BFT water color classification in tilapia aquaculture using computer vision

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ABSTRACT

Biofloc technology (BFT) is one of the most promising aquaculture cultivation methods in the modern aquaculture era because of its high efficiency level, especially in water and fodder use. Usually, the general condition of the biofloc can be known from the color of the water. By utilizing the vision sensor, BFT color identification can be done automatically, which helps cultivators find out their BFT system's condition. In this research, a classification was made for the watercolor of the BFT Tilapia system based on the microbial community color index (MCCI) value and the initial cultivation conditions where algae and nitrifying bacteria had not developed significantly. The color classifications of the bioflocs are clear, green, brown-green, green-brown, and deep-brown. Clear color is the new classification to indicate BFT water conditions in the initial cultivation phase. Further, two computer vision algorithm methods are introduced to classify the color of BFT system water. The first method combines the B/W algorithm and MCCI calculations, while the second algorithm uses the Manhattan distance algorithm approach. From the experiments that have been carried out, both computer vision algorithms methods for classifying biofloc colors have shown promising results.

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1. INTRODUCTION

Aquaculture technology has developed rapidly along with general technological developments in the 21st century. Many techniques have been developed to support aquaculture systems to become more optimal, efficient and minimise environmental destruction [1]. One of the most developed aquaculture technologies is biofloc technology (BFT) which is considered as the new "blue revolution" in aquaculture [2]. Basically, biofloc is an ecological engineering technique that relies on oxygen supply and the highly diverse microbial organisms known as nitrification bacteria which can directly decompose ammonia into organic nitrate compounds [3]-[5]. This principle of biofloc is to convert and balance organic and inorganic compounds consisting of carbon, oxygen, hydrogen and nitrogen into a mass of sludge in the form of biofloc by utilising bacteria [6], [7]. BFT was first introduced in 1970 in crustacean cultivation and has been widely used in various variations of aquaculture [8]. While seen from an economic prespective, BFT can significantly reduce expensive feed costs since the bacterial colonies in this system can become additional feed. Additionally, BFT system operate without needing to replace water, which also significantly lowers costs [9].

In the BFT system, color is proven to have a quite significant influence. Simulation of the use of light (red, green, and blue lights) has an influence on the growth and composition of tilapia [10]. Further, the color of the biofloc water indicates the dissolved content in the culture water, such as microbes and other compounds [11]. Research shows that BFT water color has an important role for fish farmers, especially in estimating the condition of the BFT system and determining actions that should be taken afterwards [12]. It can briefely provides an estimate of the microbial content contained in the cultivation water. Each biofloc color has its meaning and leads to the type of treatment that must be [13]. For example, a color that tends to be green indicates a high algae content, while a color that tends to be deep-brown indicates a relatively high bacterial and floc content in BFT water [14], [15]. To classify this water color in the BFT system, previous study formulated an equation known as the microbial community color index (MCCI) [5]. The MCCI formula extracts the RGB (red, green, and blue) components from the image. Then it calculates the ratio of the colors into an index that describes the dominance of the BFT water content between algae and heterotrophic bacteria [13].

Advance technology can help cultivator maintain even improve product quality, such as the development of advance aquaculture water quality tester and decision support system and the implementation of E-City farm to control fish and plant cultivation parameters in an integrated manner [16], [17]. More, the new sensor technologies embedding image processing software can contribute to a more optimal BFT system [12]. In this study, sensor vision and computer vision technology are used to extract the RGB component from BFT water photos. Several previous research demonstrate that image processing software can evaluate and process image color aspects. This color detection method is employed in a number of applications, from de- tecting variations in skin color to identifying road and traffic signs [18]-[20]. Although vision technology has been employed in a variety of industries, it is rarely used in aquaculture cultivation, particularly biofloc. Pimentel *et al.* [7] in their research, conducted biofloc color detection in shrimp farming to detect water quality based on MCCI calculations. However, this study has some limitations, including the lack of clear color detection in the early stages of BFT cultivation progress. The initial phase of biofloc creation takes about 2-3 weeks, and it is vital to know how quickly the BFT ecosystem forms so that fish farmers can make treatment recommendations for the pond [21]. Image processing is also utilized to check the water quality within an BFT system. A comparable work from Mahmuda *et al.* [22] employed image processing techniques to determine the quality of dissolved oxygen and ammonia levels in water based on color after processing with DO and NH reagents. In our proposed work, we conducted novel computer vision method for BFT water color classification based on the microbial content.

The objective of this study is to classify the color of biofloc water as photos captured by a camera acting as a vision sensor. The classification stretched from the first conditioning phase of BFT aquaculture to the completion of the fish-rearing cultivation phase. Furthermore, the categorized photos will be linked with the interpretation of each of these classifications. The condition of the BFT system can be predicted instantly using novel method by employing a camera to detect the color of the biofloc water, allowing advice and treatment to be supplied to the fish farmers. This prediction provides a comprehensive recommendation on the optimal conditions of BFT ponds, which would be valuable in aiding aquaculture farmers in assessing the water quality of their culture systems.

2. METHOD

2.1. The data collection

Water sample photographs were obtained weekly for 0 week to 9 weeks from twelve tilapia production ponds using the BFT technique. These twelve tilapia ponds were put inside a semi-outdoor area with a roof, which is the topic of the study's data gathering. Each pond has twenty Larasati tilapia fish (a crossbreed of black tilapia and red tilapia). The temperature was maintained between 27.61 °C to 29.92 °C, and the pH was 7.74 to 8.01. Lactobacillus is the bacteria used to develop the BFT system in this reseach.

Biofloc water samples were gathered from the pond and placed in a 20×20×30 cm transparent glass container with a white backdrop. As soon as the water was placed in the glass container, images were taken to document the consistency of the color content in the biofloc water. The photographs were taken with a DSLR camera and a tripod inside a room with low light illumination. The glass container containing the biofloc samples was put within a small studio supplied with LED lights such that the light sources were constant. The camera setup characteristics were calculated, as well as the distance between the camera and the glass container, which was approximately 1 meter. Every piece of data gathered during this method attempted to have consistent shooting setup parameters. Table 1 shows the camera setup settings. After the biofloc sample images were collected, the first step was to limit sample data by adjusting the collected image to obtain the required color area of the biofloc water sample. For further processing, a cropping operation was performed on all the data with a size of 175×175 pixels. Those photos were used as the primary data gathered for this research. The complete workflow of the whole proposed method, from water sampling to estimation for the fish cultivator, is depicted in Figure 1.

Table 1. Camera setup parameter

Parameter	Value
Lens	YN 50 nm
ISO	400
Shutter	1/250
Aperture	1.8
Focus	Manual
White balance	Auto

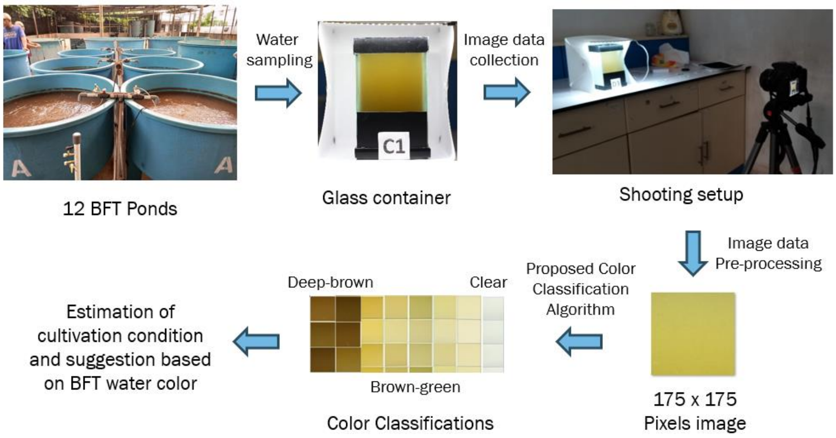


Figure 1. Workflow diagram of the experimental setup for the proposed method

Photos of biofloc solutions for each pond and week are shown in Figure 2. The data images ranged from week 0 to week 9 (W0 to W9) for each pond ID (A1 to D3). There were 12 Tilapia BFT system ponds with IDs A, B, C, and D, where each ID consists of 3 fishponds. In total, 120 data images have been collected for this research.

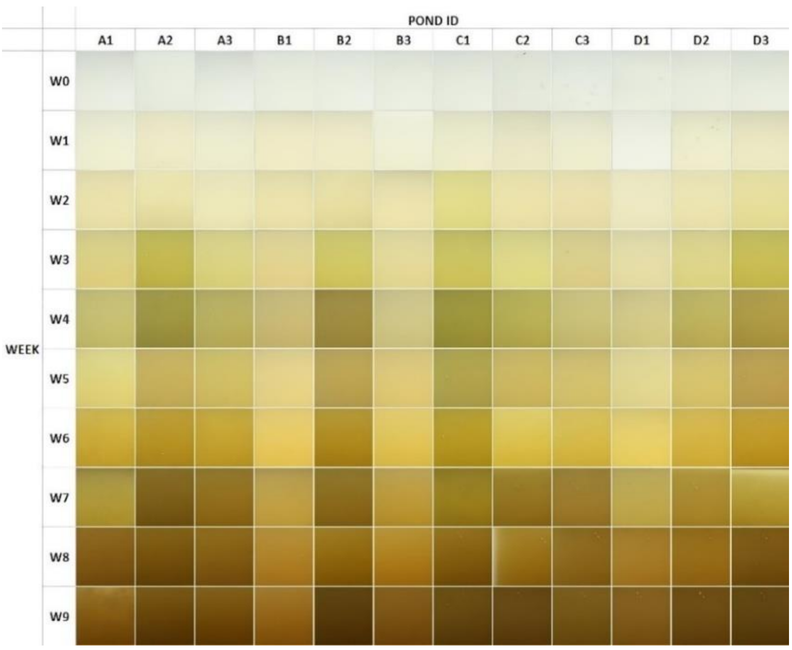


Figure 2. Biofloc water sample information during the upkeep period week 0 (W0) through week 9 (W9)

2.2. MCCI and BFT color interpretation

The MCCI is a color classification method of the BFT system based on the ratio of heterotrophic biomass to autotrophic biomass [5]. This calculation also represents the dominance of algae or bacteria in the cultivation water of the BFT system. It can be seen that if the biofloc cultivation water is green, algae are dominant. Meanwhile, if the color of the biofloc cultivation water tends tobe deep brown, then the cultivation water is dominated by heterotrophs.

The RGB components of the cultivation water picture are extracted to determinethe MCCI value. Image processing tools such as Python-OpenCV can be used to do this computation. These data are then placed into an MCCI equation. Kirk in [5] presents the MCCI algorithm as follows:

$$MCCI = \frac{R-B}{G-B} \tag{1}$$

Where,
- R is red;
- G is green;
- and B is blue.

One of the drawbacks of the MCCI scheme is that the MCCI formula can only detect the color of biofloc cultivation water from green to dark brown [5], [13]. MCCI is unable to identify the clear color of the aquaculture water, where this condition occurred in the early two weeks to three weeks of aquaculture using the BFT system. Monitoring clear watercolor is also important for cultivators to analyze whether the biofloc cultivation water is developing as it should during this period. Based on the references [13], [21], classification for the water cultivation of the BFT system is made and shown in Table 2.

Table 2. The classification of the water cultivation of the BFT system with the meaning and suggestion (based on experienced as reported by [13], [22])

Cultivation water color	Meaning	Suggestion
Clear	– Early phase of biofloc development – Small domination of algae and bacteria	– observe the development of cultivation water within two weeks to three weeks – Possible to lower aerator power (25-30 hp/ha)
Green	– High dominance of algae – Surplus oxygen produced from algae pho- tosynthesis	– check the composition of the floc in the water infrequently (25-50 ml/l for tilapia) – Set the medium aerator power (30-150 hp/ha)
Green-Brown	– Higher dominance of algae, small dominance of bacteria – Floc start to developed	– check the composition of the floc in the water regularly (25-50 ml/l for tilapia) – Set the medium aerator power (30-150 hp/ha)
Brown-Green	– Higher dominance of bacteria, small dominance of algae – Proper concentration of floc in water	– check the composition of the floc in the water regularly (25-50 ml/l for tilapia)
Deep Brown	– High dominance of bacteria – Nearly final phase of the cultivation process – High concentration of floc in water	– High aerator power (150-200 hp/ha) – check the composition of the floc in the water daily (25-50 ml/l for tilapia)

2.3. The color classification

Previous study [5], [13] classify water color based on visual examination and MCCI value analysis. According to these classifications, the MCCI score indicates four color categories: deep brown, brown-green, green-brown, and green. Refer to Table 3, these color groupings were determined based on the MCCI value. Kirk [5] study result serves as the foundation for the MCCI classification value reference, which is then validated by manual visual assessment.

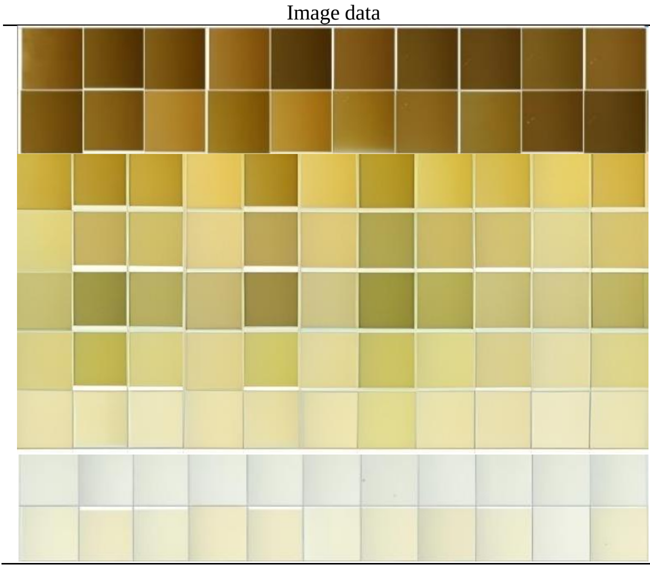
Table 3. MCCI range value for each color classification

Water color	MCCI value
Deep-brown	1.35-1.9
Brown-green	1-1.34
Green-brown	0.75-0.99
Green	<0.75

After nine weeks of images data collection, only two MCCI color groups can be defined, namely brown-green and deep brown. no green and green-brown colors were found. As previously mentioned, semi-outdoor ponds were used in this research. The environmental parameters in aquaculture like this will differ from fully outdoor pond of the same type. Algae development will be affected in the early stages of biofloc pond water conditions when they are not directly exposed to sunlight. In one rearing cycle, there were only slight green preponderances at the beginning of biofloc culture because of less growing algae and lack of direct sunlight.

In this research study, another color classification was added as clear color group because this color appears in the early weeks of cultivation. White color attribute is used for the clear color because the water sample glass container has a white background. Table 4 shows the application of color classification to the data set obtained in the data collection process. In the data collection process, from a total of 120 images, only 102 qualified for the classification process due to lack of image quality. This color classification is used as a reference/ ground truth for data training in the color detection algorithm and calculating the error result.

Table 4. Data set color classification

Image data	Water color
	Deep-brown Brown-green Clear

2.4. The data processing

To construct the biofloc water color detection technique, two computer vision methods are proposed. First is the black and white (B/W) image processing technique combine with MCCI classification formula. The second proposed method is using the manhattan distance algorithm classification approach. These methods are deeply explained as follows.

2.4.1. Method 1: B/W and MCCI classification

The first proposed method consists of two main processes. There were the “clear dataset process”, which was used to detect the clear water images, and the “MCCI dataset process”, which was used to detect the water color based on the MCCI range value. The black-and-white (B/W) algorithm was chosen in the clear dataset process since we used white as a background for the water sample container. White color detection has a similar meaning as clear color. The B/W method has been proven to have quite promising performance. A simple and straightforward binarization procedure to generate black/white comics from the video frame imagewas proposed [23]. The system is decoupled into two processes: region extension and binarization. Further, Fang *et al.* [24] introduced an approach for coloring low-resolution black-and-white old movies through objectunderstanding using OpenCV.

In the first process, the collected water color dataset was processed using the “B/W Algorithm” to distinguish between clear and MCCI water colors. This algorithm used a simple binary thresholding technique in library Python programming. OpenCV’s simple binary thresholding technique can convert an image to black and white. If the pixel value is greater than the threshold value, it is changed to the value of the “max-value” parameter. In binarization, we want the maximum value to be 255, as the pixel value for white or clear color is 255. The threshold used in this method was 127, as recommended in the official OpenCV library.

$$dst(x,y) = \begin{cases} max\,Value & if src(x,y) > T(x,y) \\ 0 & otherwise \end{cases} \quad (2)$$

Where,
- $T(x, y)$: threshold calculated individually for each pixel (adaptive method parameter);
- *src*: source 8-bit single-channel image;
- *dst* (x, y): destination image of the same size and the same type as src;
- *maxV alue*: non-zero value assigned to the pixels for which the condition is satisfied.

Figure 3 presents the flowchart of first method. Within this flowchart, the whole "clear dataset process" can be seen in Figure 3(a). To begin, the original BFT water colordataset that had been collected is converted to a black-and-white image with the B/W algorithm along with thethresholding parameter. Further, the image is converted to RGB format to get the RGB value of each pixel. Once the RGB values are obtained, the RGB mean is calculated. If the average RGB value is 255, the image isclassified as the clear water. Yet, when the average RGB value is 0, the image is classified as an MCCI datasetand forwarded to the "MCCI dataset process", as shown in Figure 3(b).

In the second process ("MCCI dataset process"), the MCCI dataset from the "clear dataset process" isthen converted to an RGB value for each image pixel. The RGB mean value is then calculated and processed with the MCCI classification algorithm, as shown in Figure 3(b). The result from the MCCI classification algorithm was to agglomerate whether the image is classified as green, green-brown, brown-green, or deep brown. The MCCI classification parameter values are referred to in Table 3.

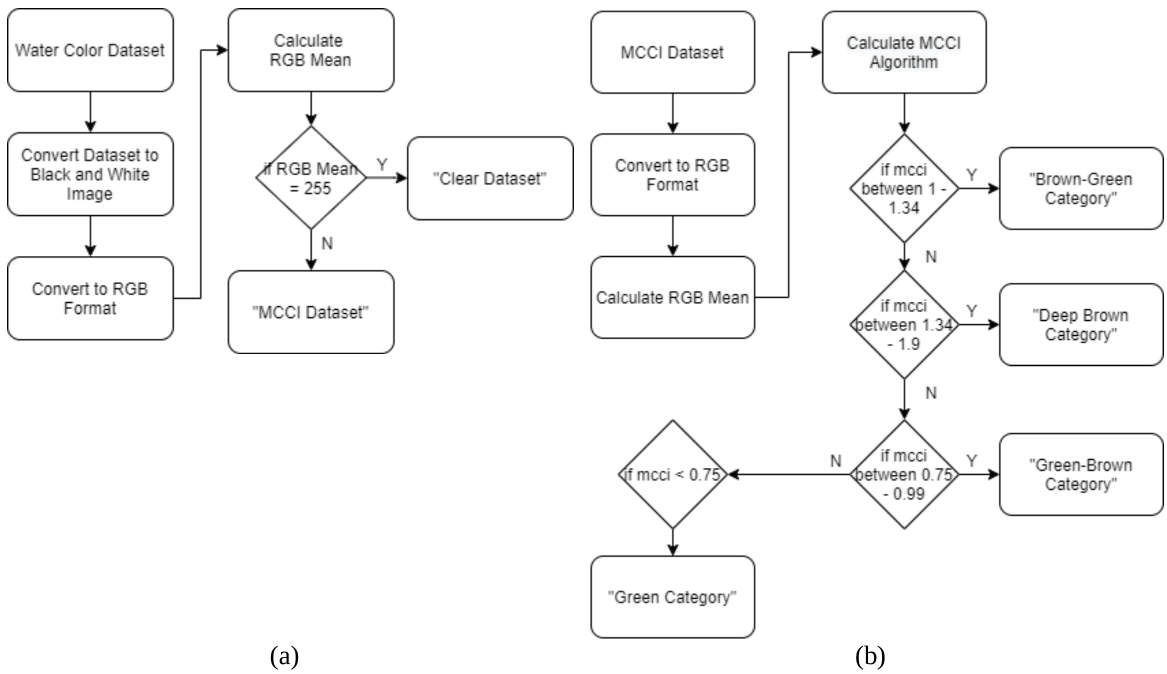


Figure 3. Flowchart of (a) clear data process and (b) MCCI data process

2.4.2. Method 2: Manhattan distance algorithm classification

In the second proposed method, an algorithm called "Manhattan distance" is used to classify the BFT water color from the dataset that has been collected. The Manhattan distance algorithm calculates the distance between the data point and the anchor point (centroid) [25]. The anchor points in this research are theRGB average value for each water color classification (clear, brown-green, and deep brown), as mentioned in Table 4. In contrast, the data point is the image dataset that will be classified. The closer the data point's value is to the anchor point, the more likely it is to be identified as part of the hue indicated by the anchor point. The Manhattan distance for classification technique has already been verified and used to categorize face expressions. The study used 3-dimensional data obtained from 121 extracted data points, using a neural network, from the subject's face when expressing six facial expressions [26].

Figure 4 shows the general flowchart of the Manhattan distance algorithm classification. After the datasets are separated between the training dataset and the test dataset, the training datasets are used to calculate each color classification's anchor points. This process obtained three anchor points for each of the clear, brown-green, and deep-brown colors. The test datasets are then used to test whether the proposed method using the obtained anchors can classify BFT watercolor. An error calculation is then performed to compare the results of the categorization by the Manhattan distance algorithm with the color classification dataset that has been done previously.

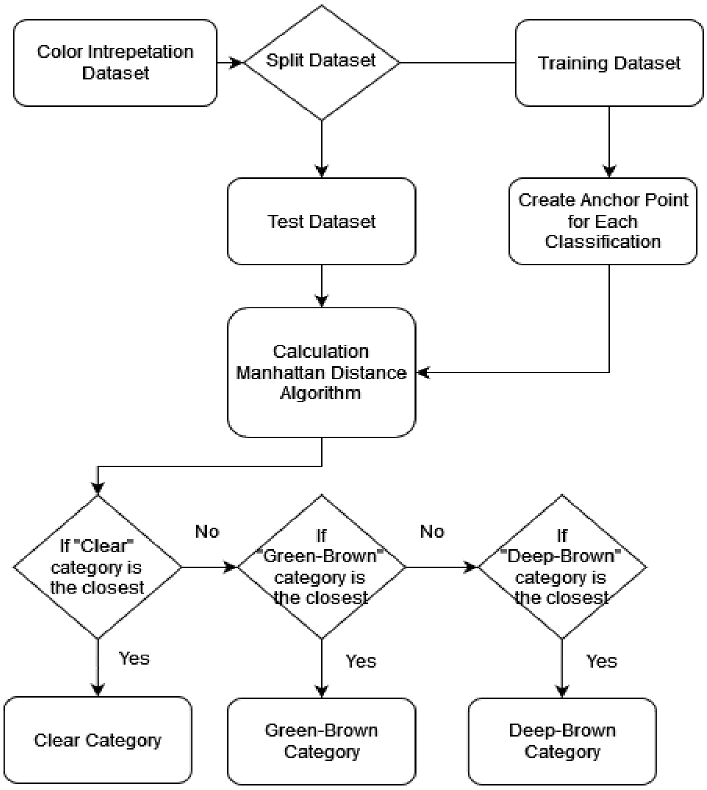


Figure 4. Flowchart of manhattan distance algorithm classification

The general equation of the Manhattan distance algorithm is shown as follows:

$$d_M = \sum_{i=1}^{n} |p_i - q_i| \quad (3)$$

where,
- d_M: Manhattan distance;
- p, q: data points.

3. RESULTS AND DISCUSSION

3.1. Result of the 1st method

The results obtained from the first method are produced from two dataset processes. The first result is the classification of clear images using a black-and-white algorithm in the "clear dataset process", which produces 35 images out of the 36 images classified as clear images. The difference in the number of these images is that there is one different image, namely image W5-D1. So, the "clear dataset process" results have an error value of 2.8%. The percentage errors were calculated by comparing the false result images to the ground truth that was previously defined.

The second result was achieved using the "MCCI dataset process" and the MCCI classification. This categorization algorithm yields two color groups in our dataset: brown-green and deep-brown. The classifi- cation of brown color produces 34 images out of 34 images classified as brown color images. The results show no difference in the number of images, but there are two different images, namely images W5-D3 and W7-C1. So, the MCCI classification software results have an error value of 5.8% for the deep-brown color category.

The brown-green color classification produces 32 images out of 33 images classified as brown-green color images. In the results, there is one difference in the number of images, but there are three different images, namely images W5-D1, W5-D3, and W7-C1. Consequently, the MCCI classification calculation yielded a significant 9% error rate for the brown-green color category. Despite this limitation, the first method demonstrates the potential for classifying the color of BFT culture water. Table 5 shows the error result from proposed method 1st for each color classification.

Table 5. The error result of method 1: B/W and MCCI classification

Method	Clear	Brown-green	Deep-brown
B&W and MCCI	2.8%	9%	5.8%

3.2. Result of the 2nd method

To begin the second method, we divide the gathered dataset into two datasets: the training dataset and the test dataset. The anchor point was calculated using the training dataset, and the error rate was calculated using the test dataset to confirm the anchor point computation. The training data set is made up of images from BFT ponds A and B. Meanwhile, the testing dataset includes all BFT water color data from all existing ponds (A, B, C, and D). The anchor points computation outputs include 3-dimensional data (R, G, and B) produced from the training dataset's average RGB value for each color classification.

Using anchor points in Table 6, we run the classification process using the Manhattan distance algorithm on the test dataset. As a result, the clear, brown-green, and brown color categories produced 0%, 6%, and 0% errors, respectively. Thirty-five data on the clear color category and 34 data poins in the brown color category data have no mistakes. Meanwhile, 33 data points in the brown-green category have two data points errors. The error results are shown in Table 7. As a discussion, in the brown-green category, the 6% errors that occur show the closeness of the data values toward the clear color category. Moreover, both datasets can be visually debated to determine which category they should go into. Improved color classification and contrast limitations will increase algorithm accuracy.

Table 6. Anchor point for each color classification

Color classification	Anchor point (R, G, B)
Clear	232.235, 230.47, 197.0
Brown-green	201.0, 181.625, 96.437
Deep-brown	126.176, 88.705, 19.764

Table 7. The error result of method 2: Manhattan distance algortihm classification

Method	Clear	Brown-green	Deep-brown
Manhattan distance	0%	6%	0%

4. CONCLUSION

To conclude, water classification using computer vision is possible to be done in the BFT Tilapia aquaculture system. The results of the two methods demonstrated that the resulting error in classifying the BFT color system was still within our tolerance limits (less than 10%). The Manhattan distance algorithm classification (second method) yields more promising results than the B/W and MCCI classification (first method). However, when confronted with a different BFT system environment, such as open-space regions where the BFT system is exposed to direct sunlight, the second method is not always superior to the first option. The second method is dependent on the training dataset, which needs data to be collected in advance. It is also necessary to visually analyze test results to confirm the anchor point for each category. The first method, on the other hand, will be more adaptable because it does not require initial classification and training. A side from the aforementioned performance comparison, both algorithm (first and second method) could be implemented as a biofloc color detecting algorithm and help to provide advice on the condition of the cultivation water to the fish cultivator. Further development is also possible with the introduction of more dependable procedures in accordance with the system's requirements.

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AUTHOR CONTRIBUTIONS STATEMENT

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Sakinah Puspa Anggraeni	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		
Toto Bachtiar Palokoto	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		
Budi Sulistya		✓		✓	✓	✓	✓		✓	✓	✓		✓	
Wisnu Sujatmiko	✓	✓		✓	✓	✓		✓		✓	✓	✓		
Reza Septiawan	✓			✓	✓			✓		✓		✓	✓	✓
Nashrullah Taufik	✓			✓		✓	✓			✓		✓	✓	
Arief Rufiyanto	✓			✓	✓			✓		✓		✓		✓
Arif Rahmat Ardiansyah		✓		✓	✓	✓	✓	✓	✓		✓	✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to animal use has been complied with all the relevant national regulations and institutional policies for the care and use of animals.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, B. Suwandi, upon reasonable request.

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