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Design and Development of a Borax Detection Device in Packaged Bread Using TCS3200 Color Sensor for Halal Product Verification

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ABSTRACT

Borax is a hazardous chemical additive that is still occasionally found in food products such as packaged bread. Prolonged consumption of borax can cause serious health risks, including cancer, nerve damage, genetic mutations, and birth defects. From a halal perspective, borax is considered haram (forbidden) due to its harmful nature and lack of health benefits, making its presence in food a violation of halal principles. Ensuring the halal and *thayyib* (wholesome) status of food products is crucial for Muslim consumers, and this includes the absence of harmful or toxic substances. This study aims to design and test a device for detecting the presence of borax in packaged bread using a TCS3200 color sensor integrated with an Arduino Uno R3 microcontroller. The working principle is based on the change in RGB values of a sample after being treated with a borax detection reagent. The device measures the RGB values to identify possible borax contamination. Experimental results showed an increase in RGB values from the first to the fifth drop of borax, followed by a decrease from the sixth to the tenth drop. These inconsistencies were influenced by several factors, including sample characteristics, surface area, ambient light intensity, and the distance between the sensor and the object. In conclusion, the prototype device has not yet achieved consistent and reliable borax detection performance. Further improvements are needed, particularly in sensor calibration, lighting control, and signal stability. However, this tool shows promising potential to be developed into a practical, low-cost, and user-friendly system that not only enhances food safety but also supports halal assurance systems by enabling early detection of non-halal contaminants such as borax in food products.

Keywords:
Arduino Uno; Borax detection; Halal assurance; Packaged bread; TCS3200 Sensor.

Introduction

Improving public health is a crucial factor in Indonesia's national development, and one key element is the quality of daily food consumption (Widayat, 2011). However, economic difficulties have led some food producers to commit fraud by adding harmful synthetic chemicals to food products. According to the Indonesian Food and Drug Authority (BPOM), commonly adulterated foods include salted fish, meatballs, crackers, and fresh noodles (Pandie et al., n.d.). One popular food product among consumers today is packaged bread (Hardiana. Safrida, Y. D. Adriana, A. Raihanaton. Maulidda, 2020). Unfortunately, many people are unaware that packaged bread may also contain synthetic additives, one of which is borax (Sari, N.K. Wahyuni, A. Ayucecharia, 2018). The reason is that borax can make packaged bread last longer and prevent it from becoming moldy quickly (Ginting, 2016).

Borax (Sodium Tetraborate Decahydrate/$Na_2B_4O_7 \cdot 10H_2O$) is a compound derived from the heavy metal boron (Shofi, 2017; Mudzkirah, 2016), often used to prolong shelf life and prevent mold growth in food products (Tubagus & Citraningtyas, 2013). In industrial applications, borax is commonly found as a preservative in wood, an insecticide, detergent additive, antifungal agent, and antiseptic in cosmetics (Gilang et al., 2019).

Although small amounts of borax may act as microbial inhibitors, continuous or excessive consumption is highly dangerous. Borax can cause acute symptoms such as nausea, vomiting, headache, hypothermia, and shock (USDA, 2006). Long-term exposure may lead to cancer, kidney failure, brain damage, fertility issues, and even death, with lethal doses at 15–25 grams for adults and 5–6 grams for children (Saputra et al., 2019). Moreover, foods containing borax look nearly identical to safe foods, making them difficult to distinguish visually (Yulianto, 2013). From a halal perspective, the use of borax in food is prohibited (haram). According to the Indonesian Council of Ulama (MUI), borax is classified as a harmful and toxic substance, with no health benefit, thus violating the Islamic principle of halalan ṭayyiban, which requires food to be not only lawful but also wholesome and safe for consumption (MUI, 2021). Currently, borax detection is mostly limited to laboratory testing, which is impractical for everyday use (Hasibuan & Effendi, 2019). Therefore, there is a need to develop a simple, affordable, and user-friendly detection tool for public use. Previous studies include those by Kusumafikri et al., who used resistance sensors (Gilang et al., 2019), and by Utari and Iwanto, who developed a color sensor-based detection system for meatballs using TCS3200 (Utari, 2015)(Iwanto, S. Dedi, 2015). TCS3200 works by reading color spectra and converting them into digital RGB values. In this study, we propose a borax detection tool for packaged bread using a TCS3200 color sensor integrated with an Arduino Uno R3, employing turmeric extract as a reagent. The curcumin in turmeric binds with boric acid to form a distinct color complex (Hartati, 2017). This tool is expected to enable the public to detect borax contamination in food conveniently while also supporting the assurance of halal and safe food products.

Methods

a. Device and Material Design

The design process consists of two main components: hardware design and software development. The hardware includes a set of electronic circuits used to detect borax levels in packaged bread, comprising an Arduino Uno R3, TCS3200 color sensor, wires, circuit holder, cardboard, and black duct tape. The software involves a C-based program implemented on the Arduino Uno R3, which functions to control the device's operation and display RGB values.
The system is designed to detect the presence of borax in packaged bread samples based on the RGB output values generated by the color sensor. The sensor reads the RGB values from samples that have been treated with turmeric and borax solution. The design schematic of the detection system is shown in Figure 1.

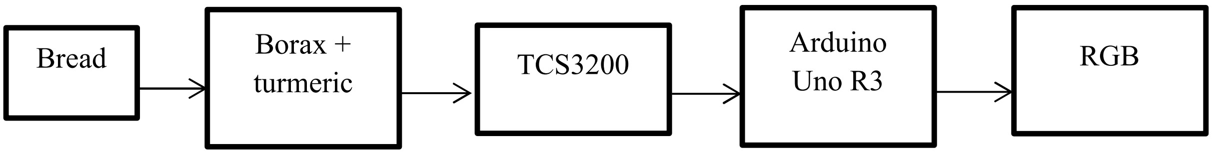

Figure 1. Device Design Diagram

The working principle of the device is as follows: the TCS3200 color sensor is positioned facing the test sample so that the color frequency of the sample can be captured by the sensor. The sensor's output is then input to the Arduino Uno R3, which is connected to the Arduino IDE software to display the digital data. Through the Arduino IDE monitor, the RGB values of each sample are displayed. These RGB data are then analyzed to determine the accuracy of the device in detecting the borax content in the tested food samples.

b. Sample Preparation and Testing

Several steps were undertaken to evaluate the borax detection performance in packaged bread samples. The concentrations of the substances used in the preparation and testing of the samples are as follows:

- Borax solution: 50%
- Turmeric solution: 16%
- Sample weight: 0.1 gram

The proportion for a single test is as follows:

The ratio of turmeric solution to borax solution is 0.2 : 0.03. A 0.1-gram sample is mixed with 0.2 mL of turmeric solution. In the first drop, 0.03 mL of borax solution is added; in the second drop, an additional 0.03 mL is added, and so on up to the tenth drop.

The first step is testing pure borax mixed with turmeric solution. The resulting data serve as the standard reference for determining borax levels in the samples. The second step involves testing bread samples mixed with turmeric and borax solutions. The data from this step are used to analyze the accuracy of the detection device in identifying borax levels in food samples.

Results and Discussions

In the sample testing using the TCS3200 color sensor, spatial dimensions, the distance between the sensor and the object, as well as exposure time, significantly affect the results. According to a study by Sitti Faizia Athifa on the evaluation of the RGB value detection characteristics of the TCS3200 sensor based on distance and object dimensions, it was found that the greater the distance between the sensor and the object, the higher the resulting RGB values. This is due to the influence of external light intensity on the sensor. Conversely, the larger the spatial dimensions of the object area (with the object height remaining constant), the lower the RGB values obtained (Athifa & Rachmat, 2019). In this study, the testing space was a cylindrical, open-top container with a diameter of 30 mm and a height of 10 mm. The distance between the sensor and the object was fixed at 50 mm throughout the experiment.

Table 1. RGB analysis data of pure borax and turmeric solution samples

No	Sample	RGB Value Measurement Using the TCS3200 Sensor										
		RGB	1st drop	2nd drop	3rd drop	4th drop	5th drop	6th drop	7th drop	8th drop	9th drop	10th drop
1	Borax	R	114	133	155	157	159	149	148	137	146	144
		G	165	175	176	189	185	183	179	174	171	165
		B	145	150	153	156	155	151	143	139	133	131

Based on the data presented in Table 1, it can be observed that from the first to the fifth drop of borax solution, there is an increase in the RGB values. In contrast, Table 2 shows a decrease in RGB values from the sixth to the tenth drop. The lowest RGB values were recorded in the first drop, with R = 114, G = 165, and B = 145. The highest RGB values were observed at the fifth drop, with R = 159, G = 185, and B = 155. However, from the sixth to the tenth drop, the RGB values declined. This decline is attributed to the excessive addition of borax solution, which diluted the mixture and reduced color intensity.

It is important to note that the composition of the food sample and turmeric solution remained constant throughout the test; only the concentration of the borax solution was incrementally increased at each stage of data collection. Each RGB value has an optimal detection range that corresponds to the distance between the sensor and the sample (A. Artiana, K. Galuh Gondo, 2020). Initially, the height of the test solution was the same, but with each successive drop, the volume of the solution increased, thereby altering the sensor's distance from the sample surface. This change in distance affected the RGB values, leading to fluctuations that do not consistently follow an upward trend. The collected RGB data serve as a reference for determining the increase in borax content in the tested food samples.

Table 2. RGB Analysis Data of Pure Borax Solution, Turmeric Solution, and Test Samples

No	Sample	RGB Value Measurement Using the TCS3200 Sensor										
		RGB	1st drop	2nd drop	3rd drop	4th drop	5th drop	6th drop	7th drop	8th drop	9th drop	10th drop
1	Sample A	R	121	129	128	146	143	145	147	147	145	143
		G	107	170	163	189	183	184	189	189	187	185
		B	153	143	135	159	153	152	156	156	155	141
2	Sample B	R	114	136	155	133	124	131	150	135	153	157
		G	168	189	217	172	154	165	200	172	203	215
		B	145	158	175	137	118	128	159	136	161	167
3	Sample C	R	114	130	129	125	136	135	140	147	129	117
		G	163	175	172	159	175	173	177	196	162	140
		B	147	148	142	125	139	136	139	155	125	104

In Table 2 above, it is evident that the changes in RGB values are not entirely linear. Several factors influenced the data obtained during the experiment. First, the base color of the food sample significantly affects RGB variation at each testing stage. According to a study by Anin Artiana et al., regarding the use of turmeric extract as a natural indicator for detecting borax in wet noodles, the curcumin content in turmeric can break down the chemical bonds in borax, causing the sample to turn brick-red upon the addition of turmeric extract (A. Artiana, K. Galuh Gondo, 2020). If the base color of the sample is not white, the change in RGB values will differ significantly. Second, light intensity in the testing environment greatly affects the RGB output. Even a small gap allowing light to reach the sensor can result in RGB values that are higher than expected. Third, sedimentation in the solutions also played a role. Both turmeric and borax solutions tended to settle quickly. This means that while the initial samples yielded accurate readings, over time, only the residual sediments from either solution remained, even though the solutions were stirred prior to each test. Consequently, in later tests, the solutions appeared clearer, affecting the sensor's ability to detect color accurately. Fourth, the texture of the food sample varied even among samples of the same type. This caused differences in how the samples absorbed the solution, thus affecting the RGB readings. Percentage values can only be calculated if a standard reference value has been established. However, in this study, each sample produced distinct RGB values, due to its unique characteristics. This variability also affected the even mixing of the added borax with the existing solution. Moreover, the testing device itself has not yet been validated against national standards. Based on the literature, there are no existing devices that use nationally standardized equipment as a benchmark for the feasibility of newly developed tools or methods. According to Iwanto et al., in their study on developing a borax detection tool using the TCS3200 sensor, the results obtained were close to the standard RGB values used for comparison, although some discrepancies were observed (Iwanto, S. Dedi, 2015). These findings are consistent with the results of the present study. Therefore, it can be concluded that using the TCS3200 color sensor to determine the exact percentage concentration of borax remains challenging.

Conclusion

Based on the results of this study, it can be concluded that the detection of borax content in packaged bread using the TCS3200 color sensor showed an increase in RGB values from the first to the fifth drop of borax. However, from the sixth to the tenth drop, the RGB values began to decrease. This pattern was influenced by several factors, including the characteristics of the sample, the distance between the sensor and the sample, the surface area of the object, and the intensity of ambient light.

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