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Measurement of Tartrazine Levels in Children's Snacks in Banda Aceh Using an Arduino Uno-Based TCS3200 Color Sensor

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ABSTRACT

This study aims to develop and validate a low-cost method based on TCS3200 color sensor and an Arduino Uno microcontroller with integrated development environment (IDE) software for the determination of tartrazine levels in children's snacks. The measurement results will be compared with the standard UV-Vis spectrophotometer method. Samples were prepared by heating and extracted using wool yarn, from which the attached samples were collected. The sampling technique was conducted on 6 types of snacks sold in Banda Aceh City. The analysis results showed that tartrazine levels ranged from 1.34 to 4.65 ppm using the TCS3200 color sensor, which were consistent with those obtained using UV-Vis spectrophotometer (1.32-4.64 ppm). Linearity (R^2) and accuracy obtained in this study were 0.987 and 93.2 to 109% for the TCS3200 color sensor, and 0.988 and 93 to 115% for UV-Vis, respectively. The intraday and interday relative standard deviations (%RSD) did not exceed 2%. Based on the t-test calculation, it was shown that the measured tartrazine levels using the TCS3200 color sensor were not significantly different from those obtained using the UV-Vis spectrophotometer.

1. INTRODUCTION

The rapid advancements in science and technology have significantly transformed various aspects of modern life, including food consumption patterns [1]. The convenience and widespread availability of fast food and snacks have made them a popular choice, especially among children [2, 3]. To enhance visual appeal and attract consumers, synthetic dyes are commonly used in food products. These dyes are favored in the food industry due to their stable properties, such as resistance to pH changes, heat, and water solubility, along with lower production costs [4]. There are many types of synthetic dyes commonly used in food products, such as Metanil yellow, Rhodamine B [5], and Tartrazine [6, 7].

Among the synthetic dyes, tartrazine (E102), also known as FD&C Yellow 5, is one of the most commonly used food colorants [8]. It imparts a bright yellow hue to various food items, making them visually appealing to children. It is commonly used in food products such as canned fruits and vegetables, wine, soft drinks, and candied fruits [7]. However, studies have raised concerns about the potential health effects of tartrazine, particularly its impact on children's neurobehavioral health. Evidence suggests a significant association between synthetic dye consumption and negative behavioural outcomes in children [9-11], prompting calls to re-evaluate safety thresholds, including the acceptable daily intake (ADI) limits currently recommended by regulatory authorities (food and drug administration/FDA) [12]. The ADI for tartrazine established by the Joint FAO/WHO Expert Committee on Food Additive (JECFA) and the EU Scientific Committee for Food (SCF), is at 7.5 mg/kg body weight, emphasizing the importance of monitoring its usage to prevent excessive consumption [13].

Traditional methods for detecting tartrazine in food include high performance liquid chromatography (HPLC) and UV-Vis Spectrophotometry [14]. HPLC, while effective, is time-consuming, costly, and requires skilled operators [15, 16]. Conversely, UV-Vis Spectrophotometry offers high sensitivity and environmental friendliness but is hindered by its lack of portability, high operational costs, and the requirement for skilled operators [17]. The advantages of these methods are their high sensitivity, environmental friendliness and non-invasive [18]. These limitations pose significant challenges, particularly in resource-constrained areas, where affordable and portable solutions are urgently needed for real-time monitoring.

Various advanced analytical methods have been developed for the detection of tartrazine in food products, each offering unique advantages in terms of sensitivity, selectivity, and practical applicability. The magnetic stirring in syringe dispersive liquid-liquid microextraction (MSIS-DLLME) technique enables effective preconcentration of tartrazine, achieving an impressive limit of detection (LOD) of 0.03 µg/L through the use of toluene as an organic solvent, with optimization via multivariate analysis [19]. Thus, this method is costly and requires proper waste disposal management. Similarly, a high cost and complex processes method was also reported; nitrogen-doped carbon quantum dots (N-CQDs) have been utilized as fluorescent probes for tartrazine detection, providing a linear detection range of 0.8–100 µM and an LOD of 0.078 µM through fluorescence quenching mechanisms [20]. Electrochemical sensors have also demonstrated significant potential in this domain. For instance, a Bismuthiol-I-based electrochemical sensor exhibits a broad detection range of 38.5 nM to 307 µM with an LOD of 9.8 nM [21]; however, its high cost remains a challenge. Additionally, the determination of tartrazine using high-performance liquid chromatography (HPLC) and liquid chromatography (LC) was also reported. This method is costly despite its high sensitivity [22, 23]. Furthermore, integrated electrochemical platforms have been designed for on-site tartrazine detection, offering high sensitivity and selectivity [24]; however, this method is also associated with high costs.

Despite these advancements, certain challenges remain unaddressed. Most of these methods rely on sophisticated instruments or require highly trained personnel, limiting their practicality in resource-constrained settings. Additionally, while these techniques achieve remarkable detection limits, their application often involves expensive reagents or complex sample preparation steps. Furthermore, although current studies indicate that tartrazine levels in food products typically fall within safety limits, concerns regarding its potential health risks, particularly its behavioural and neurotoxic effects, persist [25].

Existing studies have not sufficiently explored the integration of modern sensor technology with Arduino-based systems. Addressing this gap, this study introduces the application of an Arduino Uno-based TCS3200 color sensor for detecting tartrazine in children's snacks. The TCS3200 sensor is capable of detecting a wide range of visible colors and, when integrated with a microcontroller, provides a compact and affordable solution for real-time color analysis. This method offers several advantages, including low cost, simplicity, real-time detection, portability, and the ability to operate without the need for highly skilled analysts. Moreover, the TCS3200 sensor has been successfully reported in the analysis of other compounds in food, such as capsaicin in sauces [26] and borax in processed foods [27], demonstrating its versatility and reliability. By leveraging this technology, the proposed method offers a novel approach to overcoming the limitations of existing techniques, contributing to more effective monitoring of synthetic dye levels in food products, especially in under-resourced settings.

2. MATERIALS AND METHOTD

2.1 Materials

The materials used in this study included children's snacks distributed in Banda Aceh, Indonesia; tartrazine standard; acetic acid (10%); ammonium hydroxide (10%), purchased from Merck, Malaysia; and aqua dest.

2.2 Methods

2.2.1 Hardware installation

The hardware setup was designed based on a block diagram comprising three primary components: input, processing, and output, as illustrated in Figure 1. The input block consists of the TCS3200 color sensor, which detects color data from the sample. This input component is connected to the processing block, represented by the Arduino Uno microcontroller, responsible for processing the sensor's signals. The output block is divided into two elements: a personal computer (PC) or laptop, serving as a data storage workstation for the sensor's detections, and a 16 × 2 LCD, which provides a real-time display of the sensor's detection results. The integration of the TCS3200 color sensor with the Arduino Uno was achieved by connecting the respective pins of the sensor to the designated pins on the Arduino Uno using standard jumper cables [28]. This setup ensures seamless communication between the sensor and the microcontroller while providing both data recording and live monitoring functionalities.

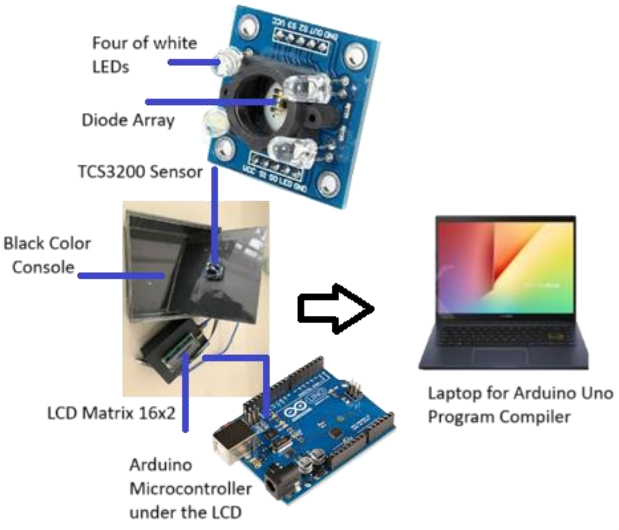


Figure 1. The hardware consists of a TCS 3200 sensor placed on the black console and connected to an Arduino Uno with a 16×2 LCD display (A laptop is used as a display and program compiler)

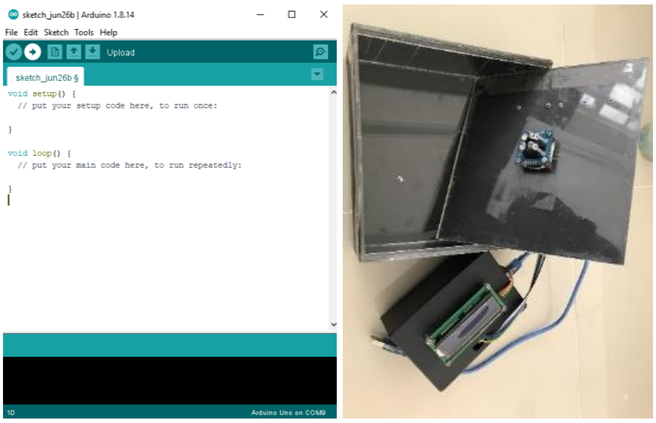
2.2.2 Software preparation

The software preparation aims to acquire RGB data displayed on a laptop or computer screen. The software used to enable the Arduino Uno to store data is the Arduino IDE 1.8.14 version, available for free from the official website). The workspace of Arduino Uno IDE 1.8.14 is shown in Figure 2(a).

The TCS3200 color sensor was utilized, featuring an 8x8 photodiode array. The sensor was positioned perpendicular to the sample at a fixed distance of 3 cm. Surrounding the sensor, four white light-emitting diodes (LEDs) were arranged to illuminate the sample from four directions. The reflected light from the sample was captured by the photodiode array and filtered sequentially through red, green, blue, and no-color filters [29]. The filtered signals were then converted into a rectangular wave with a frequency proportional to the color composition of the sample. This data was transmitted to the

Arduino Uno microcontroller for processing.

To ensure consistent readings, the sensor was housed in a black console designed to isolate the sample from external light (Figure 2(b)). The sample was positioned inside the console, with additional lighting optimized to capture the sample color accurately. Calibration of the TCS3200 sensor system was performed using standard color samples: black (RGB: 0,0,0), white (RGB: 255,255,255), red (RGB: 255,0,0), blue (RGB: 0,0,255), and green (RGB: 0,255,0). Liquid samples were placed inside cuvettes, with the cuvette wall facing the photodiode array to ensure optimal exposure to the sensor.



```
void setup() {
  // put your setup code here, to run once:

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

(a) (b)

Figure 2. (a) Arduino IDE software main menu display; and (b) Hardware installation for Tartrazine determination using TCS3200 color sensor

2.2.3 Samples preparations

The samples used in this study were snack products commonly found in Banda Aceh City, as detailed in Table 1. The samples were selected using a purposive sampling method, targeting snacks that exhibited a yellow color to align with the research objectives. Approximately 10 mL of the sample solution (± 5 – 10 g of solid sample) was placed into a 100 mL Erlenmeyer flask. To acidify the solution, 5 mL of 10% acetic acid was added. A 10 cm of wool yarn was immersed in the solution, which was then heated to boiling at 115°C for 30 minutes. Utilized the wool yarn due to its unique properties such as high porosity, and presence of functional groups (amino and carboxyl). These functional groups allow wool to interact with and adsorb tartrazine effectively. After boiling, the wool was removed (Figure 3), rinsed with distilled water, then soaked in 25 mL of 10% ammonium. The mixture was heated at 115°C for 10 minutes to release the color absorbed by the wool to ammonium solution. The solution then measurement using the TCS3200 color sensor (RGB value was recorded), and the absorbance was measured using a UV-Vis spectrophotometer at the maximum wavelength [28].

Table 1. Sample used of the study

No.	Sample	Code
1	Candied mango	A
2	Candied mackerel	B
3	ABC orange syrup	C
4	Nutrisari orange softdrink	D
5	Ale-Ale orange softdrink	E
6	Noodle	F

Figure 3. Extracted sample in wool yarn

Notes: 1. Samples of A – Candied mango; 2. B – Candied mackerel; 3. C – ABC orange syrup; 4. D – Nutrisari orange soft-drink; 5. E – Ale-Ale orange soft-drink; 6. F – Noodle

2.2.4 Preparation of 100 ppm standard stock solutions

0.01 g sample of tartrazine was weighed and transferred into a 100 mL volumetric flask. Distilled water was added to the flask, and the solution was thoroughly mixed to ensure homogeneity. This resulted in a 100-ppm tartrazine standard stock solution. From this stock solution, serial dilutions were prepared to obtain working solutions with concentrations of 1, 3, 5, 7, and 9 ppm, which were used for further analysis [30].

2.2.5 Determination of maximum wavelength for tartrazine

The determination of the maximum wavelength for tartrazine was conducted using a 5-ppm tartrazine solution. The absorbance was measured within the visible wavelength range of 420 - 432 nm using a UV-Vis spectrophotometer. The wavelength corresponding to the highest absorbance value was identified as the maximum wavelength [28].

2.2.6 Calibration curve for tartrazine standard

The calibration curve for the tartrazine standard was constructed by measuring the RGB values using the TCS3200 color sensor, the RGB value then convert to IR, IG, dan IB value using Eqs. (1)-(3). The absorbance of the standard also analyzed using an UV-Vis spectrophotometer at the maximum wavelength obtained from previous step. A series of standard tartrazine solutions were placed into a cuvette, and the measurements were recorded to establish the calibration curve [28].

$$\mathrm{IR}=\frac{R}{R+G+B} \tag{1}$$

$$\mathrm{IG}=\frac{G}{R+G+B} \tag{2}$$

$$\mathrm{IB}=\frac{B}{R+G+B} \tag{3}$$

2.2.7 Methods validation

a. accuracy

The accuracy was evaluated by calculating the percentage recovery (% recovery) for each concentration level of the sample. The measured concentrations were compared to their corresponding concentrations to determine the recovery rates [31].

b. Precision

Precision was expressed as the percent relative standard deviation (% RSD) or the coefficient of variation. Repeated measurements were conducted on the samples using both the TCS3200 color sensor and UV-Vis spectrophotometric methods. The % RSD values were then calculated and averaged for each sample concentration [31].

c. Limit of detection (LoD) and quantitation (LoQ)

The LoD and LoQ were determined statistically from the calibration curve using linear regression analysis. These values were calculated based on the standard deviation of the response and the slope of the calibration curve [31].

d. Linearity

Linearity was assessed by constructing calibration curves for both the TCS3200 color sensor and UV-Vis spectrophotometer. The linear regression equations and correlation coefficients (R^2 values) were derived to evaluate the linear relationship between the measured values and the sample concentrations [32].

e. Method comparison

The comparability of the TCS3200 color sensor method with the UV-Vis spectrophotometric method was analyzed by measuring identical samples using both techniques. Agreement between the methods was confirmed when the results were statistically similar [33].

f. Two-tailed t-test

A two-tailed t-test was performed to statistically compare the measurement results from the TCS3200 color sensor method with those from the UV-Vis spectrophotometer. The calculated t-values were compared with the critical t-values (t_{table}) at a defined significance level to assess any significant differences between the two methods.

3. RESULT AND DISCUSSIONS

3.1 Maximum wavelength (λ) of tartrazine

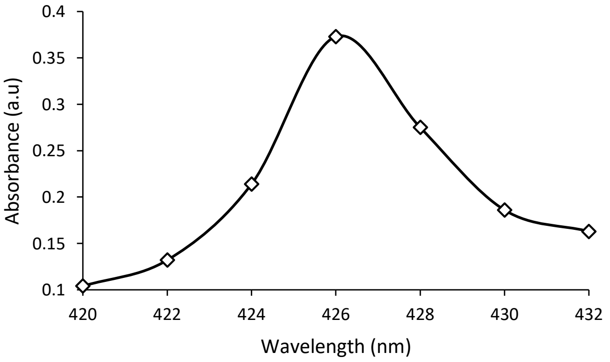


Figure 4. Tartrazine wavelength curve

The maximum wavelength (λ) of tartrazine was determined using a 5-ppm standard tartrazine solution. Measurements were performed with a UV-Vis spectrophotometer in the visible wavelength range of 420–432 nm [28]. The wavelength corresponding to the highest absorbance value was identified as the maximum wavelength (λ_{max}) as shown in Figure 4. Tartrazine exhibits a maximum absorption at a wavelength of 426 nm, with an absorbance value of 0.373. The determination of the maximum wavelength was based on the highest recorded absorbance in the spectrum.

3.2 Calibration curve standard solutions using TCS3200 color sensor

The tartrazine standard curve was generated by measuring RGB values using a TCS3200 color sensor. The standard curve was constructed using tartrazine concentrations of 1, 3, 5, 7, and 9 ppm. The RGB values were converted into the HIS (hue, intensity, saturation) color index. The HIS values served as an equivalent to absorbance values typically obtained via UV-Vis spectrophotometry [28]. The HIS values were plotted as the dependent variable (y-axis) against the corresponding tartrazine concentrations (x-axis). The results of HIS measurements presented in Figure 5.

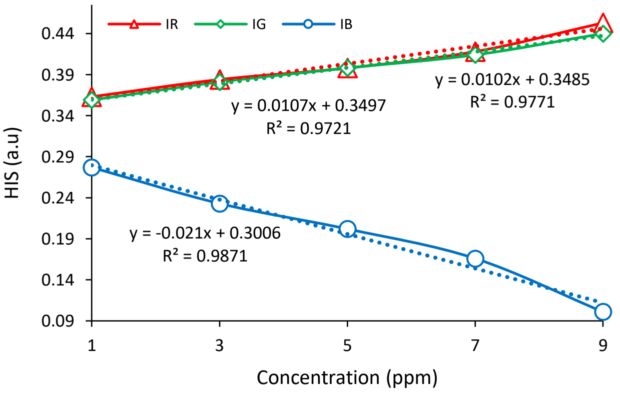


Figure 5. HIS curve of tartrazine standard solutions

Based on the HIS curve (Figure 5), the IB parameter exhibits the most linear relationship compared to IR and IG, with a slope of -0.021 and a coefficient of determination (R^2) of 0.9871. The IB regression equation was applied to determine tartrazine levels in the samples

3.3 Calibration curve standard solution using UV-Vis spectrophotometer

The tartrazine standard calibration curve was measured at the maximum wavelength of 426 nm using a UV-Vis spectrophotometer. Standard tartrazine concentrations of 1, 3, 5, 7, and 9 ppm were used. The resulting calibration curve is presented in Figure 6.

The tartrazine calibration curve was measured using a mixed blank solution of acetic acid and ammonium. The regression equation obtained was $y = 0.0768x + 0.005$, with a coefficient of determination (R^2) of 0.988. These results indicate that the tartrazine concentration is directly proportional to the absorbance. According to Lambert-Beer's law, higher concentrations result in higher absorbance values [32]. The R^2 value of TCS3200 color sensor in this study is slightly lower than that of UV-Vis method. This is due to

TCS3200 more susceptible to ambient light variations and samples inconsistencies. However, its low cost, portability, and ease of use, make it a practical alternative to UV-Vis for on-site, and resources-limited applications.

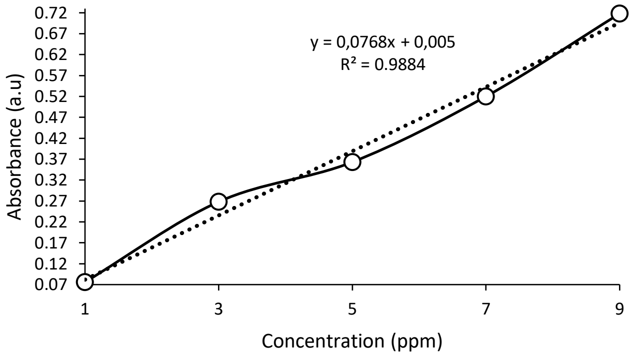


Figure 6. Tartrazine calibration curve

3.4 Validation method

3.4.1 Accuracy

The determination of accuracy is expressed as the recovery percentage (% recovery), which indicates the closeness of the measured concentration to the standard concentration [31]. Accuracy testing was conducted using tartrazine concentrations of 1, 3, and 5 ppm, measured with both a color sensor and a UV-Vis spectrophotometer. The % recovery values obtained are presented in Table 2.

Table 2. % Recovery value of the color sensor and UV-Vis spectrophotometer

X (ppm)	Xi (ppm)		% Recovery	
	Color Sensor	UV Vis	Color Sensor	UV-Vis
1	1.09	0.93	109	93
3	3.19	3.4	106	115
5	4.66	4.71	93.2	94.2

Note: X – actual concentration; Xi – calculated concentration

Table 2 presents the % recovery values obtained using the color sensor method, ranging from 93.2% to 109%, and the UV-Vis spectrophotometer method, ranging from 93% to 115%. The results from the color sensor method align with theoretical expectations, as % recovery values within the range of 90–110% are considered acceptable [31].

3.4.2 Precision

Table 3. % RSD intraday value of color sensor and UV-Vis spectrophotometer

Concentration (ppm)	Time (hour)	% RSD	
		Color Sensor	UV-Vis
1	1	0.348 ± 0.06	0.555 ± 0.31
	2	0.347 ± 0.06	1.130 ± 0.31
	3	0.241 ± 0.06	0.602 ± 0.31
4	1	0.465 ± 0.31	0.218 ± 0.22
	2	0.877 ± 0.31	0.314 ± 0.22
	3	0.259 ± 0.31	0.641 ± 0.22
5	1	0.497 ± 0.01	0.193 ± 0.04
	2	0.485 ± 0.01	0.194 ± 0.04
	3	0.469 ± 0.01	0.280 ± 0.04

Notes: Data are presented as mean ± standard deviation.

Precision is expressed as the relative standard deviation (% RSD) [32]. Precision measurements were conducted both intraday and interday using tartrazine concentrations of 1, 4, and 5 ppm, measured with a color sensor and a UV-Vis spectrophotometer. The % RSD values obtained are presented in Table 3.

The % RSD intraday values calculated using a color sensor and a UV-Vis spectrophotometer at 1, 2, and 3 hours (Table 3). The results show minor variations in % RSD values over time, likely due to the fading and clarification of the yellow color. The % RSD values obtained meet the criteria for good precision, which is defined as < 2%.

Table 4. % RSD value interday color sensor and spectrophotometer UV-Vis (n=3)

Concentration (ppm)	Time (day)	% RSD	
		Color Sensor	UV-Vis
1	1	0.348 ± 0.005	1.110 ± 0.350
	2	0.344 ± 0.005	1.01 ±0 0.350
	3	0.337 ± 0.005	1.660 ± 0.350
4	1	0.732 ± 0.028	0.314 ± 0.500
	2	0.738 ± 0.028	0.925 ± 0.500
	3	0.244 ± 0.028	1.310 ± 0.500
5	1	0.766 ± 0.023	0.278 ± 0.040
	2	0.746 ± 0.023	0.193 ± 0.040
	3	0.354 ± 0.023	0.278 ± 0.040

Note: Data are presented as mean ± standard deviations.

The results of % RSD interday calculations using a color sensor and a UV-Vis spectrophotometer on days 1, 2, and 3 show color changes at concentrations of 1 and 4 ppm (Table 4). The % RSD values varied significantly across the days, likely due to the yellow color persisting only for 3 hours before fading to clear by day 3. Despite this, the % RSD values obtained (<1.5%) meet the criteria for good precision, defined as < 2% [34].

3.4.3 LoD and LoQ

The determination of LoD is conducted to identify the smallest concentration of the analyte that can be reliably detected, while the LoQ refers to the lowest concentration that can be quantified with acceptable precision and accuracy [35]. The LoD and LoQ values were calculated using blank samples, measured with both a color sensor and a UV-Vis spectrophotometer, and the results are presented in Table 5.

Table 5. LoD and LoQ value of color sensor and spectrophotometer UV-Vis

Parameter	Color Sensor (ppm)	UV-Vis (ppm)
LOD	0.020	0.015
LOQ	0.068	0.050

Notes: LoD and LOQ – limit of detection and limit of quantification.

Based on the data presented in the Table 5, the lowest LoD for tartrazine was found at 0.020 and 0.015 ppm for the TCS3200 color sensor and the UV-Vis spectrophotometer, respectively. The LoD obtained with the TCS3200 color sensor in this study is well below the ADI limit set by JECFA and EU SCF (7.5 mg/kg or equivalent to 7 ppm), demonstrating the sensor's high sensitivity for detecting tartrazine levels at concentrations far below the safety threshold [13]. The LoD obtained also significantly lower than the tartrazine analysis results reported previously using the LC method, which was 0.23 ppm [23]. The LoD of present study also significantly lower compared to the LoD values reported from other methods, such as reversed phase – high performance thin layer chromatography with UV/Vis (RP-HPTLC-UV/Vis) method (0.27 - 0.92 ppm) and high-performance liquid chromatography with diode array detection (RP-HPLC-DAD) method (0.11 - 0.29 ppm) for tartrazine and seven other dyes [36]. The lower LoD obtained in this study indicates that the TCS3200 color sensor is more sensitive than other method for detecting tartrazine at very low concentrations. This suggests that the TCS3200 sensor can be an effective tool for on-site and real-time monitoring of tartrazine levels, especially in settings where high sensitivity is required and where more sophisticated methods like LC may not be feasible due to cost or complexity. The LoQ, was determined at 0.068 and 0.05 ppm for the TCS3200 color sensor and the UV-Vis spectrophotometer, respectively. The ability to detect low concentrations of tartrazine is crucial due to its potential health risks, including carcinogenic effects [37]. Regular monitoring using these methods can help ensure compliance with safety regulations, as seen in studies assessing beverage samples [38].

3.4.4 Linearity

The linearity test was conducted to evaluate the method's ability to provide a consistent response across varying analyte concentrations [39]. The linearity of the tartrazine standard, as observed in the calibration curves of both the TCS3200 color sensor and the UV-Vis spectrophotometer, was assessed within the concentration range of 1 to 9 ppm. The obtained R^2 values were 0.987 for the TCS3200 color sensor and 0.988 for the UV-Vis spectrophotometer. These R^2 values obtained are close to 1, indicate that the data follows a linear relationship [40].

3.4.5 Selectivity

Selectivity measurements were performed by analyzing glucose, borax, and formaldehyde, at a concentration of 10 ppm using the same method. The purpose of the selectivity test was to evaluate the method's ability to accurately measure the target analyte in the presence of potential interference from other compounds in the samples. The selectivity measurements using the TCS3200 color sensor and UV-Vis spectrophotometer of the study, presented in Table 6, Figure 7, and Figure 8, respectively.

Based on the data presented in Table 6 and Figure 7, measurements using the TCS3200 color sensor resulted in different color indices. The method applied is specific to the measurement of tartrazine levels, characterized by a yellow color index [32]. Interfering components such as sugars, borax, and formaldehyde do not significantly affect the analysis, as the TCS3200 sensor is specifically sensitive to the yellow color associated with tartrazine, ensuring reliable results despite the presence of other substances in the sample.

Table 6. HIS Selectivity value with color sensor

No.	Sample	HIS			Color
		IR	IG	IB	
1.	Glucose	0.346	0.343	0.309	🟨
2.	Borax	0.344	0.343	0.312	🟨
3.	Formaldehyde	0.344	0.344	0.311	🟨
4.	*Tartrazine*	0.518	0.453	0.028	🟨

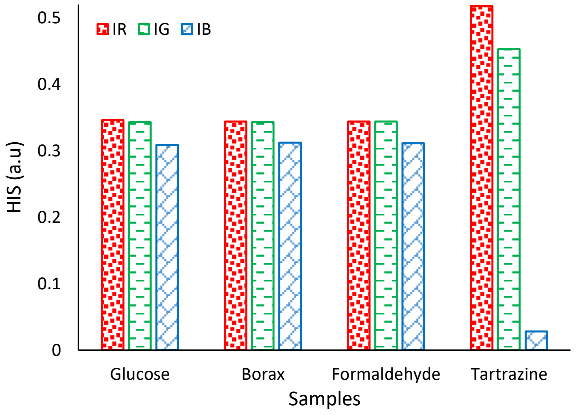


Figure 7. HIS selectivity curve with color sensor

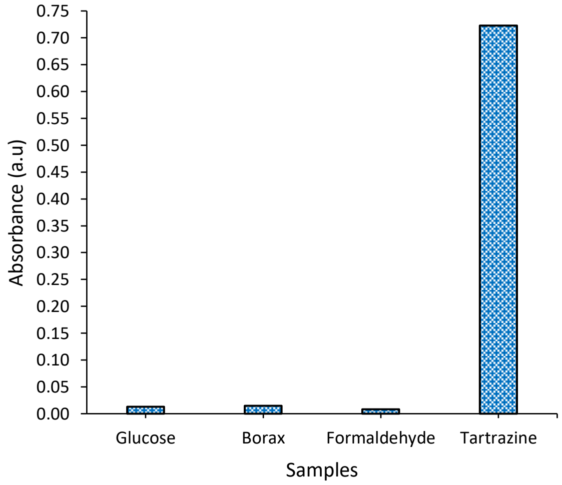


Figure 8. Selectivity curve with UV-Vis spectrophotometry

Based on Figure 8, selectivity measurements using the UV-Vis spectrophotometer indicate that the highest absorbance value corresponds to tartrazine. The method employed is specific to the measurement of tartrazine levels. This finding is aligned with previous study reported [32].

3.4.6 Sensitivity

The sensitivity values are derived from the slopes of the tartrazine standard curves for each method. Based on the linear regression equations of the standard curves, the slope value for the TCS3200 color sensor measurement, from the equation $y = -0.021x + 0.3006$ is -0.021, while the slope value for the UV-Vis spectrophotometer measurement, from the equation $y = 0.076x + 0.005$ is 0.076.

3.5 Determination of tartrazine in samples

The results of the measurements HIS, RGB, and real samples using the TCS3200 color sensor, as shown in Table 7.

Based on the data in Table 7, the RGB values obtained from each sample correspond to specific colors, which were then converted into HIS values using Eqs. (1)-(3). To determine the tartrazine concentration in the samples, the IB value for each sample was substituted into the regression equation derived from the tartrazine IB standard calibration curve. The resulting concentrations for each sample, as calculated using the TCS3200 color sensor, also shown in Table 7. From these calculations, it is evident that sample B (candied mackerel) exhibited the highest concentration of tartrazine (4.65 ppm), compared to the other samples. Analysis of absorbance and concentration of tartrazine in real samples using UV-Vis presented in Table 8.

Table 7. HIS values, RGB, and concentration of real samples

Sample	HIS			Color	X (ppm)
	IR	IG	IB		
A	0.394 ± 0.002	0.395 ±0.003	0.208 ± 0.006	🟨	4.35 ± 0.05
B	0.398 ± 0.001	0.397 ± 0.002	0.202 ± 0.001	🟨	4.65 ± 0.07
C	0.395 ± 0.002	0.396 ± 0.002	0.206 ±0.004	🟨	4.45 ± 0.10
D	0.394 ± 0.002	0.393 ± 0.002	0212 ± 0.004	🟨	4.18 ± 0.10
E	0.366 ± 0.002	0.360 ± 0.003	0.271 ± 0.002	🟨	1.34 ± 0.10
F	0.365 ± 0.001	0.366 ± 0.008	0.268 ± 0.001	🟨	1.51 ± 0.13

Note: 1. HIS – hue, intensity, and saturation; 2. IR, IG, IB – Index of red, green, and blue, respectively; 3. X – concentration of real sample measurement using TCS3200 color sensor; 4. Samples of A – Candied mango; 5. B – Candied mackerel; 6. C – ABC orange syrup; 7. D – Nutrisari orange soft-drink; 8. E – Ale-Ale orange soft-drink; 9. F – Noodle.

Table 8. Absorbance and concentration of real samples using UV-Vis spectrophotometer

Sample	Absorbance (λ)	*X* (ppm)
A	0.3354 ± 0.004	4.34 ± 0.31
B	0.3582 ± 0.005	4.64 ± 0.09
C	0.3424 ± 0.007	4.43 ± 0.19
D	0.3218 ± 0.008	4.16 ± 0.23
E	0.1116 ± 0.007	1.32 ± 0.19
F	0.1174 ± 0.011	1.47 ± 0.13

Notes: 1. Samples of A – Candied mango; 2. B – Candied mackerel; 3. C – ABC orange syrup; 4. D – Nutrisari orange soft-drink; 5. E – Ale-Ale orange soft-drink; 6. F – Noodle.

Table 8 shows that the highest absorbance value is observed in Sample B compared to the other samples. The tartrazine concentration was calculated by substituting the absorbance value into the linear regression equation obtained from the calibration curve. The concentration results for the samples are also presented in Table 8.

The finding indicate that Sample B (Candied mackerel) exhibits the highest concentration of tartrazine level (4.64 ppm). Measurements using both methods confirm that the tartrazine concentrations in all samples remain below the permissible limit established by Badan Pengawasan Obat dan Makanan Indonesia (BPOM) of known as National Agency of Drug and Food Control of Indonesia, BPOM Regulation No. 37 of 2013, which allows a maximum tartrazine concentration of 70 ppm. Excessive tartrazine levels, exceeding the regulated limits, have been associated with adverse health effects, including urticaria (allergic skin rash), rhinitis (nasal inflammation), asthma, purpura (skin bruising), and systemic anaphylaxis (shock) [4].

3.6 Comparison of methods with two-way t-test

A comparison of methods was conducted to evaluate whether the TCS3200 color sensor produced results comparable to those of the UV-Vis spectrophotometer (standard method). Table 9 presents the comparative concentrations of the samples as determined using the TCS3200 color sensor and the UV-Vis spectrophotometer.

The comparison result, demonstrates that the differences in tartrazine levels measured by the two methods are relatively small. A two-tailed t-test was performed to determine whether the two methods exhibited significant differences. The analysis was conducted at a 95% confidence interval with 8 degrees of freedom, yielding a critical t-value (T_{table}) of 2.31. The results showed that the calculated t-value (T_{count}) was less than T_{table}. Therefore, it can be concluded that the TCS3200 color sensor method provides results comparable to those of the UV-Vis spectrophotometer.

Table 9. Comparison of color sensor measurements and UV-Vis spectrophotometer (n=3)

Sample	UV-Vis	Color Sensor	T_{count}	T_{table} (8, α: 0.05)
	Concentration (ppm)	Concentration (ppm)		
A	4.34 ± 0.31	4.35 ± 0.05	0.48	2.31
B	4.64 ± 0.09	4.65 ± 0.07	0.09	
C	4.43 ± 0.19	4.45 ± 0.10	2.15	
D	4.16 ± 0.23	4.18 ±0.10	1.66	
E	1.32 ± 0.19	1.34 ± 0.10	1.81	
F	1.47 ± 0.13	1.51 ± 0.13	1.81	

Notes: 1. Samples of A – Candied mango; 2. B – Candied mackerel; 3. C – ABC orange syrup; 4. D – Nutrisari orange soft-drink; 5. E – Ale-Ale orange soft-drink; 6. F – Noodle; 7. t_{table} – ($n_1 + n_2 - 2$; α) = 8; 95%.

4. CONCLUSIONS

The results of this study reveal that tartrazine levels in snack samples circulating in Banda Aceh City vary but remain well below the permissible threshold. The TCS3200 color sensor shows accuracy and sensitivity comparable to the UV-Vis method, with a LoD of 0.02 ppm and an R^2 of 0.987. Statistical analysis using a t-test confirms that there is no significant difference between the measurements obtained with the TCS3200 color sensor and those from the UV-Vis spectrophotometer ($T_{count} < T_{table}$). These findings highlight the reliability of the TCS3200 sensor as a practical alternative for tartrazine level detection, and as a tool for food safety monitoring, especially for real-time detection in resource-limited areas.

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