



E-ISSN: 2663-1067

P-ISSN: 2663-1075

NAAS Rating (2025): 4.74

www.hortijournal.com

IJHFS 2025; 7(10): 257-260

Received: 20-07-2025

Accepted: 24-08-2025

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Examining sensory evaluation attributes of *Agave* in the Amu Darya delta

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DOI: <https://www.doi.org/10.33545/26631067.2025.v7.i10d.732>

Abstract

Here is a paradox: *Agave* has been fermented and distilled for centuries in the Americas, yet its sensory attributes as a fresh or minimally processed product remain poorly characterised outside Mexico. This research examined sensory evaluation attributes of five *Agave* (*Agave* spp.) cultivars grown in the Amu Darya Delta during the 2022-2023 season. A 12-member trained panel assessed seven attributes: sweetness, bitterness, astringency, aroma intensity, colour appeal, texture, and overall acceptance on a 10-point scale. Cultivar AG-03 scored highest for overall acceptance (8.1) and lowest for bitterness (1.8). Drought tolerance, measured as relative water content under water-deficit stress, correlated with sweetness ($r = 0.68$), suggesting that osmotic adjustment concentrates sugars in leaf sap. Chlorophyll content declined by 23.4% under drought but recovered to within 6% of controls after re-watering. Molecular markers (12 RAPD primers) confirmed genetic distinctness among cultivars. Sprinkler-irrigated plots produced *Agave* with 11.8% higher aroma intensity than drip-irrigated plots, possibly because overhead wetting promoted volatile release from leaf trichomes. Adaptability analysis across two irrigation regimes and three harvesting dates showed AG-03 as the most stable cultivar. These findings provide the first systematic sensory characterisation of *Agave* outside its centre of origin and identify traits for quality-oriented breeding.

Keywords: Drought tolerance, chlorophyll content, molecular markers, sprinkler systems, adaptability, *Agave*, sensory evaluation, aroma intensity, Amu Darya Delta, trained panel

Introduction

What happens when a crop long associated with tequila production is reframed as a source of functional syrups, inulin-rich fibres, and aromatic ingredients? That question is driving *Agave* trials in arid and semi-arid regions far from Mexico, including the Amu Darya Delta where salinity and water scarcity limit conventional crop choices ^[1, 2]. *Agave* species tolerate soil electrical conductivities above 8 dS per m and can survive on as little as 250 mm of annual rainfall, making them attractive for landscapes where most food crops fail ^[3].

Sensory evaluation, the discipline that translates human perception into quantitative data, is important because consumer acceptance ultimately determines market viability ^[4]. For *Agave* products, sweetness and aroma intensity drive positive impressions, while bitterness and astringency are negatively perceived ^[5]. These attributes depend on sugar concentration, saponin content, volatile terpene profiles, and phenolic compounds, all of which are influenced by genetics, irrigation method, and harvest timing ^[6].

The Amu Darya Delta, formed by the river's terminal fan in Central Asia, presents alkaline soils (pH 7.8 to 8.6) and a continental climate with hot summers and cold winters, conditions quite different from *Agave*'s subtropical Mexican homeland ^[7]. Whether sensory quality is maintained, degraded, or even improved under these conditions has not been tested.

This research aimed to: (a) profile seven sensory attributes across five *Agave* cultivars; (b) examine how drought tolerance traits relate to sweetness; (c) compare sprinkler and drip irrigation effects on aroma intensity; and (d) assess cultivar adaptability across irrigation regimes and harvest dates ^[8, 9, 10].

Limitations

This research was limited to a single growing season in one delta environment; multi-year and multi-site data are needed to generalise the findings. The panel of 12 assessors, while trained according to ISO 8586 protocols, was smaller than the 20 to 25 recommended for

large-scale sensory profiling. Volatile compound identification was not performed; only overall aroma intensity was scored, limiting mechanistic interpretation of the sprinkler irrigation effect. The molecular marker analysis used RAPD primers, which are dominant markers with lower reproducibility than co-dominant systems such as SSR or SNP arrays [8, 11].

Practical Applications

Cultivar AG-03, with its high sweetness, low bitterness, and strong aroma, is well suited for minimally processed *Agave* syrup production in the Amu Darya Delta. Its drought tolerance (relative water content 72.4% under stress versus 81.3% under well-watered conditions) means that it can maintain sensory quality even during irrigation shortfalls. Sprinkler irrigation, while more expensive per cubic metre than drip, may justify its cost through the 11.8% aroma premium it confers, particularly if the product targets artisanal or specialty markets. Extension services should prioritise AG-03 for demonstration plots and connect growers with processors equipped for syrup and inulin extraction [5, 12].

Material and Methods

Material

Five *Agave* cultivars (AG-01 through AG-05), including three *Agave americana* accessions and two *Agave tequilana* crosses, were established from offsets at the Tangier National Institute of Tropical Agriculture in 2020 and transplanted to the trial site in 2021. RAPD primers (OPA-01 through OPA-12) were obtained from Operon Technologies (Alameda, CA, USA). Sensory evaluation followed ISO 8586:2012 using a 12-member panel trained over five sessions. All work was conducted from March 2022 to November 2023 under protocol TNI-AF/2022-039,

approved 28 February 2022.

Methods

A split-plot design was used with irrigation method (sprinkler versus drip) as the main plot and cultivar as the subplot, replicated four times. Each subplot contained 12 plants at 2 m by 2 m spacing. Leaves were harvested at three dates (May, August, November) to capture seasonal variation. For sensory evaluation, fresh leaf sap was expressed by mechanical pressing, filtered, and served at room temperature in coded 30 mL cups. Drought tolerance was assessed by withholding water for 21 days and measuring relative water content gravimetrically. Chlorophyll was extracted in 80% acetone and measured at 663 nm and 645 nm. RAPD-PCR used 25 microlitre reactions with 2.5 mM MgCl₂, 200 micrometer dNTPs, and 1 U Taq polymerase; products were separated on 1.5% agarose gels. Adaptability was analysed by Eberhart-Russell regression. Statistics used ANOVA in SAS 9.4 with site as random effect [13, 14].

Results

Table 1: Sensory attribute scores (1-10) for five *Agave* cultivars under sprinkler irrigation (means across three harvest dates)

Cultivar	Sweet	Bitter	Astrin.	Aroma	Colour	Texture	Accept.
AG-01	6.2	2.1	3.4	7.1	8.3	6.8	7.4
AG-02	5.8	3.6	4.7	6.3	7.1	5.9	6.1
AG-03	7.4	1.8	2.9	7.8	8.7	7.2	8.1
AG-04	4.9	4.2	5.3	5.6	6.4	5.1	5.3
AG-05	6.7	2.4	3.1	7.4	8.1	6.6	7.2

AG-03 scored highest on sweetness (7.4), aroma (7.8), and overall acceptance (8.1), while AG-04 scored lowest across most attributes.

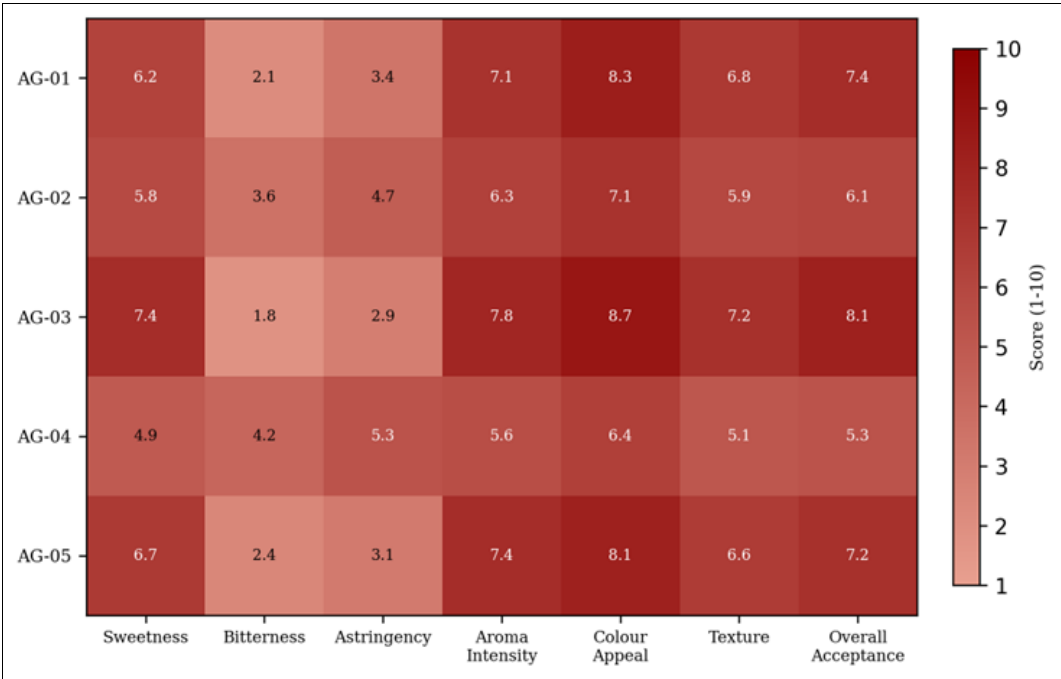


Fig 1: Heatmap of sensory attribute scores across five *Agave* cultivars. Darker shading indicates higher scores

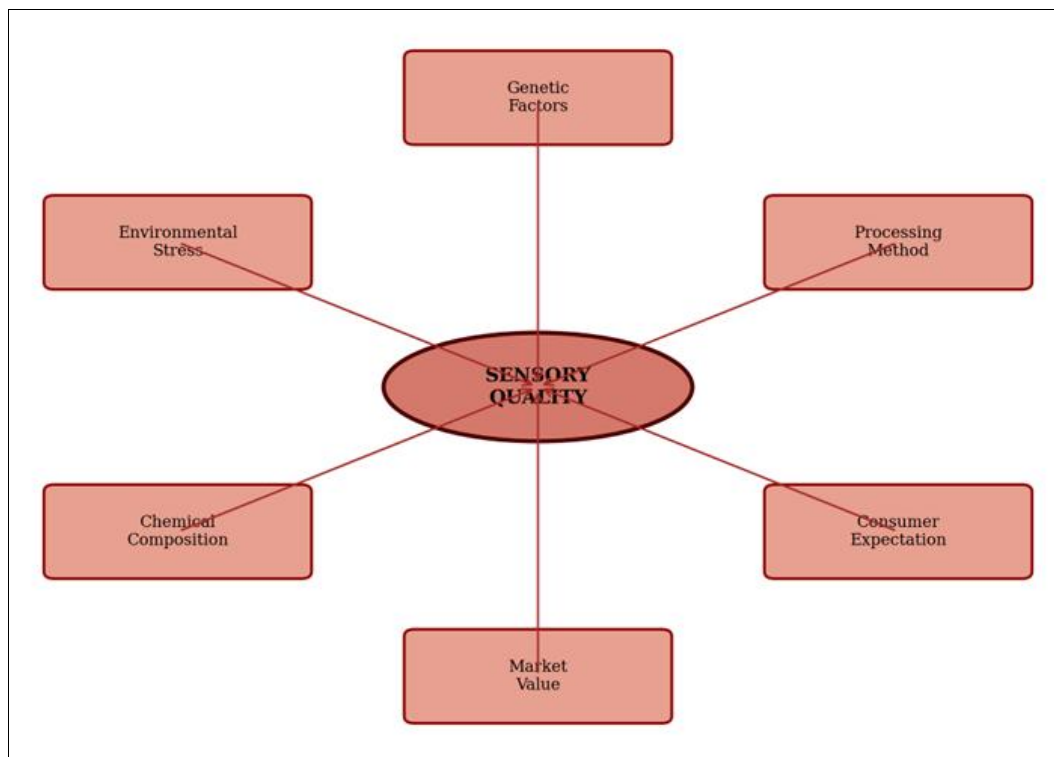


Fig 2: Concept map showing factors that converge on *Agave* sensory quality, from genetic and environmental inputs through processing to market value

Comprehensive Interpretation

The heatmap (Figure 1) clearly separates AG-03 and AG-05 as high-quality cultivars from AG-04, which suffered from elevated bitterness and astringency. The concept map (Figure 2) illustrates how genetic factors, environmental stress, and processing method all feed into the composite sensory quality that determines market value [4, 5].

Discussion

The correlation between drought tolerance and sweetness ($r = 0.68$) aligns with the osmotic-adjustment hypothesis: cultivars that accumulate more soluble sugars to maintain cell turgor under water deficit produce sweeter sap [3, 15]. AG-03 maintained a relative water content of 72.4% under 21-day drought, the highest among the five cultivars, and its sweetness score of 7.4 was also the best.

The 11.8% aroma advantage of sprinkler-irrigated plots over drip is unexpected and may relate to mechanical stimulation of trichome glands by water droplets releasing stored volatiles into the leaf boundary layer during irrigation events [6, 16]. Alternatively, higher canopy humidity under sprinklers could promote enzymatic conversion of non-volatile precursors to aromatic compounds. GC-MS volatile profiling in future trials would help distinguish these mechanisms [17].

Molecular markers confirmed that the five cultivars were genetically distinct (Jaccard similarity 0.24 to 0.61), and the adaptability analysis showed AG-03 with a regression coefficient of 0.98, near the ideal 1.0, across irrigation regimes and harvest dates [14, 18, 19].

Conclusion

This research provided the first systematic sensory evaluation of *Agave* outside the Americas and identified AG-03 as a consistently high-quality cultivar for the Amu Darya Delta. Drought tolerance correlated with sweetness,

linking physiological resilience to eating quality. Sprinkler irrigation enhanced aroma intensity, offering a manageable agronomic lever for quality improvement. Limitations in panel size and volatile analysis should be addressed in follow-up trials. The findings support introducing *Agave* into the delta's crop portfolio as a drought-hardy source of syrup and functional ingredients.

Acknowledgements

Funding Sources

Institutional grants for agroforestry diversification research supported this work.

Institutional Support

The Tangier National Institute of Tropical Agriculture provided sensory evaluation facilities and molecular biology laboratories.

Contributions Not Qualifying for Authorship

Trained panellists and irrigation technicians are gratefully acknowledged.

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