Incidence of Intentional Contamination of Fabric Dye as Fraud in Fish Quality in Various Market Stalls in Misamis Oriental, Philippines

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Abstract

Food adulteration refers to the intentional alteration of food to gain an economic advantage over the consumer. Color, appearance, taste, weight, and volume are some of these properties and characteristics that are deliberately changed. This study examines the incidence of deliberate contamination of fish sold at various fish stalls in Misamis Oriental, Philippines. The study's results revealed that various fish stalls located in different barangay communities are adding blue fabric dye to the storage containers holding iced water for the two fish species sold in the market: bigeye scad and sardine. The contaminated fish species showed light blue pigments in the skin and pectoral fins. Bluish and light green color pigmentation evident in the fish is hard to distinguish among consumers who have untrained and unfamiliar eyes. Furthermore, the fabric dye levels found in fish and their connection to three influencing variables: type of fish, market location, and sampling period. The statistical significance of p = 0.038 indicates that one or more predictor variables affect dye concentration levels in the analysis. Among the variables, only the type of fish showed a significant effect, with a negative coefficient (-99.78), suggesting that the kind of fish lowers the dye concentrations. The results showed market location (-11.44) and time of sampling (+54.48) as two variables without significant statistical relationships. Further research should include additional variables to better analyze the factors contributing to dye contamination in fish tissues.

Keywords*:* chemical contamination, fabric dye, fish fraud, fish freshness and quality fish spoilage, food safety

1. Introduction

The Philippines is an archipelagic country comprising 7,107 islands, and its inhabitants enjoy the vastness of the oceans and seas surrounding their peripheral territories. It is sufficient to say that the country is truly blessed with its abundance of natural resources thriving in these water bodies. Accordingly, fishing has been a vital source of livelihood for Filipinos residing in the various barangays near expansive bodies of water, making fish the country's second staple food after rice. The barangay is the fundamental base of the Philippine national government, complementing the municipal and provincial governments. Typically, a barangay comprises between 30 and 15,000 households, depending on the geographical area and level of economic development. A barangay is headed by the chairman together with eight barangay councilors. From 2019 to 2021, the total volume of commercial, municipal, and aquaculture fish production decreased from 4,416 to 4,248.27 metric tons (Bureau of Fisheries and Aquatic Resources [BFAR], 2021). A possible reason for the decline in production is the impact of the COVID-19 pandemic's restrictions.

The population in the Philippines has grown substantially, and the demand for basic commodities has increased accordingly. The demand for fish for food consumption and other uses has increased correspondingly. As fishing technology has improved, many municipal fishing boats have become motorized. Similarly, many commercial fishing vessels have become more prominent and more powerful. Fishing gear has evolved from a simple tool to highly sophisticated gadgets that can sweep the bottom of almost everything on the fishing grounds, including precious coral reefs.

A considerable amount of annual production becomes unsold, damaged, and spoiled due to poor postharvest technology. Post-harvest fish loss refers to fish that are either discarded because they are too small or not valuable enough to land for sale or sold at a relatively low price due to quality deterioration or market dynamics (Kruijssen *et al.*, 2020; Torell *et al.*, 2020). This means that fish operators, including fishers, processors, traders, and other stakeholders involved in fisheries, lose potential income. It also means that fewer fish are available to consumers, or consumers are supplied with low-quality fish and fish products. According to the Bureau of Fisheries and Aquatic Resources (BFAR), the current fish spoilage rate ranges between 25% and 40% due to a lack of post-harvest equipment, including blast freezers, ice-making machines, and facilities such as cold storage warehouses and fish landing sites (BFAR, 2023; Baclig, 2023).

Fish is a healthy food rich in high-quality animal proteins and polyunsaturated fatty acids, especially the (ω)-3 *eicosapentaenoic* acid and *docosahexaenoic* acid, as well as micronutrients; therefore, it spoils quickly. The main components of fish are water, protein, and fat (Cengizler, 2023; Tilami and Sampels, 2018; Mohanty *et al.*, 2019; Tacon and Metian, 2013). The spoilage of fish is a complex process driven by the actions of enzymes, bacteria, and chemical constituents. The spoilage process begins immediately after the fish's death. The process involves rigor mortis, autolysis, bacterial invasion, and putrefaction. The spoilage of fish is commonly caused by microbial growth and metabolism, which includes the production of biogenic amines, such as putrescine, histamine, and cadaverine, organic acids, sulfides, alcohols, aldehydes, and ketones, with unpleasant and unacceptable off-flavors (Gram and Huss, 1996; Kuley *et al.*, 2017). The activity of an organism can be controlled, reduced, or even retarded by proper handling and immediate lowering of the temperature. As reported, the primary methods for preventing the development of biogenic amines in food are cooling and freezing and applying hydrostatic pressures, irradiation, or controlled environment packaging (Suzzi and Gardini, 2003). The modulation of water activity and/or *NaCl* concentration may affect the composition of the microbiota, resulting in variations in the levels of biogenic amines.

To recover from economic losses, fish vendors often resort to adulterating fish with chemicals and additives not approved by the Food and Drugs Administration, which has also been reported (Hossain *et al.*, 2008; Joshi *et al.*, 2015; Noordiana *et al.*, 2011). Reviews of the articles published mentioned that formalin, also known as *formaldehyde*, is a common adulterant in fish. However, the amount of formalin is not known. Consumption of fish adulterated with formalin can cause health conditions such as abdominal discomfort, vomiting, renal injury, etc. Another colorant considered unsafe for human health is fabric or textile dyes. Textile dyes, along with a large number of industrial pollutants, are highly toxic and potentially carcinogenic, resulting in environmental degradation and various diseases in animals and humans (Dutta *et al.*, 2024; Khan and Malik, 2018; Srivastava and Sofi, 2020). On a personal note, the authors have witnessed that fabric dyes added to soaking water for fish have been used by fishmongers to deceive buyers into believing the fish is still fresh. In a report by Dey and Nagababu (2022), several artificial food dyes have been reported. However, the blue pigments in fabric dyes are not mentioned. Hence, no information on these chemicals used as food adulterants has been reported. Moreover, verbal accounts and personal experiences of witnessing the blending of fabric dye on the fish containers were observed. Since there is no detailed survey and analysis of the incidence of intentional contamination of fabric dyes in some fish species sold from Cagayan de Oro markets, this study sought to investigate the incidence of intentional fabric dye contamination in two fish species sold in various fish stalls in Cagayan de Oro City and the municipality of Opol in Misamis Oriental, Philippines. The specific objectives are:

a. assess the presence of fabric dye contamination practices in the different fish stalls in both eastern and western barangays in Cagayan de Oro;
b. determine and compare the level of fabric dye concentration in the two fish species;
c. ascertain the level of fabric dye concentration in fish samples purchased at varying time of the day.

2. Methodology

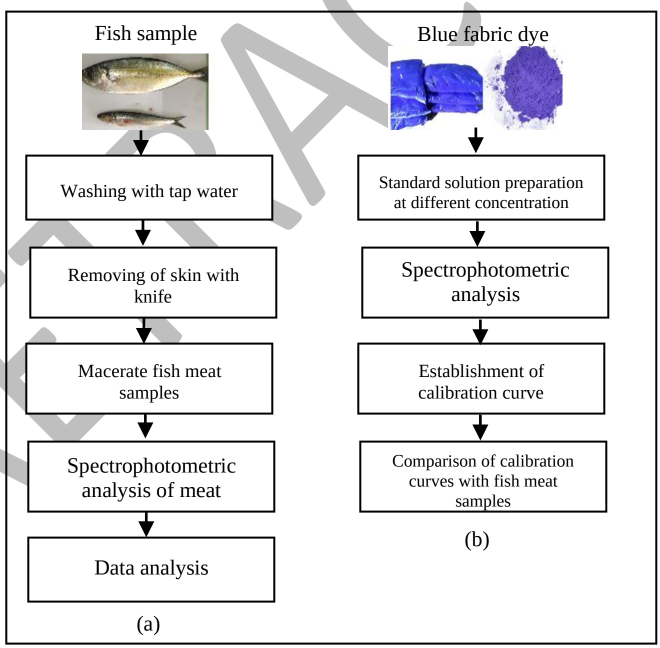


Figure 1. Process flow chart of the analysis: fish sample analysis (a); establishment of calibration curves for the fabric dyes (b)

2.1 Sourcing of Fish Samples

Fish samples used in the experiment were purchased from different fish stalls located in selected barangays in Cagayan de Oro City and Opol town in Misamis Oriental as shown in Figure 2. The portion of the map enclosed with the red rectangular boundary is the Cagayan de Oro city's center, where the different business establishments and offices of the local chief administrators are located. To the west of the city's center are the town of Opol and barangay Bulua. Opol and Bulua are about 7 km and 3.5 km from the city's center. On the other hand, the barangays of Puerto and Cugman are east of the city's center—these barangays are about 7 km and 14 km away from the city's center, respectively. The barangays of Carmen and Cogon are situated in the city's center. The selected barangays were randomly selected to test the intentional contamination of fish products sold. Red circular dots are superimposed on the map to help locate the selected study site. Since most fish traders in the barangays and towns in the region do not have refrigerated cabinets or containers similar to those found in supermarkets, fish traders locate their stalls near residential houses. Since the proximity of the test barangays ranges from 3.8 km to 14 km from the city's center, the selected barangays will confirm that the practice of intentional adulteration is present not just in the city's center but also in the nearby barangays and municipalities.

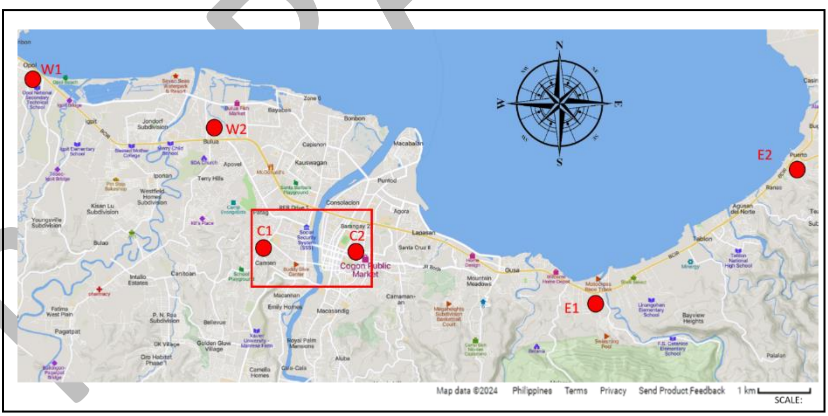


Figure 2. Screen grab of a Google map in Cagayan de Oro City and Opol in Misamis Oriental, Philippines where sampling was conducted in the study. Red circular dots indicating the location of the Eastern and Western part selected as sampling site: Opol Market (W1); Bulua (W2), Carmen Market (C1); Cogon Market (C2); Cugman Market (E1); Puerto Market (E2), (Google Maps, 2024)

Prior to the experiment, secondary information was obtained from interviews with fish traders. To confirm, a site visit was also conducted to identify the stalls. Sightings of blue-colored water from fish containers were observed in some stalls. To confirm the practice of intentional adulteration, fish samples were purchased from suspected fish stalls contaminated with fabric dyes.

2.2 Time of Sampling and Preparation of Fish Samples

Due to the Philippines' geographical location, the country experiences a tropical climate characterized by distinct dry and rainy seasons. Fresh fish products are available for sale all year round, regardless of the season. During the experiment, sampling was done from January to May 2023. The data collection period was randomly selected to confirm the practice of intentional adulteration in fish samples. This practice of intentional adulteration is a significant food safety concern.

Fish are displayed in various fish stalls from six in the morning until eight in the evening. Fish sampling was performed at 9:00 AM, 2:00 PM, and 7:00 PM. The fish samples purchased at the identified fish stalls are kept cool in an ice box during transport. The fish samples used in the study are big-eyed scad (*Selar crumenophthalmus*) and sardines (*Sardinella gibbose*). Samples purchased at 7:00 PM were placed in a freezer for 10 hours and then defrosted for 2 hours, whereas the samples purchased at 9:00 AM and 2:00 PM were prepared immediately. A control was used to test the experiment's validity using unadulterated and fresh fish samples purchased from the fish port in Kimaya, Jasaan, Misamis Oriental. The fish samples were cut, beheaded, and filleted to remove the gills and internal organs, including the intestines. Afterward, the skin was carefully removed from the flesh samples. The flesh and skin were placed separately in a container. The flesh samples were then diluted with water. The extracted liquid was then transferred into a beaker and analyzed using a UV-VIS spectrophotometer (Biobase BK-D560, China) to obtain the results.

2.3 Preparation of powder and standard solution

Two kinds of fabric dyes were purchased from the market. The two types of dyes used to ascertain the color additives added by the fish vendors in the iced water are shown below.

The color characteristics of both dyes (Master and Aniel) were measured using a Minolta CR410 Chroma meter, Tokyo Japan. Sample powders were placed in a petri dish, and the values were converted to L*, a*, and b* color coordinates.

Table 1 shows the color characteristics of both powders. The results of this measurement were given as L*, a*, and b* values. The L* represents the level of brightness or darkness between black and white, while a* and b* indicate the balance between red and green and yellow and blue, respectively. In other words, the chromaticity coordinates a* and b* describe the color of the surface being measured.

Table 1. Results in color characteristics of fabric dyes using a Chroma meter

Type of Dye	*L**	*a**	*b**	Color	Source of Powdered Sample
Aniel Powder	43.45	51.16	-72.13		
The Master Dye Powder	28.89	9.04	-10.65		

Legend:
L - brightness or darkness between black and white*
a - indicates the balance between red and green*
b - indicates the balance between yellow and blue*

For Aniel powder, the *L** value is 43.45, indicating a relatively light color. The *a** value is 51.16, showing a reddish color. The b* value is -72.13, indicating a bluish color. The corresponding HEX# color code is 674AE1, a purple shade. For the Master dye powder, the *L** value is 28.89, indicating a darker color than Aniel Powder. The *a** value is 9.04, showing a slightly reddish color. The *b** value is -10.65, meaning a slightly bluish color. The corresponding HEX# color code is 4A4055, which is a deep shade of purple color. As observed, both dyes fall within the purple/violet color range.

2.4. Preparation of a blue solution

Three samples of 2, 4, and 6 grams of each fabric dye (Master Blue brand) and Aniel dye were used, each diluted separately in 1 L of distilled water, to create standard solutions with concentrations of 2000, 4000, and 6000 ppm, respectively.

2.5 Standard calibration curve

Figures 3A and 3B display the calibration curves employed in this study. Regression lines were also established to ascertain the linearity of the data points.

The absorbance spectra of both Master and Aniel dyes at different concentrations (2000, 4000, and 6000 ppm) were obtained by scanning over a wavelength range of 200 nm to 800 nm using a UV-VIS spectrophotometer. In UV-VIS spectrophotometry, a graph was typically plotted with absorbance on the y-axis and wavelength on the x-axis. The peaks in the graphs (Figures 4a-f) were labeled as numbers 1 to 7. The absorbance peaks for Master and Aniel dyes were observed at different wavelengths and concentrations. For Master dye, the peak at 325 nm (labeled as number 4) was observed at a concentration of 2000 ppm, while the peaks at 331 nm (labeled as number 5) were observed at both 4000 ppm and 6000 ppm concentrations. For Aniel dye, the peak at 311 nm (labeled as number 7) was observed at 2000 ppm, while the peaks at 313 nm (labeled as number 5) and 319 nm (labeled as number 7) were observed at 4000 ppm and 6000 ppm, respectively.

The UV-VIS spectrum analysis shows that the resulting peak absorbs at a specific wavelength. According to Pratiwi and Nandiyanto (2022), the wavelengths of color violet absorbed in the UV-Vis spectrophotometry are 340 nm to 450 nm. This indicates that the Master dye at 6000 ppm concentration was closely related at this wavelength range. It is known that visible light is a specific case of electromagnetic radiation that ranges in wavelength from around 330 nm (violet/blue) to 800 nm (red) and is detectable by the human eye. This suggests that the sample of Master dye at 6000 ppm concentration absorbs more violet light at this wavelength than other colors in the visible spectrum. This interpretation is consistent with the findings that violet light has a shorter wavelength and higher energy than colors at the red end of the visible spectrum.

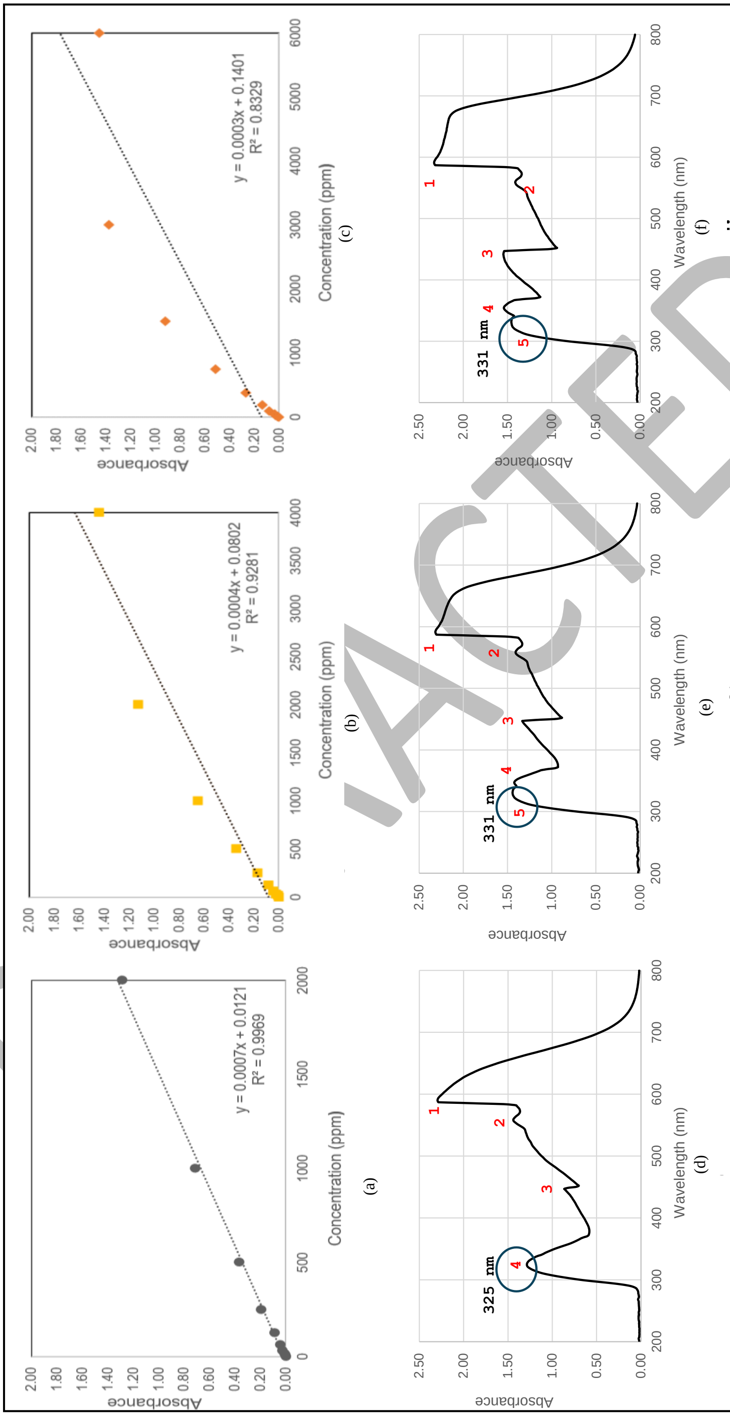


Figure 3A. Master Dye: Standard calibration curve (a-c) and wavelength scan (d-f) (200-800 nm) for the two types of blue fabric dye with absorbance at 2000, 4000, and 6000 ppm concentration

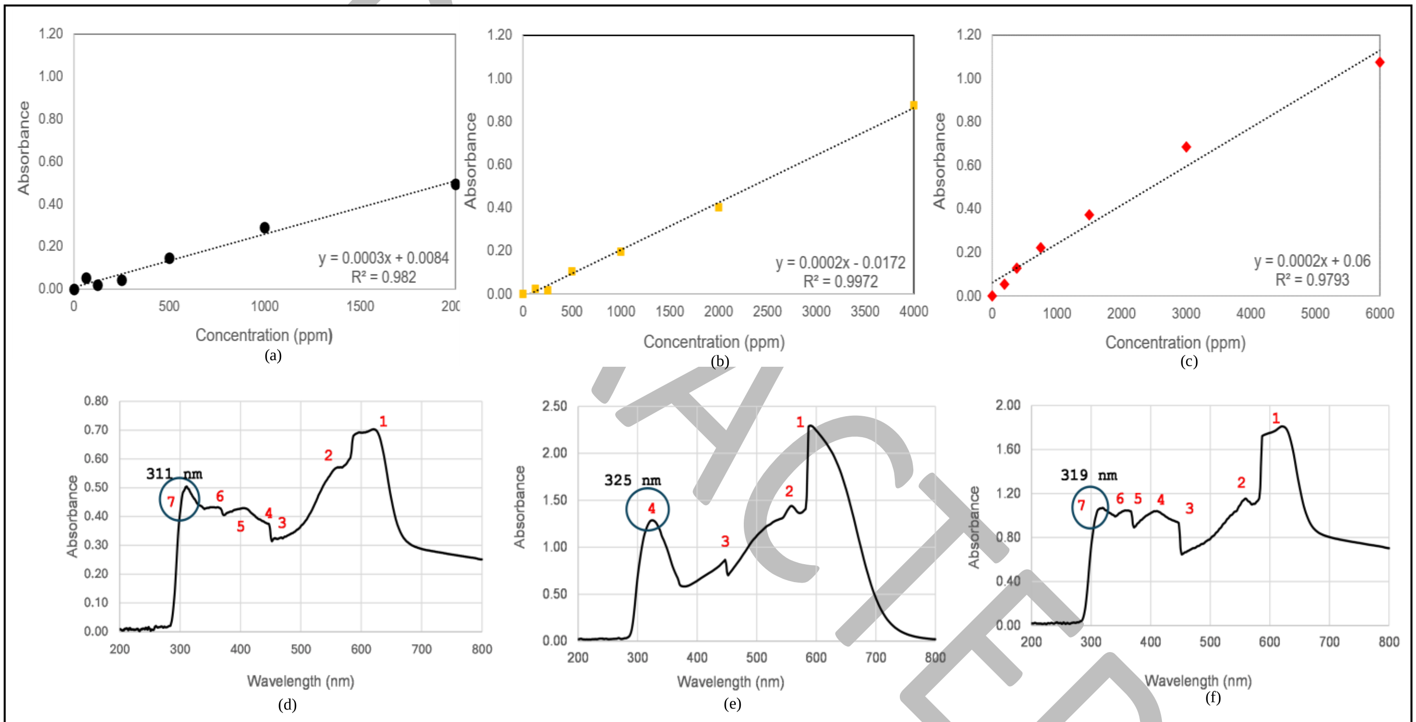


Figure 3B. Ariel Powder: Standard calibration curve (a-c) and wavelength scan (d-f) (200-800 nm) for the two types of blue fabric dye with absorbance at 2000, 4000, and 6000 ppm concentration

2.6 Experimental Set-up

The experimental setup for analyzing the blue dye contamination in fish samples follows the order of activities shown in Figure 4 below.

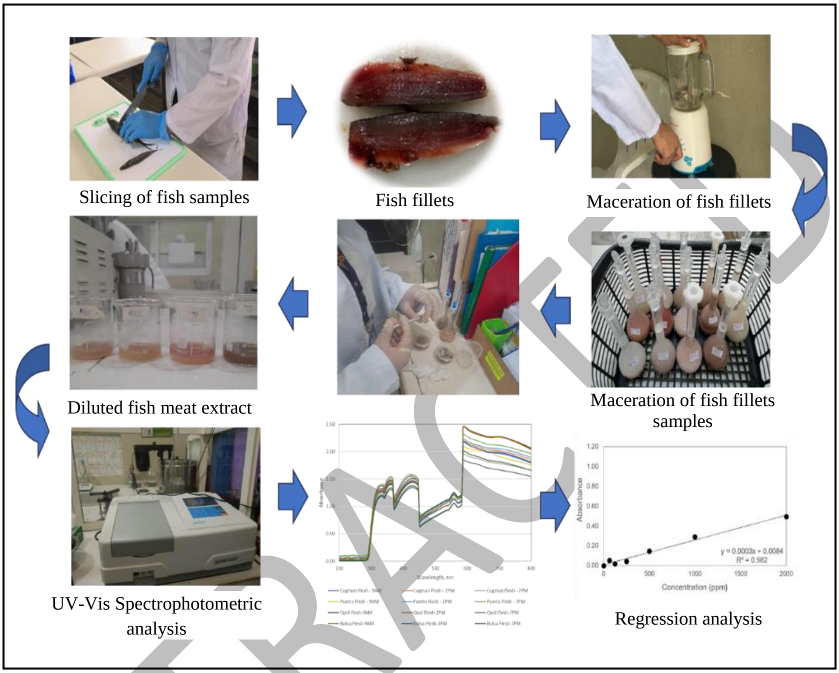


Figure 4. Process flow chart of the analysis: fish sample analysis (a); establishment of calibration curves for the fabric dyes (b)

2.7 Establishment of Model

A regression model was developed to analyze the relationship between the dye concentration and the type of fish, market location, and type of sampling.

$$Dye\ Concentration\ (ppm) = \beta_0 + \beta_1\ (Type\ of\ Fish) + \beta_2\ (Market\ Location) + \beta_3\ (Time\ of\ Sampling) \quad (1)$$

Data were collected from different market sources. The selection of predictor variables was guided by theoretical framework which could affect the concentration of the dye in fish samples. Model assumptions, including linearity and independence were assessed using statistical tests. The model was evaluated based on performance metrics such as R^2, adjusted R^2, and mean square.

2.8 Statistical Analysis

To find statistically if there is a significant difference among the suspected samples obtained from the sampling sites to the unadulterated fish samples, T-test was done among all samples at 95% confidence interval using IBM SPSS Statistics (SPSS 23.0, SPSS Inc, Chicago, IL, USA)). All the experiments were conducted in 5 replicates, and the plotted data represent the average ± SD of the observations. The evaluation of the samples was based on a $p \leq 0.05$ significance level.

3. Results and Discussion

3.1 Color of Fabric Dyes

A dye is a colored chemical substance that imparts color when applied to a substrate (Kumar *et al*., 2021). Dyes are generally soluble in solvents and can be natural or synthetic. Many dyes were initially used to color textiles, which are fiber-based materials such as threads, yarns, and fabrics made from plant and animal fibers, including cotton, hemp, flax, grass, wool, silk, and human hair. Dyes were also used to color wood, pottery, and animal hides. Dyes are compounds different from pigments, as dyes are soluble in water and are mostly made from organic material. Dyes are produced naturally or synthetically (Slama *et al.*, 2021). Natural dyes are extracted from a variety of sources, including roots, foliage, nuts, berries, flowers, insects, octopuses, and murex snails (Kaur and Chopra, 2023). On the other hand, synthetic dyes are made from chemical compounds such as mercury, lead, chromium, copper, sodium chloride, toluene, or benzene. Synthetic dyes became widely used due to their ease of application, extensive color range, and fastness (Alegbe and Uthman, 2024). Synthetic dyes have been proven to be toxic to humans (Pereira *et al.*, 2021; Slama *et al.*, 2021; Fobiri, 2022). The color quality of dyes varies in shades depending on their color intensity and the material from which the dye is derived (Satyanarayana *et al*., 2010). In organic dyes, the color quality depends on the type of mordant used. A mordant or dye fixative is used to adhere the dye to the fiber to prevent it from washing right out or fading away too soon. Mordants are solutions that can contain dissolved metal oxides, and since they are toxic, if not properly handled, they can harm the dyer's health. Using a mordant depends on the type of dye material, the fiber being dyed, and the time it takes for the dye to set. Mordants enhance the wash- and lightfastness of the dyed yarn or fabric. Commonly used metallic salt mordants include potassium aluminum sulfate (also known as alum), aluminum acetate, aluminum triformate, and ferrous sulfate. Plant-based mordants include tannins and soybean milk.

The color of the dye used in the fish samples is in shades of blue. The fish mongers use blue to mask the color of the fish so that they look fresh. Since there is no evidence of the exact type of dye used in the adulteration of fish, it is safe to speculate that natural or synthetic dye is used as a colorant in the water. Natural dyes containing blue colors include indigoid dyes, *phycocyanin*, gardenia blue, and *anthocyanins E163*, while synthetic dyes are methylene blue and indigo carmine (Olas *et al*., 2021). Since both natural and synthetic dyes have a blue color, identifying their presence in the fish samples is extremely important as both dyes pose health risks.

According to a report by Fobiri (2022) and Malomo *et al*. (2017), synthetic and natural dyes undergo three stages to cause color transfer into the fabric. The first stage is adsorption, which involves the deposition of dye molecules onto the surface of the fibers. The second stage is the diffusion of the dye molecules into the innermost part of the textile fibers. The last stage is the fixation stage. During this stage, physical or chemical bonding occurs between the dye molecules and the fiber. The efficacy of the second stage depends on the dye's molecular size, the fiber's morphology, and temperature.

3.2 Evidence of Blue Colored Water in Fish Containers

The primary type of container used to handle and distribute fish is the conical steel tank known locally as '*bañera*', which can hold about 30 to 40 kg of fish. A larger '*bañera*', with a capacity of about 70 kg, is also used to transport fish to some fish grounds and retail markets. Other types of containers are also used, such as those made from *rattan*, bamboo, wood, *polystyrene*, and plastic. They vary from region to region, even though *bañera* is always the most popular. A similar account was reported by Rayos *et al*. (2019). Many fish retailers in the different fish stalls in Cagayan de Oro use *polystyrene* boxes. *Polystyrene* is a lightweight, durable material that packages, insulates, and transports highly perishable products. It is an excellent alternative for transporting frozen fish, as it maintains uniform temperatures over long periods, resists moisture, and does not decompose when exposed to extreme temperatures. Additionally, it is lightweight and inexpensive to manufacture, making it an excellent choice for transporting frozen fish.

Figure 5 shows fish containers with blue-colored iced water where fish are stored and sold to consumers. The images were taken in one sampling site for the study. Figures 5a-5e show that the water inside the containers is bluish in tint, indicating that a blue-pigmented substance has been mixed into the water to create a deception of a fresh fish. Red arrows are provided in the figure to highlight the color differences in the image. The color of soaking water on the adjacent container found at the bottom and top in Figure 3b is reddish, indicating blood stains from the fish. However, the pan in the middle of the same picture has bluish water compared to the two other containers. According to some retailers around the sampling site that some vendors are intentionally adding a blue colored fabric dyes that are blended with the iced water. Other vendors are also using “Aniel” bluing powder that is commonly used in laundry.

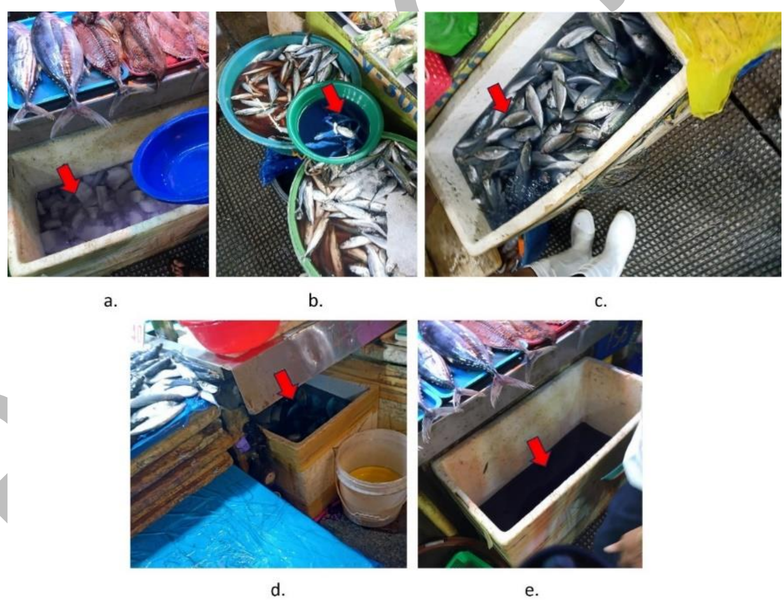


Figure 5. Images of fish soaked in water added with blue fabric dye. Picture was taken in Cogon Market, one of the sampling sites of the study

3.3 Description of Fish Soaked in Water with Blue Fabric Dyes

The bigeye scad fish (*Selar crumenophthalmus*) is a saltwater fish typically found in tropical waters around the world. This fish has large eyes covered with fatty eyelids. The elongated, spindle-shaped body is metallic blue green above and silvery-white below. It also has a thin yellow stripe running horizontally along its body from the top of its gill cover to the base of its caudal fin. Another characteristic of this fish is its deeply forked tail attached to a fairly slender base (Clarke and Privitera, 1995; Fadzly *et al*, 2017; Peñaflor, 1989; Roos *et al.*, 2007).

On the other hand, fresh sardines are characterized by their small size, silvery, elongated shape with a single short dorsal fin, no lateral line, and no scales on the head. The sardine species is a pelagic fish, meaning it is constantly on the move, with no permanent residence or depth at which it lives. Pacific sardines have a complex color system. Their color ranges from blue to green on the back, and their sides have a white-silvery color with one to three sets of dark spots along the middle. They range in length from about 15 to 30 cm and dwell in dense schools (Bagsit *et al.*, 2021; Campos and Bagarinao-Regalado, 2021; Echem, 2016; Hunnam, 2021; Willette, 2011)

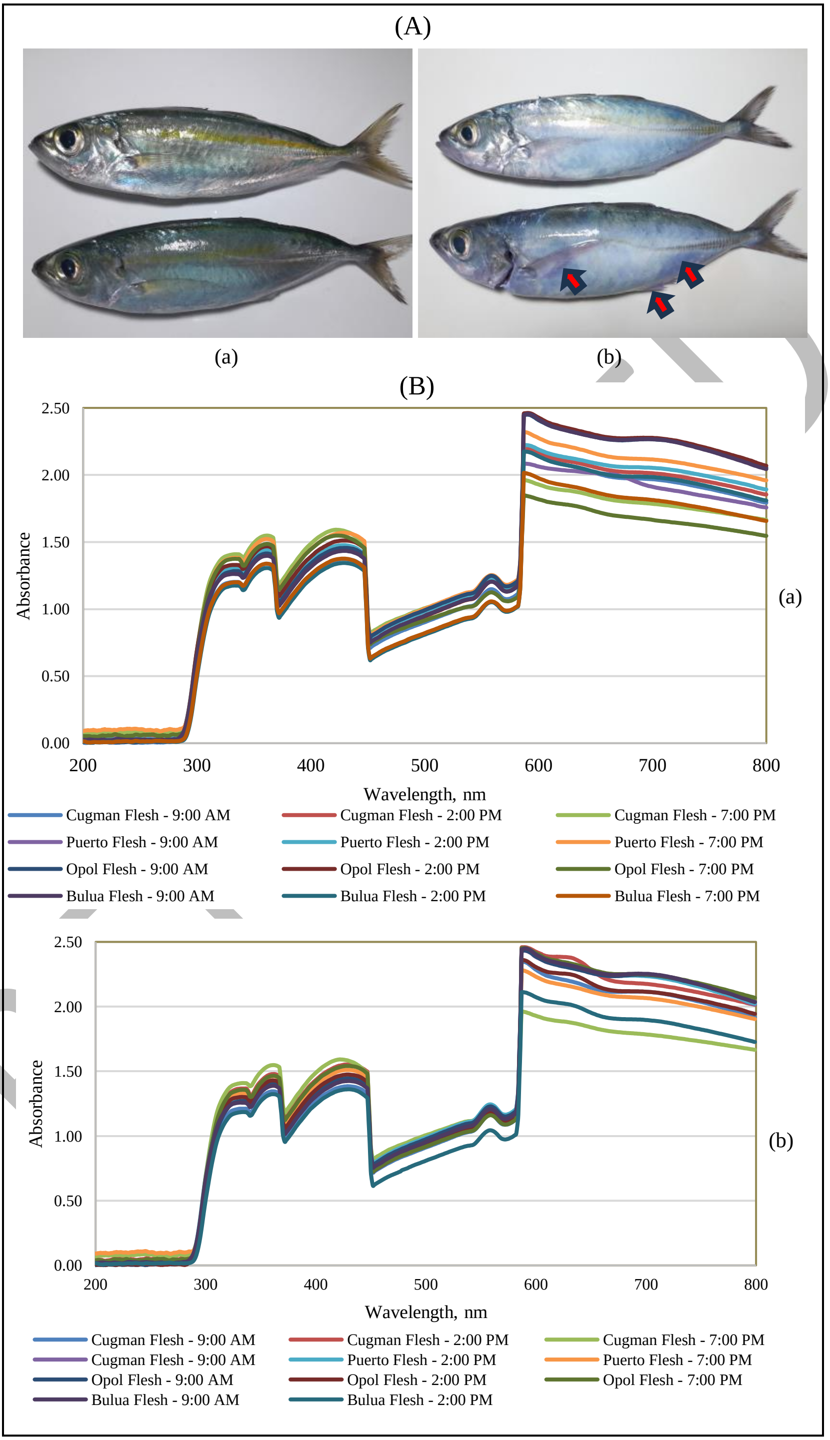
In Figure 6, fish samples of big-eye scad species soaked in blue fabric dyes show evidence of blue coloration in the skin as well as in the pectoral and anal fin. However, the light blue is not very noticeable unless illuminated by a bright light. Arrows are shown to indicate the light bluish color in the fish sample. This observation is not made at the site where the fish are sold, as most fish stalls are not well-lit. Thus, fish buyers cannot easily detect of the color difference between the fresh and adulterated fish

3.4 Presence of Fabric Dye in Fish Samples

Due to suspicion that fish products sold at the test sites were soaked in blue to deceive buyers intentionally, it is important to test using chemometric analysis to quantify the presence of dye pigments in the fish products. Different methods are used to detect adulterants. Cheah and Fang (2020) used high-performance liquid chromatography to determine adulterants in coffee. Similarly, Mohamed *et al*. (2021) used reversed-phase high-performance liquid chromatographic (RP-HPLC) strategies to detect adulterants in vinegar. Other known methods, such as the Fourier-Transform Infrared (FTIR) Spectroscopy coupled to chemometric analysis and micro-FTIR imaging, are also used in the detection of adulterants in turmeric (Shannon *et al.*, 2022). Another method used in the detection of adulterants in honeys is the UV-VIS spectrophotometer (Dimakopoulou-Papazoglou *et al.*, 2023; Nunes *et al.*, 2023; Oca *et al.*, 2023). In this study, UV-VIS spectrophotometric analysis was employed to detect the intentional adulteration of fabric dyes in fish.

UV–Vis spectrometry uses a dispersing spectrometer to measure absorbance as a function of wavelength. The UV-Vis spectroscopy technique measures how well a sample absorbs or transmits light in the ultraviolet (UV) and visible (Vis) light ranges. UV-Vis spectroscopy serves as a dependable method for identifying pollutants and various hazardous substances in samples, including organic compounds, disinfection by-products, heavy metals, and trace minerals. This technique detects contaminants by analyzing the intensity and wavelength of light that passes through a liquid sample (Khalid *et al.*, 2024; Leong *et al.*, 2018). Light retained by a particular chemical compound has unique retention spectra that differentiate it. Hence, when a liquid sample containing a specific chemical atom is tested with a UV-Vis spectrometer, a reduction in the intensity of the transmitted light occurs. This reduced intensity of light passing through the sample helps to identify the type of pollutant and its concentration.

UV absorption data for the blue dye contaminants of practical interest in this study are presented. Figures 6Ba and 6Bb show the absorbance spectra of fish samples sold from several fish markets in the Western and Eastern parts of Cagayan de Oro City. These spectra were obtained by scanning over a wavelength range of 200 nm to 800 nm. The figures reveal various peaks, including one at 331 nm that corresponds to the standard concentration shown in Figures 3A and 3B. The results indicated that the Master dye with 6000 ppm concentration has the same peaks of wavelength and absorbance as those found in the various fish markets at the eastern and western part of Cagayan de Oro City. Therefore, it is safe to conclude that at this peak at 331 nm, this is the same wavelength appropriate for calculating the concentration of an unknown blue substance found to be added in the iced water that is used to store the fishes sold in various markets. This suggests that the 331 nm wavelength could be used as a reference point or standard for measuring the concentration of certain substances in fish samples.


(A)
(a)
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(B)
Absorbance
2.50
2.00
1.50
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200
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500
600
700
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Wavelength, nm
(a)
Cugman Flesh - 9:00 AM
Cugman Flesh - 2:00 PM
Cugman Flesh - 7:00 PM
Puerto Flesh - 9:00 AM
Puerto Flesh - 2:00 PM
Puerto Flesh - 7:00 PM
Opol Flesh - 9:00 AM
Opol Flesh - 2:00 PM
Opol Flesh - 7:00 PM
Bulua Flesh - 9:00 AM
Bulua Flesh - 2:00 PM
Bulua Flesh - 7:00 PM
Absorbance
2.50
2.00
1.50
1.00
0.50
0.00
200
300
400
500
600
700
800
Wavelength, nm
(b)
Cugman Flesh - 9:00 AM
Cugman Flesh - 2:00 PM
Cugman Flesh - 7:00 PM
Cugman Flesh - 9:00 AM
Puerto Flesh - 2:00 PM
Puerto Flesh - 7:00 PM
Opol Flesh - 9:00 AM
Opol Flesh - 2:00 PM
Opol Flesh - 7:00 PM
Bulua Flesh - 9:00 AM
Bulua Flesh - 2:00 PM

Figure 6. Color difference of samples between fresh and adulterated fish: Fresh and uncontaminated big-eye scad (Aa); Contaminated big-eye scad fish (Ab); Wavelength scan (200 nm-800 nm) both fish samples (B); big-eye scad fish (Ba); sardine fish samples (Bb)

Table 2 shows the calculated concentrations in parts per million (ppm) of big-eye scad and sardine found in the flesh. The concentrations were calculated using the calibration curve based on a 6000-ppm master dye, with a slope intercept of $y = 0.0003x + 0.1401$ and a correlation coefficient of $R^2 = 0.8329$. This calibration curve was a standard to quantify the unknown concentrations of fish samples obtained from various fish markets, including Cugman, Puerto, Carmen, Cogon and Opol, and Bulua, respectively.

Table 2. Comparison of the calculated fabric dye concentration in adulterated and unadulterated fish samples obtained from eastern and western part of Cagayan de Oro City with P-values from T-tests.

A. Bigeye Fish

Market Source	Time of Purchase	Concentration of fabric dye (ppm)	p-value
Eastern Part			
Cugman	9:00 AM	3537 ± 11.04	$p<0.0001$
	2:00 PM	3862 ± 13.60	$p<0.0001$
	7:00 PM	4223 ± 34.86	$p<0.0001$
Puerto	9:00 AM	3878 ± 6.182	$p<0.0001$
	2:00 PM	3886 ± 11.74	$p<0.0001$
	7:00 PM	4134 ± 32.56	$p<0.0001$
Cogon	9:00 AM	ND	-
	2:00 PM	ND	-
	7:00 PM	3594 ± 3.35	-
Carmen	9:00 AM	ND	-
	2:00 PM	ND	-
	7:00 PM	3445 ± 6.01	-
Western Part			
Bulua	9:00 AM	3739 ± 7.926	$p<0.0001$
	2:00 PM	3448 ± 2.911	$p<0.0001$
	7:00 PM	3526 ± 6.750	$p<0.0001$
Opol	9:00 AM	3804 ± 16.680	$p<0.0001$
	2:00 PM	3963 ± 10.541	$p<0.0001$
	7:00 PM	4112 ± 18.184	$p<0.0001$

Data are presented as mean ± standard deviation (SD) from n = 5
ND denotes No Data
Uncontaminated fish flesh had a fabric dye concentration of 3757 ± 1.900 ppm

B. Sardine Fish

Market Source	Time of Purchase	Concentration of fabric dye (ppm)	p-value
		Eastern Part	
Cugman	9:00 AM	3569 ± 7.115	*p<0.0001*
	2:00 PM	4087 ± 12.89	*p<0.0001*
	7:00 PM	ND	
Puerto	9:00 AM	3802 ± 13.73	*p<0.0001*
	2:00 PM	3856 ± 5.963	*p<0.0001*
	7:00 PM	3954 ± 28.95	*p<0.0001*
Cogon	9:00 AM	ND	
	2:00 PM	ND	
	7:00 PM	3654 ± 3.33	
Carmen	9:00 AM	ND	
	2:00 PM	ND	
	7:00 PM	3699±333	
		Western Part	
Bulua	9:00 AM	3739 ± 7.926	*p<0.0001*
	2:00 PM	3448 ± 2.911	*p<0.0001*
	7:00 PM	3526 ± 6.750	*p<0.0001*
Opol	9:00 AM	3804 ± 16.680	*p<0.0001*
	2:00 PM	3963 ± 10.541	*p<0.0001*
	7:00 PM	4112 ± 18.184	*p<0.0001*

Data are presented as mean ± standard deviation (SD) from n = 5
ND denotes No Data
Uncontaminated fish flesh had a fabric dye concentration of 3757 ± 1.900 ppm

3.5 Regression Analysis and Establishment of Model

Table 3. Regression analysis of fabric dye concentration on type of fish, market location, and time of sampling.

Variable	Coefficients (β)	Standard Error	p-value
Intercept	3869.75	102.72	0.000
Type of Fish	-99.78	46.87	0.035
Market Location	-11.44	12.71	0.370
Time of Sampling	54.48	28.47	0.058
R^2		0.064	
Adjusted R^2		0.042	
p- value		0.038	

The table presents the results of the regression analysis of the relationship between the dependent variable (concentration of fabric dye) variable and the independent (type of fish, market location, and time of sampling) variables. The results indicate that the overall regression model is statistically significant, as evidenced by a p-value of 0.038. This suggests that at least one of the predictor variables has a significant relationship with dye concentration. This is evident in the type of fish which resulted in significant (*p-value* <0.05), while market location and time of sampling resulted to not significant (*p-value* >0.05). However, the model demonstrates a restricted capability to explain in the dependent variable. The R^2 value of 0.064 indicates that only 6.4% of the variation in the concentration of the dye can be attributed to the variable predictors in the model. The low R^2 value emphasizes the importance of other potential variables not included in this model. The adjusted R^2 value of 0.043 confirms that the model explanation regarding the concentration of the food dye variance since it considers both variable number and sample size. The R^2 value signifies that unconsidered variables in the present model would likely affect the dependent variable more powerfully. Moreover, using the coefficients, the established equation based on the model is presented to be:

Dye Concentration (ppm) = 3869.755 - 99.78(Type of Fish) - 11.44(Market Location) + 54.48(Time of Sampling) (2)

The intercept represents the predicted value of the dye concentration when all the predictor variables are set to zero (often the lowest or the baseline category. The expected concentration of the dye in fish sample would be around 3869.76 ppm. Also, the p-value suggests that the interception is statistically significant (*p-value* <0.05). The coefficient value of the type of fish is -99.78 which indicates that if the other variable is held constant, the concentration of the dye is estimated to decrease by 99.78 units. This means that negative coefficients signify that the type of fish statistically decreases the concentration of the dye. Holding other predictor variable as constant, the concentration of the dye is expected to decrease by 11.44 units for market location, which indicates a weak negative effect on the concentration of the dye. Lastly, if the other predictor variable is held constant, the concentration of the dye is estimated to increase by 54.48 units in the type of sampling. It is also suggested that the increase of concentration depends on the time of sampling (morning, afternoon, evening), especially that the increase of the concentration of the food dye is more evident in the evening. However, even though the time of sampling has a positive effect on the concentration of the dye, it has no significant since the p-value is slightly above the 5% threshold.

3.6 Prevalence of Intentional Fabric Dye Contamination in the Study Sites

The study sites selected in the present study are located both in the western and eastern parts and at the city's center. The Opol town and barangay Bulua are 7 km and 3.5 km from the city's center, while the Cugman and Puerto markets are 3.8 and 17 km from the city's center. Moreover, the Cogon and Carmen markets are within the city's center. Table 2 shows that the fabric dye concentration values range from 3000 – 4000 ppm. It is evident from the table that the concentration of the fabric dye in all sampling sites values exceeded 3757 ppm, particularly during the 7:00 PM sampling time. Statistical analysis confirmed the significant difference between the fish samples obtained from the fish market suspected to be tainted with fabric dyes and unadulterated fish meat samples. The T-test was calculated using Microsoft Excel version 2019. The result of the T-test is presented in Table 2 with the *P* values shown. The *P* values obtained from the T-test ranged from 0.000000021- 0.1895468. The *P* values generally are lower than 0.05. This range of values is indicative that the blue dyes in the meat sample are present in the meat sample. Not only is the blue dye present in the meat sample, but the concentration of the blue dye absorbed is also significantly different.

Since 5 of the 6 of the sampling sites have values greater than the 3757-ppm value, this is indicative that the practice of intentional adulteration in fish sold in these market sites is done particularly in the evening. Of all the sampling sites, only the Cogon market has a value lower than 3757 ppm. However, the data collected in the morning and afternoon are inconclusive since the values observed were less than 3757 ppm. A possible reason is that the fish samples are newly purchased from the fish landing in the morning. The usual practice of purchasing fish from the fish landing and other suppliers from neighboring municipalities takes 4:00 AM to 9:00 AM. During this period, the fish products are still fresh or iced, and the quality of the fish has not yet deteriorated. Due to poor postharvest storage facilities, using only styro boxes, large plastic basins, and/or conical steel tanks with broken ice, quality deterioration in fish is rapid. Thus, later in the day, the quality of the fish is characterized by pale skin and reddish eyes, and fish meat has lost its rigidity.

4. Conclusion and Recommendation

Food safety of the food we eat is a growing concern as a lot of food products undergoes processing and sometimes added with chemical unsafe for the health. Food adulteration is the intentional addition or modification of a food product with inferior, cheaper, or non-authentic substances, often to increase volume or weight, or to improve appearance, which can compromise the product's quality, safety, and nutritional value. The practice of food adulteration can lead to health hazard and financial losses. Food fraud is the deception of consumers through intentional food adulteration. In this study, the incidence of fabric dye contamination in two fish species sold in various fish stalls located in the four different communities in Cagayan de Oro City and one nearby municipality in Misamis Oriental were evaluated. The information revealed from the experiment showed that several fish stalls selling marine fish species specifically big eye scad and sardines are contaminated with blue fabric dyes. Results of the spectrophotometric analysis revealed that intentional adulteration fish samples sold early evening are intentionally contaminated with fabric dye to deceive customers of its quality and may pose health risk to consumers as fabric dyes contain chemical compounds no approve for consumption. The application of this blue fabric dye in the iced water during storage of fish violates the government policy and necessitates action. Stringent measures should be taken to avoid such malpractices and assure consumer food safety.

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