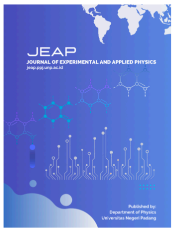
Journal of Experimental and Applied Physics
Journal Homepage: jeap.ppj.unp.ac.id
Vol. 2, No. 3, September 2024.
ISSN (Print): 2988-0378 ISSN (Online): 2987-9256



Systematic Literature Review of TCS34725 Sensor Applications in Various Fields

Widya Anisa*, Mona Berlian Sari, Yohandri, Asrizal

[1] *Department of Physics, Universitas Negeri Padang, Padang 25131, Indonesia*

Article History
Received : Dec, 16th 2024
Revised : Dec, 25th 2024
Accepted : Dec, 31st 2024
Published : Dec, 31st 2024

DOI:
https://doi.org/10.24036/jeap.v2i3.83

Corresponding Author
*Author Name: Widya Anisa
Email: widya.anisa1471@gmail.com

Abstract: The TCS34725 sensor, recognized for its precise color detection across the visible spectrum, is essential in agriculture, food safety, healthcare, security, and industry. As automation advances, reliable color detection systems are crucial for replacing subjective and inconsistent manual assessments. However, challenges such as varying lighting conditions and the need for advanced data processing techniques impact its accuracy and integration. Enhanced algorithms and machine learning applications enable real-time analysis, reducing human error and ensuring reliable results. The sensor's versatility supports applications such as monitoring crop ripeness, detecting harmful substances in food, and aiding medical diagnostics like urine analysis. This study conducts a systematic literature review to explore trends, advancements, and gaps in the sensor's applications. Findings emphasize its role in advancing Industry 4.0 by digitizing processes, fostering sustainable innovations, and improving operational efficiency, reliability, and quality of life.

Keywords: Applications, Color Detection, Light, Microcontroller, and TCS34725 Sensor

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1. Introduction

The light wave spectrum encompasses various wavelengths, ranging from visible light to invisible spectra such as infrared (IR) and ultraviolet (UV) [1]. In many fields, the ability to detect and analyze the light wave spectrum is crucial for understanding optical phenomena and their applications [2]. Advances in light spectrum detector technology have contributed to modern life, including the development of imaging software, solar energy technologies, and energy-efficient lighting. By understanding and utilizing the light spectrum, we can address global challenges such as energy demands, environmental sustainability, and human health [3]. One such sensor specifically designed to detect the light spectrum is the TCS34725 sensor.

The TCS34725 sensor is a color sensor capable of detecting the visible color spectrum with high accuracy. The integration of this sensor into various systems facilitates the collection of

How to cite:
W. Anisa, M.B. Sari, Yohandri, and Asrizal, 2024, Systematic Literature Review of TCS34725 Sensor Applications in Various Fields, *Journal of Experimental and Applied Physics,* Vol.2, No.3*,* page 105-119.
https://doi.org/10.24036/jeap.v2i3.83

accurate and real-time data [4]. It is equipped with an RGB (Red, Green, Blue) filter and an infrared light sensor, enabling it to measure light intensity under various lighting conditions [5]. The TCS34725 uses an I2C interface, which simplifies its integration with various microcontrollers and development platforms such as Arduino, NodeMCU ESP32, and Raspberry Pi [6]. The wide applications of the TCS34725 demonstrate its potential in supporting technological innovation, particularly in collecting and processing color data for more precise decision-making.

In the era of Industry 4.0, color sensors like the TCS34725 play a vital role in supporting process automation and digitization. With the advancement of technology, the TCS34725 sensor has been increasingly applied across various fields, including image processing [7], robotics [8], color recognition systems [9], light intensity measurement [10], and other industrial applications. The widespread adoption of TCS34725 in these applications underscores the need to understand and evaluate existing literature, providing new insights for developing more innovative and efficient solutions. This sensor offers several advantages, such as precise measurement of color and light intensity, fast response, and relatively low cost compared to other color and light sensing technologies [11].

In the security field, which often relies on human effort for monitoring, inspection, or object identification, numerous challenges arise, such as physical fatigue, inconsistencies in decision-making, and limitations in processing large volumes of visual data [12]. As a solution to these limitations, color sensors like the TCS34725 have been introduced as an alternative technology capable of detecting and analyzing color and light intensity with high accuracy. The TCS34725 holds significant potential in security applications, including object detection based on color, document authenticity verification, and automated surveillance for detecting visual anomalies in high-risk environments.

In the food sector, manual testing by humans remains a traditional method widely used for food processing and quality control. Manual testing often involves visual assessment by human operators, which, while offering advantages such as flexibility and subjective interpretation capabilities, has several drawbacks, including limited consistency, speed, and potential for subjective bias. The primary challenge of manual methods lies in maintaining consistent quality standards on a large scale, particularly as production volumes increase [13]. Sensors like the TCS34725 provide an automation solution that reduces reliance on manual supervision, minimizes human error, and enables real-time analysis with more objective data.

Technology in healthcare is rapidly evolving to support more accurate, faster, and efficient diagnosis and decision-making processes. Manual procedures performed by humans often require specialized skills, are time-consuming, and are prone to subjective errors [14]. For example, interpreting test results based on color changes in reagents can vary from one operator to another. In healthcare, color measurement is widely used in various procedures, such as blood analysis, urine tests, or skin condition assessments. TCS34725-based technology offers advantages, including more consistent accuracy and the ability to operate automatically without depending on individual expertise.

The use of human labor in industrial settings does have some advantages, such as flexibility and the ability to handle complex situational variations. However, this method is often limited by speed, accuracy, and the potential for errors due to human factors. For instance, in processes like product sorting based on color, human workers may struggle to maintain consistency and speed over extended periods [15]. The implementation of TCS34725 in industrial systems offers numerous benefits, particularly in processes such as automated sorting, quality control, and integration with robotics. For example, this sensor enables consistent color-based product sorting in industries like food or textiles, ensuring products meet specific color specifications during production.

In agriculture, processes that still rely on manual methods are prone to human error, resource limitations, and inconsistent outcomes [16]. One of the biggest challenges in agriculture is optimizing processes such as crop monitoring, determining the appropriate planting and harvesting times, and real-time monitoring of plant health. The TCS34725 sensor enables more precise light measurement, which can be applied to identifying plant health, soil moisture, or plant nutrient needs.

Although the TCS34725 sensor offers many advantages, challenges in its use still exist [17]. For instance, suboptimal lighting conditions can affect the accuracy of color measurements. Therefore, further research is needed to improve data processing algorithms generated by this sensor to overcome such limitations. A literature review on the applications of the TCS34725 sensor across various fields is essential to understand current trends and developments in sensor technology. By collecting and analyzing existing research, we can identify research gaps that need to be addressed and explore new applications of this sensor.

In this journal, we will present a comprehensive literature review of the applications of the TCS34725 sensor, discussing its uses across various fields, the challenges faced, and potential directions for future research. With a solid knowledge base on the applications of the TCS34725 sensor, researchers and practitioners can design innovative solutions that leverage this technology. This will not only accelerate the adoption of the technology across various sectors but also contribute to improving quality of life and enhancing the efficiency of industrial processes.

2. Materials and Method

The review method used in this article is a systematic literature review. The type of validation employed is mapping validation. This literature review process was conducted to identify and evaluate relevant research on the applications of the TCS34725 sensor across various fields, using a systematic and transparent approach, and to analyze and synthesize the data obtained. The search for literature review articles was conducted on November 15, 2024. The database used for the article search was Google Scholar, allowing for comprehensive information retrieval on the use of the sensor in modern technology to enhance efficiency and innovation across various sectors. The stages of the search selection process are explained in Figure 1.

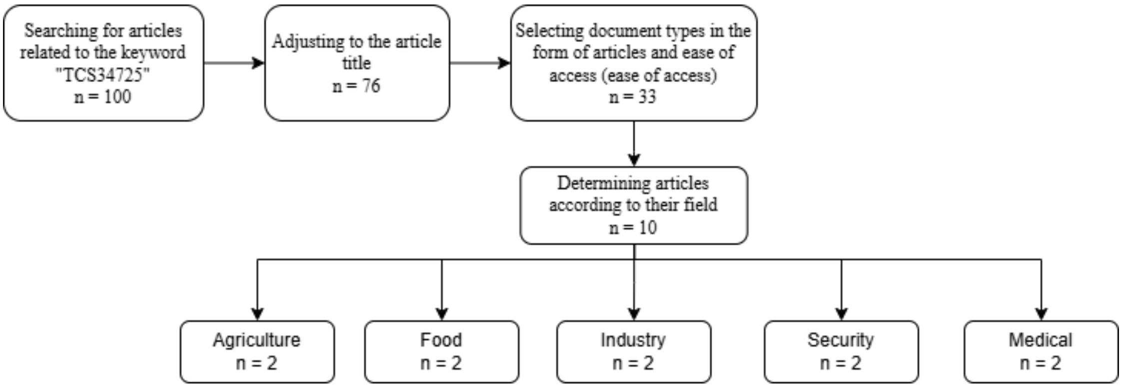

Figure 1. Literature Search Stages

Figure 1 illustrates the stages of the literature review process. The initial selection phase began with a search for articles using the keyword "TCS34725" through the Google Scholar database via the Publish or Perish software, yielding 100 sources. From this total, an initial screening was conducted to identify relevant articles, resulting in 76 articles. These articles were then analyzed based on their titles, keywords, and abstracts to ensure alignment with the research topic, narrowing the selection to 33 articles. Further screening was conducted to group articles relevant to fields that contribute to improving the quality of human life. The final selection process identified 10 articles evenly distributed across five fields, with two articles representing each field. The list of the 10 selected articles used in this review is presented in Table 1.

Table 1. List of Selected Review Articles

No.	Researcher	Field	Method
1	Luthfi, et.al	Agriculture	The agricultural sector for chili planting has developed a tool to classify the ripeness and quality of large red chili peppers (Capsicum annuum L.) using the TCS34725 sensor. This study found that the ripeness of the chili peppers could be determined by converting RGB values into YCbCr, and it also showed that the vitamin C content in the peppers increased with ripeness. The system aims to reduce damage and loss of chilies through image processing technology by photographing the chilies using a smartphone and analyzing color data to determine their ripeness level. The advantages of this research include the use of smartphones as research tools, offering practicality and accessibility, while the Color Grab application facilitates color conversion for analyzing chili ripeness. Image processing provides more accurate results compared to manual observation, and the iodimetric titration method effectively measures vitamin C content. However, the measurements may be influenced by inconsistent lighting conditions and the varying quality of smartphone cameras. Additionally, the Color Grab application might lack accuracy under certain conditions, and users require

			technical knowledge to ensure optimal measurement results.
2	Aisyah, et.al	Agriculture	A fermenter machine to improve the effectiveness of Liquid Organic Fertilizer (LOF) production for farmer groups in Gucialit Village. This study uses the TCS34725 sensor to monitor color changes in LOF during the fermentation process. The color change can be an important indicator of the quality of the organic fertilizer produced. For example, darker or richer color in the LOF could indicate a more effective fermentation process, while lighter color might suggest that the process is not yet fully completed. The advantages of this research include the use of an automated fermenter system equipped with temperature and pH control, enabling efficient and consistent POC production. This technology accelerates production by 7 days compared to conventional methods, with integrated sensors (DS18B20 for temperature, pH sensor, and TCS34725 for color monitoring) ensuring high-quality results. Remote monitoring via LCD and smartphones adds convenience, while promoting sustainable agriculture by encouraging the use of eco-friendly organic fertilizers. However, the system's complexity requires technical expertise, and its reliance on electricity may pose challenges in remote areas. Additionally, the initial investment and routine maintenance of sensors and controls are necessary for optimal performance.
3	Gusfita, et.al	Food	An effective detection device for identifying formalin contamination in food, a preservative harmful to health, has been developed. The device, named the Bolin Detector, uses the TCS34725 color sensor and can be operated via an Android phone, making it easily accessible to the general public. According to the research results, the device demonstrated a detection accuracy of 99% for chicken and beef samples contaminated with formalin. Test results show that the Bolin Detector can effectively distinguish between contaminated and non-contaminated food samples. This research presents a low-cost device for detecting formalin in food, offering quick and accurate results with 99% precision. Equipped with the TCS34725 color sensor, it easily identifies contamination through color changes and can be operated via a smartphone application, enhancing user accessibility. While the tool is efficient, its accuracy relies on the sensor's performance,

			and natural food color variations may affect results. Additionally, the device is specifically designed for formalin detection and requires periodic calibration to maintain reliability. Despite these limitations, the tool provides an affordable and user-friendly alternative to traditional laboratory methods.
4	Lorenzo, et.al	Food	In the oil industry, the use of the affordable TCS34725 RGB color sensor to identify vegetable oil mixtures in avocados has been developed. This system is designed to distinguish avocado oil from its mixtures with canola oil, sunflower oil, corn oil, olive oil, and soybean oil. The system makes a significant contribution to the development of more affordable and efficient oil analysis methods. These findings are important for the food industry to ensure the quality and authenticity of vegetable oil products. This research highlights the practicality and affordability of using the TCS34725 sensor for color analysis, offering real-time measurements without the need for complex sample preparation. Its compact size and versatility under various lighting conditions make it suitable for field applications and accessible to a wider audience. However, the accuracy of the results may vary depending on lighting intensity and environmental factors such as temperature and humidity. Additionally, the sensor has limitations in distinguishing complex color variations and may not meet the resolution requirements of more advanced applications. Despite these challenges, this approach provides an efficient and cost-effective method for color-based analysis.
5	Amalia, et.al	Security	A nominal detection system for banknotes based on an artificial neural network for visually impaired individuals using the TCS34725 detector. Money plays a crucial role as a medium of exchange, and individuals with visual impairments face challenges when conducting transactions. The development of this tool helps the visually impaired recognize banknotes, reducing the risk of errors in transactions. The research examines the implementation and performance of an artificial neural network (ANN) in detecting banknote denominations for the visually impaired using RGB values. The method applied is backpropagation, with an average accuracy of 88% in detecting various denominations. Test results show that the tool can effectively detect banknote denominations. However, some challenges remain, such as the impact of lighting and the similarity in colors between denominations, which may lead to detection errors.

			This research highlights the benefits of using an affordable and compact system for color-based analysis, offering good accuracy in differentiating similar colors, such as those found on banknotes. The system's ease of integration with microcontrollers like Arduino makes it a practical choice for portable and user-friendly applications. It can function under various lighting conditions, although external lighting can influence its performance. However, the system has limitations, such as difficulty distinguishing between very similar colors, which can lead to misidentifications, especially in currency validation. Additionally, the system's resolution may not be sufficient for applications requiring high-detail color recognition, and regular calibration is needed to ensure optimal results.
6	Maulana, et.al	Security	An automated storage system based on SCADA using the CP1H and CP1L PLCs to improve warehouse process efficiency. In this research, the TCS34725 color sensor plays a crucial role in identifying the color of boxes to be stored. The use of this sensor enables the system to accurately classify objects based on color, which is a critical step in the automated storage process. Test results show that the TCS34725 sensor provides stable and consistent output values in detecting colors, especially for red and yellow. This research demonstrates the advantages of using a highly accurate and stable system for color detection, which is crucial for identifying different objects in automated storage systems. The system's ability to integrate seamlessly with microcontroller-based platforms like PLCs and Arduino makes it ideal for efficient prototype development. It performs well under varying lighting conditions, though periodic calibration is necessary to achieve optimal results. The compact design of the system is well-suited for automation applications where space is limited. However, the research highlights challenges such as sensitivity to lighting variations, difficulty in distinguishing very similar colors, and the need for regular maintenance to prevent performance degradation due to environmental factors.
7	Khasanah, et.al	Health	Development of an infusion monitoring device based on NodeMCU ESP8266 to improve efficiency and safety in monitoring patient infusion conditions. One of the components used is the TCS34725 sensor to detect an increase in blood levels in the infusion flow. This sensor works by measuring color changes and providing real-time information to nurses, allowing them to anticipate issues before they occur. The use of the TCS34725 in this system

			demonstrates the integration of advanced technology in healthcare, aiming to reduce human errors in infusion monitoring and enhance patient safety. The research results show that this device is effective in providing early warnings, enabling better management of infusions. The advantage of the automated infusion monitoring system is that it reduces the risk of human error by nurses. Using IoT technology with the NodeMCU ESP8266, the device allows for remote monitoring, while the IR obstacle sensor ensures accurate detection of the infusion drip rate. The system is equipped with alarms, such as a buzzer and LED indicators, to alert nurses when the infusion liquid is running low. However, the system's performance heavily relies on the accuracy of the IR sensor, which can be affected by environmental factors like surrounding light. Further development is needed to add features such as app control, and the initial setup may pose challenges for users unfamiliar with this technology.
8	Chidera, et.al	Health	The use of color sensors shows great potential in medical applications, especially in the early detection of kidney diseases. Urine analysis can be identified using the TCS34725 sensor to detect color changes that indicate specific health conditions, such as the presence of albumin or dehydration. The TCS34725 measures the color of urine by detecting the intensity of light reflected from the sample. This sensor uses four photodiodes to measure the red, green, blue, and clear (transparent) components of color. By measuring the proportion of reflected light, the sensor can provide information about the color of the urine, which can indicate specific health conditions. This research highlights the advantages of using advanced sensor-based tools like TCS3200 and TCS34725, offering higher accuracy compared to human visual analysis. By integrating modern technologies such as color sensors and AI, the system enhances the efficiency and effectiveness of urine color analysis. The sensors enable portability, making the tool convenient for field or hospital use, and allow real-time analysis for quick and relevant diagnostic results. However, the use of advanced sensors increases costs, and environmental factors like lighting conditions may affect accuracy. Additionally, the system's complexity may require user training, and its reliability depends heavily on the quality and functionality of the sensors.
9	Sanwar, et.al	Industry	An automated object sorting system that combines real-time image processing with a robotic gripper mechanism. This study aims to sort objects based on shape and color using a webcam and image processing algorithms

			implemented in the Python programming language. The TCS34725 sensor serves as the main tool in this research to detect object colors with high accuracy. In the Arduino, the image processing algorithm written in Python processes the data to identify object colors in real-time. In this way, the TCS34725 enables the system to quickly and accurately recognize and group objects based on color, supporting the efficient automated sorting process in this robotic system. This research presents a robotic system leveraging Python and OpenCV for efficient real-time image processing and algorithm development. Featuring a 4-DOF robotic gripper, the system offers precise object handling, while a conveyor system streamlines object movement for organized processing. The system's ability to identify objects based on both color and shape enhances its versatility compared to single-parameter systems. However, its performance relies heavily on camera quality, which may struggle in low-light conditions. The implementation requires solid knowledge of programming and robotics, and the system may face challenges in identifying highly similar objects or handling obstructed ones.
10	Fahim, et.al	Industry	This system is designed to identify, separate, and collect objects based on the aforementioned parameters. Using a conveyor belt, the objects will be moved to the collection area after being measured. The process begins with weight measurement using a load cell, followed by color detection by the TCS34725 sensor, and concludes with height measurement. If the object does not meet the specified criteria, it will be directed to the disposal area. This research highlights an automated sorting system that classifies items based on weight, color, and height, significantly reducing reliance on time-consuming and error-prone manual labor. The system achieves high accuracy, with 100% for detecting color and height and nearly 99% for weight. Utilizing modern sensors like the TCS34725 RGB sensor, ultrasonic sensor, and load cell, it enhances sorting precision while improving overall production efficiency. However, the system heavily depends on sensor performance, and any sensor malfunction could disrupt operations. Additionally, while considered low-cost automation, the initial development cost may be higher, and the integration of multiple components adds complexity to programming and operation.

The articles used in this study focus on the application of the TCS34725 sensor in various fields, such as agriculture, food, security, health, and industry. A total of 10 relevant articles were selected based on their relevance and contribution to the development of concepts related to the use of this sensor. To strengthen the literature review, additional references were also explored to support the development of a new conceptual framework related to the application of the TCS34725 sensor. The data collection process involved extracting key information from each article, including the research objectives, methodologies used, and the main results obtained. The collected data was organized systematically to identify the main patterns of TCS34725 sensor application and to compile broader application categories through cross-literature comparative analysis. This approach is expected to provide new insights into the innovative potential of the TCS34725 sensor in various fields of science and technology.

3. Results and Discussion

The TCS34725 sensor technology, which measures RGB and clear color components, has shown great potential in various fields of research and application. In the agricultural sector, this research is crucial as it focuses on developing technologies to enhance efficiency and quality in agriculture and food processing. With increasing demand for high-quality, sustainable products, innovations supporting sustainable farming practices are key to the future of the industry. The study offers solutions for accurately monitoring and controlling organic liquid fertilizer (POC) fermentation, improving product quality and supporting organic farming.research has utilized this sensor to determine the ripeness of large red chili (Capsicum annuum L.) by converting RGB values to YCbCr and linking vitamin C content with the chili's ripeness level [18]. precise color measurement for sorting and grading chili peppers reduces human error, increases efficiency in post-harvest handling, and ensures higher quality products. Overall, this research is vital for advancing technology in agriculture, promoting sustainability, and improving productivity. This technology is expected to reduce post-harvest damage through smartphone-based image processing. Additionally, this sensor is used in fermenter machines to monitor color changes in liquid organic fertilizer (POC) during fermentation [19]. The color changes monitored by this sensor become an important indicator of the quality of the POC.

In the food sector, this research offers a cost-effective, efficient method for detecting adulterated oils and harmful contaminants like formalin, using affordable color sensors. It enables on-site analysis, benefiting small producers and farmers while ensuring quick, accurate results to protect public health and prevent economic losses. The tool empowers consumers to check product safety independently and supports regulatory bodies in enforcing quality standards, making it a vital contribution to food safety, sustainability, and consumer protection. The TCS34725 sensor has been innovatively applied, particularly in the Bolin Detector formalin detection device [20]. This device is capable of detecting the presence of formalin with 99% accuracy on meat samples and is designed to be easily operated via smartphones. Additionally, this sensor is used to analyze the authenticity of vegetable oil mixtures, such as avocado oil mixed with other oils, including canola and olive oils [21]. This technology provides the ability to identify food product quality and authenticity quickly and efficiently. With relatively affordable costs, this system offers practical analytical solutions for the food industry, significantly enhancing product quality control. The application of the TCS34725 sensor not only improves food safety but also supports transparency in the production process, making it a relevant tool to meet consumer demands for high-quality products.

In the security field, this research addresses critical challenges faced by the visually impaired in daily transactions by developing a tool to identify currency, promoting independence and financial confidence. By utilizing Artificial Neural Networks, it introduces advanced technology to improve accuracy and reduce human errors in financial exchanges. Additionally, it supports social inclusion, enabling greater participation in the economy. The TCS34725 sensor has been implemented to support the recognition of banknote denominations for the visually impaired [22]. The study also contributes to the field of automation, enhancing operational efficiency in warehouse management by reducing human error, optimizing storage, and improving security through real-time monitoring. These innovations not only benefit industries by increasing competitiveness but also serve as a foundation for future research in automation and assistive technologies, making the study highly significant for both social and technological advancement. By utilizing an artificial neural network (ANN) and the backpropagation method, this system achieves an average accuracy of 88%. However, challenges such as lighting variations and color similarities between denominations remain obstacles that affect system performance. Furthermore, the TCS34725 sensor has been applied in automated storage systems based on Supervisory Control and Data Acquisition (SCADA) to classify boxes based on color [23]. This technology improves operational efficiency in the warehousing sector through rapid and accurate object grouping. This sensor's application not only speeds up classification processes but also provides effective solutions in logistics management. With its multi-functional capabilities, the TCS34725 sensor proves to have significant potential in supporting the development of AI-based technologies and automation for various industrial needs.

In the healthcare field, this research advances medical diagnostics by leveraging urine color analysis to provide faster, more accurate health insights, reducing reliance on traditional, error-prone visual methods. By integrating sensors, it ensures objective and reliable results, enhancing diagnostic quality and efficiency. The findings hold potential for further innovation, such as smartphone integration for patient self-analysis, improving accessibility and affordability in healthcare. This study is vital for driving progress in health technology, fostering better diagnostic tools, and enabling future research in sensor-based health analysis. The TCS34725 sensor is used to develop an infusion monitoring system based on NodeMCU ESP8266 that can detect changes in blood content in the infusion flow by analyzing color changes [24]. This system provides early warnings to medical personnel, improving patient safety during treatment. Additionally, another study demonstrates the potential of this sensor in early-stage kidney disease detection through urine color analysis [25]. By measuring the light intensity reflected from the urine sample, this sensor can detect health parameters, such as the presence of albumin or signs of dehydration. This technology offers a faster and more practical approach for color-based health monitoring. The application of the TCS34725 sensor in medical applications not only supports the development of innovative diagnostic tools but also provides more affordable solutions to enhance healthcare services, particularly in early detection and preventing complications.

In the industrial sector, the rising demand for fast, accurate mass production emphasizes the value of automated sorting systems. By reducing human error, cutting costs, and ensuring consistent quality, automation aligns with Industry 4.0 trends, enhancing productivity and reducing labor reliance. Integrating image processing with robotics accelerates production while maintaining precision. With broad industrial applications, it drives efficiency, innovation, and competitiveness, making it essential for modern practices. The TCS34725 sensor is applied in an automatic object sorting system to improve manufacturing process efficiency [26]. This system integrates the color sensor with image processing algorithms based on Python, enabling real-time sorting of objects based on color and shape. This technology accelerates classification and grouping processes in production chains. Further research demonstrates the use of this sensor on conveyor belts to support the identification, separation, and grouping of objects based on parameters such as weight, height, and color [27]. With the ability to detect parameters simultaneously, this system supports more precise and efficient production while reducing human errors. The application of the TCS34725 sensor not only enhances automation in the manufacturing sector but also provides flexible and cost-effective solutions to meet the needs of modern industries. This technology highlights its potential in supporting operational optimization across various sectors.

Overall, the TCS34725 sensor demonstrates extraordinary flexibility across various applications, from agriculture, food, health, security, to industry. Its main advantage lies in its ability to detect color with high accuracy, enabling its use in image processing, quality monitoring, and system automation. However, challenges such as lighting influences and accuracy levels under specific environmental conditions still exist [5]. Further research is needed to improve the reliability and scalability of this sensor's application. With its significant contribution across multiple sectors, the TCS34725 sensor is a key technology driving color-based data innovations.

4. Conclusion

This study demonstrates that the TCS34725 sensor has significant potential in various fields, including agriculture, food, security, health, and industry. Its ability to detect color with high accuracy allows for wide applications, ranging from product quality monitoring to process automation. In the agriculture sector, this sensor helps determine fruit ripeness and monitor fertilizer quality, while in the food sector, TCS34725 is effective in detecting contamination and analyzing product authenticity. In the security field, it contributes to recognizing the nominal value of banknotes for the visually impaired, and in health, it is used for infusion monitoring and early disease detection. However, despite offering many advantages, challenges such as the influence of lighting conditions on measurement accuracy still need to be addressed through further research. The development of better data processing algorithms and adjustments to environmental conditions will enhance the reliability of this sensor. Thus, TCS34725 is a key technology that can drive innovation and efficiency across sectors, while contributing positively to quality of life and industrial processes. This study emphasizes the need for further exploration to maximize the application of this sensor on a larger scale.

Acknowledgments

The author would like to express gratitude to the faculty members of the Physics Department at Universitas Negeri Padang, as their work greatly facilitated the search for references for this review journal.

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