Research Article

Quantifying the Trade-Off Between Yield and Sensory Attributes in Strawberry Cultivars: A Data-Driven Evaluation

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Abstract |Balancing high yield with superior sensory quality is a key challenge in commercial strawberry production. This study evaluated three cultivars FORTUNA, SABRINA, and VICTORIA across two harvest seasons (2023–2024) in Larache, Morocco. A total of 1,999 composite truck samples were analyzed for soluble solids (°Brix: 7.00–8.81%), pH (3.40–3.58), average fruit weight (21.76–27.89 g), and total quantity received, complemented by a structured sensory assessment of taste, odor, texture, and visual appeal. Using two-way ANOVA and Tukey's HSD tests, seasonality emerged as the dominant factor, with cultivar effects significant for pH and fruit weight. FORTUNA outperformed its competitors, contributing 78.5% (4,228.09 tonnes) of total volume from 23 producers, with higher pH, larger fruits, and consistent °Brix mid-season. Sensory results confirmed its advantage in juiciness, smoothness, tenderness, and brightness, leading to top consumer preference. VICTORIA stood out for sweetness and color, SABRINA for firmness and acidity, but both lagged in overall appeal. These findings identify FORTUNA as a statistically validated, market-aligned cultivar combining yield and quality. The integrated framework supports decisions on varietal selection, harvest timing, and post-harvest management in export-oriented chains. Future research should address disease resistance, storage stability, and consumer targeting to refine deployment strategies.

Received | July 12 2025; **Accepted** | August 15, 2025; Published | November 05, 2025
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Citation | El Moutaouakil, S., A. Rossafi, Y. El Madhi, N. Sbai, F. Elwahab, A. Benzkour nd M. Ouhssine. 2025. Quantifying the trade-off between yield and sensory attributes in strawberry cultivars: a data-driven evaluation. Sarhad Jurnal of Agriculture, 41(4): 1802-1813.
DOI | https://dx.doi.org/10.17582/journal.sja/2025/41.4.1802.1813
Keywords | Strawberry cultivars, Physico-chemical traits, Yield optimization, Post-harvest quality, Sensory evaluation, Consumer preference.

Introduction

Strawberry (*Fragaria ananassa*) is one of the most consumed fruits in the world because of its pleasant flavor, nutritional properties and high demand on fresh and processed markets (Kumar *et al.*, 2022). The quality of strawberries is influenced by several intrinsic factors such as firmness, soluble sugar content, titratable

acidity and phenolic compounds. These attributes are essential for determining market value, consumer preference and shelf life (Ganhao *et al*., 2019).

In Morocco, the cultivation of strawberries is predominant in intensive agricultural areas, especially in the Gharb and Loukkos regions. These regions benefit from favorable climatic conditions and agricultural know-how to obtain high yields and optimum quality of fruit for export. The strawberry sector contributes significantly to the local economy by generating seasonal jobs and participating in international trade. However, to meet the strict quality standards imposed by European markets, it is essential to monitor post-harvest parameters and select varieties with characteristics adapted to market requirements (El-araby *et al*., 2023; Hasnaa *et al*., 2023). In particular, periodic evaluation of physicochemical and microbiological quality of strawberry pulp has been shown to be critical for ensuring safety and shelf life in Moroccan processing plants (El Moutaouakil *et al*., 2024).

The cultivars FORTUNA, SABRINA, and VICTORIA were selected for their contrasting agronomic and post-harvest traits. FORTUNA is a high-yielding, early-maturing variety favored in early-season markets (Menzel, 2023). SABRINA is notable for its firmness and strong resistance to transport stress, traits that contribute to extended shelf life (Urün *et al*., 2021). In contrast, VICTORIA offers superior organoleptic qualities, with a rich aromatic profile and elevated levels of bioactive compounds, such as gallic acid, supporting its high antioxidant capacity (Urün *et al*., 2021).

While numerous studies have explored the effects of environmental or agronomic conditions on strawberry performance including irrigation regimes (Ariza *et al*., 2021), storage temperatures (Hansawasdi *et al*., 2006), and climatic effects on sugar content (Menzel, 2022) comparative evaluations across cultivars remain fragmented, especially under real-world supply chain settings. In particular, recent efforts have assessed the antioxidant and sensory properties of different cultivars (Zeliou *et al*., 2018), or monitored pulp quality parameters in Moroccan processing plants (El Moutaouakil *et al*., 2024). However, few studies have simultaneously linked field-level yield, physico-chemical quality traits, and sensory attributes within a unified, season-long monitoring framework. This gap limits our understanding of how cultivar-specific traits manifest in both agronomic outputs and consumer-oriented quality under commercial conditions.

A dual-focus approach capturing both agronomic performance and intrinsic fruit quality offers a robust framework for assessing how varietal genetics interact with local environmental conditions (Ariza *et al*., 2021). This comprehensive approach facilitates the identification of factors that contribute to fruit deterioration such as fluctuations in sweetness (Brix), acidity (pH), and textural properties thereby enabling more accurate predictions of post-harvest stability (Nakro *et al*., 2023). By examining these parameters simultaneously, producers can pinpoint critical points of vulnerability in the supply chain, ultimately reducing economic losses and enhancing consumer satisfaction (Urun *et al*., 2021). Furthermore, the ability to compare variety-specific outcomes including 'Fortuna,' 'Sabrina,' and 'Victoria' under realistic production and storage conditions is instrumental in refining cultivation practices, from harvesting schedules to handling techniques (EL Oualkadi and Hajjaj, 2019). A clearer understanding of how intrinsic fruit attributes correlate with yield thus becomes essential for optimizing organoleptic and nutritional quality over extended periods (Peris-Felipo *et al*., 2020; Zeliou *et al*., 2018).

In line with this vision, the present study evaluates the post-harvest performance of three strawberry cultivars FORTUNA, SABRINA, and VICTORIA over two consecutive production seasons, through a dual-focus approach combining agronomic metrics (yield, average fruit weight) with key quality indicators (°Brix and pH). To complement this, a structured sensory analysis assessing taste, odor, texture, and visual appeal xamines how intrinsic fruit traits influence consumer preferences. This integrated, data-driven framework aims to elucidate the trade-offs between yield and quality, offering actionable insights into cultivar selection, harvest scheduling, and post-harvest management. By identifying the dominant factors shaping strawberry quality in a competitive, export-oriented context, the study contributes to both scientific understanding and improved decision-making within high-performance fruit supply chains.

Material and Methods

Study site and conditions

This study was conducted in the Larache region of

Morocco (Figure. 1), specifically at an anonymized industrial facility (35.1744° N, 6.1474° W) specializing in secondary fruit processing. The facility serves both local markets and the broader Middle East and North Africa (MENA) region, with a primary focus on strawberries. For the purposes of this study, the strawberry cultivars FORTUNA, SABRINA, and VICTORIA were supplied by a coordinated network of local partner farms. Because all varieties were cultivated within the same network of producers under unified practices, observed differences in fruit traits can be reliably attributed to varietal effects rather than environmental variability. These unified practices included synchronized planting dates, standardized irrigation schedules, and common fertilization and pest control protocols each aligned with guidelines established by the regional agricultural cooperative.

Plant material

The plant material used in this study consists of three strawberry varieties see Figure. 2 FORTUNA, SABRINA, and VICTORIA. FORTUNA is an early variety known for its high production capacity (Ariza *et al.*, 2021; Balducci *et al.*, 2016), while SABRINA is recognized for its firmness and excellent tolerance to transport (Zeliou *et al.*, 2018). VICTORIA is appreciated for its distinctive aroma and sweetness (Urun *et al.*, 2021). These varieties were chosen for their strong agronomic performance and superior organoleptic qualities, making them especially suitable for evaluating post-harvest parameters.

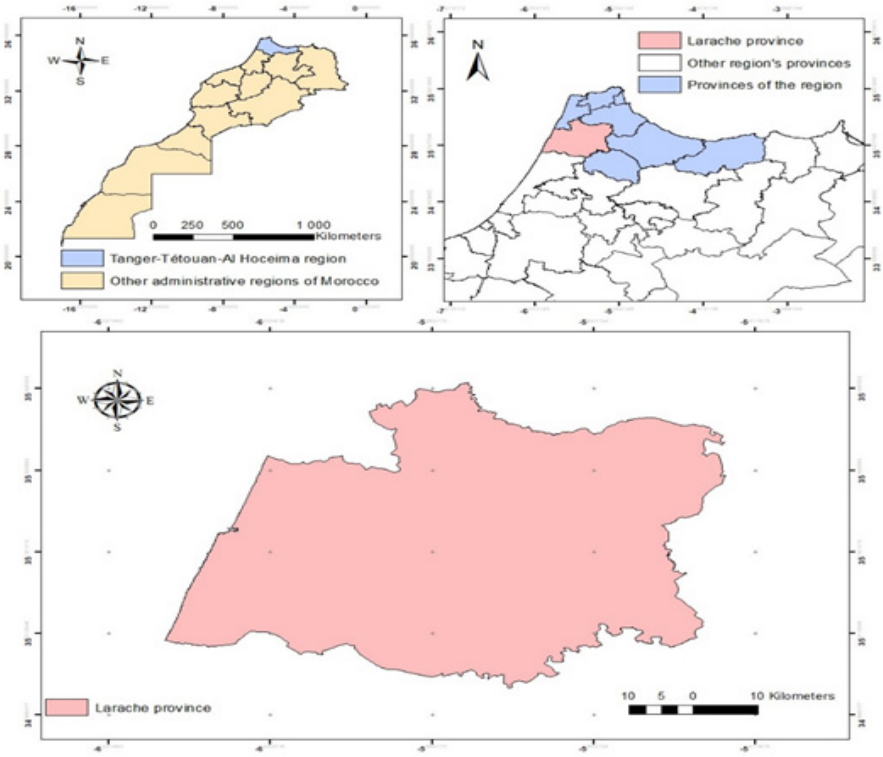

Figure 1: *Geographic map of study area*

Figure 2: *Representative samples of the three strawberry varieties: a) FORTUNA, b) VICTORIA and c) SABRINA.*

In total, 23 producers cultivated FORTUNA, 13 cultivated SABRINA, and 14 cultivated VICTORIA. This distribution allowed us to evaluate varietal performance across commercial-scale farming operations with sufficient replication per cultivar.

Data collection and processing

The analysis is based on a dataset comprising 1999 records, collected over two distinct periods: from 27 February 2023 to 05 June 2023 and from 29 January 2024 to 03 June 2024. Each record represents average measurements from three boxes per truck (sampled at the start, middle, and end of unloading) to ensure representative sampling.

Key variables summarized in Table 1 included date, producer ID, Brix (sweetness), pH (acidity), received quantity (kg), and average fruit weight (g). In addition to these variables, the dataset specifies the strawberry variety FORTUNA, VICTORIA, and SABRINA enabling a comparative analysis across different cultivars. This comprehensive data collection framework lays a solid foundation for evaluating both post-harvest performance and intrinsic quality attributes, thereby supporting actionable insights for producers and quality control managers.

Table 1: *Overview of key variables and their descriptions.*

Variable	Description
Date	The specific day on which the data was recorded.
Producer	The origin of the strawberries, allowing for comparisons across the 23 different production entities.
Brix	Indicates the sweetness of the fruit.
pH	Indicates the acidity levels of the fruit.
Received quantity	Measured in kilograms, representing the total weight of strawberries received.
Average fruit weight	The mean weight (measured in gramme) of individual fruits, determined from measurements taken from three boxes (beginning, middle, and end of the unloading process).

Rigorous preprocessing was applied following Beyer (Beyer, 1981). Missing values less than 0.3% for all critical fields were removed, reducing the dataset by 0.5%. Outliers in °Brix and pH were detected using the Interquartile Range (IQR) method and confirmed via boxplots (Figure. 3).

In terms of the fruit characteristics, °Brix, reflecting sugar content, exhibited a level of variability that is quite normal for strawberries. This was apparent in the wider range of values and the presence of some outliers, which are not unexpected. Conversely, the pH, indicating acidity, displayed a remarkable consistency across the fruit samples, with very little variation observed.

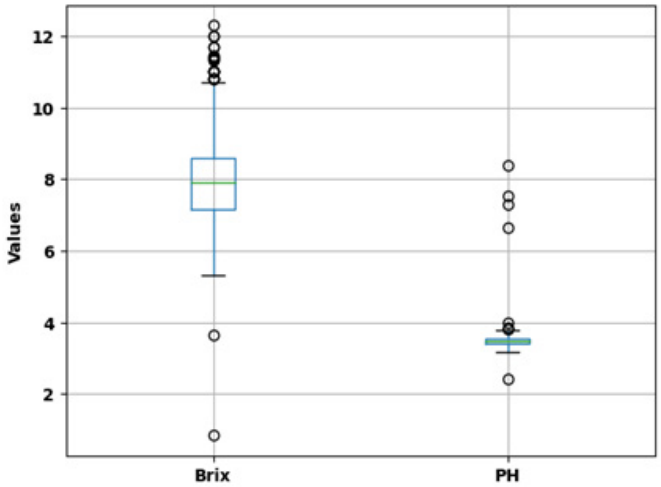

Figure 3: *Boxplot for PH and °Brix*

Data aggregation:

To reduce day-to-day variability and better highlight temporal trends, the dataset was aggregated on a monthly basis for each variety. For each month and cultivar, arithmetic means and 95% confidence intervals (CI) were calculated for key physico-chemical traits: soluble solids content (°Brix), pH, and average fruit weight (AFW). Total received quantities were also summed monthly to assess production dynamics. This aggregation strategy enabled a season-wide evaluation of varietal performance during the 2023 and 2024 harvest windows. It facilitated robust statistical analyses, including two-way ANOVA and post-hoc Tukey HSD tests, which were employed to assess the significance of observed differences across months and varieties. These analyses supported a more rigorous interpretation of trends in fruit quality and yield, particularly emphasizing FORTUNA's temporal stability and market dominance.

Sensory analysis

A structured sensory evaluation was conducted to assess taste, odor, texture, and visual attributes of the three varieties using a 5-point scale (Table 2). Each attribute was rated from 1 (least desirable) to 5 (most desirable), ensuring consistent assessment across samples.

Table 2: *Sensory attributes evaluated, along with rating scales and descriptions.*

Category	Attribute	Scale description
Taste	Sweetness	1 = Not sweet/ Acidic at all
	Acidity	→ 5 = Very sweet/ Acidic
Odor intensity	Intensity	1 = Absence of odor → 5 = Very intense
Texture	Juiciness	1 = Not juicy at all → 5 = Very juicy
	Roughness	1 = Very rough → 5 = Very smooth
	Tenderness	1 = Very hard → 5 = Very tender
Visual aspect	Color	1 = Not red → 5 = Very dark red
	Brightness	1 = Very matte → 5 = Very bright

The tasting panel consisted of 10 professionally selected and trained panelists, drawn from an initial pool of 100 candidates. The panel was formed through a multi-stage process, including basic taste recognition (sweet, salty, spicy), differentiation of complex fruit flavors, and final selection based on sensory acuity. This process aligns with established protocols consistent with ISO 8586:2012 guidelines for the selection and training of sensory assessors.

All panelists received specialized training from a flavor expert from Frulact Portugal, with a focus on fruit aroma characterization (e.g., multiple variants of strawberry, banana, mango). Panel members demonstrated high discriminatory ability in advanced aroma recognition tests and now contribute regularly to product quality control and sensory development activities at the facility.

This sensory profiling supported the quantitative findings and helped determine whether FORTUNA's agronomic and compositional advantages aligned with favorable consumer-oriented traits reinforcing its observed market dominance.

Results

Variety dominance

To evaluate varietal dominance within the local strawberry supply chain, we examined two key indicators: (i) the number of unique producers cultivating each variety, and (ii) the total quantity received across the 2023 and 2024 seasons. As shown in Table 3, the FORTUNA variety exhibited a clear leadership position, cultivated by 23 producers and yielding 4,228.09 tonnes equivalent to 78.5% of the total strawberry volume. In contrast, SABRINA and VICTORIA were grown by 13 and 14 producers, contributing 670.31 tonnes (12.4%) and 280.53 tonnes (5.2%), respectively.

Table 3: *Number of unique producers and total quantity received per variety (2023–2024).*

Variety	Unique producers	Quantity (tonnes)
FORTUNA	23	4228.09 (78.5%)
SABRINA	13	670.31 (12.4%)
VICTORIA	14	280.53 (5.2%)

Although data on cultivated area per producer were not available, the strong dominance of FORTUNA in both producer count and absolute tonnage suggests a preferential alignment with market expectations and production practices.

Monthly production trends further highlight this disparity. In 2023 (Figure 4), FORTUNA's output peaked in March (673.88 t), with sustained volumes in April (359.41 t) and May (336.36 t). SABRINA reached its highest monthly contribution in May (239.38 t), while VICTORIA remained

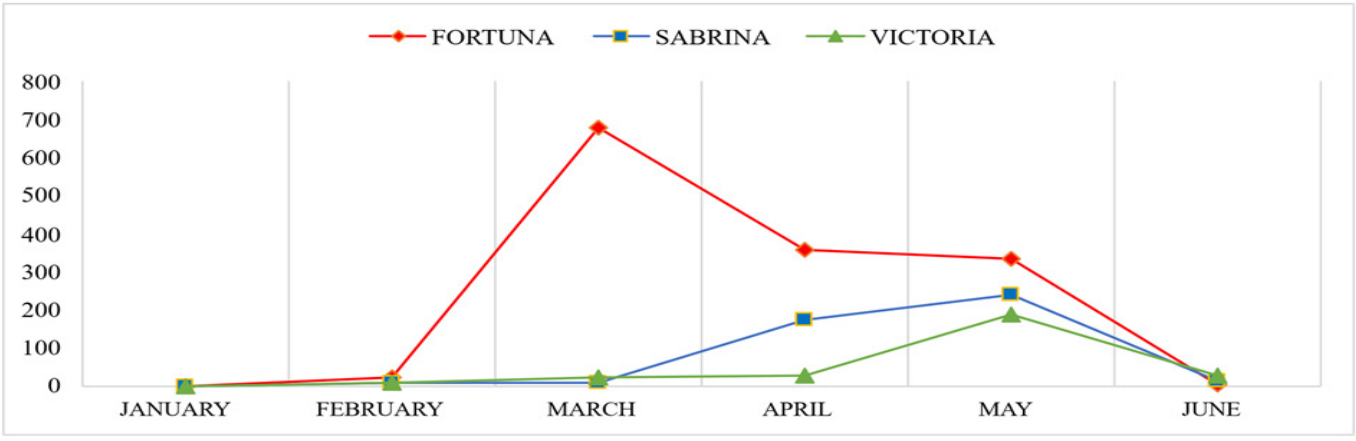

Figure.4: *Monthly production trends for 2023 (in tonnes) reveal distinct patterns among the strawberry varieties.*

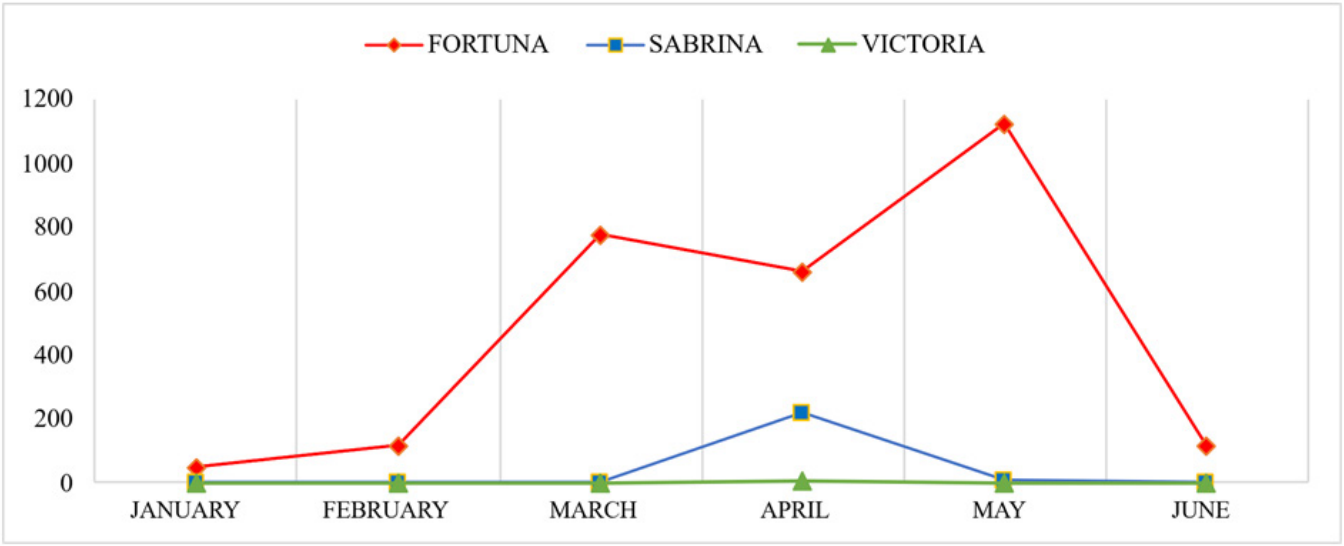

Figure 5: *Monthly production trends (2024) by variety (in tonnes).*

marginal across all months. This contrast widened in 2024 (Figure 5), where FORTUNA reached an unprecedented 1,113.58 t in May, whereas VICTORIA and SABRINA produced negligible quantities.

These cumulative trends strongly support FORTUNA's dominance in both adoption and supply, likely driven by its agronomic performance, post-harvest resilience, and alignment with commercial quality standards such as °Brix, pH, and fruit size factors explored in detail in the following sections.

Physico-chemical traits (°Brix, pH, AFW)

To robustly characterize the quality dynamics of each cultivar, we analyzed three fundamental physico-chemical parameters: soluble solids content (°Brix), acidity (pH), and average fruit weight (AFW, in grams). These attributes critically influence consumer preference, post-harvest performance, and market classification. Raw data from 1,999 composite truck samples were aggregated monthly by variety (FORTUNA, SABRINA, and VICTORIA) over the main harvest window from February to June (2023 and 2024).

For each cultivar and month, we computed the arithmetic mean and associated 95% confidence intervals (CI), providing insight into both central tendency and sampling precision. Table 4 summarizes the results for each trait (expressed as mean ± CI), while Figures 6–8 visualize the monthly evolution of the three parameters across varieties.

Table 4: *Monthly variation in °Brix, pH, and AFW (g) by variety (mean ± 95% CI)*

Month	Variety	°Brix	pH	AFW
February	F	7.00 ± 0.25	3.58 ± 0.03	27.89 ± 0.88
	S	8.23 ± 1.62	3.43 ± 0.13	26.20 ± 5.48
	V	8.84 ± 1.90	3.40 ± 0.08	26.83 ± 1.72
March	F	7.12 ± 0.07	3.50 ± 0.01	26.71 ± 0.39
	S	7.50 ± 0.56	3.46 ± 0.10	23.40 ± 5.20
	V	6.90 ± 0.38	3.47 ± 0.15	22.67 ± 4.40
April	F	8.09 ± 0.10	3.48 ± 0.01	26.39 ± 0.47
	S	7.94 ± 0.16	3.49 ± 0.02	25.66 ± 0.93
	V	7.69 ± 0.25	3.53 ± 0.06	25.34 ± 1.50
May	F	8.42 ± 0.08	3.45 ± 0.02	25.10 ± 0.14
	S	8.34 ± 0.10	3.58 ± 0.11	24.72 ± 0.53
	V	8.08 ± 0.12	3.52 ± 0.02	24.43 ± 0.45
June	F	8.47 ± 0.16	3.49 ± 0.02	27.18 ± 0.78
	S	8.81 ± 0.03	3.46 ± 0.02	21.76 ± 0.85
	V	8.81 ± 0.03	3.46 ± 0.02	22.03 ± 0.31

F: FORTUNA, S: SABRINA, V: VICTORIA

Clear temporal and varietal patterns emerge from the Table 4. °Brix levels were highest in June for SABRINA and VICTORIA (8.81 ± 0.03), suggesting late-season sugar accumulation, while FORTUNA reached its peak earlier, in May (8.42 ± 0.08), but maintained elevated levels across April and June. In February, FORTUNA exhibited the lowest °Brix value (7.00 ± 0.25), lagging behind both SABRINA and VICTORIA. These trends indicate that while SABRINA and VICTORIA may appeal more in late-season markets, FORTUNA delivers strong sweetness performance during peak production months.

Regarding pH, FORTUNA consistently displayed the highest or statistically comparable values across most of the season, particularly in February (3.58 ± 0.03) and March (3.50 ± 0.01), implying milder acidity. In contrast, SABRINA and VICTORIA exhibited slightly more acidic profiles (pH ≈ 3.40–3.46), especially at the beginning of the season. These differences, while moderate, may influence flavor perception and storage behavior.

AFW analysis underscores FORTUNA's superior fruit size and resilience. It achieved the highest average weights in both February (27.89 ± 0.88 g) and June (27.18 ± 0.78 g), whereas SABRINA and VICTORIA showed a pronounced decline in fruit weight toward the end of the season. By June, SABRINA's AFW dropped to 21.76 ± 0.85 g and VICTORIA's to 22.03 ± 0.31 g, while FORTUNA maintained its commercial caliber. This stability in fruit size under potential climatic stress is likely to contribute to FORTUNA's agronomic and market advantages.

The visual representation of these seasonal patterns is presented in Figure 6 (°Brix), Figure 7 (pH), and Figure 8 (AFW).

To assess the statistical significance of differences across months and varieties, a two-way ANOVA was conducted for each trait (°Brix, pH, and AFW). As shown in Table 5, month effects were highly significant for all traits ($p < 0.001$), indicating strong seasonal dynamics. Significant interactions between variety and month ($p < 0.01$) further confirmed that trait patterns vary differently among cultivars over time.

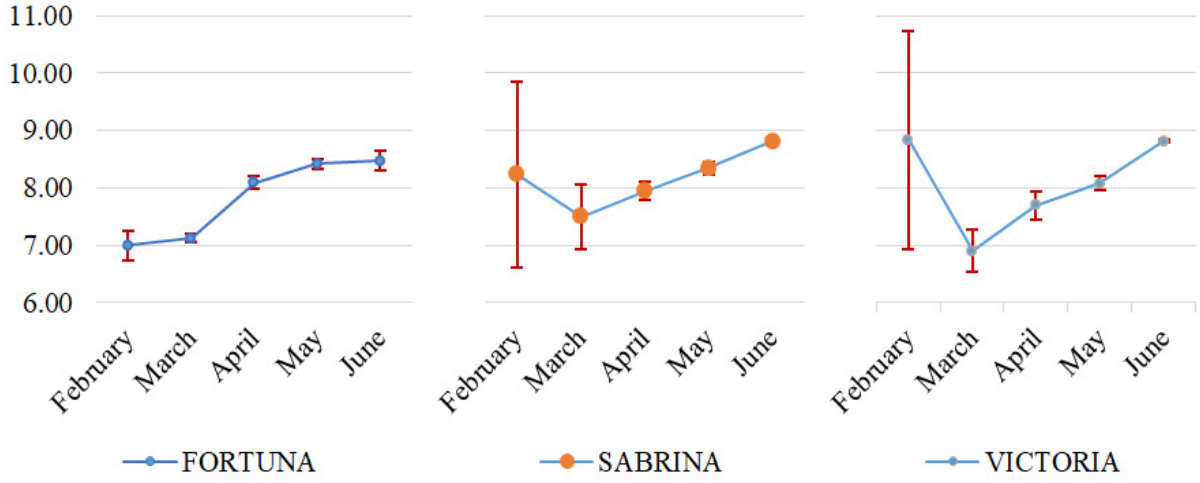

Figure 6: *Monthly evolution of °Brix values (mean ± 95% CI) from February to June for FORTUNA, SABRINA, and VICTORIA.*

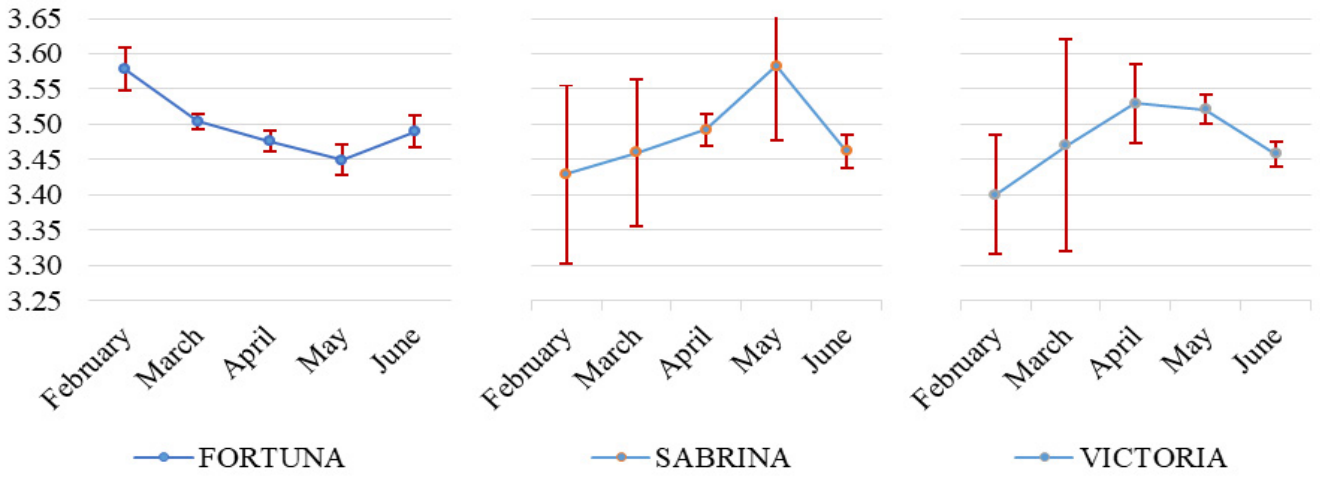

Figure 7: *Monthly pH variation (mean ± 95% CI) from February to June for FORTUNA, SABRINA, and VICTORIA*

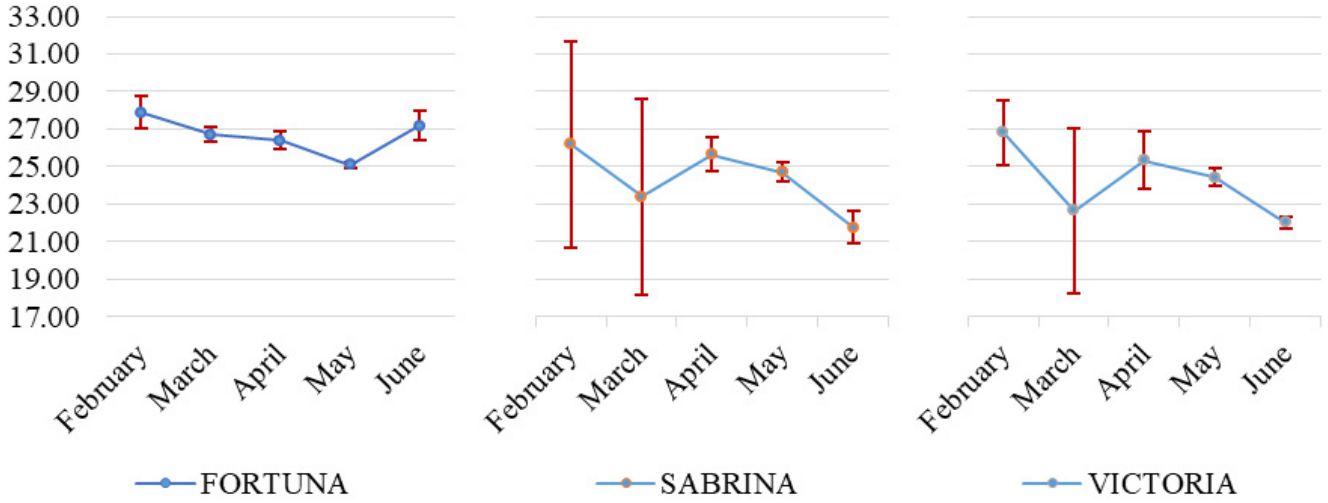

Figure 8: *Average fruit weight (AFW, mean ± 95% CI) from february to june for FORTUNA, SABRINA, and VICTORIA.*

Table 5: *Summary of two-way ANOVA F- and p-values for °Brix, pH, and AFW.*

	°Brix		pH		AWF	
Source	F-value	p-value	F-value	p-value	F-value	p-value
Variety	0.84	0.43389	10.36	0.00003	16.70	6E-08
Month	142.29	0.00000	5.54	0.00087	26.24	1E-16
Variety × Month	4.40	0.00003	3.05	0.00202	3.15	2E-03

Table 6: *Tukey HSD results for pairwise differences among varieties for °Brix, pH, and AFW.*

	°Brix		pH		AFW	
Comparison	Mean diff	p-value	Mean diff	p-value	Mean diff	p-value
F vs. S	0.3139	0.0001	0.0531	0.0019	-1.1759	0.0001
F vs. V	0.255	0.0155	0.0307	0.2468	-1.8873	0
S vs. V	-0.0589	0.8601	-0.0224	0.6081	-0.7114	0.2073

Notably, varietal differences were statistically significant for pH (F = 10.36, p < 0.001) and AFW (F = 16.70, p < 0.001), but not for °Brix (F = 0.84, p = 0.434), suggesting that while sugar levels fluctuate seasonally, varietal identity does not account for large global differences in sweetness.

Post-hoc pairwise comparisons using Tukey's HSD test (Table 6) provided more granular insights. For °Brix, FORTUNA was significantly sweeter than SABRINA (p = 0.0001) and VICTORIA (p = 0.0155), although SABRINA and VICTORIA did not significantly differ (p = 0.86). For pH, FORTUNA exhibited significantly higher pH than SABRINA (p = 0.0019), implying lower acidity; no other differences were significant. For AFW, FORTUNA fruits were significantly heavier than both SABRINA and VICTORIA (p < 0.001), supporting its commercial advantage in fruit size. There was no significant size difference between SABRINA and VICTORIA (p = 0.2073).

The statistical analyses reinforced the physiological trends observed across months and varieties. Seasonal variation (month effect) emerged as the dominant driver of differences for all three traits °Brix, pH, and AFW with highly significant F-values (p < 0.001), confirming that fruit quality evolves substantially over the harvest window. Variety also played a significant role in shaping pH and fruit weight (p < 0.001), but not sweetness (°Brix), where no global varietal effect was detected (p = 0.434). However, pairwise comparisons revealed that FORTUNA exhibited significantly higher sweetness than SABRINA and VICTORIA, and significantly larger average fruit weight than both competitors (p < 0.001). For acidity,

Table 7: *Summary of sensory analysis for SABRINA, FORTUNA, and VICTORIA, evaluating taste, odor intensity, texture, and visual zttributes on a 5-point scale.*

Sensory attribute		SABRINA	FORTUNA	VICTORIA	Scale (1-5)
Taste	Sweetness	3	4	5	1: Not Sweet → 5: Very Sweet
	acidity	4	2	2	1: Not Acidic →5: Very Acidic
Odor intensity		3	4	3	1: Absence → 5: Very Intense
Texture	Juiciness	3	5	4	1: Not Juicy → 5: Very Juicy
	Roughness	2	4	2	1: Very Rough → 5: Very Smooth
	Tenderness	3	4	4	1: Very Hard → 5: Very Tender
Visual Aspect	Color	4	4	5	1: Not Red → 5: Very Dark Red
	Brightness	2	4	3	1: Very Matte → 5: Very Bright

FORTUNA had a significantly higher pH than SABRINA, indicating milder acidity. These findings suggest that FORTUNA's mid-season advantage is supported not only by descriptive trends but also by robust statistical significance, particularly in terms of fruit size and acidity traits likely contributing to its commercial appeal.

Sensory evaluation

In addition to the quantitative assessments of °Brix, pH, and average fruit weight, we conducted a comprehensive sensory analysis to assess how each variety FORTUNA, SABRINA, and VICTORIA is perceived from a consumer perspective. This evaluation covered key organoleptic attributes, including taste (sweetness and acidity), odor intensity, texture (juiciness, roughness, and tenderness), and visual appeal (color and brightness). Table 7 summarizes the comparative sensory ratings across these parameters, providing critical insights into the overall consumer appeal of each cultivar.

Taste ratings show that VICTORIA (Sweetness = 5) is perceived as the sweetest, with FORTUNA (4) close behind and SABRINA (3) trailing. Conversely, SABRINA has the highest acidity (4), whereas both FORTUNA and VICTORIA share relatively low acidity (2 each). This suggests that SABRINA may appeal to those who prefer a sharper, more tangy flavor, while FORTUNA and VICTORIA lean toward a milder acidity profile.

In terms of odor intensity, FORTUNA tops the scale (4), followed by SABRINA and VICTORIA (3 each). FORTUNA also stands out on the texture front, particularly in juiciness (5) and smoothness reflected in its "roughness" score of 4 (where higher values indicate smoother fruit). Both SABRINA and VICTORIA (roughness = 2 each) are perceived as less smooth in comparison. Tenderness scores are comparatively similar for FORTUNA and VICTORIA (4 each), surpassing SABRINA (3).

In terms of visual attributes, VICTORIA earns the highest color score (5), reflecting a deeper red hue, while both FORTUNA and SABRINA register solid color ratings of 4. FORTUNA regains an edge in brightness (4), surpassing VICTORIA (3) and SABRINA (2). Taken together, these sensory findings suggest that while VICTORIA may have an edge in sweetness and color, FORTUNA emerges as a strong all-rounder with moderate sweetness, low acidity, high odor intensity, and particularly appealing texture and brightness. This well-balanced profile could play a key role in reinforcing FORTUNA's overall market dominance.

Discussion

The results demonstrate that FORTUNA consistently excels through a balanced combination of mid-season competitive °Brix levels, elevated pH at key periods, larger fruit size, and a superior sensory profile. These integrated traits explain FORTUNA's outperformance over SABRINA and VICTORIA in yield and market preference, driven by varietal characteristics, cultivation factors, and consumer trends (Ariza *et al*., 2021).

Brix and pH advantages

FORTUNA's mid-season °Brix and pH superiority aligns with the findings of Gude (2018), who highlighted that pre-harvest environmental and agronomic conditions such as temperature, irrigation,

and nutrient management critically modulate sugar accumulation and acidity in strawberries. Although not leading early or late season, FORTUNA's peak sweetness during April–May reflects an optimal balance of sugar synthesis and metabolism under favorable mid-season conditions, corroborating Gude's (2018) findings on strategic pre-harvest management benefits.

Fruit weight advantage

Genetic and environmental factors underpin fruit size variability among cultivars, as Dong (2025) demonstrated. FORTUNA's consistently larger fruits during the mid-season indicate its superior genetic potential amplified by optimal conditions, enhancing resilience to postharvest handling and transport. Larger fruit size correlates with increased yield and market value, reinforcing FORTUNA's commercial appeal and profitability.

Sensory appeal

FORTUNA's sensory strength lies in its harmonious sweetness, moderate acidity, and desirable texture key drivers of consumer preference and market success. Yadav (2024) emphasized the critical role of sugar-acid balance in taste perception, which FORTUNA maintains season-long. Additionally, its firmer fruit structure reduces postharvest losses and supports supply chain demands (Mezzetti, 2014; Yadav *et al*., 2024). Aroma compounds further elevate its marketability, as highlighted by El Hadi (2013), enhancing appeal for fresh and processed products.

While SABRINA's higher acidity appeals to niche consumers and VICTORIA's deeper color offers aesthetic advantages, neither matches FORTUNA's consistent, multifaceted quality. FORTUNA's stability in °Brix, pH, and fruit size during critical months ensures predictable yields and consumer satisfaction, fostering stronger market acceptance through reliability and quality.

Consistent fruit size and firmness also extend shelf life and reduce losses, critical for market penetration (Samtani *et al*., 2019). This resilience further cements FORTUNA's competitive edge by aligning grower and consumer priorities.

FORTUNA's dominance is a product of converging agronomic and sensory factors: mid-season sugar-acid balance, larger fruit size, firmness, and appealing sensory attributes. These combined qualities underpin its leading position relative to SABRINA and VICTORIA in both commercial production and market preference.

Despite the robustness of our findings, several limitations should be acknowledged. First, data were aggregated at the monthly level, and although representative truck samples were taken systematically, some degree of intra-truck or intra-day variability may have been overlooked. Second, while sensory evaluations were carried out by a trained panel, the inherent subjectivity of human perception remains a limiting factor. Third, key agronomic traits such as disease resistance, susceptibility to spoilage, or transport-related losses were not measured in this study. These parameters are crucial for a more comprehensive evaluation of cultivar performance in industrial supply chains. Future research should aim to integrate physiological stress response, cold storage behavior, and shelf-life performance to complement the current findings.

Conclusions and Recommendatoins

This study provided a comprehensive evaluation of three commercially relevant strawberry cultivars FORTUNA, SABRINA, and VICTORIA based on production volume, physico-chemical quality traits (°Brix, pH, and average fruit weight), and sensory characteristics. Among the three, FORTUNA emerged as the most robust variety, consistently demonstrating superior yield, higher fruit weight, and favorable quality parameters across both harvest seasons. Its performance was reinforced by significantly better sensory ratings in texture and odor intensity, coupled with moderate acidity and acceptable sweetness, securing its market dominance and alignment with consumer preferences.

The results of this research hold direct relevance for agricultural stakeholders and policymakers. The dominant performance of FORTUNA suggests its suitability not only for large-scale commercial adoption but also for integration into varietal improvement and national strawberry breeding programs. These insights can inform strategic decisions at multiple levels guiding farmers in variety selection, assisting agronomists in extension services, and supporting policymakers in establishing cultivar recommendation lists or regional certification schemes. Furthermore,

the study's methodology combining agronomic, physico-chemical, and sensory data could serve as a template for fruit quality monitoring frameworks across export-oriented horticultural chains.

Acknowledgements

The authors would like to thank Frulact Company for providing the data and valuable support that made this research possible.

Novelty Statement

This study is the first to systematically evaluate post-harvest performance of three commercial strawberry cultivars under real-world conditions by integrating monthly aggregated physico-chemical measurements and five-attribute sensory evaluations across two consecutive seasons.

Author's Contribution

Sana El Moutaouakil: Conceived and designed the study, coordinated the research activities, and took the lead in drafting and finalizing the manuscript.
Aicha Rossafi: Contributed to data collection, preprocessing, statistical analysis, and manuscript revision.
Youssef El Madhi: Assisted with data collection, statistical analysis, and interpretation of results.
Nabil Sbai: Contributed to the sensory evaluation and manuscript revision.
Fathalah Elwahab: Contributed to manuscript writing and revision.
Abderrahim Benzakour and Mohammed Ouhssine: Supported methodological consistency, critically reviewed the manuscript, and ensured its scientific rigor.

Generative AI or AI assisted technology statement
During the preparation of this work, the authors used generative AI tools solely to assist with language polishing and formatting. All intellectual content, data analysis, interpretation of results, and scientific conclusions were entirely conceived and validated by the authors. The authors take full responsibility for the integrity and originality of the content presented in this article.

Conflict of interest
The authors declare no conflict of interest.

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