

# PLA membranes as functional alternatives to PVC in potentiometric pH electrodes for wine and beverages



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## INTRODUCTION

**Ion-selective electrodes (ISEs)** are essential tools in the agro-food industry for fast and reliable monitoring of pH, acidity, and ionic composition in products such as wines, juices, and vinegars. They offer low cost, portability, and real-time analysis, making them ideal for on-site quality control and fermentation monitoring.

- **PVC-based membranes** have been the reference material for decades, providing good flexibility and ionic conductivity, but their chlorinated, non-biodegradable nature poses environmental challenges.
- **PLA (polylactic acid)**, a biodegradable polymer derived from renewable resources, represents a sustainable alternative. Its higher polarity and rigidity can influence ion transport and membrane uniformity, affecting sensitivity and response time.

## OBJECTIVES

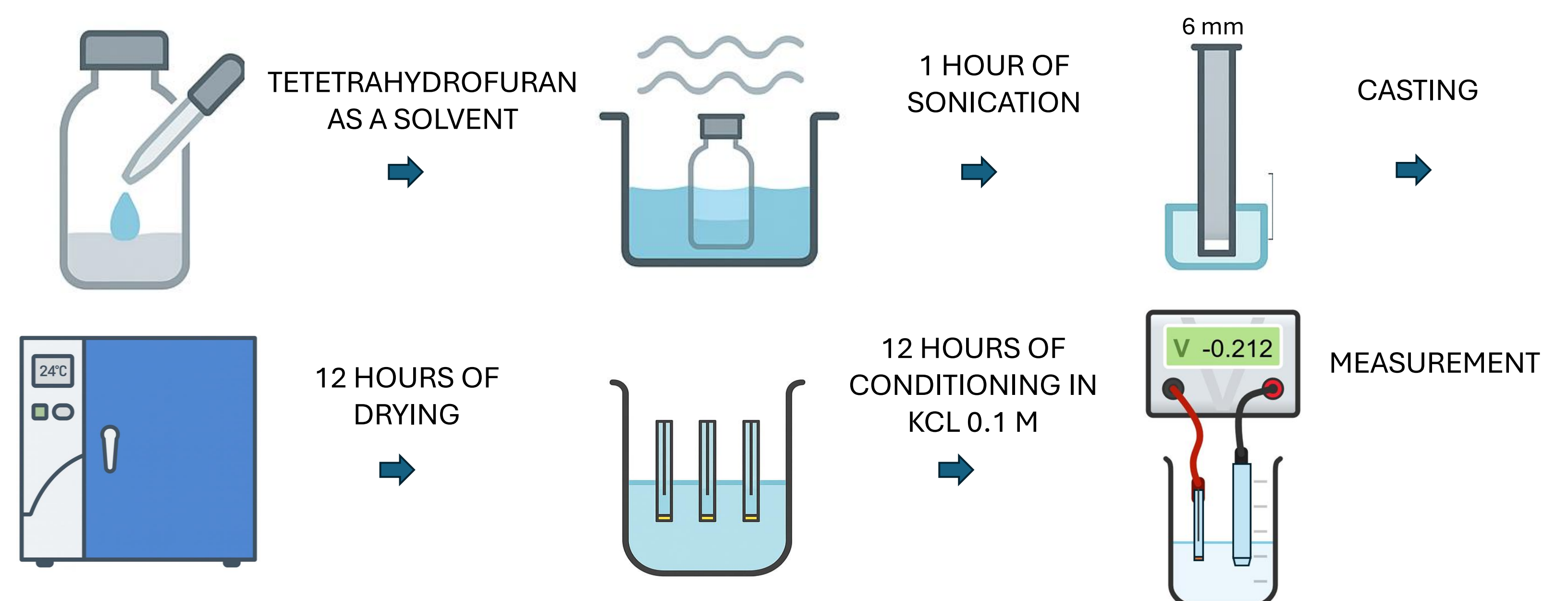
This study aims to replace PVC with PLA in pH-selective membranes while maintaining the same ionophore system (TEHA) to isolate the polymer effect.

The goal is to validate PLA as a **stable. Accurate,** and **eco-friendly** alternative for developing biodegradable and 3D-printable ISEs for agro-food applications.



## METHODOLOGY

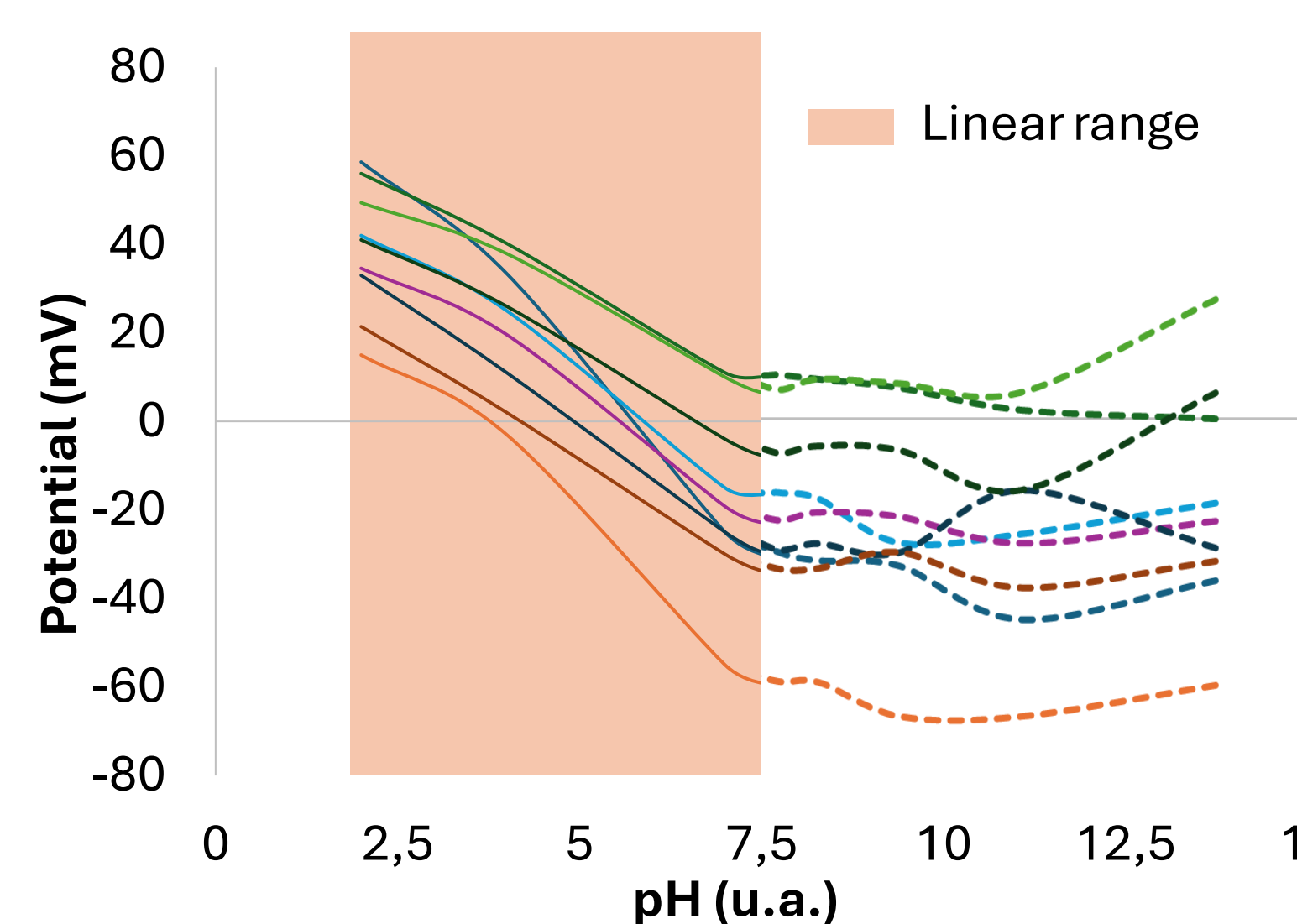
PVC:PLA FORMULATION	PVC (% w/w)	PLA (% w/w)	NPOE (% w/w)	TEHA (% w/w)	KTCIPB (% w/w)
100:0	30.3	0.0	60.6	8.0	1.0
75:25	22.7	7.6	60.6	8.0	1.0
50:50	15.2	15.1	60.6	8.0	1.0
25:75	7.6	22.7	60.6	8.0	1.0
0:100	0.0	30.3	60.6	8.0	1.0



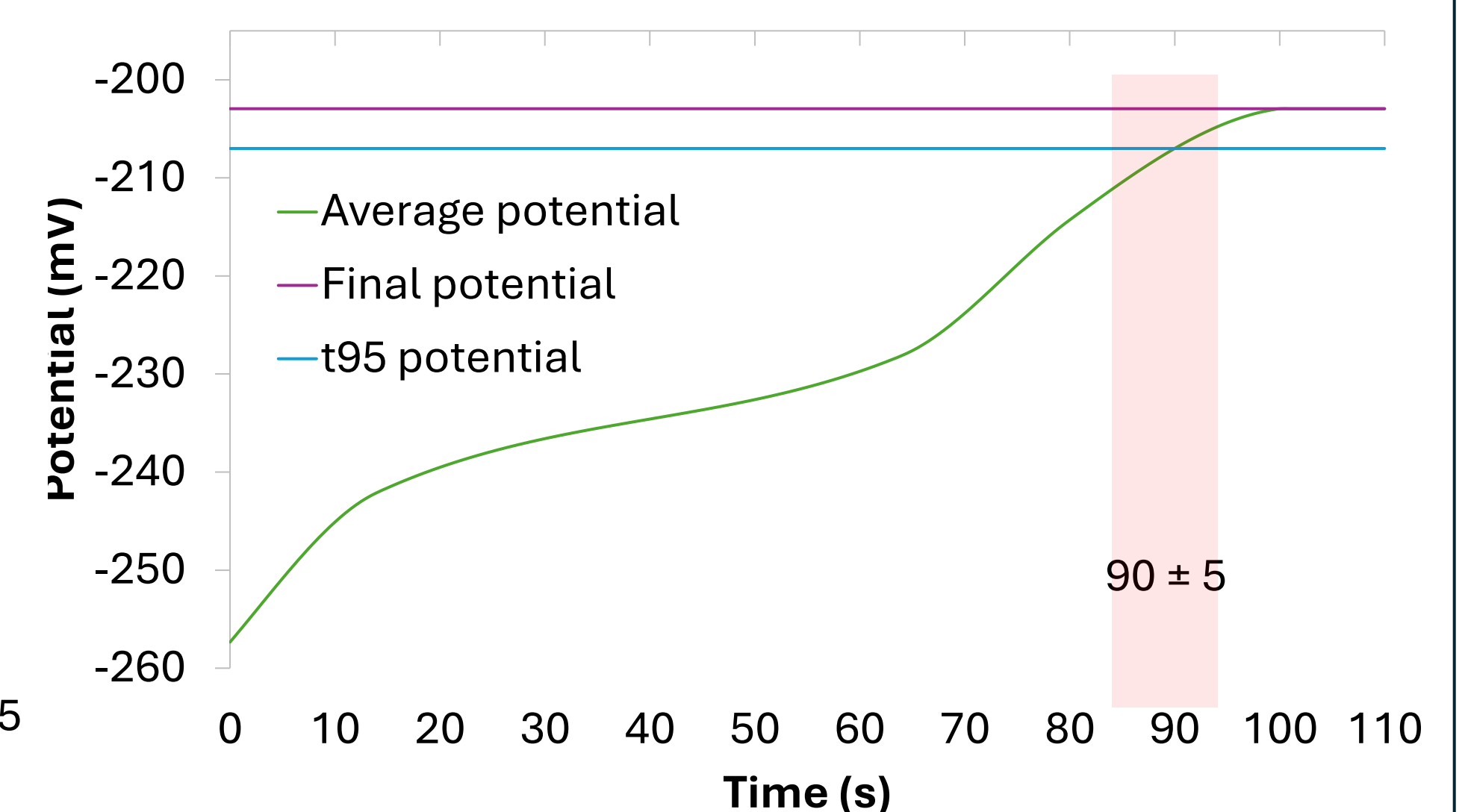
## OPTIMIZATION VALUES AND ANALYTICAL PERFORMANCE

PVC:PLA FORMULATION	SENSITIVITY (mV/pH)	ACCURACY (pH UNITS)	RESISTANCE (MΩ)
100:0	- 55 ± 3A	-0.10 ± 0.07A	0.8 ± 0.2B
75:25	- 50 ± 3A	-0.79 ± 0.15C	30 ± 6C
50:50	- 46 ± 9A	-0.79 ± 0.13C	80 ± 7D
25:75	- 31 ± 5B	-0.25 ± 0.03B	170 ± 18E
0:100	- 17 ± 2C	0.06 ± 0.11A	0.26 ± 0.07A

Formulations sharing the same letter are not statistically different (ANOVA, 95% confidence level), **confirming that PLA performs similarly to PVC** while intermediate blends show significant differences.

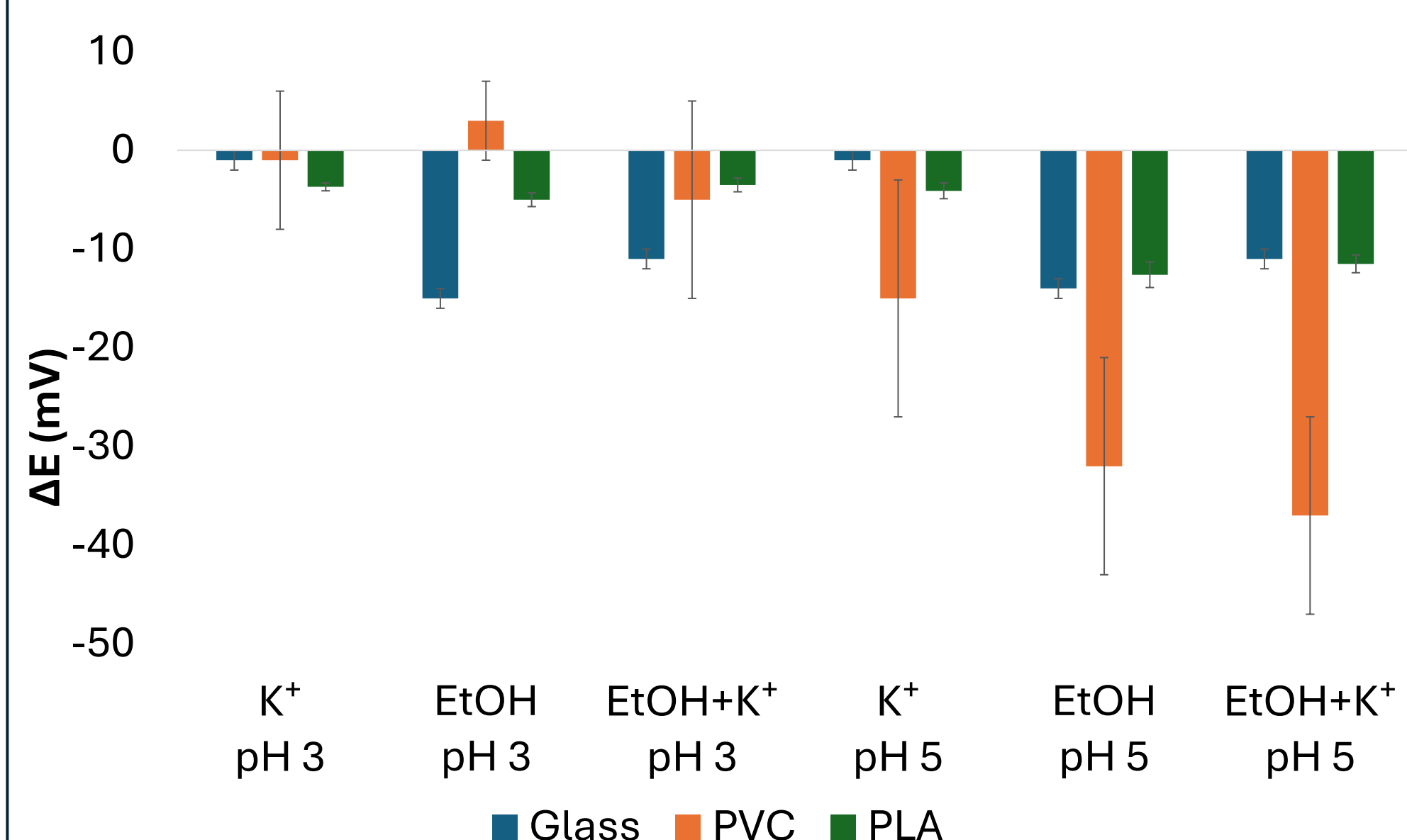


**Linearity remained high ( $R^2 = 0.992 \pm 0.002$ )** across the agro-food pH range (2–7.5), fully covering the domain of practical enological applications

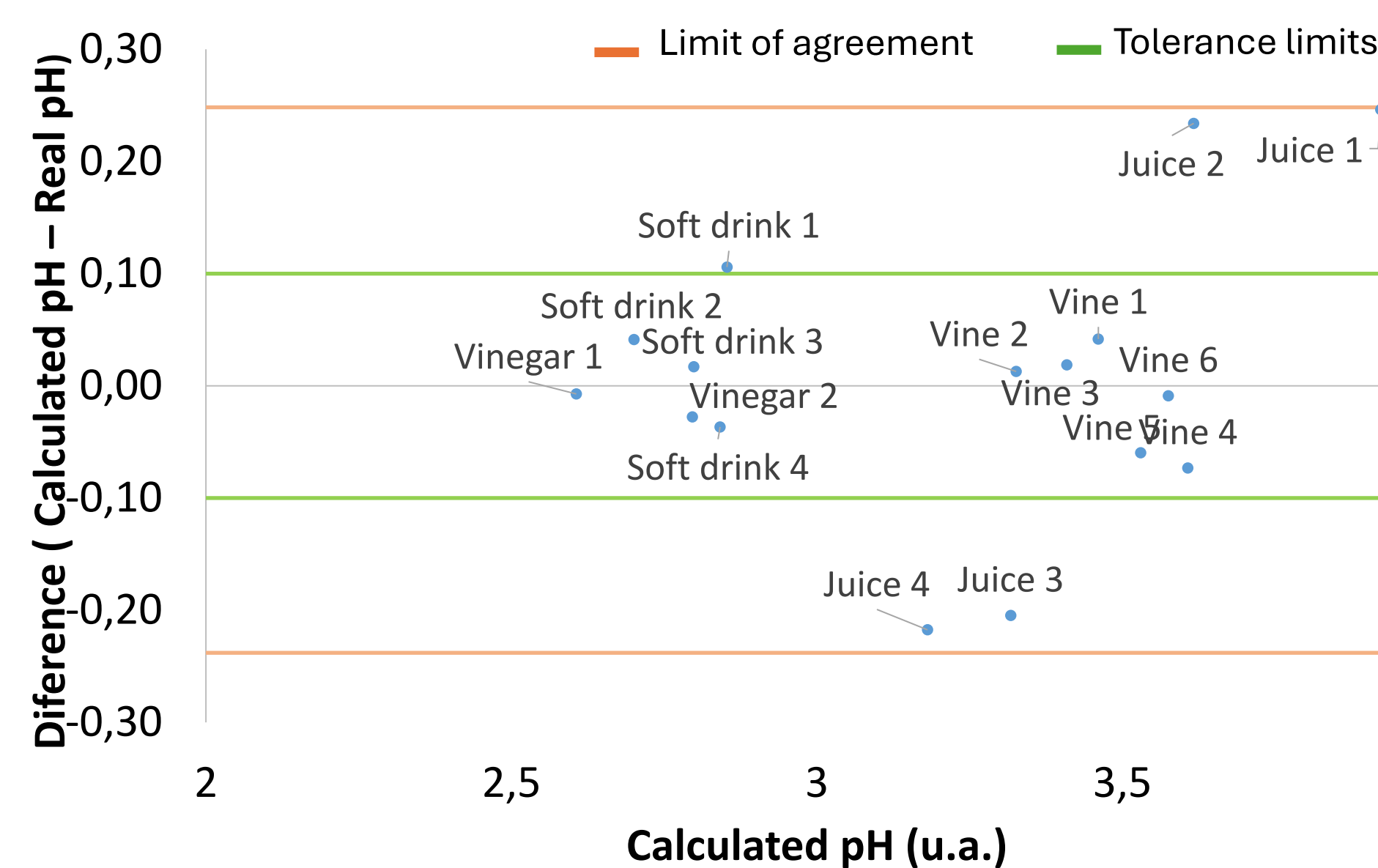


PLA membranes reach 95% of the final potential within **~90 s**, indicating a **stable and predictable response** suitable for routine measurements.

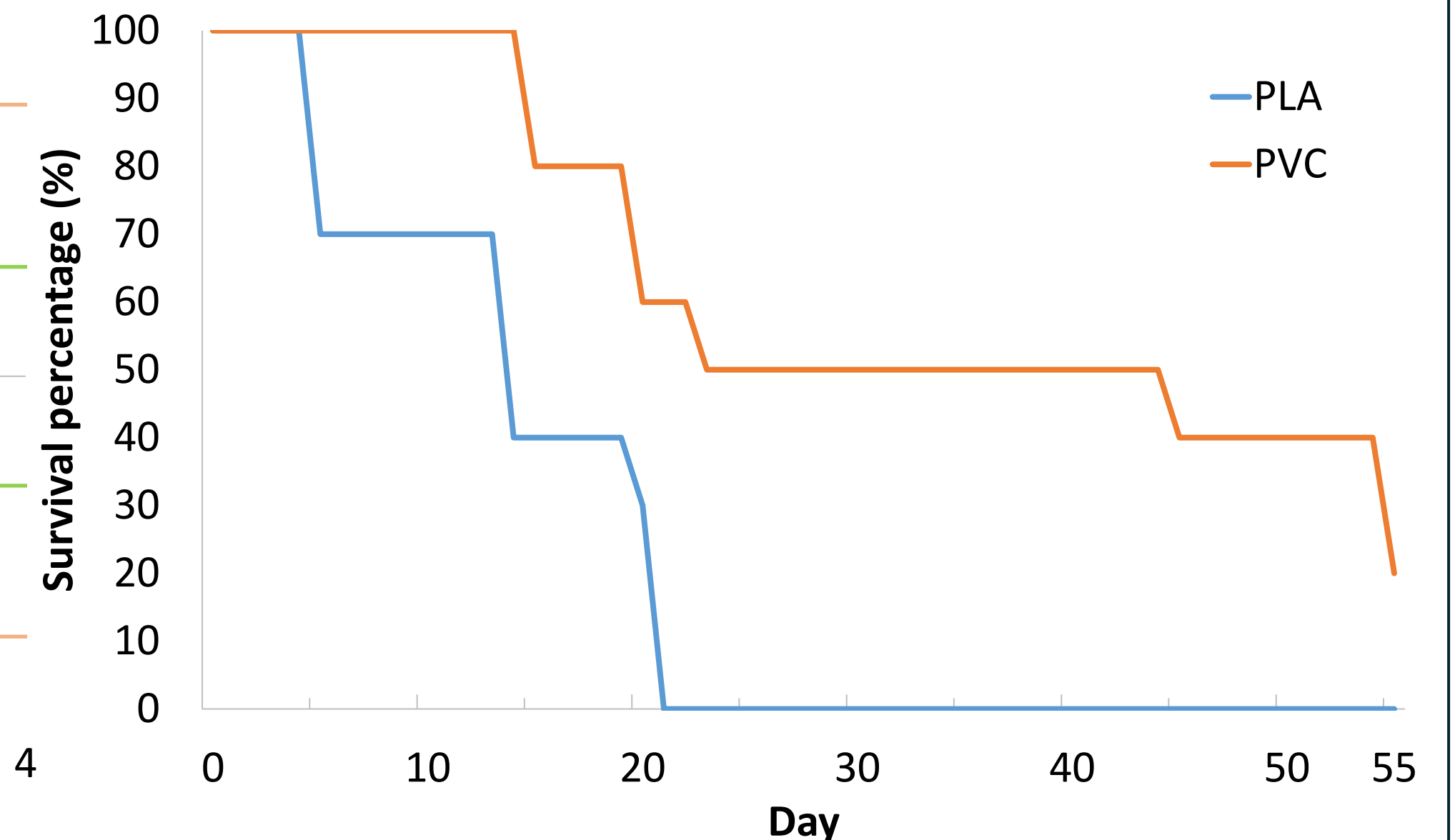
## ROBUSTNESS, ACCURACY AND LIFETIME



**PLA shows the smallest potential shifts (<5 mV) across all matrix conditions**, outperforming PVC and glass electrodes especially under acidic and ethanol-rich environments.



All PLA measurements fall within the **agreement limits ( $\pm 0.1 - 0.15$  pH)**, confirming **high accuracy in complex agro-food samples**.



PLA membranes show a predictable degradation profile with **~10 days of functional lifetime**, comparable to PVC and suitable for short-term or disposable applications.

## CONCLUSIONS

- PLA performs comparably to PVC, while intermediate blends exhibit inferior behavior due to reduced structural compatibility.
- High accuracy with minimal matrix effects, even under acidic and ethanol-rich conditions.
- Robust practical performance, characterized by strong linearity, fast response, and a functional lifetime suitable for short-term or disposable pH sensors.