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Determination of azo dyes using Smartphone Digital Image

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ABSTRACT

The development of an economical and simple colorimetric system based on a smartphone camera and image processing was included in this study. This method was applied to determine three azo dyes namely: Methyl Blue (M.B), Methyl Red (M.R) and Methyl Orange (M.O) using the smartphone's camera as a detector. The results of the radar diagrams were giving a good agreement with the results of the calibration curves which were built using data of RGB for each dye. For establishing the accuracy and precision of this method, a classical method (spectrophotometric) was used for validation. This advancement in smartphone-based detection and identification systems will revolutionize environmental monitoring, ensuring rapid and effective diagnosis of contaminants for individuals and communities. Streamlining the Digital image colorimetry DIC process on smartphones is essential to public health and safety while promoting more conscious and sustainable practices worldwide.

KEYWORDS: Colorimetric analysis, Dyes, Digital image, RGB, Smartphone's camera, Radar diagrams.

الخلاصة

تتضمن هذه الدراسة تطوير نظام قياس لوني اقتصادي وبسيط يعتمد على كاميرا الهاتف الذكي ومعالجة الصور .تم تطبيق هذه الطريقة لتحديد ثلاث أصباغ ايزو وهي: المثيل الأزرق والمثيل الأحمر و المثيل البرتقالي باستخدام كاميرا الهاتف الذكي ككاشف صوري. و أعطت نتائج مخططات الرادار توافقًا جيدًا مع نتائج منحنيات المعايرة التي تم إنشاؤ ها باستخدام بيانات RGB لكل صبغة .لإثبات دقة هذه الطريقة ودقتها ، تم استخدام طريقة كلاسيكية (قياس الطيف الضوئي) للتحقق من صحة هذه الطريقة. نقص ترجمة الفقرة الأخيرة من الخلاصة وبالتالي عدم تتطابق الخلاصة الإنكليزي والعربي

INTRODUCTION

In recent years, advancements in technology have brought forth instruments that offer even greater precision and efficiency in colorimetry applications. These sophisticated instruments provide higher sensitivity, allowing researchers and technicians to detect minute changes in color and concentration. As a result, colorimetry has become an essential tool in industries such as chemical analysis, environmental monitoring, and quality control. The ongoing development of more accurate and user-friendly devices will undoubtedly further expand the applicability and reliability of colorimetry as a powerful analytical method. The operating system and high quality of the camera made the smartphone a useful measuring instrument in many fields of science, such as analytical chemistry, medical science, and the food industry. Smartphones have been used in analytical chemistry for the determination of anions [1-3], pH [4], dyes [5][6], biogenic amines [7], iron [8], detection of mycotoxins[9], and chemiluminescence sensing for TLC imaging[10].These methods have been based on the low-cost technologies that can detect the concentration of the samples easily and quickly, on the other hand, most of these methods have been based on the analysis of basic color data (red- green- blue (RGB)) that obtained from the camera of smartphone [11][12]. The camera's detector senses the light intensity and pixel value, which range from 0 to 255. A color image obtained from a smartphone camera is made up of three such images from the basic color data RGB [13-19]. This study aims to develop a portable, simple, low-cost instrument for colorimetric determinations azo dyes based on a free and accurate program of image processing of smartphone's camera.

MATERIALS AND METHODS

Apparatus

A wooden box was used for this study and built as described by Ruba *et al*. [20], the box's dimensions are (17 × 21 × 17 cm). LED (DERIVER, Model: 8-18W) was placed on the top of the cover of the box to provide a homogeneous lighting during the photometric measurement (see Figure 1).

Photographed were received by using an iPhone smartphone ® with a digital camera resolution of 8 megapixels attached to the wooden box and with the free APP application Colorometer™. UV/Visible spectrophotometer (CARY 100-VARIAN Co.) was used to perform a reference method for comparison with the proposed method.

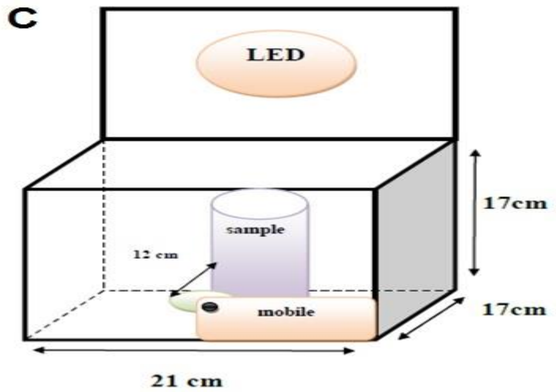

Figure 1: Colorimetry instrument of smartphone digital image; (a) a photo of smartphone colorimetry instrument with an open cover and M.R dye as a sample, (b) a photo of a smartphone colorimetry instrument with a closed cover and M.O dye as a sample and (c) Schematic diagram**.**

Materials

Three dyes were used in this study namely: Methyl Blue (M.B), Methyl Red (M.R) and Methyl Orange (M.O) were provided by the Sigma Aldrich Company.

The Procedure

Standard Solutions: Stock standard solutions of 1000mg/L were prepared by weighing accurately 0.1 gm of three dyes into three separate 100 mL volumetric flasks. A small amount of distilled water was added to each flask and diluted to the required volume with the same solvent.

Construction of calibration graph

- M.B dye: A working standard solution of 100 mg/L in distilled water was prepared for M.B dye from stock standard solution. Then, transfer (1.25- 2.5- 3.75-5- 6.25- 7.5 and 8.75 ml) of the 100 mg/L M.B dye solution to a series of 25 ml volumetric flasks and diluted with the distilled water.
- M.R dye: To a series of 25 ml volumetric flask, (2.5, 3.75, 5, 6.25, 7.5, 8.75, and 10 ml) was transferred from 1000 mg/L M.R dye stock is a standard solution. Then, the contents were diluted with distilled water.
- M.O dye: 1000 mg/L M was transferred to a series of 25 ml volumetric flasks (1, 1.25, 1.5, 1.75, 2, 2.25, and 2.5 ml). M.O dye is a stock standard solution. Then, the contents were diluted with distilled water.

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- Classical method: The standard solutions prepared above were measured by the UV/Vspectrophotometric for comparing the proposed method results with the classical method.

RESULTS AND DISCUSSION

Calibration curves:

M.B dye calibration curve:
As shown in Figure 2, the correlation coefficient R^2 was 0.997 for B values and gave the best linearity compared to the values of R^2 and G, thus the values of B were chosen for the preparation of the calibration curve.

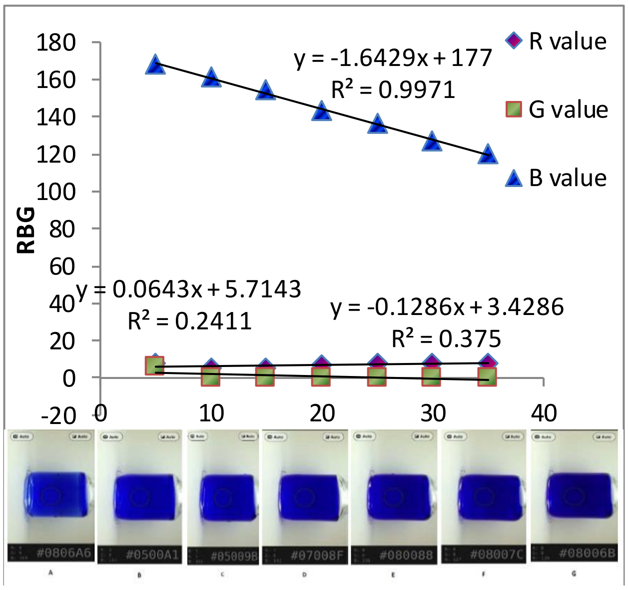


Figure 2: Calibration curve and linearity equations for determination of M.B standard solutions. The inset shows the screenshots for M.B standard solutions using Colormeter App. programs.

M.R dye calibration curve:
The best correlation coefficient of 0.997 for R^2 values compared to the values of B and G led to the choice the R^2 values for the preparation of the calibration curve for M.R dye as shown in Figure 3.

M.O dye calibration curve:
It was observed from Figure 4 that G values gave the best linearity compared to the values of B and R and the correlation coefficient R^2 was 0.995. Therefore, G values were chosen for the preparation of the calibration curve.

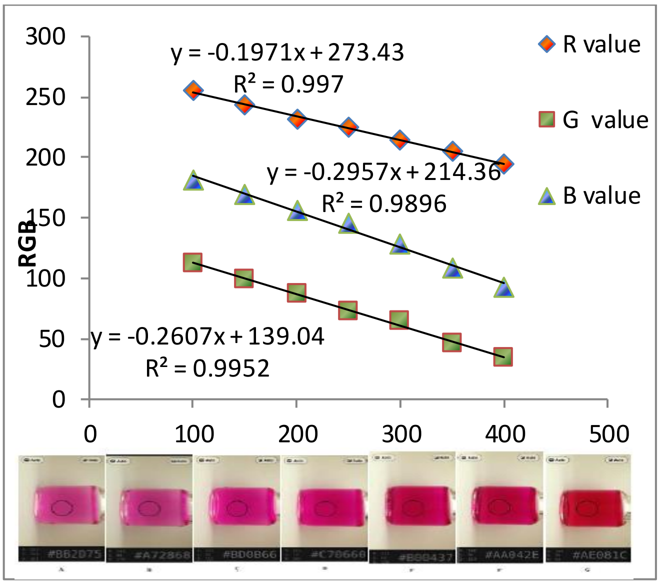


Figure 3: Calibration curve and linearity equations for determination of M.R standard solutions. The inset shows the screenshots for M.R standard solutions using Colormeter App. programs.

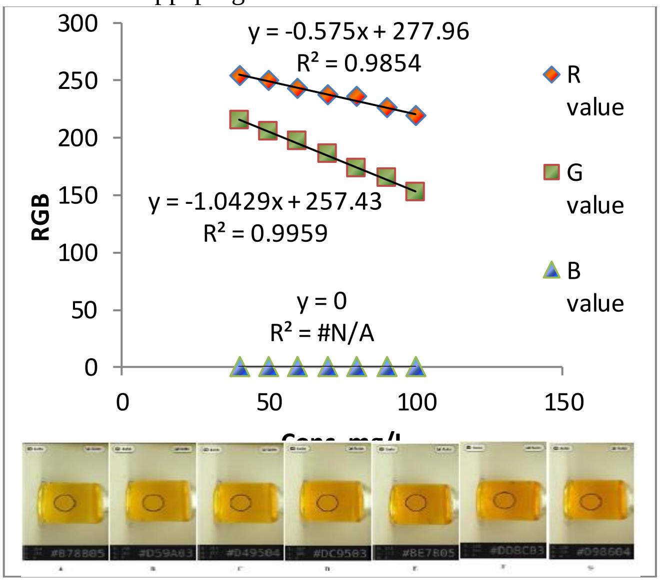
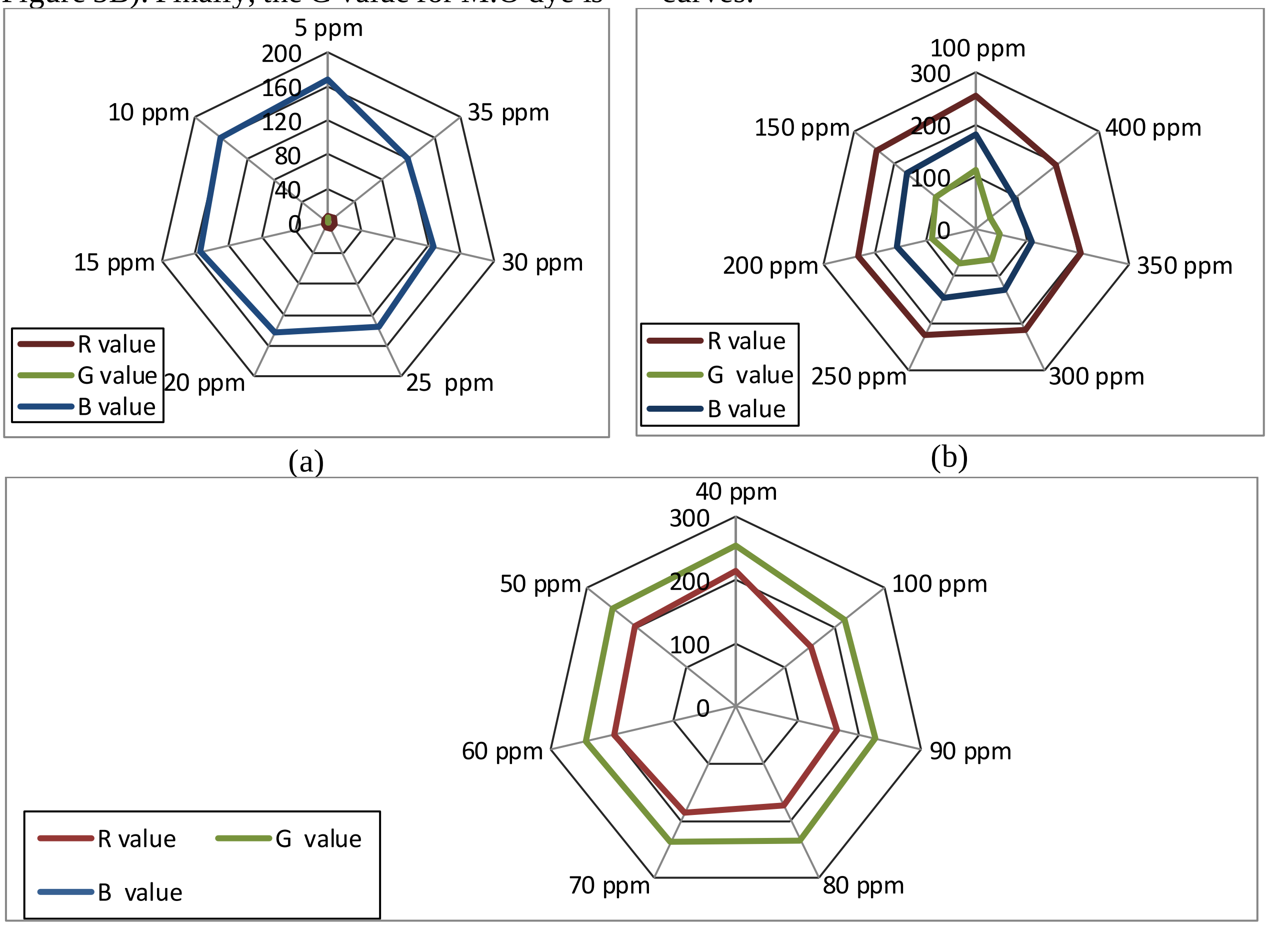


Figure 4**:** Calibration curve and linearity equations for determination of M.O standard solutions. The inset shows the screenshots for M.O standard solutions using Colorimeter App. programs.

Radar diagrams

In this study, radar diagrams were constructed using Microsoft Excel. The aim of using radar charts is to narrow the search to the best RGB values, by which achieving greater linearity and sensitivity. Figure 5 shows the resulting radar diagrams with seven concentrations axes for each dye as coordinates and three axes using R, G, B color. In Figure (5A) the B values for M.B dye shows relatively high selectivity for all seven concentrations, while there is no sense of values in the radar diagram for R and G values. On the other hand, R values for M.R dye are shown to have relatively high sensitivity for all seven concentrations rather than G and B values (Figure 5B). Finally, the G value for M.O dye is shown to have more sensitivity than the R values for all seven concentrations, while there is no sensibility for the B value in the radar diagram as shown in Figure (5C). We note that the results of radar diagrams are in a good agreement with the results obtained from linear calibration curves.



(a) (b) (c)

Figure 5: Radar diagrams profiles (a) M.B dye, (b) M.R dye, and (c) M.O dye.

Slop, intercept and LOD were calculated from the linearity equations data (in Table 1). These values indicate that the proposed method is sensitive to the determination of all three dyes.

Table 1: Analytical data for the determination of three dyes using the proposed method

Parameters	Methyl blue	Methyl red	Methyl orange
	RGB (B value)	RGB (R value)	RGB (G vale)
R^2	0.997	0.997	0.995
Linearity range(mg/L)	5-35	100-400	40-100
Equation	-1.624x + 177	-0.197x + 273.4	-1.042x + 257.4
b	-1.624	-0.197	-1.042
a	177	273.4	257.4
Standard deviation of Intercept (SD_a)	1.141	0.1310	0.2276
Limit of detection LOD (mg/L)	2.318	2.194	1.265

"b = Slope, a = intercept, SDa = Standard deviation of intercept, LOD = 3.3×SDa/S, SD_a= the standard deviation of intercepts of regression lines"

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Classical method.

The classical method of spectrophotometry was employed to compare with the proposed method. The absorbance spectrum and calibration curves of M.B, M.R and M.O showed absorption bands at wavelengths of 600, 523, and 468 nm, respectively, against distilled water, as shown in Figures 6 and 7, and Table 2.

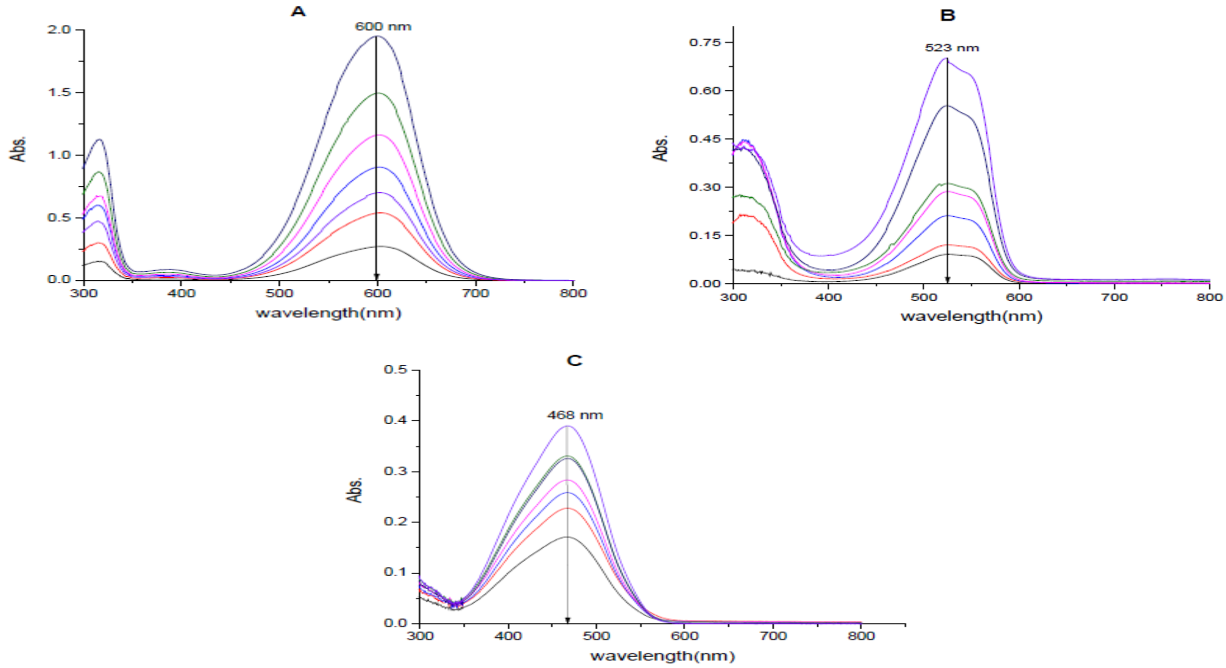

Figure 6: Absorption spectrum (A) for M.B at concentrations (5-35 mg/L) (B) for M.R at concentrations (100-400 mg/L) (C) for M.O at concentrations (40-100mg/L)

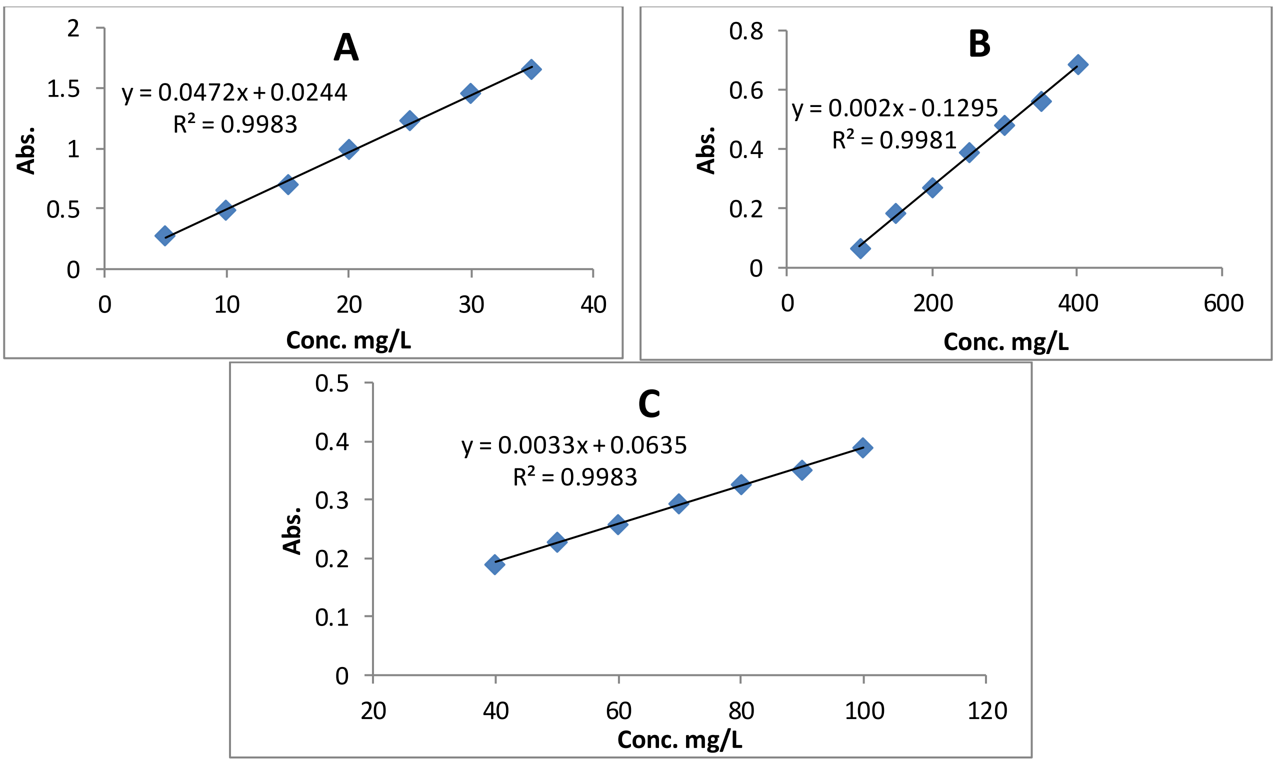

Figure 7: Calibration curves: (A) for M.B at concentrations (5-35 mg/L) (B) for M.R at concentrations (100-400 mg/L) (C) for M.O at concentrations (40-100mg/L)

Table 2: Analytical data for the determination of the three dyes using classical method

parameters	Methyl Blue	Methyl Red	Methyl Orange
	Spectrophotometric Method	Spectrophotometric Method	Spectrophotometric Method
Wavelength	600 nm	465 nm	520 nm
R^2	0.998	0.998	0.998
Linearity range(mg/L)	5-35	40-100	100-400
Equation	0.047x + 0.024	0.003x+0.063	0.002x - 0.129
b	0.047	0.003	0.002
a	0.024	0.063	- 0.129
Standard deviation of Intercept (SD_a)	0.019	0.001	0.001
Limit of detection LOD ($mg.L^{-1}$)	1.334	1.1	1.65

"b =Slope, a =intercept, SDa =Standard deviation of intercept, LOD = 3.3×SDa/S, SDa= the standard deviation of intercepts of regression lines"

Correlation between the smartphone method and the classical method

Figure 8 shows the correlation curves of two methods for three dyes. The correlation coefficients (R^2) of 0.999, 0.995, and 0.993 for the three dyes close to 1 indicated that these methods were well correlated.

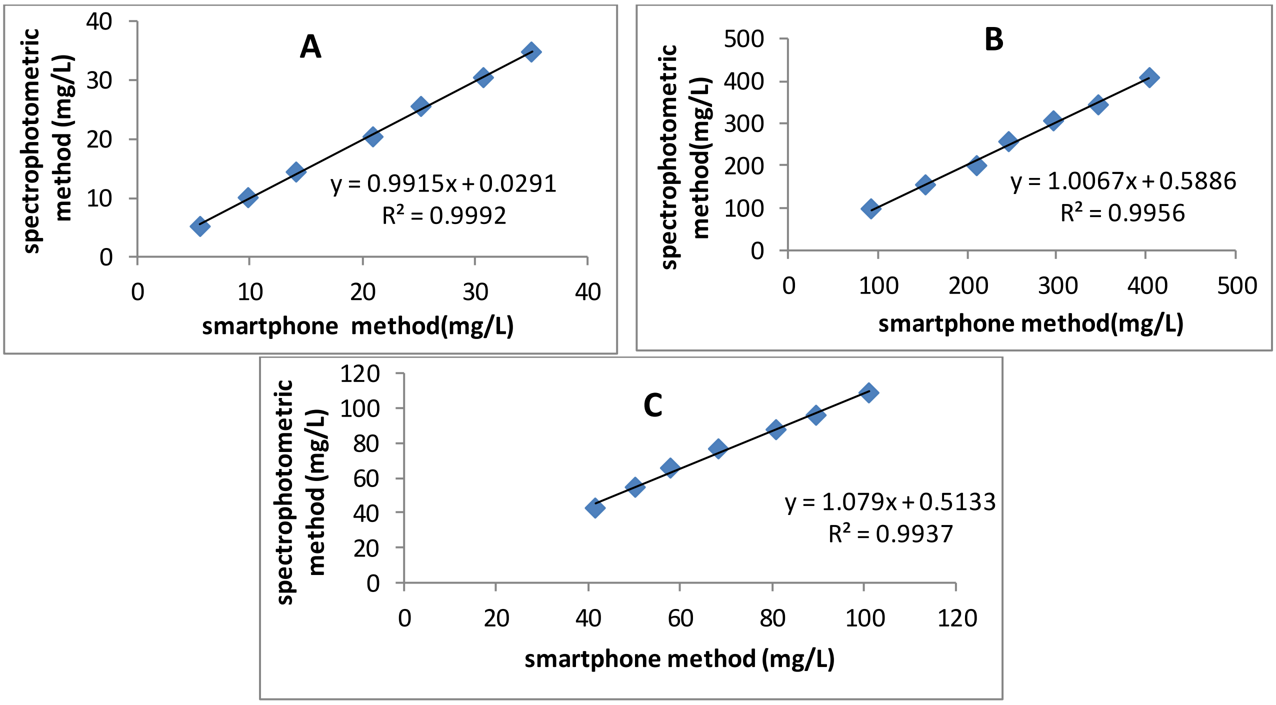

Figure 8: Correlation curves of A- M.B dye, B- M.R dye and C- M.O dye concentrations obtained with the smartphone method and the classical method.

CONCLUSIONS

In this study, a colorimetric system based on the camera of the smartphone with the Android App was used for determination of azo dyes. The proposed method was well correlated with the classical method which indicated that the results obtained from both the methods were not significantly different. As research progresses, the potential applications for smartphone-based digital image colorimetry will continue to expand, revolutionizing the way of diagnostics and analysis. Ultimately, this technology holds great promise for addressing critical issues while maintaining affordability and accessibility for a diverse range of users.

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