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Utilisation of Turmeric (*Curcuma longa* L.) Extract as a Natural Indicator for Borax Detection in Food Products

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Abstract: The widespread misuse of sodium tetraborate among informal food producers highlights the urgent need for eco-friendly, independent food screening methods. This study aimed to validate the effectiveness of turmeric rhizome (*Curcuma longa* L.) as an initial screening instrument for borax in high-moisture food clusters. An experimental method was applied through direct visual contact testing of reactive curcumin extract against seven types of wet domestic food samples. Colorimetric test results showed that deep orange boron cyano curcumin (*rosocyanine*) complex formation was detected exclusively and positively in yellow noodle samples. Six other products chicken meatballs, fish balls, pempek, white tofu, vermicelli, and crackers were confirmed negative. It is concluded that the alkaline-induced structural degradation triggered by this local natural indicator demonstrates precise reactive sensitivity, is economically viable, and is applicable as a communal preventive solution for enhancing household food safety literacy.

Keywords: curcuminoid complex, food safety, borax screening, turmeric rhizome, yellow noodles

Abstrak: *Maraknya penyalahgunaan natrium tetraborat pada produsen informal memicu urgensi penapisan pangan mandiri yang ramah lingkungan. Penelitian ini bertujuan memvalidasi efektivitas rimpang kunyit (Curcuma longa L.) sebagai instrumen skrining awal boraks pada klaster pangan tinggi air. Metode eksperimental diaplikasikan secara luring melalui pengujian kontak visual ekstrak kurkumin reaktif terhadap tujuh jenis sampel pangan domestik basah. Hasil uji kolorimetri menunjukkan manifestasi senyawa kompleks boron cyano kurkumin (resosianin) orange pekat terdeteksi positif secara eksklusif pada sampel mie kuning. Sementara itu, enam produk lainnya (bakso ayam, bakso ikan, pempek, tahu putih, bihun, dan kerupuk) terkonfirmasi negatif. Disimpulkan bahwa degradasi struktur alkalis oleh indikator alami rimpang lokal ini terbukti memiliki sensitivitas reaktif yang presisi, ekonomis, serta aplikatif sebagai solusi preventif komunal dalam meningkatkan literasi keamanan pangan rumah tangga.*

Kata Kunci: *Keamanan pangan, kompleks rososianin, mie kuning, penapisan boraks, rimpang kunyit*

INTRODUCTION

Food is a fundamental human necessity closely linked to health integrity and sustainable quality of life. Ensuring food safety has become a global priority due to the increasing incidence of hazardous chemical contamination that poses long-term health crises for consumers. According to official documents from the Indonesian National Agency of Drug and Food Control (BPOM RI, 2020), the comprehensive enforcement of regulations across the domestic food supply chain still faces considerable challenges owing to low compliance among household-scale producers. This problem is further compounded by critical misinterpretations of the maximum permissible application thresholds for additive compounds, making periodic quality monitoring absolutely necessary (BPOM RI, 2021). Strengthening interactive education on the standardisation and identification of legally approved Food Additives (Bahan Tambahan Pangan/BTP) is therefore a crucial instrument for reducing the risk of toxin exposure within communities (Waznah et al., 2025).

Sodium tetraborate decahydrate, commonly known as borax, is one of the most frequently misused non-food industrial chemical compounds for modifying the physicochemical characteristics of food products. This substance is typically applied illegally by unscrupulous food vendors to improve textural springiness and crunchiness while simultaneously extending product shelf life (Suseno, 2019). The persistent accumulation of boron residues in the human biological system is toxic and is strictly prohibited for consumption. Clinically, chronic long-term exposure to this toxicant compound has been demonstrated to cause structural damage to the kidneys, disruption of digestive function, metabolic failure, and carcinogenic manifestations (Sari et al., 2023). Consumption of this hazardous additive also directly correlates with degradation of central nervous system function and triggers acute cellular inflammation in the intestinal mucosal tissue (Nuraini et al., 2025).

Numerous prior scientific studies have explored the quantification of borax levels using conventional laboratory instrumentation with high precision. Kresnadipayana and Lestari (2017) employed UV-Vis spectrophotometry to measure borax contamination levels in imported food products with excellent quantitative accuracy. Additionally, Syafriani et al. (2024) developed an analytical scheme combining qualitative commercial rapid test kits with spectrophotometric validation at specific wavelengths to map the distribution of this hazardous substance in noodle and cracker samples. Although these instrumental methods offer high accuracy, their field implementation is hindered by expensive operational costs, complex sample destruction procedures, and dependence on centralised laboratory facilities that cannot be instantly accessed by ordinary consumers.

To overcome these operational barriers, recent research trends have shifted toward optimising the use of secondary metabolites from local plants as independent screening reagents. Swastike et al. (2015) tested organic substances to screen for borax preparations in local street food, though the visual accuracy was still influenced by the maturity of the indicator raw material. Community literacy efforts have also been pursued through guided use of surrounding plant extracts as contextual acid-base learning media and as simultaneous formaldehyde and borax detectors (Sukaryawan et al., 2026). Furthermore, a descriptive study by Muthi'ah and A'yun (2021) confirmed that pigments from turmeric rhizome (

Curcuma longa L.) possess adequate reactive affinity toward borate ions. This colour-change response has also been utilised in independent detection outreach programmes to raise household consumers' awareness of food safety (Sulistiyorini, 2024).

Despite the extensive reporting of turmeric-based natural indicator testing, most practical applications still exhibit significant structural weaknesses. Qualitative experiments using turmeric paper frequently leave dominant residual yellow colour on solid food matrices that obscures visual conclusions (Bisyaroh, 2019). Furthermore, testing based on pure natural extracts often faces pH stability issues and an inconsistent limit of detection when confronted with boron concentrations below 500 ppm (Esati & Cahyadi, 2023). This research gap is further complicated by the scarcity of comparative studies analysing the reactive behaviour of curcuminoids simultaneously across high-moisture food matrices with heterogeneous levels of springiness and filler content such as wet noodles, processed meat products, and fried goods (Artiana et al., 2019). Interactions between the alkaline borax additive and the inherent colouring agents of the commodity frequently mask the visual degradation expected by consumers (Jumrah et al., 2023).

To fill this data gap, the novelty of the present study is directed at the comparative validation of the visual contact sensitivity of curcuminoid indicators tested against seven domestic wet food varieties with differing physicochemical characteristics. The study focuses on analysing the kinetics of colour change produced through the formation of the distinctive rosocyanine complex (*boron cyano curcumin* complex) resulting from the alkaline structural degradation of borate ions by the active curcumin compound. The primary question addressed is how to validate the consistency of the reddish-brown colour produced by the natural indicator without bias from the interference of local food matrix components. The main objective of this study is to evaluate the reactivity efficiency of pure turmeric extract as a precise, non-destructive, and community-applicable early-screening instrument for borax. The significance of this research is expected to provide a robust scientific foundation for the development of eco-friendly self-testing devices, while simultaneously offering a practical preventive solution to advance independent food safety literacy without reliance on synthetic reagents (Yunicho et al., 2023).

METHODS

Research Location and Time

This laboratory experiment was conducted at the Biology Laboratory, Universitas Negeri Medan. All qualitative testing procedures and physicochemical parameter observations of the specimens were completed simultaneously on 3 March 2026. The laboratory location was selected based on the need to control macro-environmental conditions such as stable indoor lighting intensity and minimisation of atmospheric cross-contamination in order to maintain the stability of reactive curcuminoid compounds during chelation interactions (Esati & Cahyadi, 2023).

Research Type and Design

The type of research applied was a descriptive qualitative laboratory experiment. The research design focused on testing the reactivity of natural rhizome extract against the alkaline groups of sodium tetraborate decahydrate across various domestic food matrices. The experimental design employed a positive control consisting of a technical borax solution and a negative control of pure distilled water to validate the accuracy of colour changes in the natural indicator.

Instruments and Materials

The primary instruments used in this laboratory standardisation procedure included a porcelain mortar and pestle, macro dropper pipettes, glass Petri dishes, a scalpel, a beaker glass, tweezers, a stopwatch, Whatman No. 42 filter paper, and specimen code labels. The chemical and biological materials prepared consisted of fresh commercial turmeric rhizome (*Curcuma longa* L.) as the raw material for curcumin functional isolation, distilled water (*aqua destillata*), and commercially available turmeric paper as a comparative porous absorption test.

Research Sample

The target specimen cluster in this study was based on purposive sampling of wet and dry food types historically susceptible to misuse of non-food preservatives in the Medan area. The research samples comprised seven domestic food varieties: chicken meatballs, fish balls, processed pempek, silken white tofu, wet yellow noodles, rice vermicelli, and cassava starch crackers. All samples were obtained from the nearest local traditional market and transported directly to the laboratory in sterile airtight containers.

Research Procedure

The procedure began with the preparation of the natural indicator in the form of pure turmeric extract. Turmeric rhizomes were peeled, washed, grated, and pressed with the addition of distilled water at a constant weight-to-volume (w/v) ratio to obtain a homogeneous concentrated curcumin filtrate. Whatman filter paper was immersed in this filtrate for 30 minutes, then dried in a desiccator away from direct sunlight until ready-to-use natural indicator paper was obtained (Artiana et al., 2019).

The second stage involved the preparation of matrix-bound food samples. Each 10-gram sample was cut into small pieces, then ground using a porcelain mortar and pestle until maximum homogeneous pulping was achieved (Utami & Andriani, 2021). For specimens with hard, dry textures such as crackers, an initial hydration step was performed by soaking in 5 mL of warm distilled water for five minutes prior to mechanical pulping (Christica et al., 2026). The pulped samples were placed separately on glass Petri dishes lined with clean filter paper.

The third stage was the direct-contact qualitative reactivity test. Using separate dropper pipettes to prevent cross-contamination, 3–5 drops of concentrated turmeric extract were applied directly to the surface of each pulped food specimen (Muthi'ah & A'yun, 2021). In parallel, this method was also cross-confirmed by placing prepared turmeric indicator paper (*turmeric sticks*) inside the tissue cavity of each sample for a brief period to assess the capillary efficiency of borate ion binding (Bisyaroh, 2019).

Data Collection Technique and Observation Parameters

Data were collected through direct individual sensory visual observation (direct visual inspection) of the physicochemical response following reagent contact. The observation parameters in this laboratory study were rigorously defined and comprised four main indicators, Four observation parameters were rigorously defined for this laboratory study. The first was the initial physical characteristics of the samples, encompassing the inherent colour, textural springiness, and aroma of each specimen prior to treatment. The second was colour transition, referring to the identification of the spectral shift of the sample surface and indicator paper from bright yellow to brick red or reddish-brown. The third was colour degradation intensity, which assessed the depth of the covalent complex red colour formed and was categorised as negative, weakly positive, or strongly positive. The fourth was reaction time, defined as the duration of chemical reaction kinetics from the moment the first drop of reagent contacted the specimen until the appearance of a stable and conclusive distinctive colour, measured using a stopwatch (Suseno, 2019).

Data Analysis Technique

All functional parameter data recorded on the laboratory observation sheets were systematically compiled and tabulated in a comparative table. The data analysis technique employed a qualitative-comparative descriptive method by comparing all sample matrix responses against the positive control (containing sodium tetraborate) and the negative control (free of sodium tetraborate) (Swastike et al., 2015). Determination of contamination status was based on the successful curcumin-borax complexation reaction forming a stable reddish-brown boron cyano curcumin (rosocyanine) chelate compound, which constitutes a conclusive positive result (Jumrah et al., 2023; Sari et al., 2023).

RESULTS AND DISCUSSION

Qualitative Test Results for Borax in Food Matrices

Based on the laboratory experiment conducted, comprehensive data were obtained regarding the reactive response of turmeric rhizome (*Curcuma longa* L.) extract toward seven domestic food sample matrices. All food specimens were subjected to organoleptic assessment in the initial phase and their physical parameter changes were monitored after the application of the natural indicator through direct visual inspection. The laboratory observation data are presented in detail in Table 1.

The data in Table 1 show that of the seven food specimen varieties collected from the local traditional market, only the wet yellow noodle sample produced a strong positive indication of borax contamination. This was characterised by a highly contrasting visual spectral shift compared with the six other samples. The wet yellow noodle sample underwent an extreme colour change from its base colour to a deep reddish-brown, with a relatively short chemical reaction time of 12 seconds after the reagent was applied.

In contrast, the other specimens chicken meatballs, fish balls, pempek, white tofu, rice vermicelli, and cassava starch crackers consistently yielded negative results, retaining the baseline hue of the natural curcumin pigment (light to dark yellow) without spectral degradation toward brown or red. Photographic documentation showing the contrasting qualitative phase between the positive and negative specimens can be observed in Figure 1.

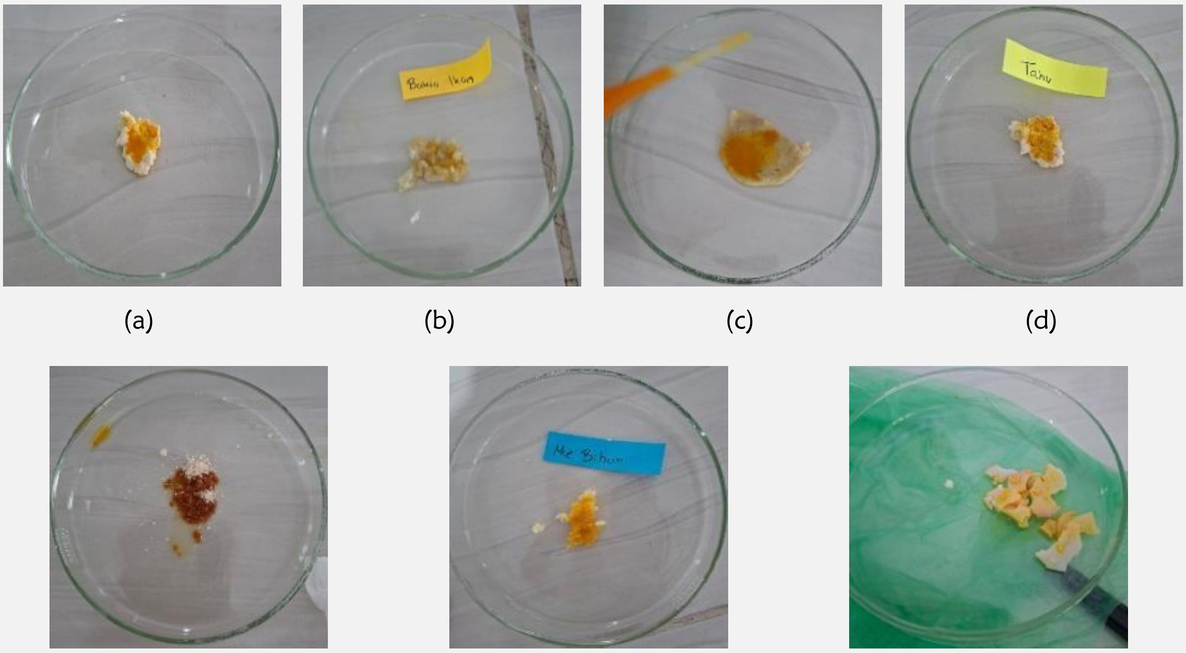
Table 1. Qualitative test results for borax content across various food samples

No.	Food Sample	Initial Physical Characteristics	Colour After Extract Application	Complex Colour Intensity	Reaction Time	Test Result	Remarks
1.	Chicken meatballs	Greyish-white, normally chewy, characteristic meat aroma	Light yellow	Negative	-	Negative	No rosocyanine compound formed
2.	Fish balls	Dull white, soft texture, fresh fish aroma	Light yellow	Negative	-	Negative	No rosocyanine compound formed
3.	Processed pempek	Light grey, normally chewy, dominant fish aroma	Dark yellow	Negative	-	Negative	No rosocyanine compound formed
4.	Silken white tofu	Clean white, soft/easily crumbled texture, characteristic soybean aroma	Light yellow	Negative	-	Negative	No rosocyanine compound formed
5.	Wet yellow noodles	Shiny yellow, very chewy, elastic/does not break easily	Reddish-brown	Strong positive	12 seconds	Positive	Boron cyano curcumin complex formed
6.	Rice vermicelli	Dull white, brittle texture, normal rice aroma	Light yellow	Negative	-	Negative	No rosocyanine compound formed
7.	Cassava starch crackers	Multi-coloured, rigid crunchy texture, tapioca aroma	Pale yellow	Negative	-	Negative	No rosocyanine compound formed

Figure 1 conclusively represents the colour-change phases on the laboratory glass Petri dishes. In the yellow noodle specimen, a zone of dull reddish-brown colour change is observed, spreading evenly across the pulped food matrix. In contrast, the surfaces of the six other food commodities were merely wetted by the liquid turmeric extract phase, retaining the bright yellow colour of the original biological indicator. This confirms the specificity of the reaction, which is only triggered by the presence of an external boron compound within the sample.

Curcumin-Borax Chelation Mechanism and Rosocyanine Complex Formation

At the molecular level, the colour transition phenomenon in the positively reacting wet yellow noodle sample is caused by the cross-ligand binding interaction between the secondary metabolite compounds of turmeric and borate ions. Curcumin (*diferuloylmethane*) isolated from turmeric extract possesses a diketone structure flanked by two phenolic rings. This structural characteristic allows curcumin to act as a bidentate chelating agent.



(a) (b) (c) (d)

(e) (f) (g)

Figure 1. Borax Content Test Results for Food Samples: (a) Chicken meatballs, (b) Fish balls, (c) Processed pempek, (d) Silken white tofu, (e) Wet yellow noodles, (f) Rice vermicelli, (g) Cassava starch crackers

When borax (sodium tetraborate decahydrate) molecules migrate into the liquid extract phase, the compound dissociates and releases borate ions into the system. Two curcumin molecules then bind to one central boron ion through functional ligand substitution at the enolic oxygen atom positions. This process triggers a stoichiometric complexation reaction that eliminates hydroxyl groups and forms a new monovalent covalent coordination chelate compound known as the boron cyano curcumin complex, or rosocyanine, characterised by a dull reddish-brown colour (Bisyaroh, 2019; Utami & Andriani, 2021). The formation of this rosocyanine complex alters the electron delocalisation within the conjugated double bonds of curcumin, causing a shift in the maximum absorption wavelength of the optical absorption band that is macroscopically perceived by the human eye as a brick-red colour (Sukaryawan et al., 2026).

Effect of Alkaline pH Conditions on the Efficiency of the Natural Indicator

The stability of the colour transformation of this natural indicator compound is strongly dependent on the local pH conditions of the reaction environment. Borax is inherently an alkaline salt formed from a weak acid and a strong base. When solid borax is hydrated by distilled water within the food matrix cavity, a partial hydrolysis reaction occurs, producing sodium hydroxide (NaOH) and boric acid (H3BO3), which automatically raises the pH of the sample solution to approximately 9.0–9.5 (Kresnadipayana & Lestari, 2017).

This alkaline pH environment acts as a crucial co-factor that triggers deprotonation of the hydrophobic phenolate groups of curcumin molecules (Guo et al., 2024). The curcumin structure in the acidic-to-neutral phase tends to adopt a stable keto spatial configuration that is bright yellow in colour. However, exposure to a pH above the indicator transition threshold converts curcumin's conformation to an ionised enol phase with very high electrophilic affinity toward boron ions (Septiana & Rohmadi, 2022). Therefore, the reddish-brown colour phase forms completely only when borate ions as the chelating central group are combined with the basic micro-environment provided by the inherent chemical properties of borax itself (Esati & Cahyadi, 2023).

Physicochemical Characteristics of the Food Sample Matrices

The strong positive result for wet yellow noodles in this experiment is linearly correlated with the initial pre-test organoleptic properties of the sample. The yellow noodles exhibited a very high degree of textural springiness, an elastic physical structure that did not break easily when pulled mechanically with tweezers, and a pronounced external sheen. The illegal use of borax in wet noodles is deliberately carried out by illicit food producers to exploit the chemical function of boron as a cross-linking agent between gluten polymer chains and wheat starch, resulting in a far more compact, chewy product that is resistant to the hydration of the boiling process (Syafriani et al., 2024). Moreover, borax possesses broad-spectrum antimicrobial properties capable of inhibiting the proliferation of moulds and putrefactive bacteria, extending the shelf life of yellow noodles beyond normal limits (Artiana et al., 2019).

In contrast, the negative responses in the silken white tofu, chicken meatball, fish ball, and pempek samples are supported by their normal physical characteristics. The white tofu tested had a soft texture that crumbled easily under gentle pestle pressure and emitted the natural sour aroma characteristic of traditional soybean coagulant. The organic acid characteristics of white tofu (pH < 6.0) inhibit curcumin deprotonation; thus, even if borax were present at very trace concentrations, rosocyanine complexation would be impeded because the curcumin structural equilibrium favours the yellow keto form (Alifia et al., 2021). In the meatball and processed pempek specimens, the observed chewiness remained within the normal range of meat/fish protein elasticity (actomyosin contraction), rather than being a result of artificial boron compound thickening (Jumrah et al., 2023).

Sensitivity, Interfering Factors, and Limitations of the Visual Detection Method

Qualitative testing with natural turmeric extract indicator has a specific limit of detection (LOD) that constrains its sensitivity. Crude turmeric extract effectively detects borax residues in food matrices when the boron analyte level exceeds a minimum visual detection threshold of approximately 500–1,000 ppm (Esati & Cahyadi, 2023). When borax contamination falls below this level, the brick-red colour change is often not visually significant, or it may be obscured by excess curcumin yellow pigment, resulting in a false negative.

Other external factors that affect the accuracy of results include the potential interference of other colourants or additives. Some food types, such as the cassava starch crackers in this study, have multi-coloured initial appearances from synthetic dyes. The presence of artificial colourants can obscure the evaluator's visual interpretation of the curcumin colour spectral shift (Muthi'ah & A'yun, 2021). Furthermore, the presence of non-borax alkaline compounds such as sodium carbonate (Na_2CO_3) or traditional ash water (

kie/bleng) commonly added to yellow noodle dough to impart the characteristic yellow colour can also raise the sample pH into the alkaline range. These non-borax alkaline conditions can momentarily trigger a reddish colour change in curcumin; however, the colour intensity is not as stable as that of the genuine rosocyanine complex and tends to quickly fade back to orange-yellow (Suseno, 2019). This visual method therefore has an inherent limitation in that it is purely subjective and qualitative, and is incapable of measuring the exact quantitative concentration of hazardous chemical substances against regulatory threshold limits (BPOM RI, 2021).

Compared with the track record of prior food safety research in Indonesia, the findings of this study reveal a pattern of persistent illegal BTP misuse in the wet noodle cluster. The positive result for wet yellow noodles is consistent with research conducted by Yunicho et al. (2023) in Makassar and Christica et al. (2026) in Medan, both of which identified yellow noodles as the food commodity most susceptible to contamination with hazardous commercial texture-preserving borax.

However, the negative results for the chicken meatball and fish ball samples in this study differ from the findings of Sari et al. (2023) in Bekasi and Swastike et al. (2015) in Wonogiri, which identified borax residues in street-vended meatball products. This variation may indicate an increase in awareness and compliance among local meatball producers in the Medan area, or may reflect the success of integrated surveillance programmes routinely conducted by the relevant government agencies (Waznah et al., 2025).

The primary advantage of the turmeric extraction method as an early screening device lies in its procedural practicality, very low operational cost, and eco-friendly nature (green chemistry), as it generates no hazardous heavy metal waste (Christica et al., 2026). This appropriate technology approach, rooted in local wisdom, breaks communities' dependence on expensive and bureaucratic laboratory instrument testing (Sukaryawan et al., 2026).

The long-term public health implications of the positive yellow noodle result serve as a serious warning. Continuous consumption of borax-laden food, regardless of the dose level, triggers biochemical toxic accumulation within the human excretory system. The body's difficulty in excreting borax can cause tubular epithelial damage in the kidneys, hepatocyte necrosis, neurological disorders, and primary reproductive system dysfunction (Suprihatin et al., 2025). These findings underscore the urgency of structured food safety education, consistent enforcement of regulations prohibiting hazardous BTP, and the importance of empowering informed consumers through independent use of natural turmeric indicators to mitigate the risks of global food toxicant contamination from an early stage.

CONCLUSION

This study successfully demonstrated that turmeric extract (*Curcuma longa* L.) possesses high effectiveness and sensitivity as a natural indicator for the qualitative detection of borax contamination in food products. The specific reaction between the active curcumin compound and borate ions under alkaline conditions was proven to produce a visually contrasting reddish-brown colour change, with an empirically applicable detection limit for initial screening. The main finding from random testing of various local food samples identified the specific misuse of borax in yellow noodle samples, while all other commodity samples were confirmed free of this prohibited preservative. The scientific contribution of this study lies in providing a simple chemometric-based visualisation that confirms the stability of natural colouring agents in responding to toxic compounds. The novelty of this research focuses on the optimisation of local extract formulation as a self-monitoring food safety instrument that is not only economical and practical but also eco-friendly (green chemistry), thereby preventively mitigating public health risks. Nevertheless, this study is limited by the qualitative visual nature of the testing, which does not yet permit absolute detection of borax concentrations in complex samples. Future research should therefore be directed toward developing standardised indicator preparation in membrane-immobilised strip test formats (incorporating polymer matrix additives) and integrating these with UV-Vis spectrophotometry for more precise quantitative analysis.

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