Sains Malaysiana 53(12)(2024): 3339-3348
http://doi.org/10.17576/jsm-2024-5312-17

Development of TCS3200 Color Sensor based on Arduino Uno Microcontroller for Determination of Capsaicin Level in Sauces

(Pembangunan Penderia Warna TCS3200 berdasarkan Mikropengawal Arduino Uno untuk Penentuan Tahap Kapsaisin dalam Sos)

KHAIRI SUHUD[1,*], DIAN UTARI[1], MUHAMMAD SYUKRI SURBAKTI[2], SAGIR ALVA[3], FAIRUZ OMAR[4] SAIFUL SAIFUL[1], LENY HELIAWATI[5], PURNAMA NINGSIH[6], ANDRIY ANTA KACARIBU[7], MUHAMMAD DAFFA HADISTYA[1], THARIQ ZAID GUNANA[1] & RINALDI IDROES[8]

[1]*Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia*
[2]*Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia*
[3]*Department of Mechanical Engineering, Faculty of Engineering, Mercubuana University, Jakarta 11650, Indonesia*
[4]*School of Physics, Universiti Sains Malaysia, 11800 USM Penang, Malaysia*
[5]*Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Pakuan-Bogor, Indonesia*
[6]*Program Studi Pendidikan Kimia, Jurusan Pendidikan MIPA, FKIP Universitas Tadulako Sulawesi Tengah, Indonesia*
[7]*Doctoral Program of Agricultural Science, Postgraduate School Program, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia*
[8]*Department of Pharmacy, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia*

Received: 5 August 2024/Accepted: 14 October 2024

ABSTRACT

A color sensor has been designed to measure the capsaicin level in commercial sauces. This system is designed using a TCS2300 color sensor as an input, and an Arduino Uno microcontroller with Integrated Development Environment (IDE) software as signal conditioning and signal processing. The measurement result will be compared to the standard Ultraviolet-Visible (UV-Vis) spectrophotometer method. The sauce samples were taken using a sampling technique, namely eight samples of sauces circulating in the city of Banda Aceh. The result showed that the levels of capsaicin using the TCS3200 color sensor and UV-Vis spectrophotometer ranged from 5.39 to 22.42 mg/L and 5.58 to 22.64 mg/L, respectively. The linearity obtained in the concentration range of 5.25 mg/L shows a linear calibration curve using the TCS3200 color sensor (R^2 = 0.9961) and UV-Vis Spectrophotometer (R^2 = 0.9973). Accuracy (% recovery) for the TCS3200 color sensor and UV-Vis spectrophotometer ranged from 98.94 to 106.63%, and 98.13 to 110.2% mg/L, respectively. In the case of interday and intraday relative standard deviation has not more than 2%. Based on the t-test assessment, it shows that the TCS3200 color sensor has no differences statistically in results with UV-Vis Spectrophotometer. These results describe that the TCS3200 color sensor can be an alternative for analyses of capsaicin in sauce samples.

Keywords: Arduino Uno; capsaicin; IDE software; sauce; TCS3200 color sensor; UV-Vis spectrophotometer

ABSTRAK

Satu penderia warna telah dibangunkan untuk mengukur kandungan kapsaisin dalam sos komersial. Sistem ini direka menggunakan penderia warna TCS2300 sebagai input, dan Arduino Uno mikropengawal dengan perisian Persekitaran Pembangunan Bersepadu (IDE) sebagai isyarat kawalan dan pemprosesan. Keputusan pengukuran dibandingkan dengan kaedah piawai spektrofotometer Ultraviolet-Visible (UV-Vis). Sampel dikumpulkan dengan menggunakan teknik pensampelan yang melibatkan lapan sampel sos dari Banda Aceh-Indonesia. Kepekatan kapsaisin yang diukur menggunakan penderia warna TCS3200 dan spektrofotometer UV-Vis masing-masing dalam julat berjulat dinamik dari 5.39 hingga 22.42 mg/L dan 5.58 hingga 22.64 mg/L. Kelinearan diperoleh dalam julat kepekatan 5.25 mg/L, menunjukkan hubungan linear yang bagi kedua-duanya, penderia warna TCS3200 (R^2=0.9961) dan Spektrofotometer UV-Vis (R^2=0.9973). Ketepatan dinyatakan sebagai % hasil berada antara 98.94 hingga 106.63% untuk penderia warna TCS3200 dan 98.13 hingga 110.2% mg/L untuk UV-Vis. Kedua-dua sisihan piawai relatif antara hari dan intrahari adalah di bawah 2%. Analisis ujian-t mengesahkan bahawa tiada perbezaan statistik yang signifikan antara kedua-dua kaedah tersebut. Keputusan ini

menunjukkan bahawa penderia warna TCS3200 mampu menjadi kaedah alternatif yang berdaya maju untuk menganalisis kapsaisin dalam sampel sos.

Kata kunci: Arduino Uno; kapsaisin; penderia warna TCS3200; spektrofotometer UV-Vis; sos

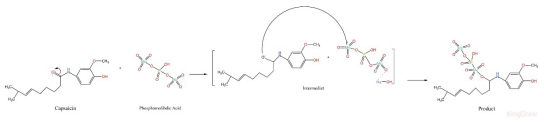
INTRODUCTION

Plant foods contain almost all of the essential mineral and organic nutrients for human, as well as several unique organic phytochemicals that have been linked to the promotion of good health (Elechi & Sule 2023). Food processing requires other additives that come from plant that can add to the taste of a dish. One of the additional ingredients that are often used is chili. In general, the Indonesian are familiar with the chili plant with various variety and its benefits. Chili is one type of spice plant that has a high economic value. Chili is widely used as a seasoning in cooking and as a traditional medicine. Chili peppers contain several chemical compounds such as vitamin C, vitamin A, vitamin B1, vitamin K, carbohydrates, calcium, phosphorus and capsaicin (Farwah et al. 2020). Capsaicin is an active compound in chili plants that gives it a spicy taste. In general, fresh chili fruit has 0.1-1.0% capsaicin content depending on the variety of chili (Sahid, Syukur & Maharijaya 2020).

Capsaicin is present in the placenta of the fruit where the seeds are attached. The content of capsaicin in chili can be used in the pharmaceutical field as an anticancer drugs and analgesics, as well as in the food industry (Chapa-Oliver & Mejía-Teniente 2016; Chung & Campbell 2016; Friedman et al. 2018; Meritt et al. 2022; Rezazadeh et al. 2023; Zhang et al. 2020). One of the processed products of the food industry is chili sauce. Chili sauce is a sauce with the main ingredient of chili peppers soaked up with spicy chili pepper content. Chili sauce can be made from mixed-chili with other complementary ingredients as flavouring ingredients and flavour enhancers of food (Prayitno, Meswari & Diauddin 2020). Analysis of capsaicin levels in sauces is important in order to make sure food security ensures access of all people at all times, both physical and economic, to the basic food they need for a healthy and active life (Lafz & Amini 2023).

Various methods are used to analyse the capsaicin levels, such as High-performance liquid chromatography (HPLC) (Tobolka et al. 2021), Microwave Assisted Soxhlet Extraction (MASE) (Barbero, Palma & Barroso 2006), and Ultraviolet-visible (UV-Vis) spectrophotometer (Pacheco et al. 2021). The disadvantages of the HPLC method are it cannot be used in field testing due to certain limitations, such as tedious sample processing, the need for professionals, and high detection costs (Wang et al. 2020). While the disadvantage of the MAE method is that it uses high temperatures for extraction, hence it can damage the structure of the compound and uneven heating during extraction (Lu & Cui 2019). Furthermore, the UV-Vis method is a method that is often applied in detecting capsaicin based on absorbance values (Rohaeti et al. 2019). The advantages of the UV-Vis method are that it has high accuracy, is quite sensitive, and the results obtained are quite accurate (Passos & Saraiva 2019). However, the disadvantages of the UV-Vis method are expensive instrumentation, complicated and time-consuming sample preparation, and require lots of reagents (Soleh et al. 2020). Based on the disadvantages conveyed, a simple method of measuring capsaicin levels was developed, namely a color sensor.

One type of sensor that will be developed for capsaicin analysis is the TCS3200 color sensor, commonly utilized for color detection. Although capsaicin is a colorless compound, it can be quantified through colorimetry by forming a complex with phosphomolybdic acid in an alkaline medium, producing a blue-colored complex as represented in Equation (1).



(1)

The TCS3200 color sensor is a light sensor programmed to convert red, green, blue (RGB) colors into frequencies composed of an 8×8 array configuration of photodiodes (Dewantara & Yulkifli 2020). The design of the TCS3200 color sensor tool has been widely developed with various bases and applications. The TCS3200 color sensor based on Arduino Nano has been developed to applied to detection of Monosodium Glutamate (MSG) in soups (Yudhana et al. 2022), and analysis of Rhodamine level in the syrup (Surbakti et al. 2022). In addition, the TCS3200 color sensor was also developed based on Arduino as color sorting machine (Borkar et al. 2019), and Arduino Uno-based to detect strawberry maturity stages (Juliano, Hendrawan & Ritzkal 2020). Arduino Uno is a series developed from a microcontroller based on ATmega 328 and Arduino Uno is one type of Arduino that is often used (standard) (Siregar, Siagian & Siregar 2022). In addition, the TCS 3200-based sensor is portable, sensitive, and has a simple and fast analysis process (Surbakti et al. 2022). Based on these description, this research focus to detect capsaicin level in the sauces sample by the Arduino Uno-based TCS3200 color sensor. The results of capsaicin measurements with the TCS3200 color sensor will be compared with UV-Vis spectrophotometer measurements including precision, accuracy, detection limit (LoD), and quantification limit (LoQ) applications in the near future.

MATERIALS AND METHODS

MATERIALS

The sauce samples (A=Delisaos Hot lava; B=Belibis; C=ABC; D=Sasa; E=Del Monte; F=Indofood) was obtained from local supermarkets in Banda Aceh City, Aceh Province, Indonesia. Other materials include standard capsaicin solution, Ethanol (96%), Phosphomolybdic Acid, Sodium Hydroxide (NaOH), Sodium Metabisulfite ($Na_2S_2O_5$) and distilled water. All Materials were analytical grade and purchased from Merck, Co. Ltd (Selangor, Malaysia).

DATA CONDITIONING AND PROCESSING

Here, the input block consists of the TCS3200 Color Sensor. The input component is connected to a process block consisting of an Arduino UNO microcontroller. Meanwhile, the output block ends with a Personal Computer (PC) component as a data storage system detected by the input block. In general, the process of the input block is to detect three parameters, and all three parameters are passed to the processing block. Furthermore, the raw data from the sensor is converted from Analog data to digital data sent to the output block as a data storage workstation. Furthermore, we design an Arduino-Uno software includes a discussion of testing mechanism TCS3200 Color Sensor. Here, the microcontroller as a tool for storing and processing data has been received from each of the sensors in the form of voltage. The software used is a microcontroller. To save the data, the Arduino Integrated Development Environment (IDE) software. The Arduino IDE software uses the C language programming language.

PREPARATION SAMPLE AND STANDARD SOLUTIONS

The six sauce samples used in this research is categorized by sample A, B, C, D, E, and F. As much as five grams of each sample was taken and put into a 100 mL beaker, then added 30 mL 96% ethanol. The sample was then stirred using a magnetic stirrer for 30 min (50 rpm). Homogeneous samples were then filtered and put into a 100 mL beaker glass to future analysis (Maula, Muhaimin & Millasari 2020). Standard of capsaicin (0.01 g) added into 100 mL measuring flask, then into it was added 96% ethanol up to tera mark, then solution was homogenized. This solution is used as a standard stock solution of capsaicin 100 mg/L. Capsaicin's maximum absorbance wavelength was determined using a UV-Vis spectrophotometer (Thermo Scientific) after complexation with phosphomolybdic acid and NaOH, which produced a blue-colored solution. The absorbance was measured over the visible wavelength λ_{max} at 650 nm. A 100 mg/L capsaicin stock solution was prepared, and aliquots of 2.5, 5, 7.5, 10, and 12.5 mL were transferred into separate 50 mL volumetric flasks to create standard solutions of 5, 10, 15, 20, and 25 mg/L. To each flask, 3 mL of 3% phosphomolybdic acid and 8 mL of 0.4% NaOH (w/v) were added, resulting in blue-colored solutions. Each mixture was diluted to 50 mL with distilled water and homogenized. These standard solutions were used for absorbance measurements via UV-Vis spectrophotometry and for RGB value determination using a TCS3200 color sensor (Maula, Muhaimin & Millasari 2020).

SAMPLE ANALYSIS

The prepared sauce samples of 10 mL were taken and put into a 50 mL measuring flask and added with 3 mL of 3% phosphomolybdic acid and 8 mL of 0.4% NaOH. Into the flask then added distilled water up to tera mark, then homogenized. Each solution is measured for RGB value with the TCS3200 color sensor method and absorbance with the UV-Vis standard method at the maximum wavelengths (Maula, Muhaimin & Millasari 2020).

DATA VALIDATION

The accuracy of the measurement analysis is expressed as a percent of recovery. Determination of accuracy where each standard solutions used is compared with the initial concentration at the same concentration (Bhagat & Saudagar 2019). The determination of the precision value (%RSD) is carried out by repetitioning against the same standard as intraday and intraday repetition using the TCS3200 and a UV-Vis color sensor methods. Furthermore, the measured average data is taken in each sample. Percentage of precision value obtained by %RSD calculation (Bhagat & Saudagar 2019). The linearity is obtained from the linear regression equation from the calibration curve data of the TCS3200 color sensors and UV-Vis. The selectiveness test was carried out by measuring capsaicin with various concentrations along with the addition of other compounds using TCS3200 color sensors and UV-Vis. Moreover, specificity tests were carried out by measuring several compounds with the same concentration and method using TCS3200 color sensors and UV-Vis.

DATA ANALYSIS

Data collected from TCS3200 color sensor to determination capsaicin level from eight samples used then compared using an UV-Vis spectrophotometry method. Here, the two-way t-test was performed to see a comparison result between the TCS3200 color sensor method and UV-vis. The two-tailed t-test is performed by looking for the t-statistic value for each method and then comparing it to the t-table. If the p-value is greater than the significance level (typically 0.05), it can be concluded that the TCS3200 color sensor method gives the same results as the UV-Vis spectrophotometer method in measuring capsaicin levels (Surbakti et al. 2022).

HARDWARE INSTALLATION

The hardware is designed to process data obtained from color sensors, displaying RGB values on computer screens and a 2×16 LCD matrix. The TCS3200 sensor serves as the input signal, which is triggered by a sinusoidal wave at a specific frequency. This frequency is then calculated and processed in the Arduino Uno to determine the corresponding RGB values. Additionally, the sensor analyzes the color based on the parameters of Hue, Intensity, and Saturation (HIS). The RGB values captured by the TCS3200 are processed to calculate the HIS components, allowing for a comprehensive analysis of the color profile. This information is then used to accurately determine the capsaicin concentration in the samples (Prabowo et al. 2023) as shown in Figure 1.

The hardware configuration was arranged before the programme deployed (Arduino-Uno software). Here, the hardware must be equipped with programming software that is used to obtain data results in the form of digital numbers or RGB values that will be displayed on a computer/laptop screen. In this study, we use Arduino Uno IDE to download the software and deployed to TCS3200 Color Sensor. Thus, the hardware must be considered in this design to connected perfectly over the pins (contained in the TCS3200 color sensor) and Arduino Uno. The cable must be connected when writing the program accordingly over Arduino IDE can also receive and process data that will be displayed on the laptop/computer screen.

RESULTS

The obtained HIS value will have the same function as the absorption value on the UV- Vis spectrophotometer. The HIS value measurements can be seen in Table 1. The concentration used in the measurement of accuracy is 5, 15, and 25 mg/L with color sensor and an UV-Vis spectrophotometer as shown in Table 2. The other compounds used were NaCl, $Na_2S_2O_5$, Borax, and Rhodamine B as shown in the Figure 2. The method used exhibits high selectivity for measuring capsaicin levels, even in the presence of interference from other compounds as presented in Figure 3. The measurements result with selectivity using the TCS3200 color sensor and UV-Vis spectrophotometer are as shown in Figures 4 and 5, respectively. Measurements are taken 5 times with the color sensor distance to the sample being 3 cm and RGB values as shown in Table 3. The total concentration obtained from the sample using the TCS3200 color sensor shown in Figure 6.

Hence, the sample that have been prepared were also measured using UV-Vis spectrophotometer at a wavelength of 650 mn. The measurement results can be seen in Table 4. Furthermore, the calculation of capsaicin levels in the sample can be done by substituting the absorbance value in the sample into the linear equation of the calibration curve. The results of the concentration in the sample as shown in the Figure 7. The data obtained from both method then compared statistically. The following comparison of samples concentrations with the TCS3200 color sensor and UV-Vis spectrophotometer presented in Table 4.

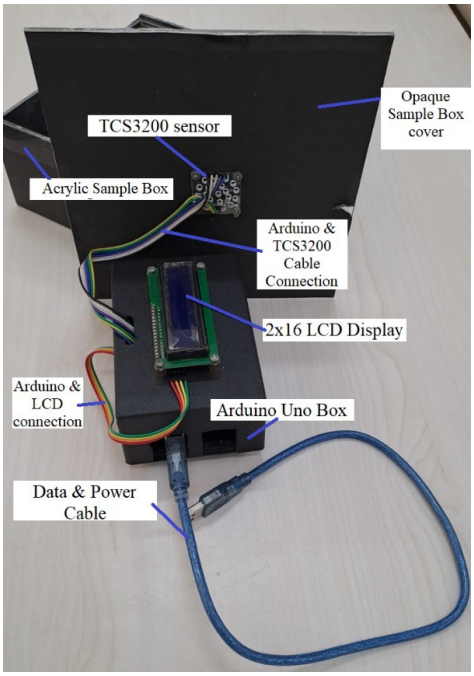


FIGURE 1. Configuration of TCS3200 color sensor system

TABLE 1. Calculation results of the standard HIS value of capsaicin

No.	Conc. (mg/L)	HIS			Color index
		IR	IG	IB	
1.	5	0.303	0.340	0.357	1.73
2.	10	0.277	0.335	0.389	3.82
3.	15	0.224	0.337	0.439	6.27
4.	20	0.201	0.318	0.481	7.39
5.	25	0.165	0.317	0.518	9.42

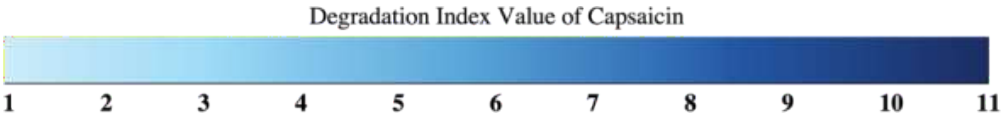


TABLE 2. The percent recovery value of color sensor and UV-Vis spectrophotometer

Concentration (mg/L)	Actual concentration (mg/L)		Recovery (%)	
	Color sensor	UV-Vis	Color sensor	UV-Vis
5	5.33	5.51	106.63	110.20
15	15.28	14.72	101.88	98.13
25	24.74	25.21	98.94	100.84

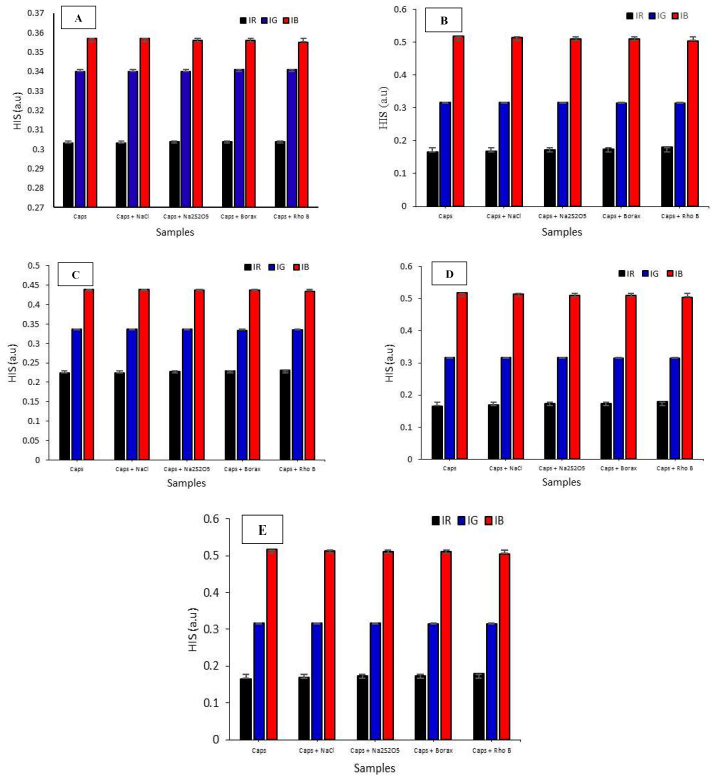


FIGURE 2. HIS specificity curve at (a) 5 mg/L; (b) 10 mg/L; (c) 15 mg/L; (d) 20 mg/L; and (e) 25 mg/L. IR: index of red; IG: index of green; IB: index of blue; Caps: capsaicin; Rh B: Rhodamine B

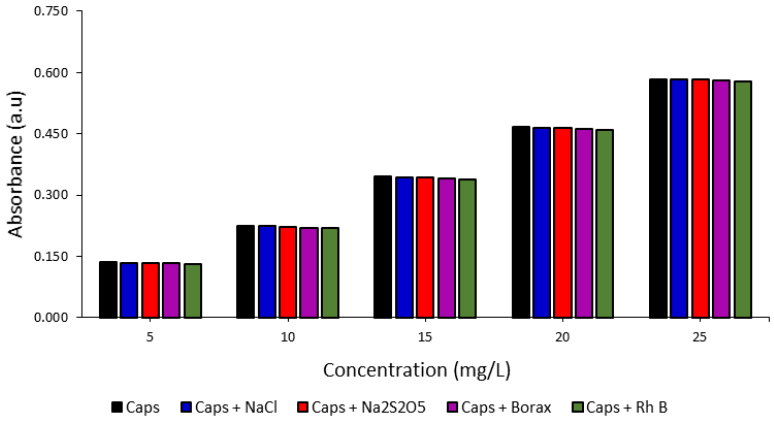


FIGURE 3. Specificity curve of UV-Vis spectrophotometers; caps: capsaicin; Rh B: Rhodamine B

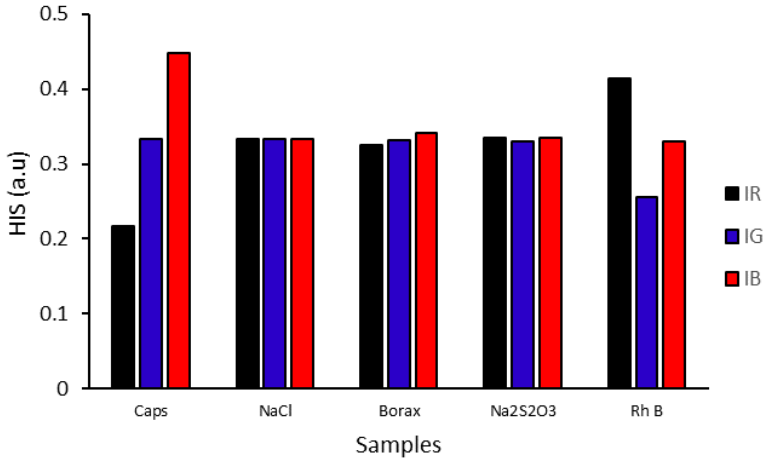


FIGURE 4. HIS selectivity curve using color sensor; caps: capsaicin; Rh B: Rhodamine B

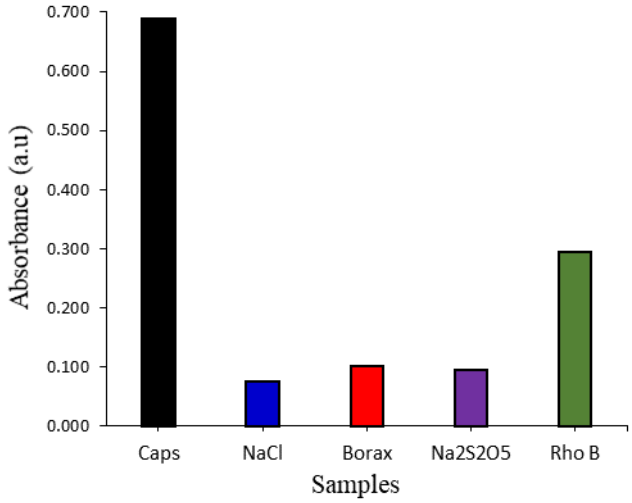


FIGURE 5. Selectiveness curve using UV-Vis spectrophotometer; caps: capsaicin; Rh B: Rhodamine B

DISCUSSION

The standard concentration of capsaicin used is 5, 10, 15, 20, and 25 mg/L that has been reacted with phosphomolybdic acid. The obtained RGB values will be converted to HIS (Hue, Intensity, Saturation) color indexes. The curve on regression equation y = 0.228x + 0.0092 with R^2 = 0.9973 is obtained. The results obtained can be concluded that the concentration of capsaicin is directly proportional to the absorbance. According to Lambert-Beer's law, the more the concentration increases, the higher the absorption produced (Mayerhöfer, Pipa & Popp 2019). Based on the correlation analysis result, tested linearity was carried out to see the ability of a method to give a good response at each concentration of the analyte (Ismail et al. 2014). Linearity testing is viewed based on the calibration curve graph of the TCS3200 color sensor and UV-Vis Spectrophotometer. We obtained the values R^2 = 0.9961 and R^2 = 0.9973 of the TCS3200 color sensor and UV-Vis Spectrophotometer, respectively. The R^2 values are close to 1 so it can be said that the data obtained are linear (Chicco, Warrens & Jurman 2021). Moreover, the determination of accuracy is expressed as % recovery. Accuracy test shows the proximity of the standard concentration value to the actual concentration.

The percent recovery (%) analysis of the color sensor method is in the range of 98.94- 106.63% and the UV-Vis spectrophotometer method is in the range of 98.13-110.2%. These results obtained are in accordance with the theory that the % recovery received is in the range of 90-110% (Maslukhah, Faridah & Lioe 2019). Furthermore, the determination of precision is expressed as a relative standard deviation (% RSD). Precision measurements are carried out intraday and interday. The concentration used in precision measurement is 5, 15, and 25 mg/L using color sensor and UV-Vis spectrophotometer.

The result of the % RSD calculation on intraday (1, 2, and 3 h) and interday precision (days 1, 2, and 3) meet the criteria of a good precision test which is > 2% (Thangabalan, Kahsay & Eticha 2018). The LoD aslo calculated to determine the smallest concentration in analytes that provide a significant response, while the determination of LoQ is to determine the smallest concentration that can be quantified (Armbruster & Pry 2008). The LoD and LoQ values of the color sensor are 1.73 and 5.78 with and LoD and LoQ values from Spectrophotometer UV-Vis are 1.31 and 4.35, respectively. Afterward, the specificity measurements were carried out by measuring capsaicin levels of various concentrations (5, 10, 15, 20, and 25 mg/L) with the addition of other compounds. The purpose of selectiveness is to see the ability of the method used in measuring a sample if there is interference from other compounds.

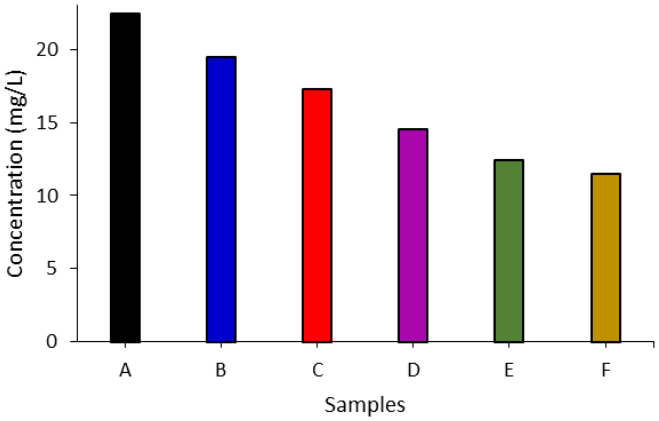
The measurements using the TCS3200 color sensor showed no significant difference compared to other methods. The method exhibits high specificity for measuring capsaicin levels, even in the presence of interference from other compounds. Similarly, no significant difference was observed in measurements using the UV-Vis spectrophotometer. Furthermore, the selectivity measurements were carried out by measuring compounds of NaCl, Borax, $Na_2S_2O_5$, Rhodamine B, and capsaicin at a concentration of 100 mg/L with the same method (Wang, Wang & Liang 2024). The purpose of selectivity is to see that the method used in this study specifically detects only one compound to be tested.

Analysis using the TCS3200 color sensor show that different color index are obtained. The method used is only specific to measure capsaicin levels with a blue color index. Figure 2 shows the specificity curve using UV-Vis spectrophotometer, it shows that the highest absorbance

TABLE 3. RGB and HIS values from the sample

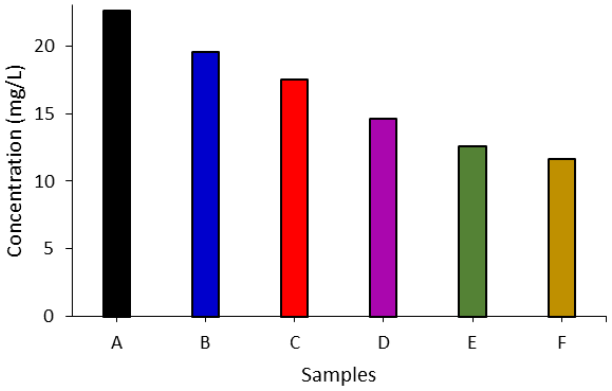
Samples	RGB			HIS (a.u)			Color index
	R	G	B	I_R	I_G	I_B	
A	57.8 ± 1.304	101.4 ± 1.140	158.2 ± 0.837	0.182 ± 0.003	0.320 ± 0.002	0.498 ± 0.002	
B	73.2 ± 0.837	113.0 ± 1.000	167.8 ± 1.096	0.207 ± 0.001	0.319 ± 0.002	0.474 ± 0.002	
C	83.2 ± 0.837	124.8 ± 0.837	174.4 ± 0.548	0.218 ± 0.002	0.353 ± 0.59	0.456 ± 0.001	
D	97.4 ± 1.140	147.4 ± 0.894	186.8 ± 0.837	0.226 ± 0.002	0.342 ± 0.002	0.433 ± 0.002	
E	105.8 ± 0.837	152.0 ± 0.707	183.0 ± 0.707	0.240 ± 0.001	0.345 ±0.001	0.415 ± 0.002	
F	127.0 ± 0.707	158.0 ± 1.000	196.4 ± 1.140	0.264 ± 0.001	0.328 ± 0.002	0.408 ± 0.002	

RGB; red – green – blue; I_R: index of red; I_G: index of green; I_B: index of blue



(Sauces- A: *Delisaos Hot lava*; B: *Belibis*; C: *ABC*; D: *Sasa*; E: *Del Monte*; F: *Indofood*)

FIGURE 6. Determination of samples concentration using TCS3200 color sensor



(Sauces- A: *Delisaos Hot lava*; B: *Belibis*; C: *ABC*; D: *Sasa*; E: *Del Monte*; F: *Indofood*)

FIGURE 7. Measurement of samples concentration using UV-Vis spectrophotometer

TABLE 4. Measurement comparison of color sensors and UV-Vis spectrophotometers

Sample	Color sensor	UV-*Vis*	^{t}statistic	^{t}table two tailed-t test
	Concentration (mg/L)	Concentration (mg/L)		
A	22.42 ± 0.328	22.62 ± 0.068	1.34	2.31
B	19.48 ± 0.190	19.55 ± 0.071	0.78	
C	17.31 ± 0.190	17.49 ± 0.071	2.00	
D	14.54 ± 0.190	14.60 ± 0.068	0.67	
E	12.39 ± 0.231	12.61 ± 0.085	2.01	
F	11.51 ± 0.231	11.65 ± 0.085	1.28	

$\alpha = 0.005\%$; $t_{table} = (n_1 + n_2 - 2)$; data presented as mean ± SD

value is found in capsaicin. The method used is only specific to measuring capsaicin levels. During investigation of capsaicin in sauce samples, we obtain the measurement of the sample using a device that has been connected to the TCS3200 color sensor. Measurements were made by inserting a sample that had been prepared into the cuvette, then measured using the TCS3200 color sensor in a lightless state. The light emitted by the four LEDs can be scattered back to the samples.

Based on the calculation result in Table 3, it can be seen that the RGB values obtained from each sample indicate a specific color. Concentration of capsaicin in the sample determination by substituting the IB value in the sample to the regression equation on the standard calibration curve of capsaicin IB. Based on the comparison result in Table 4, it can be seen that sample A has high capsaicin levels. The measurement results from the two tools showed that the difference in capsaicin levels in the sample was statistically not different. The determination of the t-test was carried out to see if the two methods have no significant differences. The calculation of the t- test is carried out in two directions with an interval of 95% confidence and the free degree 8 has a $t_{table} = 2.31$. Based on this table as well, it can be seen that the $t_{statistic}$ value < t_{table}, so it can be concluded that the measurement method of TCS3200 color sensor is as good as UV-Vis spectrophotometer.

CONCLUSION

The study successfully demonstrated the effectiveness of the TCS3200 color sensor, integrated with an Arduino Uno, for measuring capsaicin levels in sauces. Statistical analysis using a two-tailed t-test indicated no significant difference ($p > 0.05$) between the measurements obtained from the TCS3200 color sensor and those from the UV-Vis spectrophotometer. This suggests that the TCS3200 color sensor can serve as a reliable and alternative method for evaluating capsaicin content in food products. Furthermore, the analysis of sauce samples collected from Banda Aceh City showed varying capsaicin levels, with the TCS3200 color sensor recording values between 5.85 and 22.42 mg/L and the UV-Vis spectrophotometer recording values from 5.90 to 22.62 mg/L. These results highlight the potential of the TCS3200 color sensor for practical applications in food quality assessment and monitoring.

REFERENCES

Armbruster, D.A. & Pry, T. 2008. Limit of blank, limit of detection and limit of quantitation. *The Clinical Biochemist Reviews* 29(Suppl 1): S49-52.

Barbero, G.F., Palma, M. & Barroso, C.G. 2006. Determination of capsaicinoids in peppers by microwave-assisted extraction–high-performance liquid chromatography with fluorescence detection. *Analytica Chimica Acta* 578(2): 227-233.

Bhagat, R. & Saudagar, R.B. 2019. A review on analytical method development and validation. *Journal of Drug Delivery and Therapeutics* 9(3): 1064-1067.

Borkar, H., Rambhad, M., Paunikar, K., Karanjikar, A. & Gawai, J.S. 2019. A review on Arduino based color sorting machine. *International Journal for Research in Applied Science & Engineering Technology* 10(II): 43-45.

Chapa-Oliver, A.M. & Mejía-Teniente, L. 2016. Capsaicin: From plants to a cancer- suppressing agent. *Molecules* 21(8): 931.

Chicco, D., Warrens, M.J. & Jurman, G. 2021. The coefficient of determination R-squared is more informative than SMAPE, MAE, MAPE, MSE and RMSE in regression analysis evaluation. *PeerJ Computer Science* 7: 623.

Chung, M-K. & Campbell, J.N. 2016. Use of capsaicin to treat pain: Mechanistic and therapeutic considerations. *Pharmaceuticals* 9(4): 66.

Dewantara, K.S. & Yulkifli. 2020. Use of TCS3200 sensor to identify heavy metal materials. *Pillar of Physics* 13(2): 163-170.

Elechi, J.O.G. & Sule, J.I. 2023. Influence of traditional food processing systems on food safety, chemical compositions, and functional properties of pumpkin (*Cucurbita pepo* L) seed flour. *Journal of Nutrition and Food Security* 8(2): 246-256.

Farwah, S., Hussain, K., Rizvi, S., Hussain, S.M., Rashid, M. & Saleem, S. 2020. Genetic variability, heritability and genetic advance studies in chili (*Capsicum annuum* L.) genotypes. *International Journal of Chemical Studies* 8(3): 1328-1331.

Friedman, J.R., Nolan, N.A., Brown, K.C., Miles, S.L., Akers, A.T., Colclough, K.W., Seidler, J.M., Rimoldi, J.M., Valentovic, M.A. & Dasgupta, P. 2018. Anticancer activity of natural and synthetic capsaicin analogs. *Journal of Pharmacology and Experimental Therapeutics* 364(3): 462-473.

Ismail, R., Lee, H.Y., Mahyudin, N.A. & Abu Bakar, F. 2014. Linearity study on detection and quantification limits for the determination of avermectins using linear regression. *Journal of Food and Drug Analysis* 22(4): 407-412.

Juliano, A., Hendrawan, A.H. & Ritzkal, R. 2020. Information system prototyping of strawberry maturity stages using Arduino uno and TCS3200. *Journal of Robotics and Control* 1(3): 86-91.

Lafz, S. & Amini, Z. 2023. Food security of the elderly during COVID-19 pandemic. *Journal of Nutrition and Food Security* 8(3): 376-382.

Lu, Y. & Cui, B. 2019. Extraction and purification of capsaicin from capsicum oleoresin using a combination of tunable aqueous polymer-phase impregnated resin (TAPPIR) extraction and chromatography technology. *Molecules* 24(21): 3956.

Maslukhah, Y., Faridah, D. & Lioe, H. 2019. Validation of analytical method for quantification of egg cholesterol using reversed phase-high performance liquid chromatography-multiwavelength detector. *Tropical Animal Science Journal* 42(3): 230-236.

Maula, N.M., Muhaimin, M. & Millasari, M. 2020. Determination of pungency level and capsaicin concentration in sauce using UV-visible spectrophotometry. *AIP Conference Proceedings*. 2229: 030015.

Mayerhöfer, T.G., Pipa, A.V. & Popp, J. 2019. Beer's law-why integrated absorbance depends linearly on concentration. *ChemPhysChem*. 20(21): 2748-2753.

Merritt, J.C., Richbart, S.D., Moles, E.G., Cox, A.J., Brown, K.C., Miles, S.L., Finch, P.T., Hess, J.A., Tirona, M.T., Valentovic, M.A. & Dasgupta, P. 2022. Anti-cancer activity of sustained release capsaicin formulations. *Pharmacology & Therapeutics* 238: 108177.

Pacheco, M.A.L., Rojas, J.J.B., Castro-Ramos, J., Manríquez, J.F.V. & Esmonde-White, K. 2021. Optical study to identify and quantify capsaicin in optical window. *Heliyon* 7(3): e05797.

Passos, M.L. & Saraiva, M.L.M. 2019. Detection in UV-visible spectrophotometry: Detectors, detection systems, and detection strategies. *Measurement* 135: 896-904.

Prabowo, S., Sutrisno, C.K.U., Candra, K.P., Rahmadi, A. & Yuliani, Y. 2023. Colorimeter design for dry food-products inspection using tcs3200 sensor and Arduino mega-2560. *Advances in Food Science, Sustainable Agriculture and Agroindustrial Engineering* 6(2): 134-141.

Prayitno, A.H., Meswari, R. & Diauddin, M. 2020. The study of chemical contents, daily values, and microbiology of chicken chili sauce. *Canrea Journal: Food Technology, Nutritions, and Culinary Journal* 3(1): 49-56.

Rezazadeh, A., Hamishehkar, H., Ehsani, A., Ghasempour, Z. & Kia, E.M. 2023. Applications of capsaicin in food industry: Functionality, utilization and stabilization. *Critical Reviews in Food Science and Nutrition* 63(19): 4009-4025.

Rohaeti, E., Muzayanah, K., Septaningsih, D.A. & Rafi, M. 2019. Fast analytical method for authentication of chili powder from synthetic dyes using UV-vis spectroscopy in combination with chemometrics. *Indonesian Journal of Chemistry* 19(3): 668-674.

Sahid, Z.D., Syukur, M. & Maharijaya, A. 2020. Diversity of capsaicin content, quantitative, and yield components in chili (*Capsicum annuum*) genotypes and their F1 hybrid. *Biodiversitas Journal of Biological Diversity* 21(5): 2251-2257.

Siregar, I.M., Siagian, N.F. & Siregar, V.M.M. 2022. A design of an electric light control device using Arduino uno microcontroller-based short message service. *Internet of Things and Artificial Intelligence Journal* 2(2): 98-110.

Soleh, A., Saisahas, K., Promsuwan, K., Thavarungkul, P., Kanatharana, P. & Limbut, W. 2020. N-doped graphene nanoplatelets for direct capsaicin detection in chili pepper samples. *ACS Applied Nano Materials* 3(10): 10094-10104.

Surbakti, M.S., Farhan, M., Zakaria, Muhammad Isa, Sufriadi, E., Alva, S., Yusibani, E., Heliawati, L., Iqhrammullah, M. & Suhud, K. 2022. Development of Arduino uno-based TCS3200 color sensor and its application on the determination of rhodamine B level in syrup. *Indonesian Journal of Chemistry* 22(3): 630-640.

Thangabalan, B., Kahsay, G. & Eticha, T. 2018. Development and validation of a high-performance liquid chromatographic method for the determination of cinitapride in human plasma. *Journal of Analytical Methods in Chemistry* 2018: 8280762.

Tobolka, A., Škorpilová, T., Dvořáková, Z., Cusimamani, E.F. & Rajchl, A. 2021. Determination of capsaicin in hot peppers (*Capsicum* spp.) by direct analysis in real time (DART) method. *Journal of Food Composition and Analysis* 103: 104074.

Wang, M., Gao, B., Xing, Y. & Xiong, X. 2020. Preparation of an electrochemical sensor based on multi-walled carbon nanotubes/molecularly imprinted polymers for the detection of capsaicin in gutter oil by differential pulse voltammetry. *International Journal of Electrochemical Science* 15(9): 8437-8449.

Wang, X., Wang, K. & Liang, R. 2024. Environmentally friendly anti-biofouling polymeric membrane potentiometric sensors based on imprinted receptors. *International Journal of Electrochemical Science* 19(5): 100564.

Yudhana, A., Septiyani, R., Mufandi, I., Rosyady, P.A., Husein, M.F. & Abdullatif, L.I.M. 2022. A portable device based on an electrical conductivity sensor for the detection of monosodium glutamate (MSG) in soupy foods. *Instrumentation Mesure Metrologie* 21(3): 119-126.

Zhang, S., Wang, D., Huang, J., Hu, Y. & Xu, Y. 2020. Application of capsaicin as a potential new therapeutic drug in human cancers. *Journal of Clinical Pharmacy and Therapeutics* 45(1): 16-28.

*Corresponding author; email: khairi@usk.ac.id