highest overall, aroma, and appearance scores, being more liked than the fermented samples. The fermented samples in our test performed similarly, excluding Sourvisiae, which was the least liked in the three ratings (overall, aroma, and appearance liking), probably due to the high acidity of the resultant coffee (although highly acidic coffee is a noted market segment). We hypothesize that this may be attributed to the double processing employed in the inoculated samples. These fermentations were conducted on green coffee beans that had already undergone some degree of fermentation and drying once previously. Visually, we observed that the second fermentation appeared to extract color, regardless of the strains used, resulting in a lighter style of coffee. Therefore, we suspect that this specific processing method employed in our lab had some impact on the outcome of the samples. To eliminate the confounding effect of double processing, further studies could be conducted using fresh coffee cherries, which would allow for a more accurate assessment of the effects of inoculated fermentation on the final coffee product.

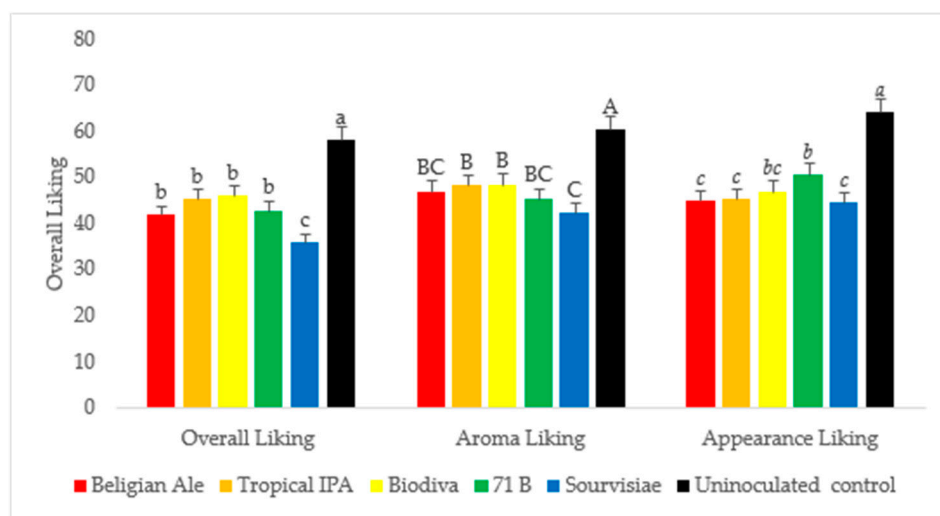


Figure 4. Hedonic scores for overall liking, aroma liking and appearance liking. Bars with different letters indicate a significant difference ($p < 0.05$) between samples.

4. Conclusions

In conclusion, the fermentation of green coffee beans with *Saccharomyces cerevisiae* and *Torulaspora delbrueckii* strains showed the potential of yeast inoculation as a technique to enhance the aroma and flavor profiles of coffee as perceived by regular coffee consumers, without the need for additional ingredients. The process resulted in significant alterations to the sensory characteristics of the coffee, yielding a floral and fruity aroma while reducing acidity and bitterness. Although the fermented samples in this experimental trial were generally less liked compared to regular black coffee, it is important to note that this could be attributed to the specific experimental constraints rather than the inherent quality of the fermented coffee. Further research is needed to identify and select specific yeast strains that can effectively enhance the desirable attributes of coffee. Exploring yeast strains, either through deliberate selection or engineering, could provide opportunities to create flavors that are better suited for coffee consumption. Additionally, optimizing the fermentation process will play a crucial role in improving the overall acceptability of the final coffee product. By advancing our understanding of yeast fermentation in coffee production, we can unlock new possibilities for creating unique and appealing coffee varieties, that may in turn appeal to a market of new consumers not currently enjoying conventional coffee flavors. As such approaches as those reported in this paper use relatively accessible technology, broader adoption could lead to new markets for coffee without the introduction of novel ingredients that may dissuade traditional consumers.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/fermentation9100865/s1>: Supplemental Tables S1 and S2.

Author Contributions: Conceptualization N.C., G.Z.J. and R.D.; methodology N.C., G.Z.J., R.D. and P.A.G.; software, N.C. and R.D.; formal analysis N.C., G.Z.J. and R.D.; investigation N.C. and G.Z.J.; resources R.D. and P.A.G.; writing—original draft preparation N.C., G.Z.J., R.D. and P.A.G.; writing—review and editing N.C., G.Z.J., R.D. and P.A.G.; supervision R.D. and P.A.G.; project administration N.C. and G.Z.J.; funding acquisition R.D. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Data available on request.

Conflicts of Interest: The authors declare no conflict of interest.

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