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Research Article

# Development of a Prototype Smart Sensing Device for Detection of Counterfeit Medicines

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## ABSTRACT

Counterfeit medicines are an important public health concern because they may contain incorrect amounts of active pharmaceutical ingredients, inappropriate substances, or may lack the intended therapeutic ingredient. Conventional analytical techniques such as chromatography, spectroscopy and mass spectrometry can provide reliable identification, but many of these methods require expensive instruments, trained personnel and laboratory facilities. The present project focuses on the development of a simple, portable and low-cost sensing device for preliminary detection of counterfeit medicines. The proposed system combines a paper-based sensing platform with color-based detection using a TCS34725 color sensor interfaced with an Arduino Nano. Controlled illumination using visible and ultraviolet light is incorporated to improve observation of color responses. The color response obtained from the test sample can be compared with that of an authentic reference sample. The system also incorporates optical character recognition (OCR) to extract printed pharmaceutical information from medicine packaging. The proposed prototype is intended as a preliminary screening tool that can provide a rapid indication of possible differences between genuine and suspected samples.

## INTRODUCTION

The definition of counterfeit drugs was established by the World Health Organization in 1992 as one that is deliberately and fraudulently mislabeled with respect to its identity and/or source. It can apply to both branded and generic products, may include products with the correct ingredients or with the wrong ingredients, without active ingredients, with insufficient active ingredients, or with fake packaging.

In 2011, the WHO proposed a new definition of substance, spurious, falsely labelled, falsified, and

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counterfeit" (SSFFC), considering public health impact. As per WHO 2019a, a counterfeit medicine is deliberately and fraudulently mislabeled concerning its identity, composition or source.

**Counterfeit products as per WHO, 2019b**

- Products made with inappropriate or inaccurate ingredients
- Products having insufficient or non-existent active components
- Products in counterfeit wrapping
- Drugs whose active components differ from those listed on the packet.
- Relabeling expired medication to increase its shelf life
- Products lacking the manufacturer's name and address
- Expired products
- Medicines without an expiration date
- Products with an inaccurate amount of the declared active ingredient
- Products with a different number of contaminants.[3,6]

As per the USFDA, counterfeit medicines/falsified medicines are described as harmful to health because they are being passed off as authentic, may contain the wrong ingredients, contain too little or no active ingredient at all, or contain other harmful ingredients. As per CDSCO, Counterfeit drugs, which are categorized into three types under the Drug and Cosmetic Act, 1940.

**Spurious and Adulterated drugs:** Drug formulations that are designed to look like another drug, particularly a well-known brand, to deceive the consumer and capitalize on the success of the original product are known as "spurious" or "imitation" drug products. The product may or may not include active substances.

**Adulterated medicines:** These include an adulterant or substituted product or are tainted with impurities, making them harmful to health.

**Grossly substandard drugs:** drugs manufactured by authorized producers that have been shown to have significant defects that lower the medication's egregious carelessness or manufacturing non-compliance with GMPs. The defects may broadly be as under:

- Active ingredient quantities that are less than 70% for products that are thermolabile and less than 5% of the allowed limits for products that are thermostable.
- Tablet/capsules failing in disintegration tests wherever prescribed.
- Liquid preparations that exhibit fungal growth.
- Parenteral preparation that exhibits excessive toxicity, pyrogen/endotoxin test failure, or sterility test.
- Vaccines that exhibit deficiencies in moisture content, toxicity, sterility, or efficacy.
- Any adulterant that makes the product harmful to health is present.

Executed in-process controls, or inappropriate storage or transportation circumstances for medicines. Examples of some such defects are as under:

- Broken or chipped tablets
- Spots, discoloration, or uneven coating are present
- The formulation's color changes
- Net content varies little
- Weight variation failures in formulations
- Formulations that don't reach the color test.
- Individual instances of foreign materials being present
- Labelling errors include Redline, Schedule H, Rx, NRx, XRx, and nomenclature errors, color, caution, etc.

## II. MATERIALS AND COMPONENTS

### Electronic Components

- Arduino Nano
- TCS34725 colour sensor
- White LED
- UV LED
- 220 Ω resistors
- Breadboard
- Jumper wires
- 5 V power supply/USB connection
- Black cardboard box

### Sensing Materials

- Whatman filter paper, Grade 1
- Sodium nitroprusside
- Sodium hydroxide
- Bromocresol green
- Selected pharmaceutical samples

For colour reaction, Azithromycin and Calcium lactate were selected. For text detection, Calcium lactate, Paracetamol and Omeprazole were selected.

### Software

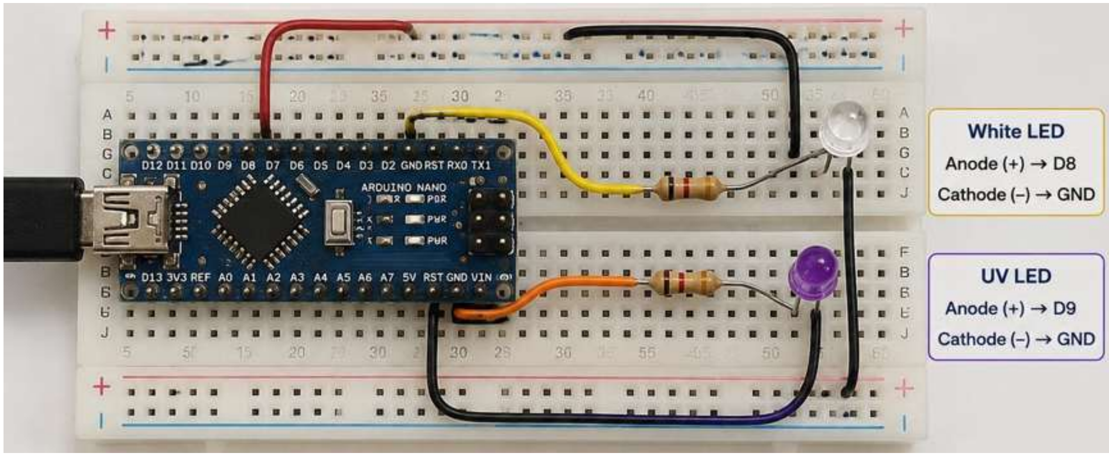
- Arduino IDE for Arduino Nano programming, TCS34725 testing and LED control
- Python for image processing, OCR, data processing and verification
- OpenCV for preprocessing, segmentation and color analysis
- Tesseract OCR for extraction of printed pharmaceutical information
- Microsoft Excel for reference database creation and comparison

## III. METHOD

### Arduino Nano-Based Color Sensor and LED Setup

The Arduino Nano was placed on the breadboard and connected to a computer using a USB cable. The Arduino Nano was used to control the white LED and UV LED. The LEDs were programmed to operate alternately, with each LED switched on for 3 seconds followed by an off period. Controlled illumination was used to provide consistent lighting during the sensing experiment.

| Component | Connection |
|---|---|
| White LED, short end (-) | 220 Ω → GND |
| White LED, long end (+) | 220 Ω → D9 |
| UV LED, short end (-) | 220 Ω → GND |
| UV LED, long end (+) | 220 Ω → D8 |




**Arduino Nano and LED setup.**

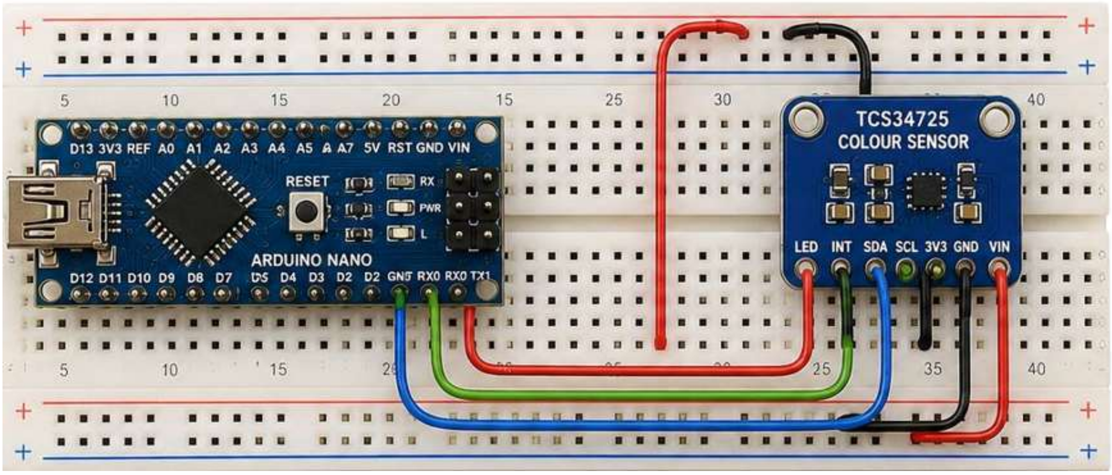
**Arduino code for UV and white Led control**

```
// 1. UV LED ON - 3 seconds

digitalWrite(UV_LED, HIGH);

digitalWrite(WHITE_LED, LOW);

delay(3000);

// 2. UV LED OFF - 3 seconds

digitalWrite(UV_LED, LOW);

digitalWrite(WHITE_LED, LOW);

delay(3000);

// 3. WHITE LED ON - 3 seconds

digitalWrite(UV_LED, LOW);

digitalWrite(WHITE_LED, HIGH);

delay(3000);

// 4. WHITE LED OFF - 3 seconds

digitalWrite(UV_LED, LOW);

digitalWrite(WHITE_LED, LOW);

delay(3000);
```

**Arduino Nano–Color Sensor Connections**

The TCS34725 color sensor module was positioned near the paper-based sensing zone at a fixed distance and angle. The white LED provided consistent illumination for color measurement, while the UV LED was used when UV illumination was required. The Arduino Nano was programmed to obtain red (R), green (G), blue (B), and clear (C) values from the TCS34725 sensor. Sensor operation was checked using blank paper before applying the medicine sample. After color development, the paper sensor was placed under the TCS34725 sensor, and the RGB values were recorded

| TCS34725 Pin | Arduino Nano |
|---|---|
| SDA | A4 |
| SCL | A5 |
| GND | GND |
| VIN | 5 V |



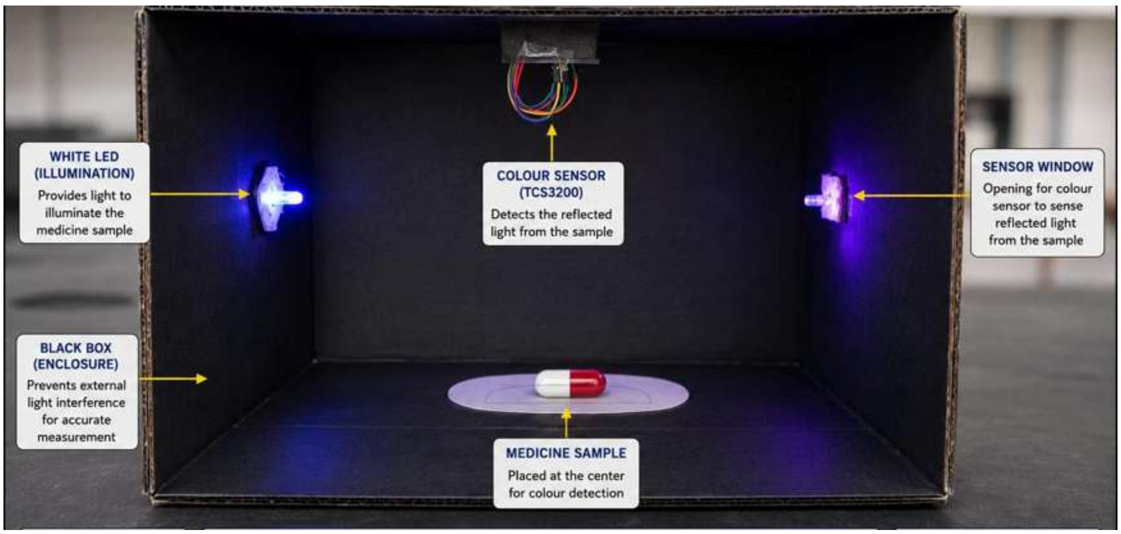

**Arduino Nano–TCS34725 color sensor setup.**

**Arduino code for TCS34725 color sensor interfacing**

```
#include <Wire.h>

#include "Adafruit_TCS34725.h"

Adafruit_TCS34725 tcs = Adafruit_TCS34725(

  TCS34725_INTEGRATIONTIME_50MS,

  TCS34725_GAIN_4X

);

void setup() {

  Serial.begin(9600);

  Wire.begin();

  if (tcs.begin()) {

    Serial.println("TCS34725 Colour Sensor Detected");

  }

 else {

   Serial.println("Colour Sensor Not Detected");

    while (1);

  }

}

void loop() {

  uint16_t r, g, b, c;

  tcs.getRawData(&r, &g, &b, &c);

  Serial.print("Red: ");

  Serial.print(r);

  Serial.print("  Green: ");

  Serial.print(g);

  Serial.print("  Blue: ");

  Serial.print(b);

  Serial.print("  Clear: ");

  Serial.println(c);

  delay(1000);

}
```

**Arrangement of Components Inside the Black Cardboard Box**

| Component | Position | Purpose |
|---|---|---|
| TCS34725 colour sensor | Top/center, facing downward | Detects RGB color |
| Paper-based sensor | Directly below TCS34725 | Holds the color reaction |
| White LED | Beside the sensor, facing paper | Provides controlled illumination |
| UV LED | Beside the sensor, facing paper | Provides controlled illumination |
| Arduino Nano | Above the cardboard box | Controls sensor and LEDs |
| Breadboard | Under Arduino Nano | Holds circuit connections |
| USB opening | Side wall | Connects Nano to laptop |
| Black cardboard | Surrounds sensing area | Reduces interference from ambient light |




**Arrangement of components inside the black cardboard box.**

## Preparation of Whatman Paper

- Grade 1 Whatman filter paper was selected for the preliminary paper-based colorimetric experiments.
- Paper pieces were cut into uniform dimensions of approximately 2 cm × 3 cm.
- A circular sensing zone of approximately 5–8 mm diameter was marked at the center of each paper piece.
- A hydrophobic boundary was drawn around the sensing zone using a wax pen/crayon to help restrict the liquid to the reaction area.
- Where wax printing/impregnation was used, the patterned paper was gently heated so that the wax penetrated the paper.
- The paper was allowed to cool and was handled with clean forces to minimize contamination.

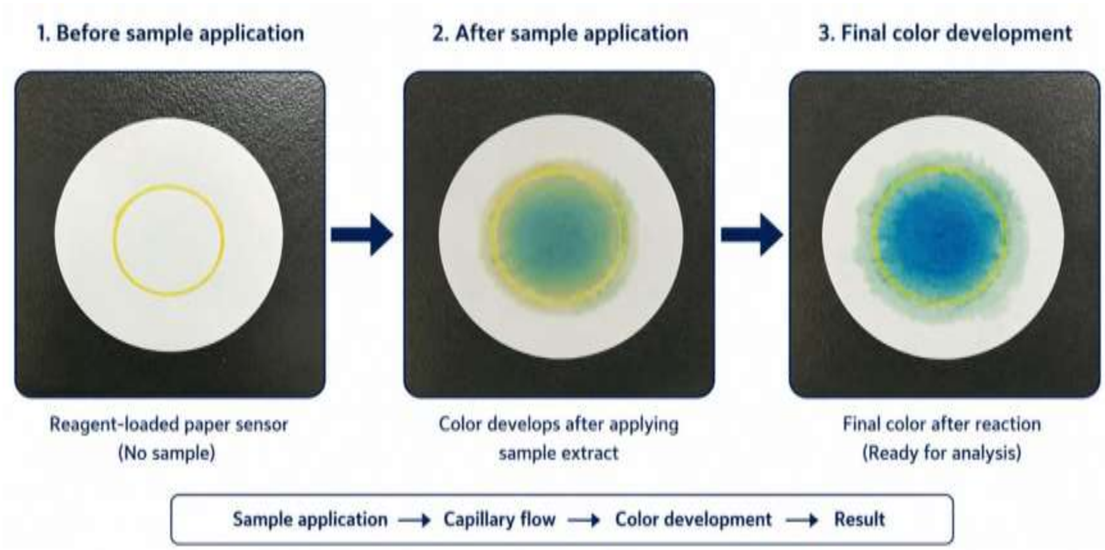
## Preparation and Application of Reagents

For Calcium lactate detection, sodium nitroprusside and sodium hydroxide (NaOH) were employed as the colour-producing reagents. For Azithromycin detection, bromocresol green was used as the colorimetric reagent. The reagents were applied to separate Whatman paper sensing zones and allowed to dry before application of the drug extract.

## Application of Sample to Paper

- Tablets were crushed using a mortar and pestle.

- The powdered tablet was dissolved in a suitable solvent.
- The liquid sample was allowed to spread through the paper by capillary action.
- The sensing zone was observed for development of a characteristic colour.
- The colour was allowed to develop for a predetermined reaction time under controlled lighting conditions.
- The developed paper sensor was positioned below the TCS34725 colour sensor.
- RGB values were recorded using the Arduino Nano.

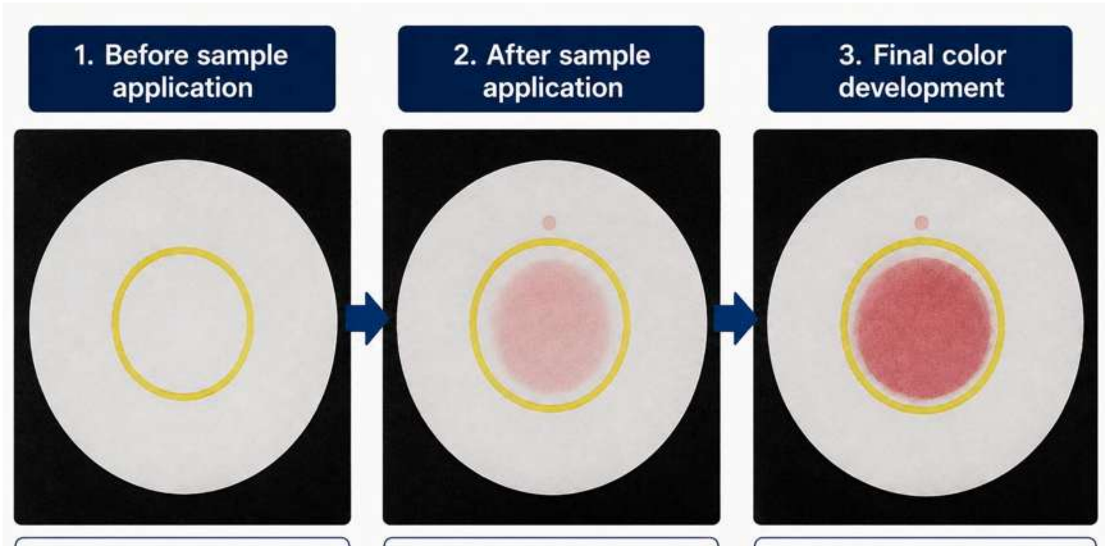



**Representative paper-based sensing sequence.**

### Colorimetric Detection of Azithromycin

After color development, the paper was placed inside the controlled illumination enclosure. The white LED was switched on to provide uniform visible illumination. The TCS34725 color sensor detected the developed color and recorded the red (R), green (G), blue (B), and clear (C) intensity values. The Arduino Nano received the sensor readings through I²C communication and displayed the values through the Serial Monitor. The obtained color values were compared with blank/standard samples to determine the color response.

| Parameter | Observed value |
|---|---|
| Sensor status | TCS34725 sensor found |
| R | 102 |
| G | 46 |
| B | 38 |
| C | 148 |
| Detected colour | Blue |




**Representative color development for the paper-based sensing reaction.**

### Colorimetric Detection of Calcium Lactate

The Calcium lactate sample was subjected to the paper-based color reaction using sodium nitroprusside and sodium hydroxide. After color development, the sensing paper was measured using the TCS34725 sensor under controlled illumination.

| Parameter | Observed value |
| --- | --- |
| Sensor status | TCS34725 sensor found |
| R | 25 |
| G | 11 |
| B | 9 |
| C | 38 |
| Detected color | Red |

### Text Detection and Identification Using OCR

A reference database was created using authenticated medicine samples. The database contained medicine identification details and package images. The reference information was organized for comparison with unknown samples. During analysis, text and color characteristics of the test sample were compared with corresponding reference data to support preliminary identification and screening of suspected counterfeit medicines.

| ID | Medicine | Strength | Manufacturer | Dosage form | Key OCR text | MFG | EXP | Batch No. | Color | Status |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | Paracetamol | 500 mg | Eurekem Laboratories | Tablet | Paracetamol Tablets IP 500 mg | FEB-26 | JAN-28 | PT4266079 | White | Genuine |
| 2 | Calcium lactate | 300 mg | Eurekem Laboratories | Tablet | Calcium Lactate Tablets IP 300 mg | NOV-25 | OCT-27 | CL25160 | White | Genuine |
| 3 | Omeprazole | 20 mg | Boheringer Ingelheim | Capsule | Omeprazole Capsules | MAR-26 | JAN-28 | B250144 | Pink + White | Genuine |

### OCR Workflow

Optical Character Recognition (OCR) was incorporated into the prototype to assist in the identification of medicines from printed labels or packaging. Images of medicine packages were captured using a camera or smartphone under controlled lighting conditions. The images were resized, denoised, adjusted for brightness and contrast, converted to grayscale, thresholder, and cropped to the region containing text. The pre-processed image was then supplied to the OCR system, which converted the detected characters into machine-readable text. The extracted text was compared with the information stored in the reference database.

**OCR-Based Authentication of Paracetamol**

**1. Image Acquisition**

The images of tablets/medicine packages were captured using a camera or smartphone under controlled lighting conditions.

**2. Image Pre-processing**

The quality of the captured images are improved before OCR analysis by the following:

- Resize the image
- Remove noise
- Adjust brightness and contrast
- Convert RGB image to grayscale
- Apply thresholding
- Crop the region containing the text

**3. Text Detection Using OCR**

The pre-processed image is given to the OCR (Optical Character Recognition) system. OCR detects the characters present on the tablet/package and converts the image-based text into machine-readable text.

**4. Text Extraction**

The detected text was extracted and compared with the text stored in the database.

OCR- based text detection and authentication of Paracetamol

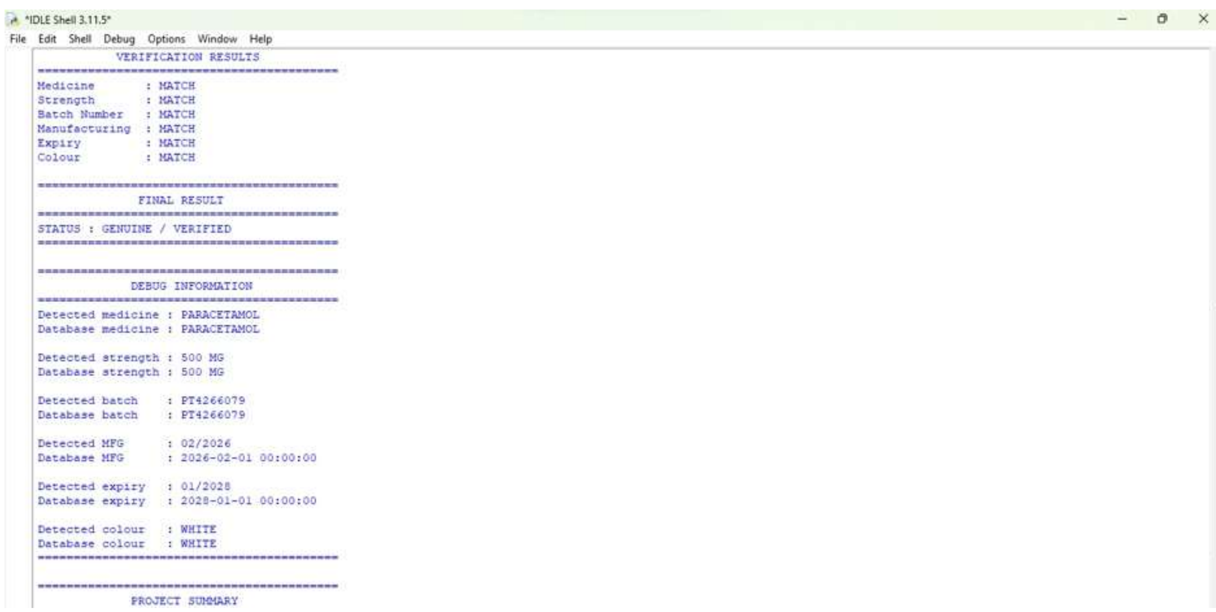
- The captured image of the paracetamol sample was processed using an Optical Character Recognition (OCR) technique to identify and extract the text printed on the medicine packaging.
- The extracted text was compared with the authentic paracetamol information stored in the previously created database. The system verified the drug name, dosage strength, and other available identifying information.
- If the detected text matched the corresponding database entry, the sample was classified as "Matched". Any mismatch or unidentified text was considered "Suspected" and could indicate a potentially counterfeit or incorrectly labelled product.


**Representative Paracetamol package used for OCR-based identification.**

**Python code for Paracetamol text recognition**

```
import cv2

import pytesseract

# Tesseract OCR path

pytesseract.pytesseract.tesseract_cmd = r"C:\Program Files\Tesseract-OCR\tesseract.exe"

# Load paracetamol image

image = cv2.imread("paracetamol.jpg")

if image is None:

    print("Error: Image not found.")

    exit()

# Resize image

image = cv2.resize(image, None, fx=2, fy=2)

# Convert to grayscale

gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)

# Remove noise

gray = cv2.GaussianBlur(gray, (3, 3), 0)

# Thresholding

_, thresh = cv2.threshold(

    gray, 0, 255,

    cv2.THRESH_BINARY + cv2.THRESH_OTSU

)

# OCR text extraction

text = pytesseract.image_to_string(thresh, config="--psm 6")

# Display detected text

print("Detected Text:")

print(text)

# Check for Paracetamol

if "paracetamol" in text.lower():

    print("Result: PARACETAMOL DETECTED")

else:

    print("Result: PARACETAMOL NOT DETECTED")

# Display processed image

cv2.imshow("Processed Image", thresh)

cv2.waitKey(0)

cv2.destroyAllWindows()
```

**Result**


**OCR- based text detection and authentication of Paracetamol**

**OCR-Based Authentication of Calcium Lactate**

The captured Calcium lactate package image was processed using the same OCR workflow. The extracted text was compared with the corresponding authenticated database entry to support preliminary identification.


**Representative Calcium lactate package used for reference comparison.**

**Python code for Calcium lactate text recognition**

```
import cv2

import pytesseract

# Set Tesseract OCR path

pytesseract.pytesseract.tesseract_cmd = (

    r"C:\Program Files\Tesseract-OCR\tesseract.exe"

)

# Load calcium lactate image

image = cv2.imread("calcium_lactate.jpg")

if image is None:

    print("Error: Image not found.")

    exit()

# Resize image for better OCR accuracy

image = cv2.resize(image, None, fx=2, fy=2)

# Convert image to grayscale

gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)

# Remove noise

gray = cv2.GaussianBlur(gray, (3, 3), 0)

# Apply thresholding

_, thresh = cv2.threshold(

    gray, 0, 255,

  cv2.THRESH_BINARY+cv2.THRESH_OTSU

)

# Perform OCR

text = pytesseract.image_to_string(

    thresh,

    config="--psm 6"

)

# Display detected text

print("\nDetected Text:")

print(text)

# Check for Calcium Lactate

if "calcium lactate" in text.lower():

    print("Result: CALCIUM LACTATE DETECTED")

else:

    print("Result: CALCIUM LACTATE NOT DETECTED")
```

```
# Display processed image

cv2.imshow("Processed Image", thresh)

cv2.waitKey(0)

cv2.destroyAllWindows()
```

**Result**

```
*IDLE Shell 3.11.5*
File  Edit  Shell  Debug  Options  Window  Help
Detected image saved:
C:\Users\acer\OneDrive - ELCOT\Desktop\counterfeitMedicineProject\calcium_lactate_detected.jpg

Tablet crop saved:
C:\Users\acer\OneDrive - ELCOT\Desktop\counterfeitMedicineProject\calcium_lactate_tablet_only.jpg

==========================================
       LOADING EXCEL DATABASE
==========================================

==========================================
         EXCEL DATABASE INFORMATION
==========================================
Medicine        : CALCIUM LACTATE
Strength        : 300 MG
Manufacturer    : EUREKEM  LABORATORIES
Dosage Form     : TABLET
MFG             : 2025-11-01 00:00:00
Expiry          : 2027-10-01 00:00:00
Batch Number    : CL25160
Colour          : WHITE

==========================================
          VERIFICATION RESULTS
==========================================
Medicine        : MATCH
Strength        : MATCH
Batch Number    : MATCH
Manufacturing   : MATCH
Expiry          : MATCH
Colour          : MATCH

==========================================
            FINAL RESULT
==========================================

STATUS : GENUINE / VERIFIED
==========================================

Press any key in an image window to close.
```

**OCR- based text detection and authentication of Calcium Lactate**

### OCR-Based Authentication of Omeprazole

The captured Omeprazole package image was processed using OCR. The extracted medicine name and available package information were compared with the corresponding reference information in the database.


**Representative Omeprazole package used for OCR-based identification.**

### Python code for Omeprazole text recognition

```
import cv2

import pytesseract

# Set Tesseract OCR path

pytesseract.pytesseract.tesseract_cmd = (
```

```
    r"C:\Program Files\Tesseract-OCR\tesseract.exe"
)

# Load Omeprazole image
image = cv2.imread("omeprazole.jpg")
if image is None:
    print("Error: Image not found.")
    exit()

# Resize image
image = cv2.resize(image, None, fx=2, fy=2)

# Convert to grayscale
gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)

# Remove noise
gray = cv2.GaussianBlur(gray, (3, 3), 0)

# Apply thresholding
_, thresh = cv2.threshold(
    gray, 0, 255,
    cv2.THRESH_BINARY + cv2.THRESH_OTSU
)

# Perform OCR
text = pytesseract.image_to_string(
    thresh,
    config="--psm 6"
)

# Display detected text
print("\nDetected Text:")
print(text)

# Check for Omeprazole
if "omeprazole" in text.lower():
    print("Result: OMEPRAZOLE DETECTED")
else:
    print("Result: OMEPRAZOLE NOT DETECTED")

# Display processed image
cv2.imshow("Processed Image", thresh)
cv2.waitKey(0)
```

**Result**

```
==================================================
              DATABASE INFORMATION
==================================================
Medicine        : OMEPRAZOLE
Strength        : 20 MG
Manufacturer    : BOEHRINGER INGELHEIM
MFG             : 2026-03-01 00:00:00
Expiry          : 2028-01-01 00:00:00
Batch Number    : B250144
Colour          : PINK + WHITE

==================================================
              VERIFICATION RESULTS
==================================================
Medicine        : MATCH
Strength        : MATCH
Batch Number    : MATCH
Manufacturing   : MATCH
Expiry          : MATCH
Colour          : MATCH

==================================================
                  FINAL RESULT
==================================================
STATUS : GENUINE / VERIFIED
==================================================

==================================================
               DEBUG INFORMATION
==================================================
Detected expiry : 01/2028
Database expiry : 01/2028
Detected MFG    : 03/2026
Database MFG    : 03/2026
Detected batch  : B250144
Database batch  : B250144
Detected colour : PINK+WHITE
Database colour : PINK+WHITE

Press any key on the image window to exit.
```

**OCR- based text detection and authentication of Omeprazole**

## IV. RESULTS AND DISCUSSION

The availability of counterfeit medicines in the pharmaceutical market poses a significant threat to public health. Counterfeit products may have incorrect drug identity, inadequate active pharmaceutical ingredients, improper strength, or misleading packaging information. Conventional authentication techniques generally depend on sophisticated analytical instruments and laboratory-based procedures, which may be expensive, time-consuming, and unsuitable for rapid field-level screening.

The prototype developed in this project combines a paper-based chemical response with electronic colour measurement. For the tested color reactions, the TCS34725 sensor produced distinct RGB/C readings: the Azithromycin test produced R = 102, G = 46, B = 38 and C = 148, with the detected color recorded as blue, whereas the Calcium lactate test produced R = 25, G = 11, B = 9 and C = 38, with the detected color recorded as red. These observations demonstrate that the prototype can capture measurable color responses from the paper-based sensing zone.

The OCR component provided a second screening parameter by extracting printed pharmaceutical information and comparing it with a reference database. The combination of chemical color response and package-text information can therefore provide two independent parameters for preliminary screening. The present findings support the feasibility of the prototype as a rapid, low-cost preliminary screening system; however, the reported results are preliminary and should not be interpreted as definitive pharmaceutical authentication without confirmatory analytical testing.

## V. CONCLUSION

This project presents the development of a portable, low-cost prototype smart sensing device for preliminary screening of suspected counterfeit medicines. The system combines paper-based colorimetric sensing, a TCS34725 RGB color sensor, controlled white/UV illumination, Arduino Nano interfacing, and OCR-based text recognition. The color response and extracted package information can be compared with authenticated reference data to generate a preliminary matched or suspected result. The prototype may reduce dependence on sophisticated laboratory instruments during initial screening and can be further developed into a smartphone-assisted medicine screening device.

## VI. LIMITATIONS AND FUTURE SCOPE

The present work represents a preliminary prototype. The manuscript reports color-response observations for selected medicine/reagent combinations and OCR-based reference comparisons, but it does not provide a sufficiently large validation dataset, sensitivity/specificity analysis, inter-day reproducibility study, or comparison with a validated reference analytical method. These aspects should be addressed in future studies.

Future development may include testing a larger number of authentic and suspected samples, establishing quantitative color thresholds, evaluating repeatability under different lighting and environmental conditions, expanding the reference database, improving OCR robustness, and integrating the sensing unit with a smartphone-based interface.

## VII. ACKNOWLEDGEMENTS

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