Digitalizing Natural Rubber Metrology: A Multi-Parameter IoT Terminal for First-Principles DRC Measurement and Fraud Detection

H.D. Suriyapperuma*, N.C. Manilgama, A.D. Rukshan, K.A.P.M. Perera, Y. Vimukthi

Department of Computer Engineering, University of Peradeniya, Peradeniya, 20400, Sri Lanka
**e21453@eng.pdn.ac.lk*

According to the Sri Lanka Export Development Board (EDB), the natural rubber industry generates approximately $870 million in annual export earnings, yet systemic measurement inefficiencies contribute to an estimated $26 million (approximately 3% of annual export earnings) in annual industrial losses. Rural collection centers currently rely on manual glass hydrometers (Metrolacs) prone to temperature errors and human manipulation or slow laboratory oven methods that delay farmer payments to bi-monthly cycles. While a prior electronic research prototype has been published, it relies on an empirical regression model requiring extensive pre-calibration data that limits its adaptability across diverse field conditions. This research proposes a compact, field-ready IoT terminal designed to bridge this gap by providing near-instantaneous Dry Rubber Content (DRC) measurements alongside multi-parameter sensing for fraud detection. The methodology involves a cyber physical system centered around an ESP32 microcontroller and high precision load cells to calculate DRC via buoyancy measurement using Archimedes' principle. Unlike the existing regression dependent model, this physics based approach provides a universal measurement independent of variations in field latex composition. A DS18B20 probe provides real time temperature compensation while a unique relay-isolation hardware architecture resolves galvanic ground loop interference between the co-submerged pH and TDS sensors. The developed system is a fully integrated, hand-held operational terminal that outperforms the accuracy of the traditional glass Metrolac at the point of collection, utilizing an MQTT-based "store-and-forward" protocol to prevent data loss in remote areas with intermittent connectivity. Validation against eight field latex samples from Sri Lankan rubber collection centers showed that our device achieved a mean error of ±0.74% DRC against the ISO 126 laboratory oven standard, compared to ±1.53% for the traditional glass Metrolac against the same standard. The worst-case error was reduced from ±7.75% to ±2.10%. These results demonstrate that the proposed system is a practical and more accurate alternative to the traditional glass Metrolac, offering rubber farmers and collection centers a faster, fairer and more reliable way to measure latex quality. Future work will expand validation across a wider range of latex sources and further improve accuracy through hardware fine-tuning and extended field trials.

Keywords: smart-metrolac, Dry Rubber Content (DRC), IoT in agriculture, supply chain transparency, adulteration detection