Al-Jahiz: Journal of Biology Education Research
ISSN 2722-5070 (Print) ISSN 2722-5275 (Online)
Vol. 6 No. 2 July-December 2025
Available online at:
http://e-journal.metrouniv.ac.id/index.php/Al-Jahiz

Qualitative and Quantitative Detection of Borax in Food Using Butterfly Pea Flower Extract

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Article Information

Article History:
Received: June 28, 2025
Revised: November 18, 2025
Published: December 9, 2025

Keywords:
Borax, Butterfly pea extract, UV-Vis spectrophotometry, Natural detector

ABSTRACT

The detection of borax in food is of critical importance due to its toxic properties, which pose serious health risks, especially when consumed continuously, even in small amounts. Therefore, an environmentally friendly, accessible, and easy-to-use detection method is needed for broader application, particularly in routine food monitoring. This study introduces a novel quantitative detection approach using butterfly pea flower (Clitoria ternatea L.) extract as a natural indicator, combining visual colorimetry and UV-Vis spectrophotometry for dual-mode borax analysis. Unlike previous studies that focused solely on qualitative color observation, this research establishes a quantitative correlation between absorbance and borax concentration, supported by strong linearity (R^2 = 0.9942) and high sensitivity (LoD = 0.026 ppm; LoQ = 0.088 ppm). The butterfly pea extract, rich in anthocyanins, produced a distinct blue color that shifted to green upon interaction with borax, forming a specific butterfly pea–borax complex with a maximum wavelength (λmax) at 624 nm. Application to real meatball samples revealed borax contents of 0.528% and 0.4641% in two samples, respectively. The integration of butterfly pea extract with turmeric paper as a dual-confirmation system enhances analytical reliability while maintaining cost-effectiveness and environmental safety. This work contributes a validated, eco-friendly, and quantitative natural detection method that bridges the gap between laboratory precision and community-based food safety monitoring.

How to Cite: Fitriani, D, Karyadi, B., Nursa'adah, E. (2025). Qualitative and Quantitative Detection of Borax in Food Using Butterfly Pea Flower Extract. *Al Jahiz: Journal of Biology Education Research*. 6(2), 400–415. DOI: https://doi.org/10.32332/al-jahiz.v6i2.11116.

Published by: Al-Jahiz: Journal of Biology Education Research
Website: https://e-journal.metrouniv.ac.id/index.php/Al-Jahiz/index

INTRODUCTION

Food is a primary human need that must be fulfilled daily to sustain life and support activity (Whitney & Rolfes, 2019). Along with technological and industrial developments, various types of processed foods have become increasingly diverse in terms of form, taste, and shelf life (Monteiro

et al., 2019). To improve product quality and extend shelf life, manufacturers often add food additives or chemical substances to processed food products (Hastuti & Rusita, 2020). Food additives are chemical compounds added to food to enhance its flavor, color, texture, and resistance to physical or microbiological spoilage (Emilia et al., 2020).

However, despite the permitted use of food additives, there are serious challenges in the form of the misuse of unregulated or excessive additives (EFSA, 2020). One such case that is still frequently found in Indonesia is the use of borax (sodium tetraborate) in processed food products, particularly in meatballs (*bakso*) (BPOM, 2019). Meatballs are one of the most popular and widely consumed foods in Indonesia due to their savory taste and chewy texture (Wijaya, 2019). Unfortunately, this desirable texture often motivates some producers to use borax, which is in fact a prohibited additive (Khoiroh et al., 2024). Borax is an inorganic compound in the form of white crystals that dissolve in water and is typically used in non-food industries such as glass production, detergents, wood preservatives, and pesticides (Juwita et al., 2021). Although it is not intended for human consumption, this compound is often misused in food products due to its ability to enhance elasticity, chewiness, and storage stability in various processed foods such as meatballs, noodles, tofu, and crackers (Yuliantini & Rahmawati, 2019).

The misuse of borax in food poses significant health risks, as it is toxic both acutely and chronically. In the short term, consuming borax can cause digestive disturbances such as nausea, vomiting, and diarrhea, and in higher doses, may lead to seizures and organ failure (Lestiana Bolo et al., 2023). In the long term, exposure to borax can damage the liver, kidneys, and central nervous system, and increase the risk of reproductive disorders and cancer (Tubagus & Citraningtyas, 2013). For this reason, the Indonesian government has strictly prohibited the use of borax as a food additive through the Regulation of the Minister of Health of the Republic of Indonesia No. 033 of 2012 (Suntaka et al., 2015).

Despite this regulation, field findings still show that borax continues to be used by certain producers. Suseno (Suseno, 2019) reported that out of 10 randomly selected meatball samples in Medan City, 80% tested positive for borax, with concentrations ranging from 0.08% to 0.29%. Meanwhile, Ati et al. (Ati et al., 2024) found that 5 out of 25 meatball samples sold in Kupang City also contained borax. These facts indicate that the presence of borax in processed food, particularly meatballs, remains a real threat to food safety and public health (Rahayu et al., 2024). Given the urgency of this issue, the early detection of borax in food products is a pressing need to prevent public health risks (Suntaka et al., 2015). Several methods have been developed to detect the

presence of borax in food, including thin-layer chromatography (TLC) and mass spectrometry (MS), which are known for their high accuracy (Chien et al., 2021). However, these methods require expensive laboratory equipment and skilled personnel, making them impractical for educational settings or community use (Asyani et al., 2024).

These limitations present challenges for routine monitoring by communities or food safety agencies. Therefore, a detection method that is efficient, low-cost, environmentally friendly, and applicable for both visual and instrumental analysis is required. One promising alternative is the use of butterfly pea flower (*Clitoria ternatea* L.) extract as a natural indicator (Rahim et al., 2020). This plant is known to contain anthocyanins, a type of flavonoid pigment that undergoes significant color changes in response to pH shifts or interaction with certain ions, including borate (Gafar et al., 2022); (Dangles & Fenger, 2018). Under acidic conditions, anthocyanins appear reddish-purple, while in alkaline conditions, they shift to blue or green depending on the pH level (Rifqi, 2021).

The use of butterfly pea extract as a borax detector shows potential not only for qualitative detection through visible color changes but also for quantitative analysis using UV-Vis spectrophotometry, by measuring light absorbance after interaction with borax (Hidayah et al., 2024). Additional advantages include its environmental friendliness, as it is plant-based and renewable; low cost, making it suitable for household or small laboratory use; ease of use for both direct visual inspection and instrumental absorbance measurements; and reproducibility and stability over certain pH ranges, allowing it to be further developed into a field detection kit (Shabrina et al., 2025).

So far, anthocyanins from butterfly pea flowers have been more commonly applied in the food industry as natural coloring agents, in cosmetics as bioactive antioxidants, and in biochemistry as pH indicators (Rifqi, 2021). However, their potential application for borax detection in an analytical context remains underexplored and represents an innovative solution for food monitoring programs based on green chemistry principles (Shabrina et al., 2025). By integrating green chemistry, the utilization of butterfly pea extract as an indicator supports a low-waste, user-safe, and environmentally harmless approach. Therefore, this study aims to develop a borax detection method in food, specifically in meatball products, using butterfly pea extract for both qualitative detection (via color change) and quantitative detection (via UV-Vis spectrophotometry), to strengthen sustainable and practical food safety monitoring systems in the community.

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RESEARCH METHODS

Materials

The materials used in this study included fresh butterfly pea flowers (*Clitoria ternatea L.*) collected from residential gardens in Bengkulu, Indonesia. Anhydrous borax (sodium tetraborate, $Na_2B_4O_7$, pro analysis grade, purity ≥99.0%, PT Brataco, Jakarta, Indonesia), sodium nitrite ($NaNO_2$, pro analysis grade, purity ≥98.5%, PT Brataco, Jakarta, Indonesia), sodium nitrate ($NaNO_3$, pro analysis grade, purity ≥99.0%, PT Brataco, Jakarta, Indonesia), sodium chloride (NaCl, pro analysis grade, purity ≥99.0%, PT Brataco, Jakarta, Indonesia), and formalin solution (formaldehyde 37% in water, PT Brataco, Jakarta, Indonesia) were used as chemical reagents. Distilled water (aquadest, laboratory grade) was used as solvent. Fresh meatballs (bakso) were purchased from several meatball vendors across different districts in Bengkulu Province, Indonesia, and used as test samples.

The instruments utilized comprised a UV-Visible spectrophotometer (Genesys 150, Thermo Fisher Scientific, Waltham, MA, USA) for absorbance measurements. A custom-built mini photo studio equipped with LED lighting (5500K color temperature) was used for standardized image capture. Data quantification and graphing were performed using Microsoft Excel 2019 (Microsoft Corporation, Redmond, WA, USA).

Procedures

Preparation of Butterfly Pea Flower Extract

Fresh butterfly pea flowers were collected immediately before extract preparation to ensure maximum anthocyanin content and prevent degradation. The plant was identified based on its distinctive morphological characteristics including bright blue petals, butterfly-shaped corolla structure, and climbing growth habit, which are typical features of C. ternatea L. as described by Suarna and Wijaya (2021). Only the blue flower petals (corollas) were used in this study, excluding the sepals and other flower parts.

The use of fresh flowers was based on the consideration that they contain a higher total anthocyanin content compared to dried flowers. Drying or heating processes can lead to the degradation of anthocyanin compounds, thereby reducing their effectiveness as a natural indicator (Putri et al., 2022). Therefore, the use of fresh flowers was expected to yield an optimal anthocyanin extract. A total of 5 grams of fresh butterfly pea flower petals were weighed, rinsed with distilled water to remove impurities, then soaked in 100 mL of water heated to 80 °C for 15 minutes. The

mixture was subsequently filtered using Whatman No. 1 filter paper to obtain the anthocyanin pigment extract.

Qualitative and Quantitative Analysis

For the qualitative analysis (selectivity test), the specificity of the butterfly pea extract indicator toward different food additives was evaluated. Each test solution including formalin (37% formaldehyde), sodium chloride (NaCl), sodium nitrite ($NaNO_2$), sodium nitrate ($NaNO_3$), and borax ($Na_2B_4O_7$) was prepared at a concentration of 1000 ppm in distilled water. A volume of 4 mL of each test solution was mixed with 0.5 mL of butterfly pea extract (8:1 v/v ratio) in a test tube. Color changes were visually observed and photographed under standardized lighting conditions using the mini photo studio. The UV-Vis absorbance spectrum was recorded in the wavelength range of 400-700 nm using a spectrophotometer to identify the maximum absorbance wavelength (λmax) and confirm specific interactions. The selectivity was evaluated based on the distinctiveness of color change and the magnitude of wavelength shift (Δλmax) compared to the blank (distilled water mixed with butterfly pea extract in the same ratio) (Shabrina et al., 2025).

For the quantitative analysis (sensitivity test), borax standard solutions with concentrations of 0 (blank), 250, 500, 750, and 1000 ppm were prepared in distilled water. Each borax solution (4 mL) was mixed with 0.5 mL of butterfly pea extract (8:1 v/v ratio), and the mixture was allowed to equilibrate for 5 minutes at room temperature. The UV-Vis absorbance was measured at the maximum wavelength (λmax) determined from the qualitative analysis. A calibration curve was constructed by plotting the absorbance (y) at λmax versus borax concentration (C, ppm). Linear regression analysis was performed using the equation (Barzallo et al., 2023):

$y = mx + c$

where:

y = absorbance at λmax (dimensionless)

x = borax concentration (ppm)

m = slope or sensitivity coefficient (ppm^{-1})

c = y-intercept (absorbance of blank)

The coefficient of determination (R^2) was calculated to evaluate the linearity of the calibration curve. The sensitivity of the method was represented by the slope value (a). The limit of detection (LOD) and limit of quantification (LOQ) were calculated using the standard deviation

(SD) of the blank measurements (n=3) and the slope of the calibration curve (Shrivastava & Gupta, 2011):

LOD = 3.3 × (SD/slope)

LOQ = 10 × (SD/slope)

where LOD represents the minimum detectable concentration and LOQ represents the minimum quantifiable concentration of borax in the sample.

Sample Collection and Preparation

Meatball samples were collected using a purposive area-based sampling technique to represent different geographical locations within Seluma Regency, Bengkulu Province. Ten villages/sub-districts were purposively selected based on their distribution across the regency and the availability of meatball vendors. From each selected area, one fresh meatball sample (approximately 100 grams) was purchased from a local street vendor or market seller. The selection criteria included: (1) meatballs sold as ready-to-eat food, (2) vendors actively selling at the time of collection, and (3) samples representing the most commonly consumed meatball type in each area. Sample collection was conducted over a period of few days (September, 2024) during peak market hours (08:00-11:00 local time) to ensure fresh samples. Each sample was immediately placed in a sterile, sealed plastic container, labeled with a unique code (MB-01 to MB-10) indicating the source location, and transported to the laboratory in a cooler box with ice packs to maintain freshness. Upon arrival at the laboratory, samples were stored at 4°C and analyzed within 24 hours of collection to minimize degradation of any potential additives.

The ten sampling locations were: (1) Tumbuan Village, (2) Talang Tinggi, (3) Napal, (4) Tais, (5) Sidomulyo, (6) Talang Perapat, (7) Padang Rambun, (8) Rena Panjang, (9) Mandi Angin, and (10) Lubuk Lintang. These locations were selected to provide broad geographical coverage of meatball vendors across Seluma Regency.

Borax Detection in Meatball Samples

The application of the butterfly pea extract indicator for borax detection in real food samples was performed following the method adapted from Yan et al., (2021) with modifications. Meatball samples were collected and stored in dry containers, each labeled according to its source location. A portion of 2 grams from each sample was taken, added to 20 mL of distilled water, then homogenized and allowed to stand for 10 minutes. The mixture was filtered using filter paper to obtain a clear filtrate. As a preliminary screening test, turmeric indicator paper was dipped into each filtrate for 5 seconds. Upon dipping the paper into the samples, a color change from yellow to brown or reddish-brown occurred in borax-positive

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samples, while negative samples retained the yellow color. For quantitative testing, 0.5 mL of the butterfly pea extract was added to 4 mL of the meatball filtrate. The color change was observed visually, and the absorbance was measured using UV-Vis spectrophotometry. The borax concentration in the meatball samples was calculated using the linear regression equation obtained from the calibration curve (sensitivity test), $x = (y - c)/m$.

RESEARCH RESULT

Qualitative Test of Butterfly Pea Extract

The butterfly pea flower extract produced a dark blue solution (Figure 1(a)), which is a characteristic color of anthocyanin pigments under neutral to slightly basic conditions. This is due to the presence of anthocyanins as the primary pigment in butterfly pea flowers, particularly the delphinidin type, which appears blue to purple depending on the pH level (Angriani, 2019). A blank solution was also prepared by diluting 0.5 mL of the extract with 4 mL of distilled water (Figure 1(b)). This blank solution was then measured for its absorbance using a UV-Vis spectrophotometer to determine its maximum wavelength. The resulting absorbance spectrum is presented in Figure 1.

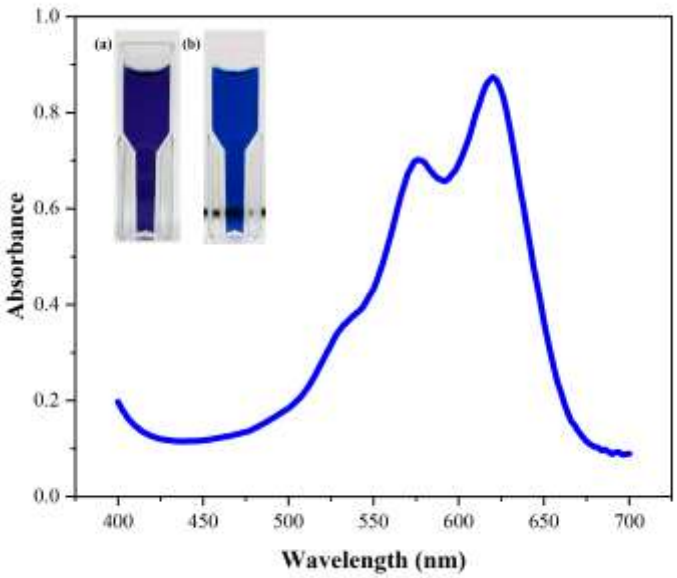

Figure 1. UV-Vis absorbance spectrum of the blank solution. Inset is a visual view of (a) the extract of butterfly pea flower, and (b) the blank solution prepared by diluting the extract with distilled water (0.5:4, v/v).

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The absorbance maximum was observed at 620 nm, which corresponds to the highest absorbance value of the natural complex derived from the butterfly pea extract. Further selectivity testing of the butterfly pea extract was conducted using several test solutions, including formalin, NaCl, borax, $NaNO_2$, and $NaNO_3$, each at a concentration of 1000 ppm. As shown in Figure 2(a), only the borax solution induced a significant color change from blue to green, whereas the other solutions retained a light reddish-blue color similar to that of the blank. The UV-Vis spectrum in Figure 2(b) further confirmed that only the borax solution caused a noticeable spectral shift in the absorbance peak from 620 nm to 624 nm.

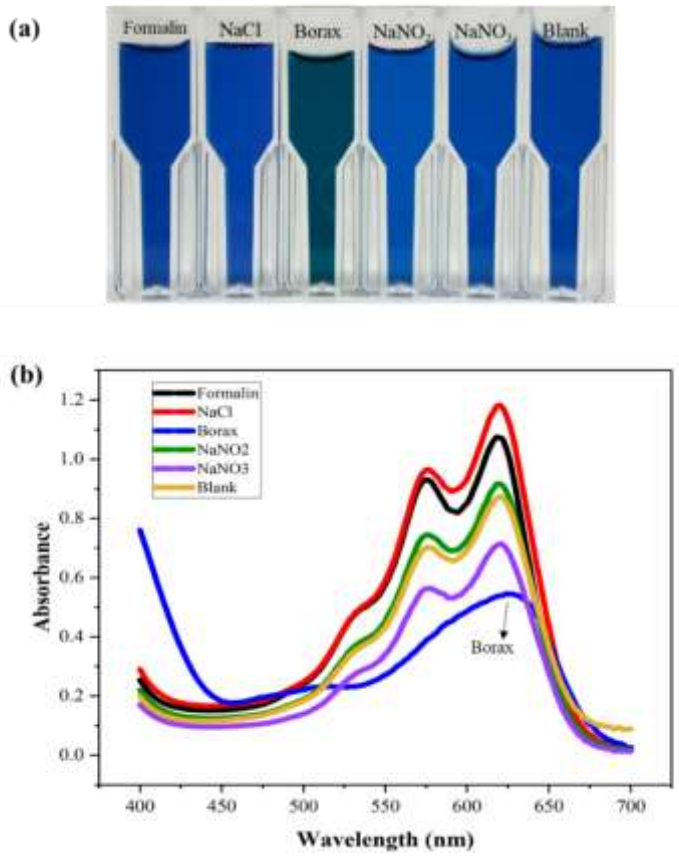

Figure 2. (a) Visual color response of butterfly pea extract after complexing with various saline solutions and formalin at a concentration of 1000 ppm, (b) UV-Vis absorbance spectrum of the solution in Figure 2(a)

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Quantitative Analysis of Butterfly Pea Extract

Quantitative analysis, or sensitivity testing of borax, was conducted at the maximum absorbance wavelength (λmax) of the anthocyanin pigment in butterfly pea extract, which was observed at 624 nm. A calibration curve was constructed using borax solutions at concentrations of 0 ppm, 250 ppm, 500 ppm, 750 ppm, and 1000 ppm.

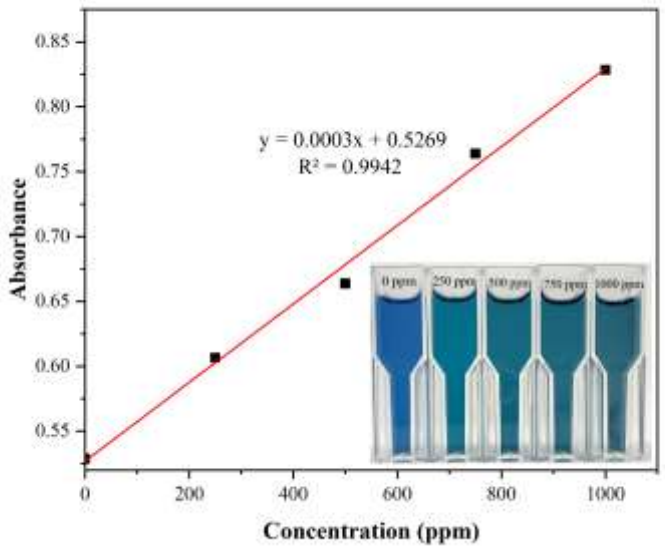

Figure 3. Calibration curve of butterfly pea extract - borax by UV-Vis Spectrophotometry. Inset is a digital image of bay flower extract - borax complex in various concentrations.

The linear regression equation shown in Figure 3 indicates a strong relationship, as evidenced by the high coefficient of determination (R^2) value of 0.9942, which is close to 1. The linear regression equation (1):

$$y = 0.0003x + 0.5269 \quad (1)$$

This equation was subsequently used to calculate the borax concentration in the samples based on the measured absorbance values (y), where x represents the borax concentration.

Determination of LoD and LoQ

The limit of detection (LoD) and limit of quantification (LoQ) were determined to validate the sensitivity and analytical performance of the UV-Vis spectrophotometric method using butterfly pea flower extract as a natural detector for borax. The values of LoD and LoQ were calculated using the following equations (2) and (3) (Dillingham et al., 2017):

$$LoD = (3 \times SD)/slope \quad (2)$$

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$$LoQ = (3 \times SD)/slope \quad (3)$$

Based on the calculations, the LoD was found to be 0.026 ppm and the LoQ was 0.088 ppm.

Determination of Borax in Meatball Samples

Meatball samples were collected from ten different areas in Seluma Regency, Bengkulu Province, namely: (1) Tumbuan Village, (2) Talang Tinggi, (3) Napal, (4) Tais, (5) Sidomulyo, (6) Talang Perapat, (7) Padang Rambun, (8) Rena Panjang, (9) Mandi Angin, and (10) Lubuk Lintang. A total of ten meatball samples were collected, as shown in Figure 4.

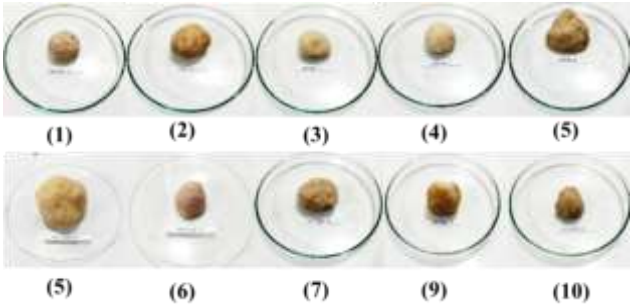

Figure 4. Meatball samples were collected from various locations

The color response of the meatball samples after reaction with butterfly pea flower extract is presented in Figure 5. Among the ten samples tested, only samples 2 (from Talang Tinggi) and 6 (from Talang Perapat) displayed a color transition from blue to green (Figure 5), which is characteristic of borax presence. The other eight samples retained their blue coloration, consistent with the negative control.

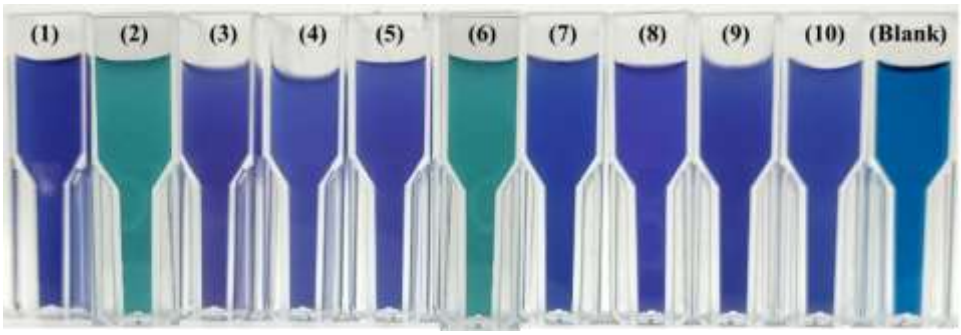

Figure 5. Visual color responses of 10 meatball samples after reaction with butterfly pea extract.

The qualitative analysis of borax in these meatball samples was further confirmed using turmeric paper as a secondary indicator, as shown in Figure 6. The detection limit of turmeric paper has been reported to reach 0.1783 ppm (Nurma, 2017). Upon dipping the paper into the

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samples, a color change from yellow to brown or red occurred in borax-positive samples (Safitri, 2024).

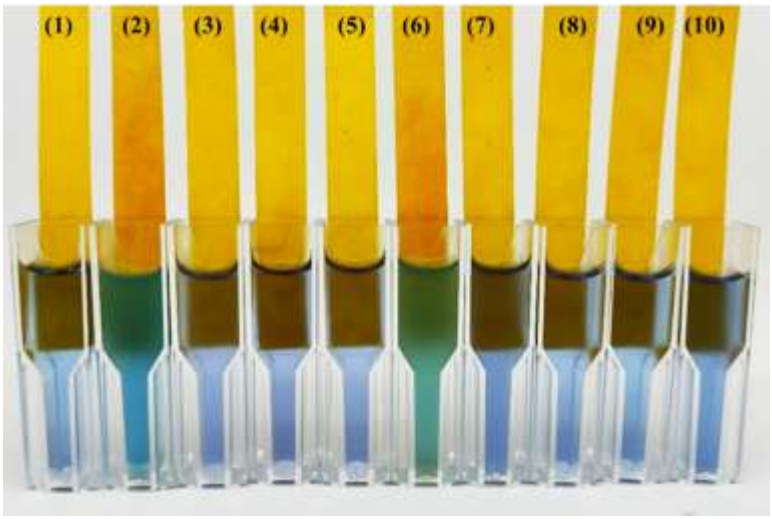

Figure 6. Results of borax testing on 10 meatball samples using butterfly pea extract and turmeric indicator paper

After completing the qualitative tests using butterfly pea flower extract, the next step was to perform quantitative analysis of borax concentration using UV-Vis spectrophotometry. Based on the absorbance measurements, borax concentrations in sample 2 and sample 6 were found to be 0.528% and 0.4641%, respectively.

DISCUSSION

The butterfly pea flower extract produced a dark blue solution, a characteristic of anthocyanin pigments under neutral to slightly basic conditions. This is attributed to the delphinidin-type anthocyanins, which appear blue to purple depending on pH level (Angriani, 2019). The observed absorbance maximum at 620 nm aligns with literature, as blue anthocyanins generally absorb within 520–620 nm (Khaodee et al., 2018). Only borax caused a color shift from blue to green and a spectral shift from 620 nm to 624 nm, indicating a new complex between borax and anthocyanin. These findings highlight the selectivity and sensitivity of butterfly pea extract for borax detection (Trisdayant, 2022).

The calibration curve for borax showed a strong linear relationship with an R^2 value of 0.9942, indicating a reliable model for determining borax concentration. According to Zaka & Sutopo (Zaka & Sutopo, 2017), this value implies 99.42% of absorbance variation is explained by borax concentration (Supharoek et al., 2022). With LoD of 0.026 ppm and LoQ of 0.088 ppm, the method demonstrates excellent sensitivity. These values support the use of butterfly pea extract in

detecting and quantifying borax, even at low concentrations, making it suitable for simple, eco-friendly analytical applications and routine food safety monitoring. In real food samples, samples 2 and 6 from Seluma Regency showed a green color change, confirming borax presence, which was corroborated by turmeric paper results. Quantitative analysis showed borax levels in those samples exceeded safe limits (0.528% and 0.4641%), reinforcing the urgency of monitoring borax using accessible and environmentally safe methods like this natural indicator approach.

The detection of borax at concentrations of 0.528% and 0.464% in samples 2 and 6 has significant public health implications, as these levels far exceed the Indonesian regulatory limit of 0 mg/kg (BPOM Regulation No. 11/2019) and pose risks of chronic toxicity including kidney damage and reproductive disorders (Pizzorno, 2015). The 20% contamination rate in Seluma Regency highlights the need for enhanced food safety surveillance in traditional markets. This study demonstrates that butterfly pea extract offers a practical, low-cost alternative to conventional methods (HPLC, ICP-MS), enabling rapid screening with simple equipment suitable for resource-limited settings and community-based monitoring programs.

This study has several limitations. First, the small sample size (n=10) and purposive sampling from a single regency limit the generalizability of findings to broader populations. Second, potential matrix interferences from complex food components were not comprehensively evaluated, which may affect detection accuracy in real samples. Future research should include larger-scale, multi-regional studies with rigorous method validation according to international standards.

CONCLUSION

This study successfully developed and validated a method for detecting borax in food products using butterfly pea flower extract as a natural detector in conjunction with UV-Vis spectrophotometry. The use of fresh butterfly pea flowers was shown to be effective due to their anthocyanin content, which is sensitive to the presence of borax and produces a distinct and significant color change from blue to green. This characteristic enables the extract to be used for both qualitative and quantitative detection. The selectivity test demonstrated that only borax caused a visible color change and a shift in absorbance wavelength, confirming the specificity of the butterfly pea extract toward borax. The resulting calibration curve exhibited a strong linear correlation between borax concentration and absorbance, with an R^2 value of 0.9942. The limit of detection (LoD) was calculated to be 0.026 ppm, and the limit of quantification (LoQ) was 0.088

ppm, indicating that the method is highly sensitive and capable of detecting low concentrations of borax.

Application of this method to meatball samples collected from different regions revealed that two out of ten samples tested positive for borax. Sample 2 contained 0.528% borax, while sample 6 contained 0.4641%, as confirmed by visual color change in the extract, turmeric paper testing, and quantitative measurements using UV-Vis spectrophotometry. In conclusion, butterfly pea flower extract demonstrates significant potential as an eco-friendly and effective natural indicator for detecting borax in food. This method is feasible for widespread application, particularly in community-level food safety monitoring and in small to medium-scale food industries.

ACKNOWLEDGMENTS (if applicable) (Garamond, size 12)

The authors would like to express their sincere gratitude to the Chemistry Education Laboratory, University of Bengkulu, for providing the facilities and equipment necessary to carry out this research.

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