ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIII, Issue IX, September 2024

Peecheck 2.0: Design and Improvement of Rapid and Low-Cost Urine Analysis Device for Rural Health Care

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DOI: https://doi.org/10.51583/IJLTEMAS.2024.130902

Received: 31 August 2024; Accepted: 16 September 2024; Published: 26 September 2024

Abstract: The research paper introduced improvements to PeeCheck, a portable urine analyzer, addressing the need for versatile, rapid, and low-cost urine analysis tools, particularly in resource-constrained rural healthcare settings. The focus was on evaluating the accuracy and speed of reading the urine strip and the electrical characteristics of the portable urine analyzer device across various parameters. PeeCheck 2.0 represented enhancements in medical diagnostics using urine as a non-invasive sample. By incorporating the integration of technologies such as versatility in using variations of urine strips and data cloud storage using the Raspberry Pi Pico W microcontroller, PeeCheck 2.0 was designed to analyze 14 colorimetric urine characteristics, aiding in the pre-diagnostic of health issues associated with kidney and metabolic-related diseases. The study evaluated PeeCheck 2.0's performance through the analysis of urine samples collected from 3rd- and 4th-year electrical engineering students and compared the results with those obtained from standard laboratory urinalysis. The findings highlighted PeeCheck 2.0's potential to enhance health outcomes and reduce healthcare disparities in rural communities by providing healthcare providers with a low-cost and reliable solution for rapid detection and addressing health concerns in areas with limited resources. The study findings demonstrated that PeeCheck 2.0 achieved significant accuracy and speed in analyzing urine samples across 10 colorimetric parameters compared to standard laboratory methods. PeeCheck 2.0 obtained an overall accuracy of 92.470 percent in its analyses. Results from the evaluation with urine samples collected from electrical engineering students showed a high correlation with laboratory urinalysis, validating PeeCheck 2.0's efficacy in detecting key indicators of kidney and metabolic-related diseases. However, continuous programming-based calibration optimized PeeCheck 2.0 by adjusting parameters in real-time with data and sensor feedback, ensuring consistent accuracy and reliability in urine parameter testing. This research underscored PeeCheck 2.0's role in advancing medical diagnostics through innovation in urine analysis technology, contributing to improved healthcare delivery and outcomes in rural and underserved communities.

Keywords: urine reagent strip, color sensor, portable urine analyzer, urinalysis, cloud storage

I. Introduction

Access to quality healthcare remains a challenge for many Filipinos, particularly in rural areas where only 25 percent have access to essential health services compared to 46 percent in urban areas [1]. Despite recent improvements, such as telemedicine and mobile health units reaching remote communities [2], there is still a critical need for accessible, rapid, and cost-effective diagnostic tools. PeeCheck 2.0 aims to address this gap by providing a versatile and low-cost urine analysis device capable of detecting various health conditions, including kidney diseases and diabetes, using urine as a non-invasive biomarker [3], [4].This improved version of PeeCheck enhances diagnostic capabilities in resource-constrained environments, supporting the Philippines' efforts to bridge healthcare disparities and achieve Sustainable Development Goals related to health, reduced inequalities, and sustainable communities. By offering a reliable and efficient solution for early health screening, PeeCheck 2.0 has the potential to significantly improve health outcomes and access to care in rural communities, aligning technical innovation with practical healthcare needs.

Significance of the Study

The rationale for developing PeeCheck 2.0 is primarily practical and focuses on addressing pressing healthcare challenges in rural and underserved communities in the Philippines. Despite progress in healthcare delivery, significant disparities remain, particularly in rural areas where access to medical services is limited. PeeCheck 2.0 aims to bridge this gap by providing a low-cost, rapid, and portable urine analysis tool that leverages telemedicine and AI technologies for health monitoring and early detection of kidney and metabolic-related diseases.

Practical Significance

- Health and Safety: PeeCheck 2.0 offers a crucial solution for monitoring the general health of individuals in rural areas, where regular access to healthcare professionals is often scarce. By enabling the early detection of health issues through urine analysis, it helps healthcare providers in these regions address potential concerns promptly and maintain the well-being of their patients over time.
- Economic Benefits: The device is designed to be affordable and accessible, significantly reducing healthcare expenses by preventing the need for costly treatments and hospitalizations through early detection. It also supports the economy by improving productivity; healthier individuals are less likely to miss work due to illness. Additionally, rural residents save on travel costs for healthcare consultations, and healthcare facilities can cut expenses by using PeeCheck 2.0 instead of

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more expensive urinalysis equipment.

- Social Impact: By enabling telemedicine and remote consultations, PeeCheck 2.0 fosters connections and provides easier access to healthcare services for people in remote areas. This reduces the need for long-distance travel, thereby alleviating transportation burdens and enhancing overall health outcomes. The device also empowers rural healthcare facilities to extend their reach and deliver comprehensive care, ensuring essential services are accessible to all, regardless of location.
- Sustainability: Integrating cloud storage for data management ensures the secure and sustainable handling of health information, minimizing data loss and facilitating informed decision-making. AI-driven analysis of urine test results offers timely insights, helping to create personalized treatment plans and improving the quality of care provided by healthcare practitioners. PeeCheck 2.0 also supports government health agencies by providing real-time data collection and analysis, aiding in public health surveillance and policy formulation.
- Ethical Considerations: PeeCheck 2.0 enhances access to quality healthcare, potentially saving lives by simplifying pre-diagnostic procedures and preventing disease progression. It promotes health equity by empowering rural health units, practitioners, and patients, thus contributing to the overall quality of life and well-being in resource-constrained settings.

By addressing these practical needs, PeeCheck 2.0 not only improves healthcare delivery in rural areas but also supports broader goals of health equity, economic sustainability, and social well-being, making a significant contribution to the healthcare landscape in the Philippines.

The Problem

Despite significant progress in healthcare access for rural Filipinos, there remains a critical need for versatile, rapid, and cost-effective urine analysis tools to diagnose and monitor health conditions accurately in resource-constrained environments. The current PeeCheck system is limited in its diagnostic capabilities and requires enhancements to address these gaps and provide reliable, non-invasive, and accessible healthcare solutions for underserved rural communities in the Philippines.

Scope and Limitations

In this study, we addressed the limitations of the existing PeeCheck urine analysis system by enhancing its diagnostic capabilities and technological components. Our goal was to expand its detection range from four specific health parameters (protein, pH level, glucose, and specific gravity) to include bilirubin, urobilinogen, ketone, blood, creatinine, nitrite, leukocytes, ascorbate, microalbumin, and calcium, thereby facilitating broader health evaluations and aiding in the diagnosis of metabolic, systemic, endocrine, and urinary tract disorders. We upgraded key hardware elements, such as replacing the color sensor and touchscreen display, and transitioning from the Arduino Nano to the more powerful Raspberry Pi Pico W for improved processing, memory, and connectivity. Additionally, we incorporated cloud storage, Telecare AI, a medication recommendation system, and an SMS generator to enhance data handling and communication. However, our study did not cover systemic or confirmatory diagnoses, complex medical diagnostics, the development of advanced AI algorithms, large-scale clinical trials, or long-term reliability testing. These exclusions ensured a focused approach on improving PeeCheck's functionality and impact in resource-constrained healthcare settings.

II. Methodology

This research utilized a quantitative research approach to design and improve the rapid and low-cost urine analysis device, PeeCheck 2.0, for rural healthcare. The quantitative approach was applied to achieve the study's objectives, providing a comprehensive understanding of the research scope. This method involved using data and mathematical computations based on observations and findings to evaluate the variables tested in the study.

The researchers employed the quantitative approach to assess the system's performance. They evaluated the sensor’s accuracy by comparing its readings with those from conventional laboratory-grade equipment. This comparison allowed the researchers to determine the precision of the sensor and identify any potential discrepancies between its output and the results obtained from the laboratory-grade apparatus. These findings were crucial for making informed decisions regarding the design, enhancement, and future implementation of the PeeCheck 2.0 system.

Project Construction

The researchers designed and built an improved functional prototype of a rapid and low-cost urine analysis device for rural health care. They visited physical and online electrical stores to purchase and obtain the materials required for construction of the prototype. Tests will be conducted on each material to assess functionality. Once these components are assembled into a system, Arduino IDE software will used C++ programming language to program the entire setup.

- Acquisition of Required Materials for the Prototype

The researchers acquired materials for the PeeCheck 2.0 urine analysis device, including the central hub, Raspberry Pi Pico W. Local physical retailers were canvassed first, and the remaining parts were obtained online. Components were examined for defects to ensure the prototype's integrity.

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Once all materials were ready, an initial design was created using Solid Edge software for system component arrangement. After confirming functionality, the researchers programmed the PeeCheck in Arduino IDE.

- Programing of codes and Assembly of the device

The researchers made the prototype by following the initial design and schematic diagram. After creating the prototype, the researchers moved the programmed code from Arduino IDE to the Raspberry Pi Pico W and uploaded it to the prototype. Data was sent to the prototype for this. Then, the researchers checked if the system works well and provided accurate results. After they got the right consistency and precision in the sensor output, they finished up and completed the prototype.

Testing and Evaluation

The accuracy and performance of the device was validated through comprehensive testing. The researchers focused on assessing the sensor's measurement readings and data reading speed to ensure the proper functioning of the prototype.

- Prototype Testing

A series of tests were conducted to gauge the color sensor's functionality. One specific test involved using a URS-14 with a urine sample to showcase the sensor's capability to detect changes in the color and intensity of the strip. The sensor's response to these strip alterations was meticulously monitored, data was recorded, and the results were analyzed to verify the sensor's proper functionality.

For the study, the researchers gathered 22 males and 8 females with a total of thirty (30) participants of similar ages from fourth-year electrical engineering students from PUP (Sta. Mesa). Each participant provided two 60ml urine samples, stored in a sterile vial. A trial of 14-parameterurinalysis was conducted using URS-14 urine strips to read protein, pH level, glucose, specific gravity, bilirubin, urobilinogen, ketones, blood, creatinine, nitrite, leukocytes, ascorbate, microalbumin, and calcium. The researchers performed one trial on each urine sample to evaluate the PeeCheck 2.0 prototype, with two trials conducted in case of a numerical value result, taking the second result as the result, ensuring a reliable assessment of the device's accuracy.

- Comparison and Evaluation with Urinalysis Results

To assess the accuracy of the prototype, standard urinalysis tests were immediately conducted by a third-party laboratory using the same urine samples from the participants. The results from both tests underwent a Percentage Difference analysis using Microsoft Excel to determine any significant disparities between the prototype and standard urinalysis. Additionally, the mean percentage difference between the prototype's sensor readings and conventional urinalysis values was computed, providing an accurate assessment of the device's clinical utility in detecting urinary biomarkers.

Table 1: Percentage Difference Analysis Equation

Equation 1	$\%Difference = \frac{PeeCheck\ SRV - Urinalysis\ SRV}{Urinalysis\ SRV}(100)\%$
Equation 2	$MD = \frac{\Sigma\%\ difference\ per\ sample}{Total\ no.\ of\ samples\ per\ parameter}$
Equation 3	$\%Accuracy\ per\ parameter = 100\% - MD\ per\ parameter$
Equation 4	$\%Device\ Overall\ Accuracy = \frac{\Sigma\%Accuracy\ per\ parameter}{Number\ of\ parameters}$

As shown in Equation 1, the Percentage Difference (% Difference) in the device was calculated by subtracting the PeeCheck sample result value (PeeCheck SVR) from the Urinalysis sample result value (Urinalysis SVR), dividing by the Urinalysis SVR, and then multiplying the result by 100. This formula provided a measure of the deviation between the PeeCheck and Urinalysis results, expressed as a percentage.

The mean difference (MD) was obtained by dividing the total number of samples per parameter (total no. of samples per parameter) by the cumulative percentage difference per sample (Σ % difference per sample), as shown in Equation 2.

The accuracy percentage for each parameter was obtained by subtracting the mean difference for each parameter from 100 percent, as indicated by Equation 3.

The device's overall accuracy percentage was determined by taking the average of the accuracy percentages from all parameters, as indicated by Equation 4.

- Speed of Analyze Mode in Different Urine Strip Variations

To evaluate the speed (time per strip) of the prototype device, the researchers tested urine samples with 14-parameter strip using mobile timer to monitor the analyzing mode time from the stepper motor running until the result was shown. The urine sample was tested with 14-parameter urine strips. Through this testing, the researchers determined the speed of testing using 14 parameter strips.

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To evaluate the accuracy of the speed or the precision of the time duration for analyzing the strips, the researchers collected five testing time durations for each strip variation and calculated the average time for each strip variation.

- Testing Electrical Characteristics

The electrical characteristics, including input voltage, current draws, and power consumption of the prototype, were assessed during various modes—Standby with Wi-Fi (before stepper motor usage), Analyze with Wi-Fi, Standby without Wi-Fi (before stepper motor usage), Analyze with Wi-Fi, Standby with Wi-Fi (after stepper motor usage), and Standby with Wi-Fi (after stepper motor usage). This assessment aimed to evaluate device power efficiency, identify potential energy-saving opportunities, and estimate long term operating costs. Actual electrical parameters were measured using the RPI CORE INA 219 power monitor module for Raspberry Pi devices, with an OLED displaying voltage input and current draw readings.

To evaluate the data accuracy of the electrical characteristics, the researchers accumulated three testing results from different modes of usage. These modes included Standby with Wi-Fi (before stepper motor usage), Analyze with Wi-Fi, Standby without Wi-Fi (before stepper motor usage), Analyze with Wi-Fi, Standby with Wi-Fi (after stepper motor usage), and Standby with Wi-Fi (after stepper motor usage). Data was recorded three trials of minute and compute for the average of that minute during the standby modes, while average of electrical characteristics was noted during the analyze modes.

III. Analysis & Discussion

This chapter presents an overview of the findings obtained from the PeeCheck 2.0 evaluation and provides a comprehensive analysis and interpretation of these results.

PeeCheck 2.0 Design

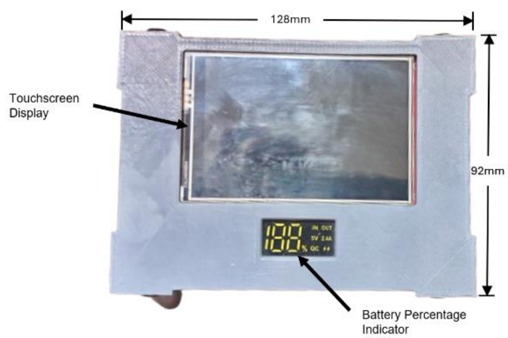

Fig. 24 Front View of Actual PeeCheck 2.0

The PeeCheck 2.0 is a prototype designed for pre-diagnostic urine sample testing, aiming to detect early urinary and metabolic health conditions. It features a touchscreen display and battery percentage indicator on the front for user-friendly control and battery indicator.

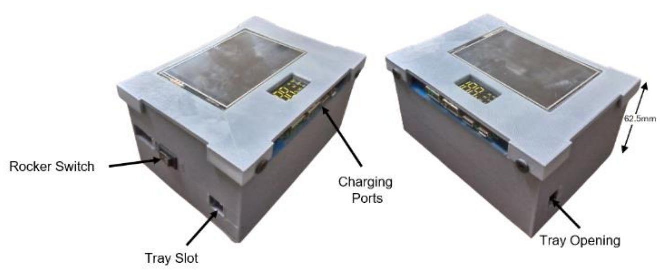

Fig. 25 Isometric View of Actual PeeCheck 2.0

The device contains a charging port, an SD card mounting port, a rocker switch for system power, tray opening and tray slot on the side for the urine strip tray.

IV. Comparison of PeeCheck 2.0 and Laboratory Urinalysis Results

- Urobilinogen in Urine Test

Table 2: Comparison of Urobilinogen-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks
1	16 (Negative)	Negative	Similar

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2	16 (Negative)	Negative	Similar
3	16 (Negative)	Negative	Similar
4	16 (Negative)	Negative	Similar
5	3.3 (Negative)	Negative	Similar
6	16 (Negative)	Negative	Similar
7	16 (Negative)	Negative	Similar
8	3.3 (Negative)	++	Dissimilar
9	16 (Negative)	Negative	Similar
10	3.3 (Negative)	Negative	Similar
11	16 (Negative)	Negative	Similar
12	16 (Negative)	Negative	Similar
13	3.3 (Negative)	Negative	Similar
14	3.3 (Negative)	Negative	Similar
15	3.3 (Negative)	Negative	Similar
16	3.3 (Negative)	Negative	Similar
17	3.3 (Negative)	Negative	Similar
18	3.3 (Negative)	Negative	Similar
19	3.3 (Negative)	Negative	Similar
20	3.3 (Negative)	Negative	Similar
21	3.3 (Negative)	Negative	Similar
22	3.3 (Negative)	Negative	Similar
23	3.3 (Negative)	Negative	Similar
24	3.3 (Negative)	Negative	Similar
25	3.3 (Negative)	Negative	Similar
26	3.3 (Negative)	Negative	Similar
27	3.3 (Negative)	Negative	Similar
28	3.3 (Negative)	Negative	Similar
29	3.3 (Negative)	Negative	Similar
30	3.3 (Negative)	+	Dissimilar
Percentage Accuracy			93.333%

Table 2 provides a comparative analysis of urobilinogen detection results between PeeCheck 2.0 and standard urinalysis. A negative result indicates absence of urobilinogen, while "+" and "++" denote trace and moderate amounts respectively. PeeCheck 2.0 demonstrated strong agreement with standard urinalysis, matching results in 28 out of 30 samples, with only two discrepancies. This performance yields a high percentage accuracy of 93.333 percent, highlighting PeeCheck 2.0's reliability in urobilinogen detection.

- Bilirubin in Urine Test

Table 3: Comparison of Bilirubin-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks
1	Negative	Negative	Similar

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2	Negative	Negative	Similar
3	Negative	Negative	Similar
4	Negative	Negative	Similar
5	Negative	Negative	Similar
6	Negative	Negative	Similar
7	Negative	Negative	Similar
8	Negative	Negative	Similar
9	Negative	Negative	Similar
10	Negative	Negative	Similar
11	Negative	Negative	Similar
12	Negative	Negative	Similar
13	Negative	Negative	Similar
14	Negative	Negative	Similar
15	Negative	Negative	Similar
16	Negative	Negative	Similar
17	Negative	Negative	Similar
18	Negative	Negative	Similar
19	Negative	Negative	Similar
20	Negative	Negative	Similar
21	Moderate (50)	Negative	Dissimilar
22	Negative	Negative	Similar
23	Negative	Negative	Similar
24	Negative	Negative	Similar
25	Negative	Negative	Similar
26	Negative	Negative	Similar
27	Negative	Negative	Similar
28	Moderate (50)	Negative	Dissimilar
29	Negative	Negative	Similar
30	Negative	Negative	Similar
Percentage Accuracy			93.333%

Table 3 compares the detection of bilirubin between PeeCheck 2.0 and standard urinalysis. Results include negative findings for absence of bilirubin, and varying levels denoted as small and moderate. PeeCheck 2.0 exhibited strong agreement with standard urinalysis, showing 28 out of 30 matching results with only two discrepancies. This performance translates to a high accuracy rate of 93.333 percent for bilirubin detection in urine, underscoring PeeCheck 2.0's reliability in this parameter.

- Ketone in Urine Test

Table 4: Comparison of Ketone-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks
1	Negative	Negative	Similar
2	Negative	Negative	Similar

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3	Negative	Negative	Similar
4	Negative	Negative	Similar
5	Negative	Negative	Similar
6	Negative	Negative	Similar
7	Negative	Negative	Similar
8	Negative	Negative	Similar
9	Trace (0.5)	Negative	Dissimilar
10	Negative	Negative	Similar
11	Negative	Negative	Similar
12	Negative	Negative	Similar
13	Negative	Negative	Similar
14	Negative	Negative	Similar
15	Negative	Negative	Similar
16	Negative	Negative	Similar
17	Negative	Negative	Similar
18	Trace (0.5)	Negative	Dissimilar
19	Trace (0.5)	Negative	Dissimilar
20	Negative	Negative	Similar
21	Negative	Negative	Similar
22	Negative	Negative	Similar
23	Negative	Negative	Similar
24	Negative	Negative	Similar
25	Negative	Negative	Similar
26	Negative	Negative	Similar
27	Negative	Negative	Similar
28	Negative	Negative	Similar
29	Negative	Negative	Similar
30	Negative	Negative	Similar
Percentage Accuracy			90.000%

Table 4 compares ketone detection results between PeeCheck 2.0 and standard urinalysis, where a negative result indicates absence of ketones in the urine sample and trace indicates minimal amounts. PeeCheck 2.0 and standard urinalysis exhibit 27 matching results and 3 discrepancies. This indicates that PeeCheck 2.0 achieves a high accuracy of 90.000 percent in testing for ketones in urine samples, demonstrating its reliability in this parameter compared to standard laboratory analysis.

- Blood in Urine Test

Table 5: Comparison of Blood-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks
1	Negative	Negative	Similar
2	Negative	Negative	Similar
3	Negative	Negative	Similar

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4	Negative	Negative	Similar
5	Negative	Negative	Similar
6	Negative	Negative	Similar
7	Negative	Negative	Similar
8	Negative	Negative	Similar
9	Negative	Negative	Similar
10	Negative	Negative	Similar
11	Moderate (80)	Negative	Dissimilar
12	Negative	Negative	Similar
13	Negative	Negative	Similar
14	Negative	Negative	Similar
15	Negative	Negative	Similar
16	Negative	Negative	Similar
17	Negative	Negative	Similar
18	Moderate (80)	Negative	Dissimilar
19	Moderate (80)	Negative	Dissimilar
20	Negative	Negative	Similar
21	Negative	Negative	Similar
22	Negative	Negative	Similar
23	Negative	Negative	Similar
24	Moderate (80)	Negative	Dissimilar
25	Negative	Negative	Similar
26	Negative	Negative	Similar
27	Negative	Negative	Similar
28	Negative	Negative	Similar
29	Moderate (80)	Negative	Dissimilar
30	Small (25)	Negative	Dissimilar
Percentage Accuracy			80.000%

Table 5 compares blood detection results between PeeCheck 2.0 and standard urinalysis, categorizing results as negative (no Red Blood Cells - RBCs detected) and moderate (significant presence of RBCs). PeeCheck 2.0 and standard urinalysis demonstrate 24 matching results and 6 differing results. This indicates that PeeCheck 2.0 achieves an accuracy rate of 80.000 percent in detecting blood in urine samples, reflecting moderate reliability in this parameter compared to standard laboratory analysis.

- Protein in Urine Test

Table 6: Comparison of Protein-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks
1	Negative	Negative	Similar
2	Negative	Negative	Similar
3	Negative	Negative	Similar
4	Negative	Negative	Similar

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5	Negative	Negative	Similar
6	Negative	Negative	Similar
7	Negative	Negative	Similar
8	Negative	Negative	Similar
9	Negative	Negative	Similar
10	Negative	Negative	Similar
11	Negative	Negative	Similar
12	Negative	Negative	Similar
13	Negative	Negative	Similar
14	Negative	Negative	Similar
15	Negative	Negative	Similar
16	Negative	Negative	Similar
17	Negative	Negative	Similar
18	Negative	Negative	Similar
19	Negative	Negative	Similar
20	Negative	Negative	Similar
21	Negative	Negative	Similar
22	Negative	Negative	Similar
23	Negative	Negative	Similar
24	Negative	Negative	Similar
25	Negative	Negative	Similar
26	Negative	Negative	Similar
27	Negative	Negative	Similar
28	Negative	Negative	Similar
29	Negative	Negative	Similar
30	Negative	Negative	Similar
Percentage Accuracy			100%

Table 6 compares protein detection results between PeeCheck 2.0 and standard urinalysis, where a negative result indicates absence of protein in the urine sample. PeeCheck 2.0 and standard urinalysis exhibit 30 identical results, indicating perfect agreement. This suggests that PeeCheck 2.0 is highly reliable for detecting protein in urine, achieving an accuracy rate of 100 percent in this parameter compared to standard laboratory analysis.

- Nitrite in Urine Test

Table 7: Comparison of Nitrite-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks
1	Negative	Negative	Similar
2	Negative	Negative	Similar
3	Negative	Negative	Similar
4	Negative	Negative	Similar
5	Negative	Negative	Similar

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6	Negative	Negative	Similar
7	Negative	Negative	Similar
8	Negative	Negative	Similar
9	Negative	Negative	Similar
10	Negative	Negative	Similar
11	Negative	Negative	Similar
12	Negative	Negative	Similar
13	Negative	Negative	Similar
14	Negative	Negative	Similar
15	Negative	Negative	Similar
16	Negative	Negative	Similar
17	Negative	Negative	Similar
18	Negative	Negative	Similar
19	Negative	Negative	Similar
20	Negative	Negative	Similar
21	Negative	Negative	Similar
22	Negative	Negative	Similar
23	Negative	Negative	Similar
24	Negative	Negative	Similar
25	Negative	Negative	Similar
26	Negative	Negative	Similar
27	Negative	Negative	Similar
28	Negative	Negative	Similar
29	Negative	Negative	Similar
30	Positive	Negative	Dissimilar
Percentage Accuracy			96.667%

Table 7 compares nitrate (nitrite) detection results between PeeCheck 2.0 and standard urinalysis, distinguishing between negative (no nitrites detected) and positive (nitrites detected) results. PeeCheck 2.0 and standard urinalysis demonstrate 29 matching results and 1 differing result. This indicates that PeeCheck 2.0 achieves a high accuracy of 96.667 percent in testing for nitrites in urine samples, highlighting its reliability and effectiveness in this parameter compared to standard laboratory analysis.

- Leukocytes in Urine Test

Table 8: Comparison of Leukocytes-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks
1	Negative	Negative	Similar
2	Negative	Negative	Similar
3	Negative	Negative	Similar
4	Negative	Negative	Similar
5	Negative	Negative	Similar
6	Negative	Negative	Similar

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7	Negative	Negative	Similar
8	Negative	Negative	Similar
9	Negative	Negative	Similar
10	Negative	Negative	Similar
11	Negative	Negative	Similar
12	Negative	Negative	Similar
13	Negative	Negative	Similar
14	Negative	Negative	Similar
15	Negative	Negative	Similar
16	Negative	Negative	Similar
17	Negative	Negative	Similar
18	Negative	Negative	Similar
19	Negative	Negative	Similar
20	Small (70)	++ (Small)	Similar
21	Negative	Negative	Similar
22	Small (70)	Negative	Dissimilar
23	Negative	Negative	Similar
24	Negative	Negative	Similar
25	Negative	Negative	Similar
26	Negative	Negative	Similar
27	Small (70)	+++ (Moderate)	Dissimilar
28	Negative	Negative	Similar
29	Small (70)	Negative	Dissimilar
30	Negative	Negative	Similar
Percentage Accuracy			90.000%

Table 8 compares leukocyte-in-urine results between PeeCheck 2.0 and standard urinalysis, categorizing results as negative (no leukocytes detected), small (few leukocytes), and moderate (moderate leukocytes). PeeCheck 2.0 and standard urinalysis exhibit 27 matching results and 3 differing results. This indicates that PeeCheck 2.0 achieves a high accuracy of 90 percent in detecting leukocytes in urine samples, underscoring its reliability in this parameter compared to standard laboratory analysis.

- Glucose in Urine Test

Table 9: Comparison of Glucose-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks
1	Negative	Negative	Similar
2	Negative	Negative	Similar
3	Negative	Negative	Similar
4	Negative	Negative	Similar
5	Negative	Negative	Similar
6	Negative	Negative	Similar
7	Negative	Negative	Similar

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8	Negative	Negative	Similar
9	Negative	Negative	Similar
10	Negative	Negative	Similar
11	Negative	Negative	Similar
12	Negative	Negative	Similar
13	Negative	Negative	Similar
14	Negative	Negative	Similar
15	Negative	Negative	Similar
16	Negative	Negative	Similar
17	Negative	Negative	Similar
18	Negative	Negative	Similar
19	Negative	Negative	Similar
20	Negative	Negative	Similar
21	Negative	Negative	Similar
22	Negative	Negative	Similar
23	Negative	Negative	Similar
24	Negative	Negative	Similar
25	Negative	Negative	Similar
26	Negative	Negative	Similar
27	Negative	Negative	Similar
28	Negative	Negative	Similar
29	Negative	Negative	Similar
30	Negative	Negative	Similar
Percentage Accuracy			100%

Table 9 compares glucose detection results between PeeCheck 2.0 and standard urinalysis, where negative results indicate absence of glucose in urine. Both PeeCheck 2.0 and standard urinalysis show identical negative results for glucose detection, indicating perfect agreement. PeeCheck 2.0 achieves a high accuracy rate of 100 percent in this parameter, demonstrating its reliability and consistency in detecting the absence of glucose in urine samples.

- Specific Gravity in Urine Test

Table 10: Comparison of Specific Gravity-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks	Percentage Difference (%)
1	1.015	1.015	Similar	0.000
2	1.015	1.015	Similar	0.000
3	1.015	1.015	Similar	0.000
4	1.025	1.020	Dissimilar	0.490
5	1.010	1.005	Dissimilar	0.498
6	1.015	1.010	Dissimilar	0.495
7	1.015	1.025	Dissimilar	0.976
8	1.015	1.020	Dissimilar	0.490
9	1.015	1.015	Similar	0.000

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10	1.015	1.015	Similar	0.000
11	1.015	1.020	Dissimilar	0.490
12	1.015	1.020	Dissimilar	0.490
13	1.015	1.020	Dissimilar	0.490
14	1.015	1.005	Dissimilar	0.995
15	1.015	1.015	Similar	0.000
16	1.000	1.005	Dissimilar	0.498
17	1.015	1.020	Dissimilar	0.490
18	1.015	1.010	Dissimilar	0.495
19	1.015	1.025	Dissimilar	0.976
20	1.015	1.010	Dissimilar	0.495
21	1.015	1.015	Similar	0.000
22	1.015	1.005	Dissimilar	0.995
23	1.015	1.005	Dissimilar	0.995
24	1.015	1.020	Dissimilar	0.490
25	1.015	1.010	Dissimilar	0.495
26	1.015	1.020	Dissimilar	0.490
27	1.015	1.020	Dissimilar	0.490
28	1.015	1.020	Dissimilar	0.490
29	1.015	1.020	Dissimilar	0.490
30	1.015	1.020	Dissimilar	0.490
Mean Difference				0.460
Percentage Accuracy				99.540%

Table 10 compares specific gravity results between PeeCheck 2.0 and standard urinalysis, where specific gravity values ranging from 1.005 to 1.030 indicate normal kidney function and fluid balance. The mean difference analysis across 30 samples shows a minimal mean difference of 0.460 percent between PeeCheck 2.0 and standard urinalysis, with seven samples demonstrating perfect agreement (0.000 percent difference). PeeCheck 2.0 achieves a high percentage accuracy of 99.540 percent in measuring specific gravity compared to standard urinalysis. This high accuracy is reflected in 23 out of 30 samples having percentage differences close to zero (0.000 percent), indicating PeeCheck 2.0's measurements closely align with those of the standard method. Minor deviations are observed in the remaining samples, with percentage differences ranging from 0.490 percent to 0.995 percent.

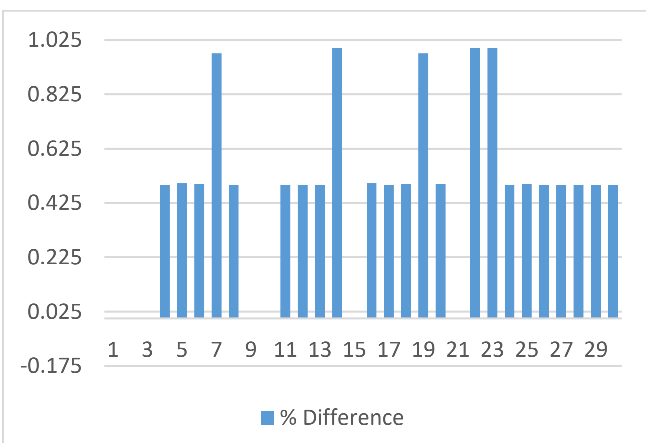

Fig. 26 Comparison of the Urine Specific Gravity Percentage

In comparing standard urinalysis and PeeCheck for specific gravity, most of the results from PeeCheck 2.0 testing showed a percentage difference greater than zero. Out of 30 samples, only seven demonstrated an exact zero percent difference in specific gravity.

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- pH Level in Urine Test

Table 11: Comparison Ph Level-In-Urine Test Results

Sample No.	PeeCheck 2.0	Urinalysis	Remarks	Percentage Difference (%)
1	8.000	6.000	Dissimilar	33.333
2	5.000	8.000	Dissimilar	37.500
3	5.000	6.000	Dissimilar	16.667
4	8.000	6.000	Dissimilar	33.333
5	5.000	6.500	Dissimilar	23.077
6	8.000	8.000	Similar	0.000
7	5.000	5.000	Similar	0.000
8	5.000	6.000	Dissimilar	16.667
9	5.000	6.500	Dissimilar	23.077
10	5.000	5.000	Similar	0.000
11	5.000	6.000	Dissimilar	16.667
12	5.000	5.000	Similar	0.000
13	8.000	5.000	Dissimilar	60.000
14	5.000	5.000	Similar	0.000
15	5.000	5.000	Similar	0.000
16	5.000	6.000	Dissimilar	16.667
17	7.500	5.000	Dissimilar	50.000
18	5.000	5.000	Similar	0.000
19	5.000	5.000	Similar	0.000
20	8.000	6.000	Dissimilar	33.333
21	7.500	5.000	Dissimilar	50.000
22	8.000	6.500	Dissimilar	23.077
23	5.000	7.000	Dissimilar	28.571
24	5.000	5.000	Similar	0.000
25	5.000	6.000	Dissimilar	16.667
26	5.000	5.000	Similar	0.000
27	7.500	5.000	Dissimilar	50.000
28	5.000	5.000	Similar	0.000
29	5.000	6.000	Dissimilar	16.667
30	5.000	5.000	Similar	0.000
Mean Difference				18.177
Percentage Accuracy				81.822%

Table 11 compares the pH level results between PeeCheck 2.0 and standard urinalysis across 30 samples. The pH values range from highly acidic (pH 5) to alkaline (pH 8). The mean difference between PeeCheck 2.0 and standard urinalysis is minimal, calculated at just 0.460 percent, with seven samples showing perfect agreement (0.000 percent difference). However, the overall percentage accuracy of 81.822 percent indicates that PeeCheck 2.0 measures pH levels with approximately 81.822 percent accuracy compared to the standard method. This variability suggests some deviation between the two methods across the samples, emphasizing the need for further calibration or adjustments to enhance accuracy in pH level measurements.

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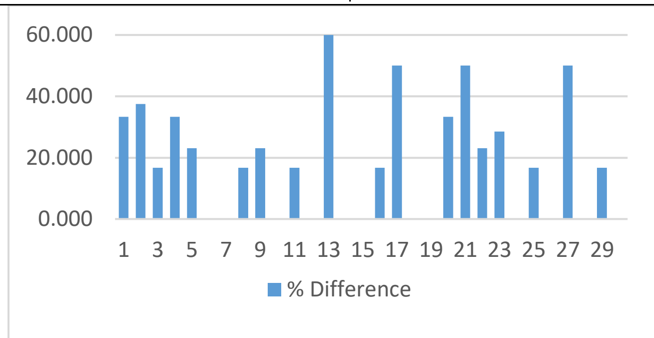

Fig. 27 Comparison of Urine pH Level Percentage Difference

In comparing standard urinalysis and PeeCheck for pH level, most of the results from PeeCheck 2.0 testing showed a percentage difference greater than zero. Out of 30 samples, only 12 demonstrated an exact zero percent difference in specific gravity.

Overall Accuracy

$$\% \, Device \, Overall \, Accuracy = \frac{\Sigma \, \% \, Accuracy \, Percentage}{No. \, of \, parameters}$$

$$\% \, Device \, Overall \, Accuracy = \frac{924.695}{10} = 92.470\%$$

The overall accuracy of PeeCheck 2.0 was computed by aggregating the accuracy percentages of all tested parameters and dividing them by the total number of parameters. This calculation demonstrates that PeeCheck 2.0 exhibits strong overall reliability, achieving an accuracy rate of 92.470 percent across its comprehensive range of tested parameters.

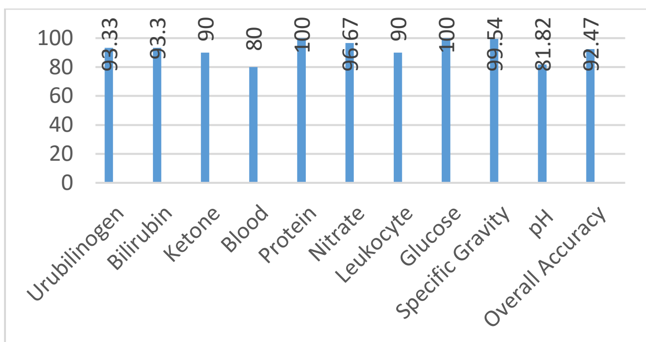

Fig. 28 Accuracy of PeeCheck 2.0

Figure 28 presents the accuracy performance of PeeCheck 2.0 across 10 parameters. Notably, glucose and protein measurements achieve perfect accuracy at 100 percent. Specific gravity follows closely with 99.540 percent accuracy, while nitrate detection is highly accurate at 96.667percent. Bilirubin and urobilinogen both demonstrate accuracy rates of 93.333 percent. Ketone and leukocyte measurements each achieve 90 percent accuracy. However, blood and pH level measurements exhibit lower accuracies at 80 percent and 81.822 percent, respectively. Overall, PeeCheck 2.0 maintains a robust accuracy of 92.470 percent across all tested parameters, indicating its efficacy in urine analysis for various health indicators.

Speed of Analyze

Table 12: Measurement of Speed in Analyzing 14 Parameters

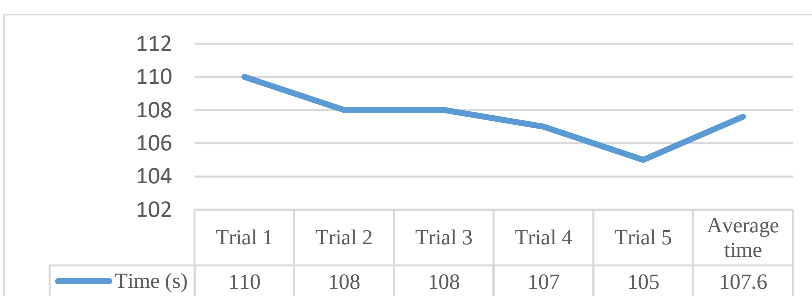

Table 12 presents the speed of PeeCheck in analyzing 14-parameter strips. The measurement begins when the URS 14 is selected and ends when the results are displayed. Based on five trials, the average analysis time was 107.6 s.

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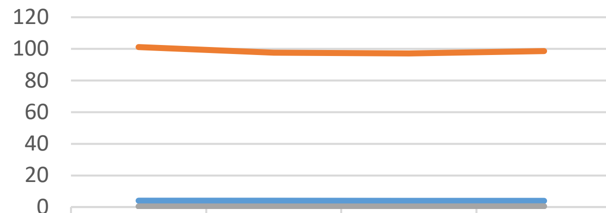
Determination of Electrical Characteristics

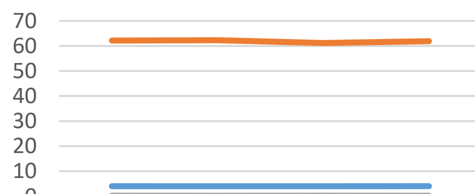
Table 13: Measurement of Electrical Characteristics in Standby Mode (Before Stepper Motor Usage)



	Trial 1	Trial 2	Trial 3	Average
Voltage (V)	4.041	4.011	4.019	4.024
Current (mA)	101.15	97.67	97.11	98.61
Power (W)	0.408	0.391	0.391	0.397

Enabling Wi-Fi on the device causes a minor increase in voltage from 4.021V to 4.024V, indicating a slight impact on electrical parameters. However, the more notable effect is observed in the current draw, which rises to 98.610 mA when Wi-Fi is enabled. This leads to a significant escalation in power consumption, increasing from 0.249W to 0.397W compared to operation without Wi-Fi. The continuous energy consumption by the Wi-Fi module to sustain network connectivity, even in standby mode, contributes significantly to this heightened power usage. Effective management of Wi-Fi usage is therefore essential for optimizing battery life and enhancing overall power efficiency in electronic devices.

Table 14: Measurement of Electrical Characteristics in Standby Mode (Before Stepper Motor Usage)



	Trial 1	Trial 2	Trial 3	Average
Voltage (V)	4.032	4.015	4.015	4.021
Current (mA)	62.19	62.29	61.17	61.883
Power (W)	0.251	0.249	0.246	0.249

Devices operate efficiently without Wi-Fi, maintaining a stable voltage of 4.021V. The current draw is significantly reduced at 61.883 mA compared to when Wi-Fi is enabled, leading to lower power consumption measured at 0.249W. This absence of continuous energy demand from the Wi-Fi module results in overall reduced power consumption, which is advantageous for extending battery life and optimizing power efficiency across both standby and operational modes.

Table 15: Measurement of Electrical Characteristics in Standby Mode (After Stepper Motor Usage)

	Trial 1	Trial 2	Trial 3	Average
Voltage (V)	3.952	3.949	3.947	3.949
Current (mA)	547.22	551.56	551.33	550.037
Power (W)	2.165	2.174	2.171	2.17

With Wi-Fi enabled, using the stepper motor results in a slight increase in power consumption during standby, with an average voltage of 3.949V, a current draw of 550.037 mA, and a power consumption of 2.170 W. This suggests that Wi-Fi adds to the power load, necessitating effective power management to minimize energy use and prolong battery life after mechanical activities.

Table 16: Measurement of Electrical Characteristics in Standby Mode (After Stepper Motor Usage)

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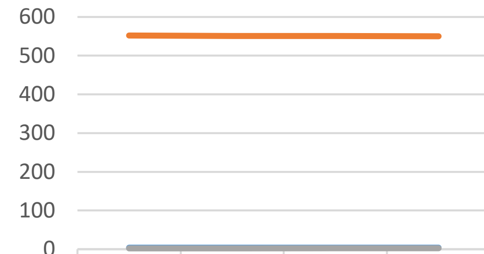
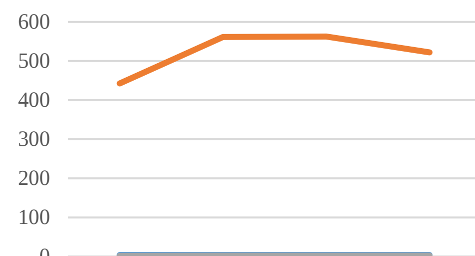


	Trial 1	Trial 2	Trial 3	Average
Voltage (V)	3.934	3.934	3.934	3.934
Current (mA)	552.08	550.54	550.68	550.1
Power (W)	2.171	2.166	2.167	2.168

Without Wi-Fi, the stepper motor operation results in an average voltage of 3.934V, with a slightly higher current draw averaging 551.100 mA, leading to an average power consumption of 2.168 W.

Despite Wi-Fi being disabled, the power consumption remains comparable to when Wi-Fi is enabled, indicating significant energy usage to maintain readiness after mechanical activity. This underscores the importance of effective power management strategies to minimize energy consumption and maximize battery life for the device.

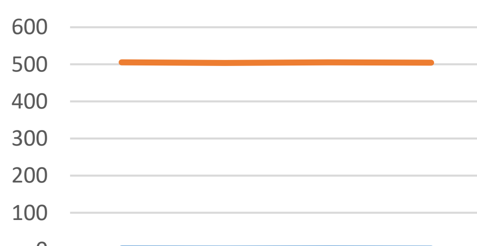
Table 17: Measurement of Electrical Parameters in Analyze Mode



	Trial 1	Trial 2	Trial 3	Average
Voltage (V)	3.983	3.983	3.983	3.983
Current (mA)	442.72	561.8	562.7	522.407
Power (W)	1.764	2.238	2.242	2.081

When Wi-Fi is enabled, the voltage remains nearly identical at around 3.98V. However, the current usage is higher at 522.407 mA compared to when Wi-Fi is disabled. This results in a higher power consumption of 2.081W with Wi-Fi, indicating an increase of about 0.079W compared to without Wi-Fi. The presence of Wi-Fi increases power consumption in both standby and active analysis modes due to the workload and the maintenance of Wi-Fi connections.

Table 18: Measurement of Electrical Parameters in Analyze Mode Without Wi-Fi



	Trial 1	Trial 2	Trial 3	Average
	Analyze Mode without Wi-Fi			
Voltage (V)	3.967	3.961	3.959	3.963
Current (mA)	505.42	503.74	505.17	504.777
Power (W)	2.009	1.997	2	2.002

With Wi-Fi disabled, the voltage remains around 3.960 V, and the current usage drops to 504.777 mA. This results in a lower power consumption of 2.002 W, highlighting a reduction in power usage by about 0.079W compared to when Wi-Fi is enabled. Managing Wi-Fi usage effectively can contribute to conserving battery life and improving power efficiency. Minimizing time spent in active analysis mode is also crucial to reduce overall power consumption.

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Charging and Discharging Cycle of PeeCheck 2.0

$$Charging\ Time = \frac{\text{Battery Capacity (mAh)}}{\text{Charging Current(mA)}} = \frac{\text{59400mAh}}{\text{3000 mA}} = 19.8\ h$$

Using a three-ampere fast charging pin, it takes approximately twenty hours to fully charge a 59,400-mAh battery. Factors like battery health, specific charging devices and charging efficiency may influence the actual charging time.

$$Run\ time = \frac{\text{Battery Capacity (mAh)}}{\text{Average Current(mA)}} = \frac{\text{59400mAh}}{\text{381.469 mA}} = 155.7 = 6.5\ days$$

A fully charged 54,900-mAh battery, discharging at an average current of 381.469 mA, is estimated to last approximately 155.7 h as a power source. Factors like battery age, temperature, and device efficiency can affect the actual runtime. Regular monitoring of actual runtime under specific usage conditions is advisable for accurate assessments and battery management.

V. Conclusion

The study evaluated the PeeCheck 2.0 prototype, a pre-diagnostic urine analysis tool, against standard laboratory urinalysis across ten urine parameters, including Protein, pH level, Glucose, Specific Gravity, Bilirubin, Urobilinogen, Ketone, Blood, Nitrite, and Leukocytes. The device demonstrated high accuracy, particularly excelling in detecting protein and glucose with perfect 100 percent accuracy, making it particularly effective for early screening of kidney function and diabetes. Additionally, it showed over 80 percent accuracy for other parameters such as specific gravity (99.540 percent), nitrites (96.667 percent), bilirubin (93.333 percent), and urobilinogen (93.333 percent), confirming its reliability for early health screening. Although pH level and blood detection showed slightly lower accuracies of 81.820 percent and 80 percent, respectively, they still reflect good reliability. PeeCheck 2.0's rapid analysis time of approximately 107.6 seconds underscores its efficiency, making it a valuable tool for timely and comprehensive diagnostic results. However, the evaluation of the device's electrical characteristics revealed significant power consumption, particularly with Wi-Fi enabled, highlighting the need for effective power management.

To further improve the development and testing of PeeCheck 2.0, a more comprehensive study is recommended, including a diverse sample set from various demographics, health conditions, and geographic locations, to ensure the device's efficacy across a broader population. Additionally, potential concerns about the device's portability and long-term durability should be rigorously addressed by testing it in various environmental conditions, such as extreme temperatures, humidity, and usage scenarios. These tests will help identify any practical limitations or areas for improvement in real-world settings.

To enhance PeeCheck 2.0's functionality, the study advises hardware upgrades, such as integrating additional sensors and implementing continuous calibration through machine learning algorithms to account for variations in urine samples over time. Ergonomic design improvements are suggested to enhance portability and user-friendliness, making it more accessible for different users, especially in remote areas where it could serve as a preliminary screening tool before seeking treatment at tertiary hospitals. By broadening the scope of testing and focusing on practical aspects of durability, the device's reliability and applicability in diverse settings can be more thoroughly demonstrated, ensuring it meets the needs of both everyday users and healthcare professionals.

Appendix

Fig. 36 URS-14 Color Chart.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIII, Issue V, May 2024

Acknowledgment

The researchers would like to express their heartfelt gratitude and appreciation to all the individuals who have contributed to the successful completion of this thesis. Their support, guidance, and encouragement have been instrumental throughout this journey.

First and foremost, the researchers extend their deepest gratitude to their esteemed thesis advisor, Kristian Carlo B. Victorio, for his unwavering support, invaluable mentorship, and insightful feedback, which have been pivotal in shaping the direction of this research.

The researchers are also immensely grateful to the research panelists: Edison E. Mojica, Daniel P. Durias, and Faustino Rural, for their thoughtful guidance, constructive criticism, and support throughout the research process.

The researchers would like to extend their sincere gratitude to the previous PeeCheck 1.0 researchers whose groundbreaking work provided the crucial framework for our research. Especially, to thank John Cedric Olaivar for his continuous availability and support, which have been essential to this project's success. The creation of PeeCheck 2.0 has greatly benefited from his advice and experience.

Additionally, the researchers express their heartfelt thanks to the third- and fourth-year participants from the College of Engineering and Architecture. Their willingness to participate and share their insights was essential to the success of this study. Their contributions are deeply appreciated.

The researchers would like to extend their profound appreciation to their families for their unwavering support, understanding, and encouragement throughout this journey. Their love and patience have been a source of strength and motivation.

Finally, the researchers gratefully acknowledge the programmers, John Louie Caluminga and Romeo Escolano, who provided crucial technical support and assistance. Their expertise and dedication were invaluable in the successful execution and implementation of our research goals and completion of this project.

References

1. Asael, (2023). Access to Healthcare in the Philippines: Addressing Disparities and Challenges. Secret Philippines.
2. Yuki, (2023). Advancements in Rural Health Care in the Philippines. The Borgen Project.
3. Balhara, N., Devi, M., A. Balda, M. Phour, and Giri, A., (2023). “Urine; a new promising biological fluid to act as a non-invasive biomarker for different human diseases,” ScienceDirect, vol. 5, pp. 40–52.
4. Sequeira-Antunes, B. and Ferreira, A., (2023). “Urinary biomarkers and point-of-care urinalysis devices for early diagnosis and management of disease: A review,” Biomedicines, vol. 11, no. 4, p. 1051.