

Portable Multimodal Screening of Patchouli Oil Using Gravimetric–Ultrasonic Density Measurement and Smartphone Image Colorimetry

Dek Rina

Universitas Syiah Kuala

M. Syukri Surbakti

msyukris@usk.ac.id

Universitas Syiah Kuala

Malahayati Malahayati

Universitas Syiah Kuala

Research Article

Keywords: Patchouli oil, adulteration screening, density measurement, smartphone image colorimetry, RGB, Internet of Things

Posted Date: October 27th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11348283/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

A portable measurement platform was developed for preliminary screening of patchouli-oil samples by combining gravimetric–ultrasonic density estimation, smartphone-based RGB/HSL image acquisition, temperature monitoring using a W1209 controller, and Internet of Things data transmission. Density measurements were compared with reference values for 16 sample compositions comprising pure Gayo Lues and Aceh Besar patchouli oils, mixtures with palm oil or kerosene, and adulterant controls. Based on the 16 tabulated paired central values, the mean signed difference (instrument minus reference) was $+0.00075 \text{ g cm}^{-3}$, the mean absolute error was $0.006875 \text{ g cm}^{-3}$, the root-mean-square error was $0.006946 \text{ g cm}^{-3}$, and the coefficient of determination for linear regression was $R^2 = 0.9749$. The mean absolute percentage error was 0.796%. An exploratory paired t-test yielded $t(15) = 0.421$, $p = 0.680$; this non-significant result is not interpreted as proof of method equivalence. Because replicate-level readings, calibration records, and the definition of the reported $\pm$ terms were not supplied, these statistics characterize the tabulated central values rather than full metrological performance. The prototype is therefore presented as a preliminary screening platform, not a substitute for standardized laboratory authentication.

1 Introduction

Patchouli essential oil, obtained from *Pogostemon cablin* (Blanco) Benth., is an important fragrance material with a complex and naturally variable chemical composition. Its quality depends on botanical material, processing, storage, and the relative abundance of constituents such as patchoulol. Published reviews document both the compositional diversity of patchouli oil and the possibility of adulteration, supporting the need for objective quality-control procedures rather than visual judgement alone [1].

The addition of a second liquid can change the apparent density and optical appearance of patchouli oil. The response is not necessarily unique to adulteration: natural variation between source oils, the identity and density of the adulterant, blend fraction, and temperature can all affect the measured value. Density should therefore be treated as a screening feature, not as a stand-alone chemical identity test. Confirmatory chemical methods, including chromatographic profiling where appropriate, remain important when authenticity must be established [1, 2].

Essential-oil density is temperature-dependent. For comparability, measurements should be made at a controlled reference temperature and the procedure should be consistent with a relevant reference method. ISO 279 specifies a reference method for relative density of essential oils at 20°C, while the applicable Indonesian patchouli-oil specification is SNI 2385:2019 (confirmed in 2025) [3, 4]. These standards provide measurement and product-quality context; they do not turn a single density reading into a universal adulteration classifier.

Pycnometry offers a reference route for determining density, whereas a portable electronic system can reduce manual calculation and facilitate field-level screening. The potential benefit of portability must be balanced against calibration, vessel geometry, sample-temperature control, and uncertainty. For this

reason, instrument performance should be assessed using paired measurements and an agreement analysis rather than correlation alone [5].

Smartphone image colorimetry provides an accessible way to quantify sample appearance, but RGB values depend on the camera, illumination, image processing, geometry, and sample container. Controlled lighting and fixed acquisition geometry are essential, and colour values should be interpreted as comparative features within the specified imaging setup rather than universal chemical identifiers [6]. Converting RGB to hue, saturation, and lightness (HSL) changes the representation of colour but does not remove camera-dependent effects.

Microcontroller-based acquisition and IoT communication can automate calculations and digitally record measurements. Connectivity, however, is a data-management function rather than evidence of analytical accuracy. The measurement chain must be evaluated independently using calibration, repeatability, uncertainty, and method-comparison procedures.

This study describes a portable Densitymeter Patchouli Oil (DCO) prototype that combines mass and liquid-height measurements, temperature monitoring, controlled smartphone image colorimetry, and wireless data transmission. The objectives are to describe the measurement architecture and governing equations, summarize the recorded density and colour responses for selected patchouli-oil/adulterant samples, and identify the evidence required for metrological validation. The study is framed as a prototype feasibility investigation; it does not claim a validated classification model or universal detection threshold.

2 Materials and methods

2.1 Study design and samples

Patchouli oil samples from Gayo Lues and Aceh Besar were examined alongside mixtures prepared with palm oil or kerosene at nominal adulterant fractions of 25%, 50%, and 75% (v/v). The source table records one nominal 100 cm³ volume per mixture and a mass value for each listed composition. The source manuscript also reports separate pure-oil values of 0.934 ± 0.002 g cm⁻³ (Gayo Lues) and 0.925 ± 0.003 g cm⁻³ (Aceh Besar), while its mixture table uses 0.950 g cm⁻³ as the pure-oil baseline. Because sample identifiers and measurement-method labels are insufficient to establish whether these are different batches or different measurement chains, the origin-specific values are not pooled with the mixture series. The numerical audit below uses the seven explicitly tabulated mass–volume pairs only. The raw paired DCO–pycnometer readings and image-level observations were not supplied; consequently, inferential method-comparison statistics cannot be recalculated from the document alone.

Figure 1 summarizes the measurement architecture. Density and temperature were acquired by the electronic instrument, while RGB/HSL features were extracted from smartphone images in a separate

but coordinated workflow. The optical features were not measured directly by the ESP8266 circuit; the two data streams were associated by sample identity during analysis.

The prototype integrates mass measurement, ultrasonic liquid-level measurement, temperature monitoring, a local display, and wireless data transfer. Its analytical performance depends on calibration and the stability of each measurement stage, not simply on successful operation of the electronics.

A load cell coupled to an HX711 amplifier was used to measure the mass associated with the sample and measurement vessel. An HC-SR04 sensor measured the distance to the liquid surface, from which liquid height was inferred using the vessel geometry. The ESP8266 handled data processing and Wi-Fi communication. The measurement procedure identifies a W1209 temperature controller/sensor module, and this designation is used consistently in the present description. The actual module and probe should be checked against the laboratory device before submission because the original component table also listed DS18B20.

Samples were brought toward 20°C before measurement, and temperature was monitored during acquisition. Because the source record does not report the equilibration duration, accepted temperature range, or paired temperature-reference readings, the residual temperature contribution to measurement uncertainty cannot be quantified from the supplied manuscript.

The integrated workflow can reduce manual calculation and transcription and provide a route for digital traceability. Claims of field readiness would additionally require documented sensor calibration, vessel-geometry calibration, repeatability, and robustness tests under the intended operating conditions.

2.2 Instrumentation system

The density measurement chain comprised a load cell/HX711 amplifier for mass, an HC-SR04 ultrasonic sensor for liquid-level estimation, a W1209 temperature controller with its temperature probe, and an ESP8266 microcontroller. A 16 × 2 LCD provided local display, and Wi-Fi supported transmission to the IoT platform. Smartphone image acquisition was performed separately in a light-shielded chamber. The W1209 was used for temperature monitoring/control; the exact probe type and its calibration status should be reported according to the laboratory record.

The smartphone was positioned at a fixed orientation above a sample in a transparent cuvette inside an opaque chamber with white LED illumination. RGB values and derived HSL features were extracted with a smartphone application. Reproducibility requires reporting the smartphone model, camera settings, exposure and white-balance control, sample-to-camera distance, cuvette path length, region-of-interest selection, and image-averaging procedure. These details are not fully specified in the available source record.

Density and colour measurements were associated by sample identity and then considered as complementary screening variables. Since RGB/HSL features depend on the camera and imaging

conditions, comparisons are valid only when acquisition settings and processing are consistent across the groups.

2.3 Smartphone-based RGB imaging

The imaging chamber was intended to reduce ambient-light interference, with the smartphone camera fixed above the cuvette and white LED illumination used during image capture. The same cuvette type, fill level, camera geometry, illumination, and image-processing settings should be maintained across samples.

Images were acquired under nominally consistent conditions, and RGB values were extracted with a smartphone application. The source manuscript refers to an image resolution of up to 4096 pixels but does not identify the actual image dimensions or camera model. Since RGB channels are device-dependent digital values, a colour reference and repeatability assessment are needed before the features can be treated as transferable between devices [6].

2.4 Reference instruments

Pycnometer readings were used as the density reference. The source manuscript does not provide paired temperature-reference data or a traceable colour standard. Consequently, this study cannot claim validated temperature accuracy or traceable colour measurement. Density-method agreement should be evaluated from paired sample-level differences; correlation alone is insufficient [5].

2.5 Measurement procedure

Before measurement, each sample was brought toward 20°C. The load cell measured mass and the ultrasonic sensor measured the distance to the liquid surface. If the vessel has a uniform cylindrical cross-section, liquid volume is calculated from the internal radius r and liquid height h as

$$V = \pi r^2 h \text{ (Eq. 1),}$$

provided that the height datum and vessel dimensions have been calibrated. Density is then

$$\rho = m/V \text{ (Eq. 2).}$$

For independent mass and volume uncertainties, first-order uncertainty propagation gives

$$u(\rho)/\rho \approx \sqrt{[(u(m)/m)^2 + (u(V)/V)^2]} \text{ (Eq. 3).}$$

This expression shows why ultrasonic height uncertainty and vessel geometry can dominate the density uncertainty when volume is inferred indirectly. The source manuscript does not supply calibration uncertainties for the load cell, ultrasonic sensor, or vessel geometry, so a numerical combined uncertainty cannot be calculated responsibly.

An aliquot was transferred to a transparent cuvette and imaged in the controlled chamber. RGB values and HSL parameters were extracted using the same nominal workflow for all samples. Although the procedure requires no chemical reagent, transfer, cuvette cleanliness, fill level, and image acquisition may affect repeatability.

For repeated measurements x_i , the sample mean is

$$\bar{x} = (1/n)\sum x_i \text{ (Eq. 4),}$$

and the sample standard deviation is

$$s = \sqrt{[\sum (x_i - \bar{x})^2 / (n - 1)]} \text{ (Eq. 5).}$$

These statistics describe repeatability only when the replicate structure is known. Technical repeats of one aliquot are not equivalent to independent sample preparations or independent oil batches; the source record does not adequately distinguish these units.

2.6 Data processing and statistical analysis

For paired DCO and pycnometer readings, define the residual for sample i as $e_i = \rho_{\text{DCO},i} - \rho_{\text{ref},i}$. Bias is $\text{mean}(e_i)$, mean absolute error is

$$\text{MAE} = (1/n)\sum |e_i| \text{ (Eq. 6),}$$

and root-mean-square error is

$$\text{RMSE} = \sqrt{[(1/n)\sum e_i^2]} \text{ (Eq. 7).}$$

These metrics must be calculated from the same verified paired dataset. A Bland–Altman analysis can additionally estimate bias and limits of agreement as $\text{mean}(e) \pm 1.96s_e$ when the distributional assumptions are appropriate [5]. Correlation and R^2 measure association, not agreement or interchangeability. Because the individual paired readings are absent, no numerical bias, MAE, RMSE, confidence interval, t-test, or limits of agreement are reported as validated results in this revision.

3 Results and discussion

3.1 Density response of pure and adulterated samples

The complete 16-sample comparison supplied for this revision is used as the primary density dataset (Table 3). For each sample, the reference and DCO values are retained exactly as reported, including their stated $\pm$ values. Across the 16 reported central values, the reference densities span 0.775–0.928 g cm⁻³ and the instrument densities span 0.780–0.934 g cm⁻³. The density response is physically plausible in broad terms: samples containing more low-density adulterant generally show lower density. However, the blend densities are not strictly monotonic across origins and adulterant types, which indicates that

concentration alone does not explain all between-sample variation. Differences in the initial oil density, sample preparation, temperature, and measurement uncertainty may contribute. The $\pm$ values are retained as supplied; because their statistical definition (standard deviation, standard error, or instrument uncertainty) was not specified, they are not reinterpreted.

Table 1
Hardware components and their functions

No.	Component	Model / Type	Function
1	Microcontroller	ESP8266 (WiFi)	Data processing, density calculation, IoT communication and data integration
2	Mass Sensor	Load Cell + HX711	Sample mass measurement
3	Volume Sensor	HC-SR04 (Ultrasonic)	Liquid height measurement for volume calculation
4	Temperature Sensor	W1209 temperature controller	Temperature control during measurement
5	RGB Imaging Unit (Smartphone-Based)	Smartphone Camera + Imaging Chamber + RGB Analysis Application	RGB image acquisition and colour feature extraction (R, G, B, Hue, Saturation, Lightness)
6	Display	LCD 16×2 I2C	Display density and temperature
7	Communication	WiFi (IoT)	Wireless data transmission to IoT platform

A lower-density adulterant is expected to reduce the density of a blend, but the response should be checked against a mixture model. Under an ideal volume-additivity approximation, $\rho_{mix} \approx (1 - \phi)\rho_p + \phi\rho_a$ (Eq. 8), where ϕ is the adulterant volume fraction, ρ_p is the patchouli-oil density, and ρ_a is the adulterant density. Using the study-record component values $\rho_p = 0.950 \text{ g cm}^{-3}$, $\rho_{palm} = 0.820 \text{ g cm}^{-3}$, and $\rho_{kerosene} = 0.780 \text{ g cm}^{-3}$, the expected densities are 0.9175, 0.8850, and 0.8525 g cm^{-3} for 25%, 50%, and 75% palm oil, and 0.9075, 0.8650, and 0.8225 g cm^{-3} for the corresponding kerosene blends. The model is an idealized consistency check rather than a substitute for measurement; non-additive volumes and temperature mismatch can cause departures, but large residuals require investigation of mixture preparation, mass readings, vessel calibration, and sample labels.

The model in Table 2 demonstrates the expected direction of change when a lower-density adulterant is added under a volume-additivity assumption. It is not used to overwrite or reinterpret the actual sample-specific results in Table 3. Any quantitative evaluation of blend non-ideality would require component densities measured at the same temperature and verified volume fractions.

The tabled mixture densities generally decrease with increasing nominal adulterant fraction, but the 75% values do not agree closely with the ideal volume-weighted model. Consequently, the dataset does not yet support a validated concentration-response slope, an adulteration detection threshold, or a quantified classification error.

The ideal volume-weighted model is retained as a qualitative physical check, but the complete sample-specific reference/instrument dataset in Table 3 is the primary evidence for method comparison. Since the pure-oil reference baselines differ by origin and the uncertainty meaning is unspecified, a single universal mixture baseline should not be used to judge every blend. Observed values remain distinct from model predictions.

3.2 Density measurement comparison

Using the 16 paired central values in Table 3, with each listed DCO result paired to its corresponding reference result, the mean signed difference (DCO – reference) is $+0.00075 \text{ g cm}^{-3}$, the mean absolute error (MAE) is $0.006875 \text{ g cm}^{-3}$, and the root-mean-square error (RMSE) is $0.006946 \text{ g cm}^{-3}$. The mean absolute percentage error (MAPE), calculated relative to each reference value, is 0.796%. Linear regression of DCO values against reference values gives $R^2 = 0.9749$ (Pearson $r = 0.9874$; $n = 16$). These calculations reproduce the previously stated $R^2 \approx 0.975$ and $\text{RMSE} \approx 0.00695 \text{ g cm}^{-3}$ from the supplied table, but they do not validate the earlier 3.23% mean error or 96.76% accuracy claim; those terms are removed because their definitions and arithmetic were not supported. The statistics are calculated from the 16 tabulated means, not from raw replicate-level observations, and therefore describe agreement at the table-value level only. They must not be interpreted as full metrological validation or as independent evidence of repeatability.

3.3 Physics-based consistency check and limits of statistical validation

As an exploratory paired comparison of the 16 reported central values, a paired t-test gives $t(15) = 0.421$, $p = 0.680$. This indicates that the data do not provide evidence of a non-zero average difference under the assumptions of the test; it does not demonstrate equivalence between methods. The result is limited because the input values are summary values with reported $\pm$ terms, not the underlying replicate observations. A full validation should use replicate-level paired measurements, a predefined acceptable error, calibration traceability, and a Bland–Altman assessment. From the 16 central-value differences, the mean bias is $+0.00075 \text{ g cm}^{-3}$ and the approximate 95% limits of agreement are -0.01323 to $+0.01473 \text{ g cm}^{-3}$; these limits are exploratory and should not replace an analysis of replicate-level data.

Table 2

Illustrative ideal volume-weighted density predictions; these are not measured values

Blend fraction	Model inputs	Ideal-model density (g cm ⁻³)
25% palm oil	0.950 patchouli; 0.820 palm oil	0.9175
50% palm oil	0.950 patchouli; 0.820 palm oil	0.8850
75% palm oil	0.950 patchouli; 0.820 palm oil	0.8525
25% kerosene	0.950 patchouli; 0.780 kerosene	0.9075
50% kerosene	0.950 patchouli; 0.780 kerosene	0.8650
75% kerosene	0.950 patchouli; 0.780 kerosene	0.8225

The ideal mixture model is an approximation assuming volume additivity and measurements at the same temperature. It is used only as a plausibility check; the 16 sample-specific reference and instrument values are reported separately in Table 3.

The plotted predictions are model calculations, not measurements. The difference at 75% adulterant fraction is a data-quality flag requiring repeat preparation and measurement; the model curve must not be substituted for observed data.

Table 3
Complete reference and DCO density results supplied for the 16 sample compositions

No.	Sample type	Reference density (g cm ⁻³)	Instrument density (g cm ⁻³)
1	100% Gayo Lues	0.928 ± 0.001	0.934 ± 0.002
2	100% Aceh Besar	0.919 ± 0.002	0.925 ± 0.003
3	75% Gayo Lues : 25% palm oil	0.908 ± 0.002	0.915 ± 0.003
4	75% Gayo Lues : 25% kerosene	0.901 ± 0.002	0.895 ± 0.003
5	75% Aceh Besar : 25% palm oil	0.912 ± 0.003	0.905 ± 0.004
6	75% Aceh Besar : 25% kerosene	0.883 ± 0.003	0.890 ± 0.004
7	50% Gayo Lues : 50% palm oil	0.871 ± 0.001	0.880 ± 0.002
8	50% Gayo Lues : 50% kerosene	0.862 ± 0.001	0.855 ± 0.002
9	50% Aceh Besar : 50% palm oil	0.867 ± 0.001	0.875 ± 0.002
10	50% Aceh Besar : 50% kerosene	0.848 ± 0.001	0.855 ± 0.002
11	25% Gayo Lues : 75% palm oil	0.852 ± 0.002	0.845 ± 0.003
12	25% Gayo Lues : 75% kerosene	0.823 ± 0.002	0.815 ± 0.003
13	25% Aceh Besar : 75% palm oil	0.848 ± 0.002	0.840 ± 0.003
14	25% Aceh Besar : 75% kerosene	0.821 ± 0.002	0.815 ± 0.003
15	100% palm oil	0.814 ± 0.001	0.820 ± 0.004
16	100% kerosene	0.775 ± 0.002	0.780 ± 0.003

Statistical calculation note: all summary statistics above were recalculated from the 16 central reference and instrument values in Table 3. The ± quantities were copied from the supplied dataset and are not used as replicate-level observations because their meaning and sample sizes were not specified.

3.4 RGB/HSL response and statistical limitations

Smartphone imaging provides a complementary description of sample appearance. RGB/HSL features depend on the sample, illumination, cuvette path length, camera processing, and region-of-interest selection; therefore, the findings apply only to the controlled setup represented in the experiment. The available plots show different RGB/HSL distributions among sample groups, but without replicate-level values they support only qualitative observation, not verified p-values or a general-purpose classifier.

The source plots show different RGB/HSL distributions among the groups represented in the original dataset. In the absence of replicate-level colour values and a documented experimental unit, these plots can be described qualitatively but cannot support independently verified p-values. A classifier would

require independent oil batches, blinded samples, a held-out test set, and performance measures such as sensitivity, specificity, balanced accuracy, and confidence intervals.

HSL features represent image appearance through hue, saturation, and lightness. These features can describe colour differences under fixed acquisition conditions, but statistical differences in HSL values do not by themselves demonstrate reliable identification of adulteration in unknown samples.

3.5 Requirements for confirmatory colour statistics

One-way ANOVA F-statistics and p-values were reported for RGB/HSL features, but the underlying observations, group sizes, experimental unit, residual diagnostics, and post-hoc comparisons were not available for recalculation. These values are therefore not presented as validated inferential results. A defensible analysis must use independent sample preparations or oil batches as the experimental units, check model assumptions, and apply appropriate multiplicity-adjusted post-hoc comparisons. Statistical significance alone would not establish useful classification performance.

3.6 Overall discussion

The principal contribution is a prototype measurement chain connecting gravimetric mass measurement, ultrasonic liquid-height estimation, controlled smartphone imaging, and digital data transfer. The physics-based audit confirms the arithmetic consistency of the tabulated mass/volume densities and identifies a material discrepancy between the 75% blend observations and an ideal volume-weighted mixture model. This is a useful diagnostic finding, but it is not a substitute for independent metrological validation. The method-comparison and colour inferential statistics remain unverified until raw records are recovered.

IoT connectivity can support remote viewing and digital traceability but does not independently improve analytical accuracy. For a field workflow, records should include sample identifiers, timestamps, temperature, calibration status, raw sensor readings, derived density, and image-acquisition settings, together with flags for measurements outside the validated operating range.

The main limitations are the limited sample set; conflicting pure-oil baselines; large model residuals for the 75% blends; absent paired DCO–pycnometer readings; unavailable raw RGB/HSL observations; incomplete calibration and uncertainty records; and unresolved temperature-module identity. No machine-learning classifier was validated. The next experimental stage should repeat the 75% blends, document component densities and temperature, calibrate mass and volume channels, collect paired reference readings, and preregister the statistical plan before evaluating blinded samples.

4 Conclusion

This study describes an IoT-enabled portable densitometer combined with controlled smartphone RGB/HSL image acquisition for preliminary patchouli-oil screening. The prototype integrates electronic mass measurement, ultrasonic liquid-height estimation, temperature monitoring, local display, and

wireless data transmission. The tabulated densities are arithmetically consistent with $\rho = m/V$, but comparison with an ideal volume-weighted mixture model identifies material discrepancies for the 75% blends. The previously reported DCO–pycnometer agreement statistics and RGB/HSL ANOVA cannot be independently reproduced from the available document; therefore, the current evidence supports prototype feasibility but not a numerical accuracy claim, method equivalence, or a validated adulteration classifier.

Declarations

Funding: This research was funded by Universitas Syiah Kuala.

Competing interests: The authors declare that the DCO instrument is associated with Indonesian intellectual-property application S00202505785. The authors declare no other competing interests.

Author contributions:

Dek Rina: conceptualization, methodology, investigation, software, data curation, formal analysis, and writing—original draft.

M. Syukri Surbakti: supervision, methodology, validation, and writing—review and editing.

Malahayati: supervision, validation, and writing—review and editing.

Data availability: The data used in this study are described in the manuscript. Additional underlying records, including replicate-level density measurements, paired DCO–pycnometer readings, calibration records, and raw RGB/HSL observations, are available from the corresponding author upon reasonable request, subject to their availability in the original research records.

Ethics approval: Not applicable because the study did not involve human participants or animals.

Acknowledgements: The authors acknowledge institutional support from Universitas Syiah Kuala.

References

1. van Beek TA, Joulain D (2018) The essential oil of patchouli, *Pogostemon cablin*: A review. *Flavour Fragr J* 33:6–51. <https://doi.org/10.1002/ffj.3418>
2. Souhoka FA, Al Aziz AZ, Nazudin N (2020) Patchouli oil isolation and identification of chemical components using GC-MS. *Indones J Chem Res* 8:108–113. <https://doi.org/10.30598/ijcr.2020.8-fas>
3. International Organization for Standardization (1998) ISO 279:1998 Essential oils—Determination of relative density at 20°C—Reference method. ISO, Geneva. <https://www.iso.org/standard/25308.html>
4. Badan Standardisasi Nasional (2019) ; confirmed 2025) SNI 2385:2019 Minyak atsiri nilam [Pogostemon cablin (Blanco) Benth.] (ISO 3757:2002, MOD). BSN, Jakarta

5. Bland JM, Altman DG (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1(8476):307–310. [https://doi.org/10.1016/S0140-6736\(86\)90837-8](https://doi.org/10.1016/S0140-6736(86)90837-8)
6. Fan Y, Li J, Guo Y, Xie L, Zhang G (2021) Digital image colorimetry on smartphone for chemical analysis: A review. *Measurement* 171:108829. <https://doi.org/10.1016/j.measurement.2020.108829>

Figures

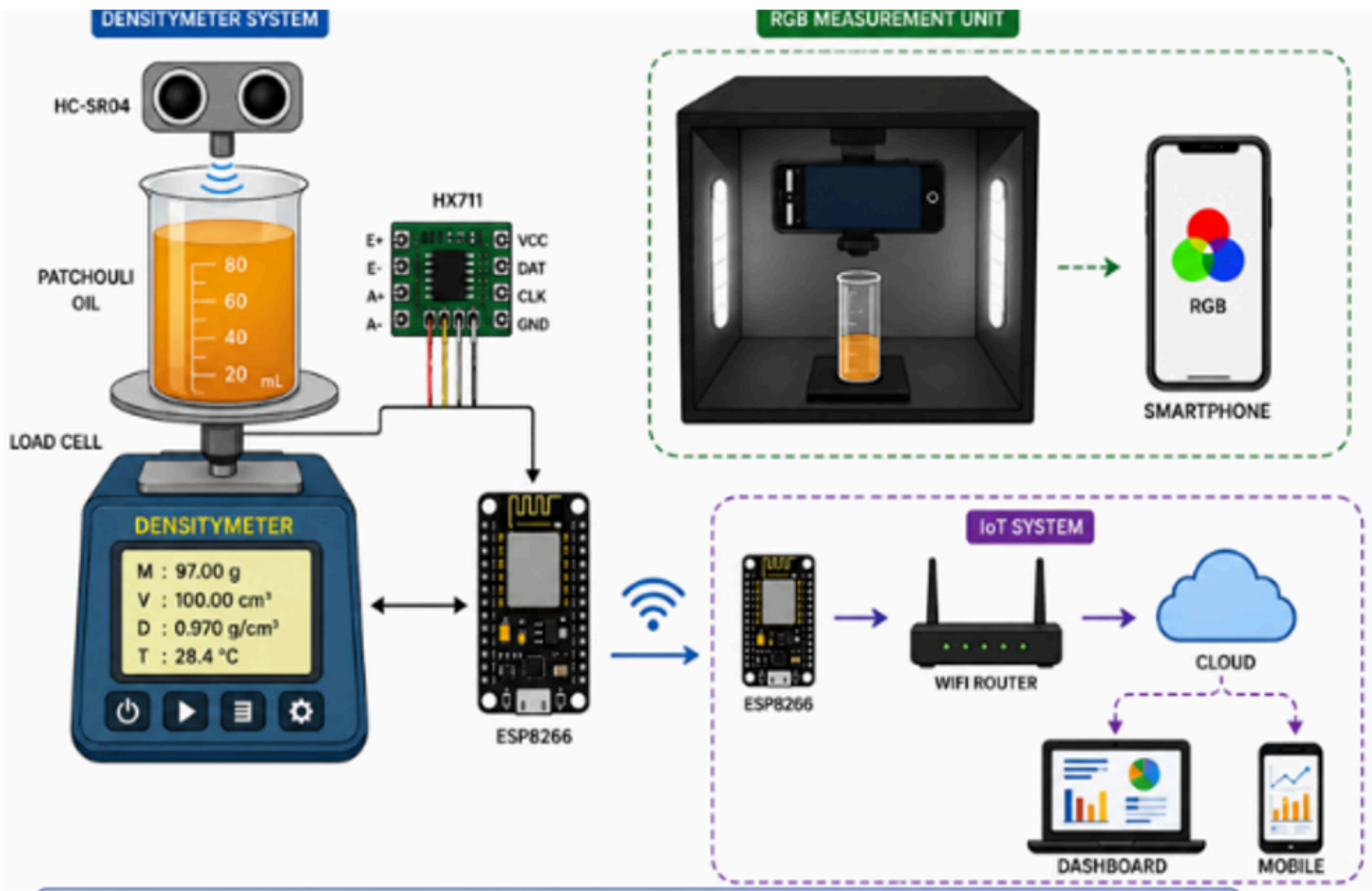


Figure 1

Experimental architecture of the IoT-enabled densitometer and the separate smartphone-based RGB imaging system



Figure 2

Photograph of the developed Densitymeter Patchouli Oil (DCO) during measurement

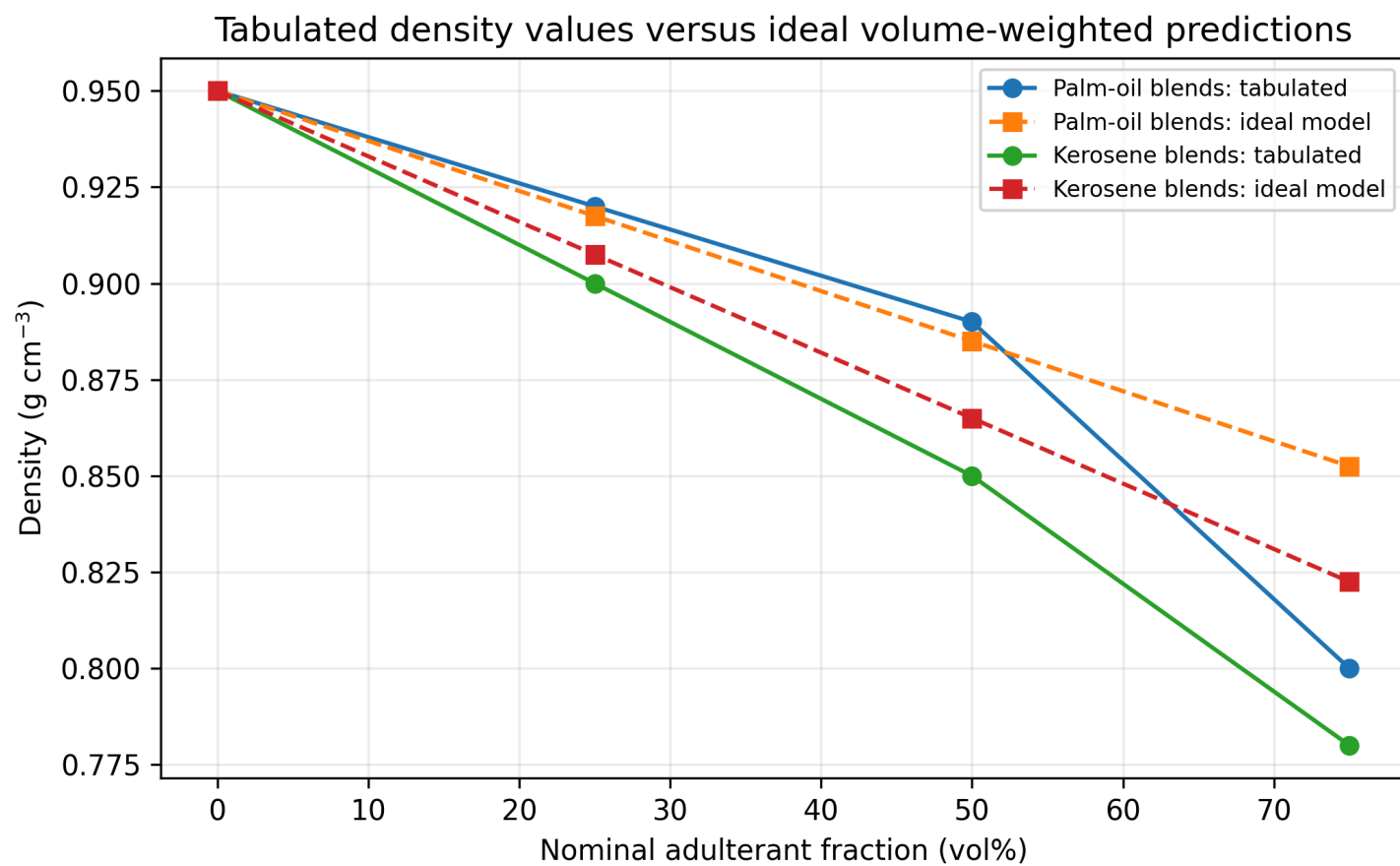


Figure 3

Observed tabulated densities and ideal volume-weighted predictions for palm-oil and kerosene blends