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Effectiveness of Purple Cabbage Flower (*Brassica oleracea var. capitata f. rubra*) Extract as a Natural Indicator for Borax Identification in Food Products

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Abstract: The misuse of borax as a preservative in school snacks poses a serious threat to food safety, necessitating practical and accessible solutions for the general public. This study aimed to evaluate the effectiveness of purple cabbage (Brassica oleracea var. capitata f. rubra) extract as a natural indicator for the qualitative detection of borax. Laboratory experiments were conducted at the Biology Laboratory of Universitas Negeri Medan using the maceration method with water as the solvent to extract anthocyanin pigments. Food samples tested included meatballs, tofu, yellow noodles, and crackers. The results showed that purple cabbage extract successfully detected borax in yellow noodle samples through a colour change from purple to bluish-green, caused by the deprotonation of anthocyanins under alkaline conditions. These findings demonstrate that purple cabbage extract is a valid, economical, practical, and environmentally friendly screening tool to support public food safety monitoring.

Keywords: Anthocyanin, Borax, Food Safety, Natural Indicator, Purple Cabbage

***Abstrak:** Penyalahgunaan boraks sebagai pengawet pada jajanan sekolah merupakan ancaman serius terhadap keamanan pangan yang menuntut solusi praktis bagi masyarakat. Penelitian ini bertujuan untuk mengevaluasi efektivitas ekstrak bunga kol ungu (Brassica oleracea var. capitata f. rubra) sebagai indikator alami untuk mendeteksi kandungan boraks secara kualitatif. Eksperimen laboratorium dilakukan di Laboratorium Biologi Universitas Negeri Medan menggunakan metode maserasi dengan pelarut air untuk mengekstraksi pigmen antosianin. Sampel makanan yang diuji meliputi bakso, tahu, mie kuning, dan kerupuk. Hasil penelitian menunjukkan bahwa ekstrak bunga kol ungu mampu mendeteksi boraks pada sampel mie kuning melalui perubahan warna indikator dari ungu menjadi hijau kebiruan akibat reaksi deprotonasi antosianin pada kondisi basa. Berdasarkan temuan tersebut, ekstrak kol ungu terbukti valid dan layak digunakan sebagai instrumen skrining awal yang ekonomis, praktis, serta ramah lingkungan untuk mendukung kemandirian masyarakat dalam pengawasan keamanan pangan.*

***Kata Kunci:** Antosianin, Boraks, Indikator Alami, Keamanan Pangan, Kol Ungu*

INTRODUCTION

Food safety is a fundamental pillar in safeguarding public health, particularly for school-age populations who are highly dependent on daily snacks within educational environments. Processed food products in wide circulation are frequently targeted for misuse by irresponsible manufacturers who add hazardous chemicals to enhance the visual appeal, texture, and shelf life of their products (Salim et al., 2026). Although government regulations explicitly prohibit the use of non-food substances, the practice of adding illegal additives remains prevalent in various regions due to suboptimal enforcement and limited producer awareness of healthy food quality standards (Sulistiyorini, 2024; Syafriani et al., 2024). This phenomenon demands serious attention from academics and health authorities to develop early detection instruments that are practical and accessible to the general public as a means of mitigating health risks from hazardous substance contamination in the local food supply chain (Berliana et al., 2021).

Borax, or sodium tetraborate, is one of the most commonly misused illegal food additives (Bahan Tambahan Pangan/BTP) that has been systematically prohibited by the Indonesian National Agency of Drug and Food Control (BPOM) for use in food products. Nevertheless, the frequency of borax use among traditional food producers remains relatively high (Ayuliansari et al., 2024). Functionally, borax is often added to products such as meatballs, wet noodles, and crackers because of its ability to impart springiness and crunchiness while also serving as an economical preservative (Auliya et al., 2022). According to Sulistiyorini (2024), this substance is particularly sought after by unscrupulous vendors because of its easy availability and comparatively low price relative to legally approved food additives, so that economic motives frequently override consumer safety considerations.

The physiological impacts of long-term borax consumption are extremely hazardous to the human biological system due to its accumulative nature in the body (Andriani & Utami, 2023). Chronic exposure to this compound can trigger systemic metabolic disorders affecting vital organs such as the liver, kidneys, spleen, and central nervous system (Sulistiyorini, 2024). At high concentrations, borax causes acute symptoms including nausea, persistent vomiting, diarrhoea, and potentially fatal acute renal failure (Gaffar et al., 2023). In children, borax exposure can even trigger growth retardation and cellular toxicity that endangers their long-term development. Given these systemic hazards, the presence of borax in food cannot be tolerated, even at low concentrations.

In response to this problem, various prior studies have focused on developing simple borax detection methods using natural bio-indicators rich in phytochemical compounds, particularly curcumin and anthocyanins. The use of turmeric extract has been proven effective in detecting borax through the formation of a reddish-brown rosocyanine complex (Riniati et al., 2020; Sulistiyorini, 2024). In addition, butterfly pea flower (*Clitoria ternatea*) has also shown potential as a qualitative indicator owing to the sensitivity of its pigments to the alkaline properties of borax (Auliya et al., 2022). However, most of these independent detection methods still face limitations in terms of colour stability during storage and the fluctuating availability of raw materials across different seasons (Puspitasari et al., 2022).

On the other hand, standard laboratory testing methods such as alkalimetric titration and UV-Vis spectrophotometry, although highly accurate, require large operational costs and sophisticated equipment that are inaccessible to ordinary citizens or educational institutions (Syafriani et al., 2024). Limited laboratory infrastructure and complex technical procedures constitute major barriers to real-time food safety monitoring in the field (Auliya et al., 2022). This situation creates an urgent research gap regarding the need for more practical and economical early screening instruments that nonetheless maintain a clear and reliable level of visual validity to support community self-monitoring of food quality.

Purple cabbage (*Brassica oleracea* var. *capitata* f. *rubra*) has emerged as a promising natural indicator candidate owing to its high anthocyanin concentration and superior stability profile compared with other flowering plant pigments (Castañeda-Ovando et al., 2009; Senja et al., 2014). The anthocyanin pigments in purple cabbage are known to be highly sensitive to changes in pH, enabling them to produce a contrasting colour response when reacting with alkaline substances such as borax through a deprotonation mechanism (Gustriani et al., 2016; Yessica, 2023). This advantage makes purple cabbage a green laboratory-based solution that is safe for both users and the environment compared with synthetic indicators, which can generate hazardous chemical waste. The development of detection methods using anthocyanin pigments has been extensively explored; one example is the use of dragon fruit peel extract as a natural acid-base titration indicator (Meganingtyas & Alauhdin, 2021). Research by Nurjanah et al. (2020) also utilised anthocyanin pigments from purple cabbage as a natural indicator for analysing hydroquinone in skin-whitening creams.

The novelty of the present study lies in the optimisation of anthocyanin extraction from purple cabbage as a rapid testing medium applied directly to various local food samples with a high contamination risk in the Medan area. Unlike previous studies that may have focused on general applications, this study is specifically directed at producing a visually contrasting test result, particularly on yellow noodle matrices where borax content is often difficult to distinguish by sensory evaluation alone. This approach is expected to serve as an educational model enabling communities to independently validate food safety without complete dependence on conventional laboratory testing (Nuryanti et al., 2019; Sulistiyorini, 2024).

The primary objectives of this study are to identify the presence of borax in various processed food samples using purple cabbage extract as a natural indicator, and to analyse in depth the colour transformation that occurs in anthocyanin pigments following interaction with hydroxyl ions generated by borax hydrolysis in food samples. Through this series of experimental tests, the practicality and effectiveness of the purple cabbage-based detection method are expected to be measurable as an economical early screening alternative for consumers choosing safe food products. The significance of these findings is expected to make a tangible contribution to reducing the prevalence of illegal preservative use in the community.

METHODS

Research Location and Time

This experimental study was conducted on 3 March 2026. All stages from material preparation and pigment extraction to sample testing were carried out at the Biology Laboratory, Universitas Negeri Medan. This location was selected to ensure equipment sterility, procedural accuracy, and consistent environmental control throughout the testing process.

Research Type and Design

This study was a descriptive qualitative laboratory experiment, employing a direct observational approach to evaluate the visual colour-change response of anthocyanin pigments extracted from purple cabbage upon contact with borax-contaminated food samples.

Instruments and Materials

The primary material used was fresh purple cabbage obtained from a local market in Medan. The food samples tested comprised seven product variants: white tofu, chicken meatballs, fish balls, yellow noodles, rice vermicelli, fish crackers, and pempek. The main equipment included a mortar and pestle for the maceration process, dropper pipettes for reagent application, filter paper, a scalpel, an analytical balance, and digital documentation equipment. The solvent used in the extraction process was distilled water, to obtain pure anthocyanin filtrate free of synthetic chemical contamination.

Research Procedure

Indicator Extract Preparation: Fresh purple cabbage was washed thoroughly and cut into small pieces, then ground using a mortar and pestle by the maceration technique. The resulting filtrate was filtered through filter paper to separate the concentrated liquid anthocyanin extract from the fibrous residue.

Sample Preparation: Food samples were cut into uniformly sized small portions (approximately 1 × 1 cm) or weighed to equal masses to ensure consistent treatment across each test unit.

Detection Test: Two to three drops of purple cabbage extract were applied directly to the surface of each food sample using a dropper pipette. Samples were left undisturbed for 3–5 minutes to allow the chemical reaction between borate ions in the sample and the anthocyanin pigments to proceed (Rochyani et al., 2017).

Data Collection Technique

Data were collected through direct visual observation of colour changes occurring on the surface of each sample after extract application. Colour changes were recorded chronologically and documented photographically to maintain the validity of the empirical data. The primary observation parameter was the colour transition from purple (the natural anthocyanin colour) to green or bluish-green, indicating the presence of borax.

Data Analysis Technique

Data were analysed using a qualitative descriptive approach. The colour-change mechanism was grounded in the theory of deprotonation of the anthocyanin molecular structure, which is sensitive to pH changes (Castañeda-Ovando et al., 2009). Observed colour changes were compared with a negative control (sample without borax) and a positive control (standard colour reference from the literature). Conclusions regarding food safety were drawn by comparing the visual colour response of each sample against BPOM food safety regulations concerning the prohibition of borax in food products.

RESULTS AND DISCUSSION

Qualitative testing of seven processed food samples obtained from a local market in the Medan area provided a clear picture of food safety conditions in the field. Based on the observational data presented in Table 1, significant variation in visual response was found between food samples meeting health standards and those indicated to contain illegal food additives (BTP).

Table 1. Qualitative Test Results for Borax in Food Samples

Food Sample	Initial Colour	Colour After Extrac Application	Test Result	Remarks
Chicken Meatballs	Greyish-white	Remained purple	Negative (−)	No borax detected
Fish Balls	Greyish-white	Remained purple	Negative (−)	No borax detected
Pempek	White	Remained purple	Negative (−)	No borax detected
White Tofu	White	Remained purple	Negative (−)	No borax detected
Rice Vermicelli	Transparent white	Remained purple	Negative (−)	No borax detected
Yellow Noodles	Yellow	Changed to green	Positive (+)	Borax detected
Fish Crackers	White	Remained purple	Negative (−)	No borax detected

Based on Table 1, most processed food samples—including chicken meatballs, fish balls, pempek, white tofu, rice vermicelli, and fish crackers—yielded negative results, as no colour change was observed in the indicator after treatment. This suggests that these products were likely produced in accordance with food safety standards. Producer compliance with BTP regulations, as stipulated in BPOM Regulation No. 22 of 2023, is crucial for reducing the still-high incidence of food poisoning cases in Indonesia (Berliana et al., 2021). In contrast, the yellow noodle sample showed a colour change in the indicator from purple to bluish-green, which constitutes strong evidence of borax contamination.

The contrasting visual response between the positive and negative samples is illustrated in Figure 1. Negative samples retained the original purple cabbage pigment, while the yellow noodle sample exhibited a very clear colour transition. This colour change confirms that purple cabbage extract is effective as a rapid, real-time early screening instrument for detecting alkaline substances in food structures (Yessica, 2023). The method offers cost-efficiency advantages compared with standard spectrophotometric methods that require complex optical equipment (Syafriani et al., 2024).

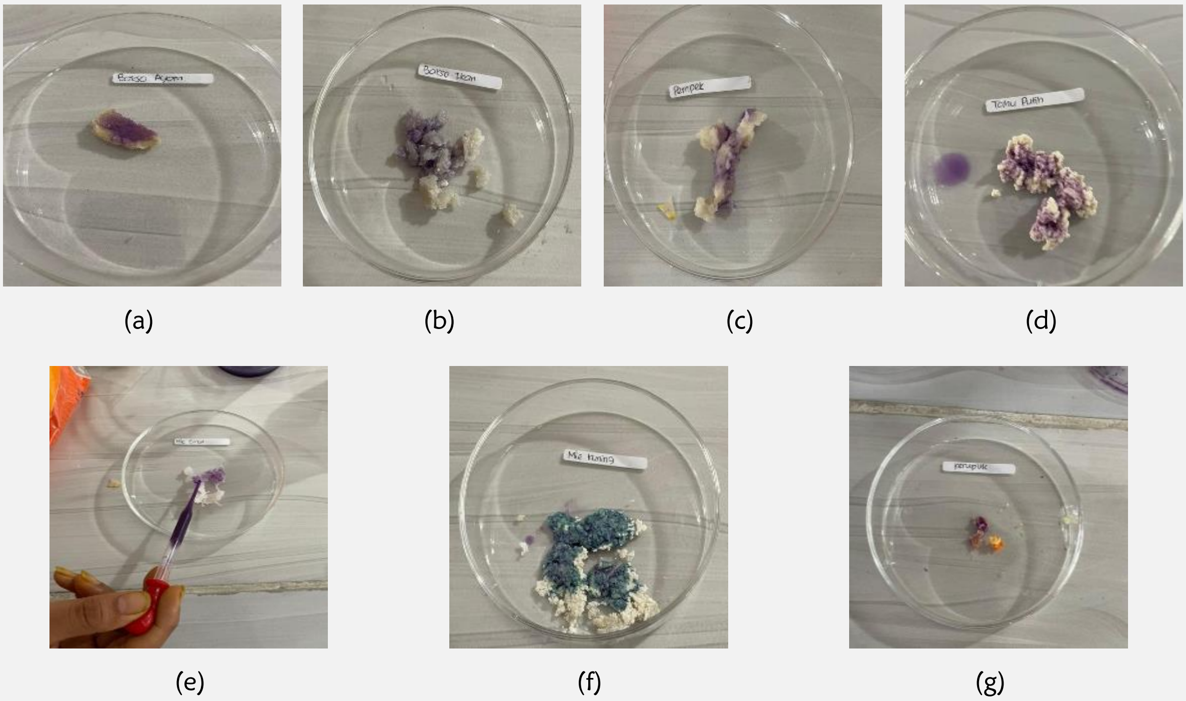

Figure 1. Borax Content Test Results for Food Samples: (a) Chicken meatballs, (b) Fish balls, (c) Pempek, (d) White tofu, (e) Rice vermicelli, (f) Yellow noodles, (g) Fish crackers

The effectiveness of purple cabbage as a bio-indicator is based on its abundant anthocyanin content—a group of amphoteric flavonoid pigments. Anthocyanins possess the unique ability to dynamically alter their molecular structure and colour profile in response to changes in environmental pH (Castañeda-Ovando et al., 2009). In acidic conditions, anthocyanins exist in the flavylium cation form, which appears red or deep purple (Senja et al., 2014). However, upon exposure to alkaline compounds such as borax, a deprotonation process occurs that alters the configuration of the conjugated double bonds in the flavylium cation (Riniati et al., 2020).

In terms of chemical mechanism, borax (sodium tetraborate) in water undergoes hydrolysis to produce boric acid and strongly alkaline hydroxyl ions (OH^-). The interaction of these hydroxyl ions with the anthocyanin pigments triggers a shift in molecular structure. Consistent with the findings of Gustriani et al. (2016), purple cabbage anthocyanins exhibit a very clear pH response range: the colour remains purple at neutral pH, shifts to bluish-green at pH 10.5–12.0, and becomes yellow under more extreme alkaline conditions. It is this sensitivity of purple cabbage anthocyanins at pH 9–11 that enables the visual detection of borax through a colour change to bluish-green (Riniati et al., 2020).

The positive finding in the yellow noodle sample confirms the misuse of illegal BTP for technological purposes. Borax is frequently added to noodle products because of its ability to increase springiness and textural integrity, preventing easy breakage (Auliya et al., 2022). Although it provides commercial advantages and high economic value for producers, the use of borax is severely hazardous to health due to the accumulative nature of the compound in the human body (Sulistiyorini, 2024). Excessive exposure can cause kidney and liver damage, making the earliest possible identification using natural indicators a crucial preventive step for communities (Gaffar et al., 2023).

Compared with other detection methods, purple cabbage extract offers a far sharper visual response than turmeric-based indicators. Turmeric relies on the reaction of curcumin with boron to form a reddish-brown rosocyanine complex (Sulistiyorini, 2024; Taupik et al., 2025). The principal limitation of turmeric indicators is that the natural yellow base colour of food often masks this colour change, making interpretation less contrasting. Purple cabbage, by contrast, provides a far more contrasting colour gradient, particularly on light-coloured or pale-yellow food matrices such as noodles.

Furthermore, the stability of purple cabbage anthocyanins is superior to that of pigments from other flowering plants, which tend to degrade rapidly. Extraction using ethanol or acidified water has been demonstrated to increase pigment yield and stability (Nuryanti et al., 2019; Senja et al., 2014). This stability advantage makes purple cabbage a more reliable indicator candidate for field-test screening needs compared with expensive synthetic indicators that may also pose environmental contamination risks (Puspitasari et al., 2022; Yessica, 2023). In line with current green materials research trends, the characteristics of natural pigment mixtures are being continuously developed not only for chemical indicators but also for more environmentally friendly materials technology applications (Rahmatullah et al., 2025).

The development of this method makes a significant contribution to public education on independent food safety monitoring. Members of the public—particularly housewives and school canteen managers—can use everyday kitchen ingredients to validate food quality without resorting to expensive and time-consuming laboratory procedures (Taupik et al., 2025). This is highly relevant for breaking the chain of borax toxin exposure that remains prevalent in school environments (Gaffar et al., 2023).

It should be noted, however, that this method retains its inherent limitations as a qualitative screening test. The procedure cannot precisely measure the concentration of borax in milligrams per kilogram (mg/kg) as UV-Vis spectrophotometry does, which requires sample destruction and distillation processes (Syafriani et al., 2024). Additionally, external factors such as light intensity and the storage temperature of the indicator can affect anthocyanin degradation (Castañeda-Ovando et al., 2009). Positive results from purple cabbage screening should therefore ideally be validated by standard laboratory testing to determine the severity of the contamination.

The long-term implication of this research is the creation of a more responsive culture of independent food safety monitoring. Integrating natural indicator-based methods into school chemistry practicum curricula can raise students' early awareness of the dangers of illegal food additives. Given their ease of access and simple procedure, these methods are expected to be widely adopted to narrow the gap in borax use among small-scale vendors, in pursuit of a healthier and safer educational environment for younger generations.

CONCLUSION

This study successfully demonstrated that purple cabbage (*Brassica oleracea* var. *capitata* f. *rubra*) extract is an effective, practical, and economical natural indicator for the qualitative detection of borax in food samples. The experimental analysis showed that the anthocyanin pigments in purple cabbage produce a highly contrasting visual response upon borax exposure a colour transformation from purple to bluish-green resulting from the deprotonation of the anthocyanin molecular structure under alkaline conditions. This finding confirms that anthocyanin-based natural indicators not only function as accurate early screening tools for high-risk food products such as yellow noodles, but also represent a green chemistry solution supporting independent food safety monitoring. Nevertheless, this method retains limitations in determining borax concentrations with precision. Future research is therefore recommended to optimise the extraction method to improve indicator colour stability over a longer period and to test the effectiveness of this method across a wider range of more complex food matrices.

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