Instituto Nacional
de Ciências e Tecnologia de Timor-Leste

Relatório de Investigação Científica INCT 2025

Identification of the presence of borax in meatballs (bakso) sold in Timor-Leste: Risks to public health and food safety

(Identificação da presença de bórax em almôndegas (bakso) vendidas em Timor-Leste: Riscos para a saúde pública e segurança alimentar)

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Dezembro de 2025

Instituto Nacional
de Ciências e Tecnologia de Timor-Leste

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Área de Conhecimento: Saúde

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Identification of the presence of borax in meatballs (bakso) sold in Timor-Leste: Risks to public health and food safety

Abstract

This study aimed to identify the presence of borax in meatballs (bakso) sold in Timor-Leste and assess associated public health risks. Using a mixed-methods approach, structured interviews were conducted with stakeholders (vendors, consumers, health professionals) across five municipalities to assess knowledge of food adulteration risks. Laboratory analysis was performed on 103 meatball samples collected from restaurants, supermarkets, and mobile vendors across multiple regions. Samples were tested using two validated qualitative methods: turmeric swab test, purple sweet potato extract test, and semi-quantitative borax test kits. Survey results revealed critical knowledge gaps, with 91.3% of customers unaware of borax's health impacts, yet high consumer trust (78.5%) existed. Laboratory testing found no borax (0%), but unexpectedly identified formalin adulteration in 16.5% of samples, with certain regions showing contamination rates as high as 40%. Organoleptic analysis confirmed formalin masked spoilage, deceiving consumers. The findings reveal a significant public health threat lies not in borax but in unregulated formalin use, highlighting urgent needs for revised food safety policies, targeted inspections, and consumer education on chemical adulterants.

Keywords: Borax, Formalin, Adulteration, Food Safety, Meatball (Bakso), Public Health, Risk Assessment

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Abbreviation

AIFAESA	:	Autoridade de Inspeção e Fiscalização da Atividade Económica, Sanitária e Alimentar
CNAP-NFS	:	The Consolidated National Action Plan for Nutrition and Food Security
FTIR	:	Fourier-Transform Infrared Spectroscopy
INFORDEPE	:	Instituto Nacional de Formação de Docentes e Profissionais da Educação
HACCP	:	Hazard Analysis and Critical Control Points
HPLC	:	High-Performance Liquid Chromatography
INCT	:	Instituto Nacional de Ciências e Tecnologia Timor-Leste
NFNSP	:	The National Food and Nutrition Security Policy
SPSS	:	Statistical Package for the Social Sciences
UNTL	:	Universidade Nacional Timor Lorosa'e
WHO	:	The World Health Organization

1 Introduction

1.1 Contextualization

In recent years, food safety has become a growing public concern across many developing countries, including Timor-Leste. With the expansion of urban food markets and the informal food sector, street foods such as bakso—a popular meatball dish—have become widely consumed due to their affordability and convenience. However, the lack of strict food safety regulations and enforcement has raised concerns about the potential misuse of chemical substances in food preparation. One such harmful chemical is borax (sodium borate), which is often illegally added to processed foods like bakso to improve texture and shelf life, despite its well-documented toxicity.

Borax, a substance primarily used in industrial and household cleaning products, is not approved for use in food by health authorities such as the World Health Organization (WHO) and under the Codex Alimentarius Commission framework—the international reference for food standards and safety (Codex-Alimentarius, 2023). Its ingestion, especially over time, poses significant risks to human health, including kidney damage, reproductive issues, and gastrointestinal distress. Despite these dangers, anecdotal evidence and limited investigative reports from neighboring Southeast Asian countries suggest that borax continues to be used in some meat products to enhance firmness and prevent spoilage. This practice often occurs in contexts with weak enforcement of food safety regulations, limited application of a hazard-analysis system such as Hazard Analysis and Critical Control Points (HACCP), or low consumer awareness.

In Timor-Leste, where food safety infrastructure and laboratory testing capabilities are still developing, there remains a significant gap in the implementation of internationally recognised food control systems such as HACCP, and in aligning with Codex-based standards. Nationally, the country has adopted several relevant policies and strategies:

1. The National Food and Nutrition Security Policy (NFNSP) sets out a multi-sectoral framework to address food security, nutrition and food safety—explicitly noting the need to improve food transportation, storage, processing and packaging, and to apply regulations and enforcement especially for meat and fish (CEPAD-TL, 2017).

2. In 2018 Timor-Leste became the 188th member of the Codex Alimentarius Commission, signalling a commitment to developing national food control systems and standards (WHO, 2018).

3. The Consolidated National Action Plan for Nutrition and Food Security (CNAP-NFS), approved in 2020, advanced multi-sectoral action across agriculture, health, trade and other sectors for food security and nutrition, underscoring the importance of food safety as part of access to safe nutritious food (TL-UN, 2022).
4. More recently, the government has advanced a draft national food safety (or food law) framework—workshops in 2024–2025 illustrate that a new food law is under preparation to strengthen food control, institutional roles, and enforcement (Tatoli, 2025).

Despite these policy commitments, implementation gaps remain: for example, as of 2021 it was reported that Timor-Leste lacked an integrated national quality control laboratory for food testing, limiting the capacity to detect chemical adulterants (TATOLI, 2021).

This research therefore seeks to fill a critical knowledge gap by identifying the presence (or absence) of borax in bakso sold in Timor-Leste's markets and street food stalls. By applying principles aligned with HACCP and Codex Alimentarius—such as hazard identification, risk assessment, and control measures—the study aims to provide evidence-based recommendations for improving food safety management in the country.

By assessing the extent to which borax is used in local bakso products, this study will contribute to the broader understanding of food safety practices in Timor-Leste. The findings can support public health awareness campaigns, policy formulation, and regulatory reforms aimed at protecting consumers from chemical hazards. Moreover, the research underscores the urgent need for routine food monitoring, vendor education, and the gradual establishment of national food control systems aligned with international standards. In this way, the study supports national efforts to build a safer, more transparent, and accountable food system in Timor-Leste.

1.2 Literature Review

Bakso (meatballs) is a highly popular street food in Southeast Asia. However, the illicit use of borax (sodium tetraborate) as an additive to improve meatballs' texture and shelf-life poses critical public health and food safety risks. This review synthesizes global and regional research on the identification of borax in meatballs, detection methodologies, prevalence in Southeast Asia, associated health hazards, and policy implications, with a specific contextualization for Timor-Leste.

1.2.1 Borax: Chemical Profile and Food Applications

Borax is a boron compound with multiple industrial uses, prohibited in food production in many countries due to its toxicological profile (Cirino, 2023; Pongsavee, 2009). Nonetheless, it is sometimes employed illegally in meatball production to enhance elasticity and shelf life (Aiadkaeo et al., 2022; Firmansyah et al., 2024). The rationale often cited is economic, as borax can improve the appearance and physical properties of meat products, making them more marketable.

1.2.2 Methods for Borax Detection in Meatballs

Several methodologies are used to detect borax in food:

- Curcumin (Turmeric) Paper Test: This qualitative test involves using turmeric paper, which, upon exposure to borax, changes from yellow to reddish-brown, indicating a positive result (Aiadkaeo et al., 2022; Firmansyah et al., 2024). The test is cost-effective, rapid, and widely employed in field studies;
- Fourier-Transform Infrared Spectroscopy (FTIR): Offers confirmation through spectral analysis, identifying borax-specific bonds in the sample (Firmansyah et al., 2024);
- Histochemical Staining: It was discovered that, specialized stains can visualize boric acid localization in tissues, supplementing chemical analyses (Yoshida et al., 1991).
- Other Laboratory-Based Assays: Quantitative methods, including spectrophotometry and HPLC, are used for more precise measurement of borax concentrations in food matrices (Aiadkaeo et al., 2022).

1.2.3 Prevalence of Borax in Meatball Products

Numerous studies across Southeast Asia and Africa consistently document the illegal use of borax in meatball products:

- In Bangkok, Thailand, borax was detected in 62.5% of sampled pork balls, 70% of fish balls, and 75% of beef meatballs, suggesting widespread non-compliance in the informal food sector (Aiadkaeo et al., 2022);
- Studies in Indonesia reported detection rates ranging from 10% to as high as 46% in various regions, depending on the market and enforcement levels (Gemantari et al., 2024; Harimurti et al., 2020; Rahim et al., 2022; Sari et al., 2021);
- Research in Kendari City and Mandonga Wet Market also confirmed the presence of borax, alongside other illegal additives such as formalin (Wardati et al., 2019);
- While direct data for Timor-Leste is lacking, the nation's regional proximity and similar informal food environment suggest a risk of similar practices. Existing reports on imported frozen meat products in Timor-Leste further highlight the potential for food safety hazards linked to chemical adulterants (Carvalho et al., 2023).

Prevalence of borax in several countries can be seen in the flowing table.

Table 1. Prevalence of Borax Contamination in Meatballs: A Global Perspective from the Scientific Literature

Region/Country	Total sample tested	Type of test used	Key results (%+)	Author(s) & year
Africa				
Nigeria	20	Qualitative (Turmeric Paper)*	85% (17/20)	(Sogbesan et al., 2019)
Ethiopia	60	Wet Qualitative Method (Turmeric)	48.3% (29/60)	(Girmay et al., 2020)
Egypt	35	ICP-OES**	22.9% (8/35)	(El-Nabawy et al., 2017)
Asia				
Bangladesh	45	Spectrophotometric Method	64.4% (29/45)	(Hossain et al., 2019)
Indonesia	30	Turmeric Paper Test***	40% (12/30)	(Lestari et al., 2021).
Pakistan	80	Qualitative (Turmeric Test Strips)	30% (24/80)	(Ali et al., 2020)
Malaysia	21	Qualitative Test & FTIR	23.8% (5/21)	(FSQD, 2018)

- *Se: ~90-95%; **Se: Gold standard test; ***Se: ~90-95%

1.2.4 Health Risks Associated with Borax Consumption

The consumption of borax-contaminated meatballs presents acute and chronic health risks:

- Acute Toxicity: Signs of borax poisoning include skin irritation, nausea, persistent vomiting, abdominal pain, diarrhea, and, in severe cases, kidney failure, seizures, and coma (Cirino, 2023; NTIS, 1983; Rahim et al., 2022);
- Chronic Exposure: Long-term ingestion is associated with circulatory depression, CNS disorders, growth retardation, and toxicity to embryonic development (Pongsavee, 2009; Rahim et al., 2022). Borax exposure can reduce immune cell proliferation and induce genetic defects in human chromosomes (Pongsavee, 2009);
- Population-Level Concerns: Children are especially vulnerable to even low doses, with fatalities possible from ingestion of as little as 5-10g (Cirino, 2023).

1.2.5 Regulatory and Food Safety Implications

Borax is universally recognized as a prohibited food additive by authorities in most countries, including regional neighbors and Timor-Leste (Poison-Control, 2025). Several incidents in Southeast Asia have prompted stronger regulatory enforcement, including factory shutdowns and market inspections (KT, 2017). Despite this, food surveillance studies routinely document noncompliance, indicating challenges in enforcement and public awareness.

Food safety education targeting vendors and consumers, coupled with routine testing—especially at open markets—is essential for risk mitigation. Timor-Leste's food safety modules emphasize hygiene and the critical avoidance of chemical additives like borax as cornerstones of public health (ILO, 2016).

The illegal use of borax in meatballs remains a documented threat across Southeast Asia. The health risks extend from acute poisoning to chronic toxicity, with the potential for widespread public health implications if left unchecked. While studies specific to Timor-Leste are needed, the risk contextually exists due to similarities with neighboring markets. Strengthening detection, regulation, and public education are critical pathways to safeguarding food safety.

1.3 Problematization

Timor-Leste has experienced documented public health concerns following the detection of formalin contamination in imported seafood, frozen meat, and locally produced foods. Scientific studies have confirmed that formalin, a substance prohibited as a food additive, has been found at levels well above international safety thresholds in a significant portion of food products sold in major supermarkets around Dili. This situation has highlighted systemic vulnerabilities in Timor-Leste's food safety controls and sparked public anxiety around chemical food hazards (Amaral et al., 2025; Carvalho et al., 2023; Dili-weekly, 2017; Tabassum et al., 2019).

Rationale for Extending Research Beyond Formalin:

- Precedent of Formalin Contamination: The confirmed use of formalin in food demonstrates that illegal and dangerous food preservation practices are possible and, disturbingly, recurrent in Timor-Leste's food supply chain (Amaral et al., 2025; Carvalho et al., 2023; Dili-weekly, 2017; Tabassum et al., 2019).
- Regulatory Gaps: The presence of formalin is symptomatic of broader gaps in food safety oversight, monitoring infrastructure, and enforcement capacity, suggesting a risk that other substances may also be misused in food products (Codex-alimentarius, 2018; Tatoli, 2025).
- Consumer Vulnerability: Widespread public unawareness about food chemical risks, combined with traditional markets' prevalence and limited institutional food quality control, increases susceptibility to food adulteration and abuse of non-food grade chemicals.

Risk Multiplication: From Formalin to Borax and Other Additives

The discovery of formalin as a dangerous adulterant prompts critical reflection on the potential presence of other hazardous substances—such as borax—in popular foods like meatballs (bakso). Like formalin, borax is prohibited as a food additive, yet research in other Southeast Asian contexts has repeatedly demonstrated its use in meatballs to improve texture, prolong shelf life, and enhance appearance (Khairiyati et al., 2023; Rahim et al., 2022; Zachawerus et al., 2023). Consumption of borax-contaminated food is associated with a spectrum of acute and

chronic health risks, ranging from gastrointestinal disturbances to organ damage and carcinogenic effects (Khairiyati et al., 2023; Rahim et al., 2022).

Food Safety Infrastructure

The recent establishment of a Food Quality and Safety Testing Laboratory in Timor-Leste signals progress yet simultaneously underscores the urgent need for systematic research into multiple contaminants in the national food supply. Until analytical testing and regulatory enforcement are routine, the risk of widespread, undetected chemical adulteration in various food categories cannot be dismissed (Tatoli, 2021, 2025).

Public Health Implications

Extending research from formalin to borax and other chemical hazards is necessary to:

- Comprehensively map risk exposure: Limiting investigations to formalin or a single food additive is insufficient in a context lacking robust food safety systems;
- Develop evidence-based interventions: Only through identifying the full extent of chemical contamination can effective policy, regulatory, and educational responses be formulated;
- Protect vulnerable populations: Children, pregnant women, and those with pre-existing health conditions are at greater risk for adverse effects from chronic exposure to illegal chemicals in food (Khairiyati et al., 2023; Rahim et al., 2022).

Why Focus on Meatballs (Bakso)?

- Popularity and Consumption Patterns: Bakso is a widely consumed street and restaurant food in Timor-Leste, often prepared under conditions where regulatory scrutiny and quality assurances are limited;
- Regional Evidence: Multiple studies in neighboring countries have revealed disturbing rates of borax contamination in meatball samples, with most exceeding safe limits (Khairiyati et al., 2023; Rahim et al., 2022; Zachawerus et al., 2023);
- Difficulty of Detection: Organoleptic methods (texture, color, taste) are unreliable for identifying chemical adulteration, further necessitating laboratory-based surveillance.

The identification of formalin in diverse foods in Timor-Leste is not an isolated incident but part of a worrying trend that may include the illegal use of borax and perhaps other chemicals in widely consumed foods like meatballs. This underscores the critical importance of expanding food safety research and routine monitoring to encompass various hazardous substances, thus ensuring public health and the integrity of Timor-Leste's food system (Amaral et al., 2025; Carvalho et al., 2023; Rohani et al., 2023; Tatoli, 2025).

1.4 Hypothesis Formulation

Null Hypothesis (H0) - Borax is absent in meatballs (bakso) sold in Timor-Leste, and there are no significant risks to public health or violations of food safety standards.

Primary Hypothesis (H1) - Borax is present in meatballs (bakso) sold in Timor-Leste, posing measurable risks to public health and violating food safety regulations.

Should H0 becomes the primary outcome of this study, additional test to identify the presence of formalin will be conducted.

The hypothesis is based on regional evidence that borax has been extensively used as an illegal food additive in meatball production in neighboring Southeast Asian countries, where it enhances texture and shelf-life but endangers consumer health. Reports of other hazardous chemicals like formalin in Timor-Leste's food supply further justify the premise that borax may also be in use locally, necessitating systematic identification and risk assessment to guide public health interventions.

1.5 Objectives

General Objective:

To determine the presence and concentration of borax in meatballs (bakso) sold in Dili and selected municipalities of Timor-Leste, and to assess associated public health and food safety risks—including screening for formalin contamination where applicable.

Specific Objectives

1. To identify and detect the presence of borax in meatballs (*bakso*) sold in Dili and selected municipalities, including Aileu, Baucau, Bobonaro, and Covalima.
2. To assess borax contamination across different points of sale-restaurants, mobile *bakso* sellers, supermarkets, and shops selling meatballs.
3. To conduct interviews with restaurant owners, *bakso* customers, and vendors to gather information on awareness, practices, and perceptions regarding the use of borax in *bakso*.
4. To purchase *bakso* samples as ordinary customers to ensure unbiased and representative sampling of market products.
5. To analyze the collected *bakso* samples in the laboratory for the presence and concentration of borax, and **if samples test negative for borax, to perform an additional formalin test** in light of the findings by Amaral et al. (2025) on formalin contamination in meat and fish imported into Timor-Leste.
6. To evaluate the laboratory findings to assess the potential risks of borax and/or formalin contamination to public health and food safety in Timor-Leste.

These objectives aim to provide a comprehensive understanding of the prevalence of borax in bakso across key urban and municipal centers, reflecting real market conditions and stakeholder perspectives. This will support evidence-based interventions to protect consumer health.

1.6 Importance of the Research

This research is vital for protecting public health, strengthening food safety, informing policy, and building institutional capacity in Timor-Leste. By providing concrete evidence on the prevalence and risks of borax in meatballs, the project will empower stakeholders to implement effective measures and build consumer confidence in the national food supply. The justification for this research as follows:

A. Safeguarding Public Health

- Borax is a hazardous chemical prohibited in food due to its toxic effects on human health, including possible kidney damage, digestive disorders, and increased cancer risk with long-term exposure;
- Regular consumption of contaminated meatballs (bakso) could pose significant health risks, especially among vulnerable groups such as children, pregnant women, and those with existing health conditions;
- Identifying borax use is crucial to prevent chronic exposure and potential public health crises.

B. Ensuring Food Safety and Consumer Protection

- Food adulteration undermines consumer trust and endangers public safety;
- The research responds to regional evidence of borax and other prohibited additives being used in meatball production, indicating that Timor-Leste may face similar risks if left unchecked;
- By systematically investigating meatballs sold across Dili and selected municipalities (Aileu, Baucau, Bobonaro, Covalima), the research will generate concrete data to support policy and enforcement actions.

C. Addressing Regulatory and Institutional Gaps

- Previous findings of formalin in the Timor-Leste food supply revealed systemic weaknesses in food safety enforcement;
- Monitoring for borax extends the horizon of food safety research, supporting the efforts of public health institutions to develop and enforce better regulations, inspection practices, and food safety standards;
- Engaging health authorities and food business stakeholders through interviews will also inform capacity-building and community education initiatives.

D. Informing Policy and Interventions

- Results will provide factual evidence for the government and stakeholders to develop targeted interventions, such as public awareness campaigns, training for food handlers, and stricter legal penalties for food adulteration
- The study's findings can inform the establishment of routine surveillance systems for chemical hazards in street and market foods, strengthening the overall food safety infrastructure.

E. Closing Data Gaps and Supporting Regional Research

- Empirical data on food contamination in Timor-Leste is extremely limited.
- The study fills an urgent research gap and serves as a model for similar investigations on other foodborne chemical hazards.
- It contributes to regional knowledge and aligns with broader public health frameworks in Southeast Asia that emphasize safe food and consumer protection.

1.7 Organization of the Work and Geographic Location (Study Location(s)

1.7.1 Organization of the Work

The research on identifying the presence of borax in meatballs (bakso) sold in Timor-Leste and assessing related public health and food safety risks is organized through a systematic, multi-step process:

- Preparing questionnaires tailored for various stakeholders, including bakso customers, bakso sellers operating from shops, restaurants, and gerobak pentolan (mobile pushcarts);
- Obtaining human ethical approval from the Instituto Nacional de Ciência e Tecnologia (INCT) to ensure compliance with ethical research standards;
- Securing letters of authorization from INCT directed to local authorities such as the Presidents of the selected municipalities, the President of AIFAESA, and relevant health authorities;
- Training enumerators, specifically students from the Department of Animal Health at the National University of Timor-Leste (UNTL), to conduct interviews and sample collection with accuracy and professionalism;

- Conducting interviews across diverse stakeholder groups to gather qualitative and quantitative data regarding bakso consumption and safety practices;
- Purchasing bakso samples from various research sites to obtain representative samples for analysis;
- Testing all collected meatball samples at the Instituto Nacional de Formação de Docentes e Profissionais da Educação (INFORDEPE) to detect the presence of borax and evaluate food safety risks.

1.7.2 Geographic Location (Study Locations)

The study is conducted across multiple municipalities in Timor-Leste, strategically chosen to represent diverse demographic and market settings. The selected locations include:

- Dili – the capital city and main urban center;
- Aileu – a municipality with a mix of urban and rural characteristics;
- Baucau – the second-largest city (see Table 2), known for its diverse consumer base;
- Bobonaro – a western municipality (this was an additional site, not initially planned for);
- Covalima – a southern municipality with growing commercial activity.

The number population of these five municipalities are described in Table 2.
Table 2. Total population in the research areas across 5 municipalities

Municipality	Sex		Total
	Male	Female	
Aileu	28,093	26,231	54,324
Baucau	68,117	66,761	134,878
Bobonaro	53,704	52,935	106,639
Covalima	37,604	36,329	73,933
Dili	164,765	159,973	324,738

These locations provide a comprehensive overview of bakso consumption patterns and potential food safety issues across Timor-Leste.

2 Methodology

2.1 Materials and methods

2.1.1 Materials

To ensure reliable detection of borax and formalin in *bakso* (meatball) samples, a combination of **qualitative and semi-quantitative test kits** and **natural indicator reagents** were employed. The materials used in this study were selected based on their proven sensitivity, accessibility within the local context, and compatibility with laboratory and field-based food safety analysis protocols. Both **chemical-based and plant-based indicators** were included to strengthen the accuracy and confirmatory value of results obtained through different testing approaches.

The following materials and equipment were used in the analytical process:

- **Purple Sweet Potato (*Ipomoea batatas L.*):** Used as a natural colorimetric indicator for borax detection. The anthocyanin pigments in purple sweet potato react with borax to produce a distinct color change, providing a simple yet effective screening method suitable for preliminary laboratory or field testing.
- **Turmeric Toothpick Indicator:** Employed as an additional natural reagent for borax testing. Curcumin, the active compound in turmeric, exhibits a measurable color change from yellow to reddish-brown upon exposure to alkaline substances such as borax, thus serving as a confirmatory test.
- **Borax Semi-Quantitative Test Kit (Labtest):** A commercially available test kit designed to provide an approximate concentration of borax in food samples. This kit allows for rapid estimation of contamination levels and serves as an intermediate method between qualitative screening and instrumental analysis.
- **Borax Qualitative Test Kits (Labtest and Chem-Kit):** Two distinct qualitative kits were used to detect the presence or absence of borax in *bakso* samples. Cross-verification using two brands (Labtest and Chem-Kit) was conducted to increase diagnostic reliability and minimize false-negative or false-positive outcomes.
- **Formalin Qualitative Test Kit (Chem-Kit):** Utilized to identify the presence of formalin in samples that tested negative for borax. This test detects formaldehyde residues through a reagent-based colorimetric reaction, in line with the secondary

testing protocol adopted due to prior reports of formalin contamination in food products in Timor-Leste (Amaral et al., 2025).

- **Distilled Water:** Served as a solvent and diluent in sample preparation and reagent activation to avoid interference from minerals or impurities present in tap water.
- **Mortar and Pestle:** Used to grind and homogenize meatball samples prior to testing, ensuring even distribution of potential contaminants and accurate representation of the sample matrix.
- **Stamp (Weighing Stamp):** Applied to measure or portion consistent quantities of *bakso* samples for both qualitative and semi-quantitative testing.
- **Glass Beaker (Pyrex):** Utilized for sample mixing, reagent preparation, and temporary containment of liquid extracts during testing. Pyrex glassware was chosen for its chemical resistance and heat stability.
- **Filter Paper:** Used to separate solid particles from liquid extracts prior to testing, facilitating clearer observation of colorimetric reactions.
- **Spatula:** Employed for sample transfer and reagent handling to maintain precision and prevent contamination between tests.
- **Tubes and Containers:** Served as vessels for reaction mixtures and for storage of test samples during the analytical procedure.
- **Pipette:** Used to dispense accurate volumes of reagents and sample extracts, ensuring reproducibility and control over reaction conditions.

2.1.2 Methods

2.1.2.1 Interviewing

Prior to sampling, relevant stakeholders such as restaurant owners, supermarket owners, bakso consumers and health professionals were interviewed in order to understand their views on the risks associated with the use of borax and their general knowledge of adulterated foods. These interviews were carried out in selected municipalities - Dili, Baucau, Aileu and Covalima and Bobonaro (additional municipality) - using structured questionnaires that make it possible to collect consistent and comparable data, contributing to a better understanding of the local context.

2.1.2.2 Sample collection

A total of 103 meatball (*bakso*) samples were collected from five municipalities in Timor-Leste: Dili, Aileu, Baucau, Bobonaro, and Covalima. Sampling was carried out at various points of sale, including restaurants, supermarkets, and mobile *bakso* sellers, to obtain a representative overview of products available to consumers.

At each sampling site, Global Positioning System (GPS) data were recorded using the Epicollect5 mobile application to accurately document the geographic coordinates of each sampling location. This ensured spatial traceability and allowed for precise mapping of sample origins across the surveyed municipalities.

Samples were purchased as ordinary customers to minimize the risk of vendor bias or concealment. Each sample was carefully labeled with its corresponding site information, GPS coordinates, date of collection, and source type. Immediately after collection, samples were placed in cool boxes containing ice blocks, maintaining a temperature range of approximately 0–5°C during transportation to the laboratory. Upon arrival, all samples were checked for labeling integrity and subsequently stored in a freezer at −16°C until analysis.

2.1.2.3 Sample transportation and sample storage

All meatball (*bakso*) samples were purchased from selected outlets, carefully labeled with their respective sampling locations, collection dates, and point-of-sale types. Immediately after collection, the samples were placed in cool boxes containing ice blocks to maintain a temperature of approximately **0–5°C** during transportation to the laboratory. This controlled temperature range was maintained to minimize microbial activity and prevent chemical degradation.

Upon arrival, the samples were inspected for labeling integrity and subsequently transferred to a **freezer maintained at −16°C** for storage until the day of analysis. Freezing was employed to preserve the physicochemical properties of the samples and to ensure that neither borax nor formalin concentrations were altered prior to laboratory testing. All handling procedures followed standard food sample preservation protocols to maintain sample integrity and prevent cross-contamination.

2.1.2.4 Sample testing

There are five tests used to detect the presence of borax in bakso samples, ensuring greater accuracy and reliability in the results. There is also formalin testing as an additional testing when all samples were negative of borax. The test used in this research can be seen in the. Following table:

Table 3. Type of test used in this research

Test#	**Test type**	**Description**	**Remarks**
Test 1	Qualitative	The purple sweet potato extract test	For borax
Test 2	Qualitative	Qualitative turmeric swab test.	For borax
Test 3	Qualitative	The qualitative test kit 1	For borax
Test 4	Qualitative	The qualitative test kit 2	For borax
Test 5	Semi quantitative	Semi quantitative test kit	For borax
Test 6	Qualitative	Formalin	For Formalin

Each sample was tested using four qualitative tests (test 1 to test 4), semi quantitative test (test 5). If all samples were negative of borax, an additional test of formalin was conducted (test 6). This approach aims to guarantee the accuracy and reliability of the results, allowing for a more robust assessment of the presence of borax in the products analyzed. The proposed methodologies are as follows:

2.1.2.4.1 **Borax qualitative test Using Purple Sweet Potato Extract**

A qualitative test for borax was performed using purple sweet potato extract as a natural anthocyanin indicator. The procedure consisted of two stages: anthocyanin extraction and sample testing. In the extraction stage, fresh purple sweet potatoes were thoroughly washed and steamed until soft. The cooked tubers were mashed and macerated in ethanol at a ratio of 1:2 (50 g purple sweet potato in 100 mL ethanol). The mixture was allowed to stand for approximately 45–60 minutes, with occasional stirring, until the purple pigment visibly faded. The extract was then filtered using filter paper to obtain a clear anthocyanin solution.

For the borax detection stage, 1 mL of the obtained anthocyanin extract was mixed with the food filtrate sample. A change in color was observed visually. A blue-black coloration indicated a positive reaction for borax presence, while the absence of color change

indicated a negative result. This method is based on the interaction between borate ions and anthocyanin pigments, leading to the formation of a deep blue complex (Rahma et al., 2023).

2.1.2.4.2 **Borax qualitative test Using the Turmeric Toothpick Method**

A qualitative test for borax was conducted using the turmeric toothpick method. Wooden toothpicks were first soaked in turmeric extract and then inserted into the food samples. The results were compared against negative and positive controls. The negative control consisted of turmeric-soaked toothpicks inserted into meatballs prepared without borax, showing no color change (remaining yellow). The positive control used meatballs intentionally prepared with added borax, in which the turmeric-treated toothpicks changed color from yellow to brick-red (rosy-red). This color transformation occurs due to the formation of a rosocyanin complex, produced by the reaction between boric acid/borax and protonated curcumin. This reaction principle forms the chemical basis for simple borax or boric acid screening using turmeric as a natural indicator (Yoshida et al., 1991).

2.1.2.4.3 **Borax qualitative test Using Labtest® and Chemkit Borax Test Kits**

Qualitative detection of borax in food samples was carried out using two commercial kits: Labtest® Borax Test Kit and Chemkit Borax Test Kit, both consisting of liquid reagents and indicator paper. A 25 g portion of the food sample was mixed with 50 mL of hot water, finely chopped, homogenized, and filtered to obtain the extract. Approximately 1–3 mL of the filtrate was transferred into a reaction tube and mixed with five to twenty drops of Borax Reagent 1 depending on the kit instructions. The treated extract was then applied to Borax Reagent 2 indicator paper, or the strip was briefly immersed in the reaction mixture. The test strip was allowed to stand and air-dry for several minutes and, in the case of the Chemkit, exposed to light for up to 10 minutes. A positive reaction was indicated by a visible color change from yellow to orange/red or dark red. This color change results from the formation of a red rosocyanine complex between boron and curcumin. Positive samples were subsequently subjected to semi-quantitative analysis to estimate borax concentration. The Chemkit method has a detection limit of 50 mg/L as borax**,** 1.25 mg/L as boron, and 7.5 mg/L as boric acid, ensuring high sensitivity for screening borax contamination in food (Saputro & Fauziyya, 2021).

2.1.2.4.4 **Semi-Quantitative Test of Borax Using Borax Rapid Test Kit (Labtest®)**

The semi-quantitative analysis of borax using the Borax Rapid Test Kit (Labtest®) was performed only on samples that showed a positive result in the qualitative screening test. A total of 25 g of food sample was mixed with 50 mL of hot water, chopped, crushed, and homogenized before being filtered to obtain the liquid extract. Subsequently, 5 mL of the filtrate was transferred into a reaction tube and three drops of Borax Reagent 1 were added, followed by gentle mixing. One strip of Borax Reagent 2 indicator paper was prepared, and three drops of the reaction mixture were placed onto the surface of the paper. The strip was left to stand for several minutes at room temperature. A negative control and positive control were prepared alongside the sample to ensure test validity. A positive reaction was indicated by a color change from yellow to orange/red or dark red. The final color intensity on the indicator paper was visually compared to the borax color-reference chart provided in the kit to estimate the borax concentration level in the sample.

2.1.2.4.5 **Qualitative Test for Formalin Using Chemkit® Formalin Test Kit**

Qualitative detection of formalin was carried out using the Chemkit® Formalin Test Kit. Since all samples in this study were liquid, approximately 1 mL of each sample was placed into a reaction tube. Then, 3–5 drops of Formalin Reagent - I were added carefully dropwise, and the tube was immediately capped. Subsequently, 1 mg of Formalin Reagent - II was added using the applicator stick provided, and the mixture was gently shaken to ensure homogeneity. The reaction mixture was allowed to stand for 3–5 minutes. A purple-blue coloration indicated the presence of formalin, while the absence of color change indicated a negative result. This method operates within a detection limit of 0.1–2 mg/L (ppm)for formalin.

2.1.2.4.6 Organoleptic observation of meatballs.

Organoleptic observations were made to assess changes in the characteristics of the meatballs after they had been stored at room temperature for three days. The parameters observed included color, texture, aroma and the presence of mold or mucus growth.

- On the first day, changes in color, aroma, texture and the presence or absence of slime or mold on the surface of the meatballs were observed.

- On the second day, the same parameters were observed again and compared with the results of the first day.
- Day 3: final observation to assess the degree of organoleptic changes that had occurred during storage.

Observations were also made to assess the condition of the burgers stored in containers at room temperature for three days, based on the physical changes that occurred. Physical observations could include:

- The meatballs are in good condition, not moist, not soggy, not sticky and showing no signs of mold;
- Meatballs are wet, watery, slimy.
- Meatballs are wet, watery, slimy; Meatballs have mold pustules, leaving an unpleasant smell.

2.2 Definition of the Research Universe (Population) and Sample or Definition of the Experimental Model

The Research Universe (Population) in this study is defined as the entire group of sellers of meatballs in Restaurants, shops, and mobile bakso sellers (Gerobak) at selected sites in Timor-Leste, specifically in Aileu, Baucau, Bobonaro, Covalima, and Dili. This population includes all individuals or entities selling meatballs in these locations, representing the target group relevant to the research objective.

The Sample of the research consists of at least 50 meatball (bakso) samples collected from different restaurants in the city of Dili, along with another 50 samples taken from supermarkets located in Dili and restaurants located in four different municipalities outside the capital, which represent the three regions of the country. This sample is a subset of the larger population, selected to be representative for evaluating the presence of borax in meatballs sold across these areas.

In terms of the Experimental Model, the research uses a sampling approach where meatball samples collected from the defined population (sellers in specific locales) are analyzed for

borax contamination to assess potential risks to public health and food safety. This model involves:

- Defining the population universe by geographic and vendor type boundaries.
- Collecting representative samples from restaurants, shops, and supermarkets to cover urban and regional variations.
- Laboratory testing of these samples for borax presence as the primary experimental analysis.

This approach allows for inferences about borax contamination prevalence and associated health risks in the meatball market of Timor-Leste based on the sampled subset of sellers and products.

Summary:

- Population (Universe): Sellers of meatballs in restaurants, shops, and gerobaks in Aileu, Baucau, Bobonaro, Covalima, and Dili;
- Sample: Minimum 100 meatball samples; 50 from Dili restaurants, 50 from supermarkets in Dili and restaurants in 4 municipalities;
- Experimental Model: Sampling and lab analysis of meatball samples from defined population to detect borax presence and assess food safety risks.

This definition aligns with standard research principles where the population is the entire group fitting inclusion criteria, and the sample is a manageable, representative subset used for testing and analysis.

Other populations in the research on borax presence in bakso (meatballs) in Timor-Leste include bakso customers and health authorities from the selected five research sites: Aileu, Baucau, Covalima, and Dili.

- The bakso customers population consists of individuals who consume meatballs in these areas. Their sample will include at least 50 customers from Dili and at least 10 customers from municipalities outside of Dili (Aileu, Baucau, Covalima). This population helps understand consumer exposure and perception related to bakso safety.

- The health authority's population includes officials and personnel responsible for food safety regulation and public health in these sites. Their sample will be composed of at least 10 health authority representatives from Dili and at least 5 from municipalities outside Dili. This group is essential for assessing institutional awareness, regulations, and enforcement regarding borax use in food products.

Together with the sellers and product samples already defined, these additional populations provide a comprehensive view of borax risks from production, consumption, and regulatory perspectives across urban and regional areas of Timor-Leste.

2.3 Techniques and Instruments for Data Collection

2.3.1 Techniques for Data Collection are conducted as follows:

- Structured Interviews: Data on respondents' perspectives were collected through structured interviews conducted in the targeted municipalities (Aileu, Baucau, Covalima, and Dili). The interview for respondents in Bobonaro was not included because it was just an additional target.
- Interviews were carried out face-to-face with respondents belonging to the four categories: meatball sellers in restaurants, meatball sellers in shops or supermarkets, bakso customers, and health authorities.
- The interviews aimed to gather consistent and comparable information regarding awareness, practices, perceptions, and regulatory aspects related to the use of borax in meatballs.

2.3.2 Instruments for Data Collection:

- Structured Questionnaires: Four types of structured questionnaires were developed, each tailored to a specific respondent group:
    - Questionnaire for meatball sellers in restaurants
    - Questionnaire for meatball sellers in shops or supermarkets
    - Questionnaire for bakso customers

    - Questionnaire for health authorities
- These questionnaires contain standardized questions designed to obtain quantitative and qualitative data relevant to each group's role in the meatball supply chain and food safety environment.
- The questionnaires cover topics such as knowledge and attitudes about borax, meatball handling and selling practices, consumer behavior, and enforcement or monitoring activities by health authorities.

In addition to collecting data on perspectives from different respondents, the research also gathered data on the presence of borax in bakso by conducting laboratory testing of meatball samples as described in section 2.1.2. These tests involved analyzing the collected bakso samples from various sellers (restaurants, shops, supermarkets) across the selected municipalities to detect borax content.

This method ensures systematic data collection across multiple stakeholder groups, allowing for comprehensive analysis of borax presence risks in Timor-Leste's meatball market. Together, these data sources enable a comprehensive assessment of borax presence and associated public health risks.

2.4 Data Collection, Analysis and Data Transcription

Data were collected using the methods described in section 2.3, which involved structured interviews with targeted respondents and laboratory testing of meatball samples for borax presence.

The structured questionnaire was designed and deployed digitally using the Epicollect5 mobile data collection platform (https://five.epicollect.net), which facilitated efficient and standardized data gathering in the field. All collected data, including the responses from these digital questionnaires and the laboratory results, were systematically recorded and organized on a centralized server.

The data from Epicollect 5 were then exported as Microsoft Excel file to enable preliminary organization and cleaning. Subsequently, the cleaned dataset was imported into SPSS version 16 for statistical analysis. The data was analyze using descriptive statistics.

This approach ensured rigorous data analysis to support valid conclusions about the risks borax poses to public health and food safety in the study areas.

3 Data analysis and discussions

3.1 Analysis of Results

3.1.1 Laboratory results

Table 4. Test result of borax identification and formalin in various sites

Municipality	Source of samples	Borax Test*			Formalin Test		
		Negative	Positive	Total	Negative	Positive	Total
Aileu	Restaurant	8	0	8	7	1	8
	Sub-total	**8**	**0**	**8**	**7**	**1**	**8**
Baucau	Restaurant	7	0	7	5	2	7
	Sub-total	**7**	**0**	**7**	**5**	**2**	**7**
Bobonaro	Restaurant	5	0	5	3	2	5
	Sub-total	**5**	**0**	**5**	**3**	**2**	**5**
Covalima	Restaurant	6	0	6	6	0	6
	Supermarkets	1	0	1	0	1	1
	Sub-total	**7**	**0**	**7**	**6**	**1**	**7**
Dili	Restaurant	56	0	56	46	10	56
	Supermarkets	8	0	8	7	1	8
	Mobile seller	12	0	12	12	0	12
	Sub-total	**76**	**0**	**76**	**65**	**11**	**76**
Total	**Restaurant**	**82**	**0**	**82**	**67**	**15**	**82**
	Supermarkets	**9**	**0**	**9**	**7**	**2**	**9**
	Mobile seller	**12**	**0**	**12**	**12**	**0**	**12**
Grand Total		**103**	**0**	**103**	**86**	**17**	**103**

*There are a series of test using for borax testing, but all were negative

This table presents the results of chemical testing for two hazardous adulterants, borax and formalin, across 103 samples collected from various vendors in multiple municipalities (see Figure 1).

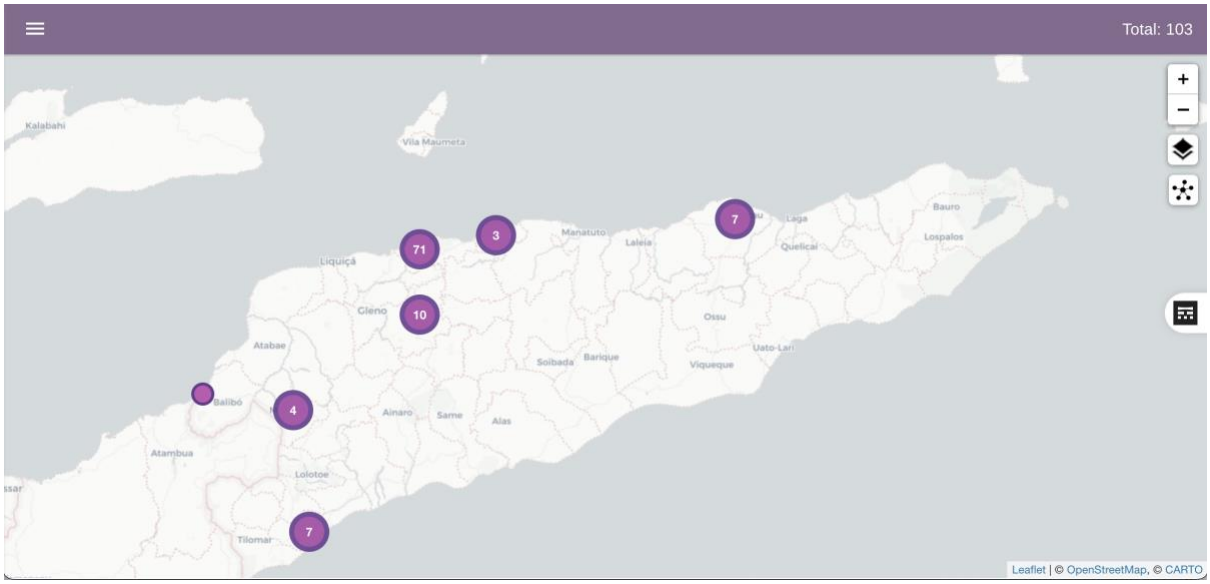


Figure 1. Sample collection sites in different municipalities (created using Epicollect5)

A. Borax Testing Results:

Universal absence of Borax: A decisive finding is that 0% (0/103) of the sampled meatballs tested positive for borax. This result was consistent across all municipalities (Aileu, Baucau, Bobonaro, Covalima, Dili) and all vendor types (Restaurants, Supermarkets, Mobile Sellers).

B. Formalin Testing Results:

Significant Presence of Formalin: In stark contrast to the borax results, 16.5% (17/103) of all samples tested positive for formalin.

Geographical Variation: The prevalence of formalin was not uniform:

- Highest Prevalence: Bobonaro had the highest rate at 40% (2/5 samples positive).
- High Prevalence: Baucau followed at 28.6% (2/7).
- Moderate Prevalence: Dili, which contributed the most samples, had a 14.5% positive rate (11/76). Covalima had a 14.3% rate (1/7), with its single positive case originating from a supermarket.
- Lowest Prevalence: Aileu had a 12.5% rate (1/8).

Variation by Vendor Type:

- Restaurants were the most significant source of formalin-contaminated samples, contributing 15 out of 17 total positive cases (88.2% of all positives). The formalin positive rate for restaurant samples was 18.3% (15/82);

- Supermarkets had a 22.2% positive rate (2/9);
- Mobile Sellers had a 0% positive rate (0/12).

3.1.2 Organoleptic observation of positive samples

Table 5. Organoleptic observation of meatballs positive for formalin

Day	CONDITIONS OF POSITIVE SAMPLES			Total positive samples
	Good	Beginning to spoil	Spoiled	
Day 1	14	3	0	17
Day 2	9	5	3	17
Day 3	9	4	4	17

This table tracks the physical spoilage of the 17 meatball samples that tested positive for formalin over a three-day period under ambient conditions. The key findings focus on the change in their organoleptic properties (appearance, smell, texture):

Day 1 (Initial State): The overwhelming majority of formalin-positive samples (82.4%, 14/17) were observed to be in "Good" condition on the first day. A smaller portion (17.6%, 3/17) showed signs of beginning to spoil. None were classified as spoiled.

Day 2 (Progressive Spoilage): A significant shift occurred. The number of samples in "Good" condition dropped from 14 to 9. The number of "Beginning to spoil" samples increased to 5, and for the first time, 3 samples (17.6%) were recorded as fully "Spoiled".

Day 3 (Advanced Spoilage): The degradation continued. The number of "Good" samples remained at 9, but the number of "Spoiled" samples increased to 4 (23.5%).

3.1.3 Restaurant owners' perspective on borax

3.1.3.1 Business duration

Table 6. Restaurant Bussiness duration

Bussiness duration	Frequency	Percent	Valid Percent
<1 year	30	29.1	33.7
1 to 5 years	32	31.1	36
>5 years	27	26.2	30.3
Total	89	86.4	100

The Table presents data on the operational duration of 89 businesses, which constitutes 86.4% of a larger sample (N=103). The findings reveal a business landscape dominated by relatively new enterprises:

- Predominance of New Businesses: A significant majority (69.7%) of the businesses have been operating for less than five years. This is broken down into:
- 33.7% (30 businesses) are very new, operating for less than 1 year.
- 36.0% (32 businesses) have been operating for 1 to 5 years.
- Established Businesses are a Minority: Only 30.3% (27 businesses) represent more established entities that have operated for over 5 years.

A frequency analysis of business operational duration (n=89) revealed a market characterized by its novelty, with a majority of enterprises (69.7%) operating for less than five years. Specifically, 33.7% were in their first year of operation, and 36.0% had been operating for 1-5 years. Established businesses (>5 years) constituted a minority (30.3%). This distribution suggests a dynamic entrepreneurial landscape with a high rate of new business formation. However, it also implies potential challenges related to business sustainability and high turnover rates, underscoring the need for targeted support mechanisms focused on improving the survival and growth of nascent enterprises. A limitation is that data for this variable was missing for 13.6% of the total sample (N=103).

3.1.3.2 Meat Sourcing Practices

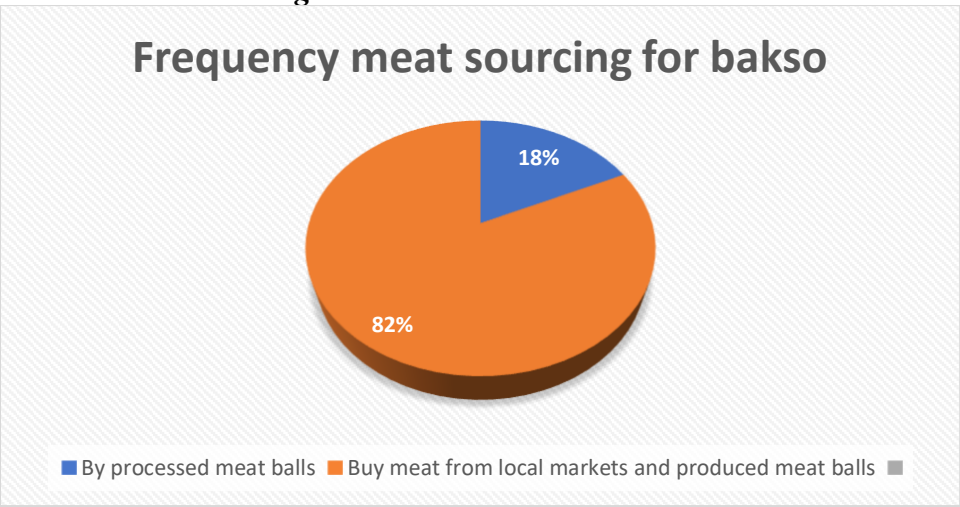


Figure 2. Frequency chart of "Source of meat for producing meatballs, valid n=89

Figure 2 presents the sourcing strategies of 89 food businesses for producing meatballs (bakso).

- Predominant Practice: The vast majority of businesses (82.0%, 73 businesses) report that they buy meat from local markets and produce their own meatballs.
- Minority Practice: A significantly smaller proportion (18.0%, 16 businesses) source their meatballs by purchasing pre-processed meatballs.
- The percentage (82.0%) underscores that an even larger majority of vendors are directly responsible for the entire production process. This heightens the concern that food safety risks are decentralized and dependent on the knowledge and practices of individual vendors.
- With over 80% of production occurring in-house, the need for targeted training and regulation at the level of small-scale producers becomes even more critical. Public health authorities must prioritize reaching these individual vendors with education on safe food handling and the dangers of chemical adulterants like borax and formalin.

Table 7. Source of meat for making meatballs based on different research sites

Municipality	Source	Formalin Test		
		Negative	Positive	Total
Aileu	By processed meat balls	3	0	3
	Buy meat from local markets and produced meat balls	4	1	5
	Total	7	1	8
Baucau	By processed meat balls	2	2	4
	Buy meat from local markets and produced meat balls	3	0	3
	Total	5	2	7
Covalima	By processed meat balls	1	0	1
	Buy meat from local markets and produced meat balls	5	1	6
	Total	6	1	7
Dili	By processed meat balls	7	1	8
	Buy meat from local markets and produced meat balls	47	10	57
	Total	54	11	65
Maliana/Bobonaro	Buy meat from local markets and produced meat balls	3	2	5
	Total	3	2	5
Total	By processed meat balls	13	3	16
	Buy meat from local markets and produced meat balls	62	14	76
Grand Total		**75**	**17**	**92**

This contingency table (Table 7) presents a cross-tabulation of two critical variables: the source of meatballs, the municipality of operation, and the result of formalin testing. The key findings are:

- Overall Contamination Rate: Out of 92 samples tested, 18.5% (n=17) tested positive for formalin, a prohibited and hazardous food additive.
- Contamination by Source:
  - In-House Production: Meatballs produced in-house from local market meat had a 18.4% positive rate (14 out of 76).
  - Pre-Processed Meatballs: Pre-processed meatballs had a slightly higher 18.8% positive rate (3 out of 16). The difference between sources is negligible.
- Significant Regional Variation: The prevalence of formalin contamination is not evenly distributed and is concentrated in specific municipalities:
  - Maliana/Bobonaro: Exhibits the highest contamination rate at 40% (2 out of 5 samples).
  - Baucau: Has a high contamination rate of 28.6% (2 out of 7 samples).
  - Dili: As the largest sample (n=65), Dili has an absolute number of 11 positive cases, representing a 16.9% contamination rate.
  - Aileu & Covalima: Have lower but still concerning rates of 12.5% (1/8) and 14.3% (1/7), respectively.

These results reveal a serious and widespread public health issue with distinct geographical patterns.

1. Widespread Adulteration Problem:
   - The overall contamination rate of 18.5% is alarmingly high. It indicates that formalin misuse is not an isolated incident but a systemic problem within the surveyed region, posing a significant health risk to consumers.
2. The Production Source is Not the Primary Risk Factor:

The near-identical contamination rates between in-house and pre-processed meatballs (18.4% vs. 18.8%) is a critical finding. It signifies that the risk of formalin adulteration is pervasive across the supply chain. The hazard is introduced both by:

- Local Producers who may add formalin directly to their in-house products to preserve them.
- Upstream Suppliers who provide pre-processed meatballs already contaminated with formalin. This shifts the focus from a single point of failure to a multi-level problem requiring comprehensive intervention.

3. Geographical "Hotspots" for Intervention: The data clearly identifies priority regions for urgent public health action:

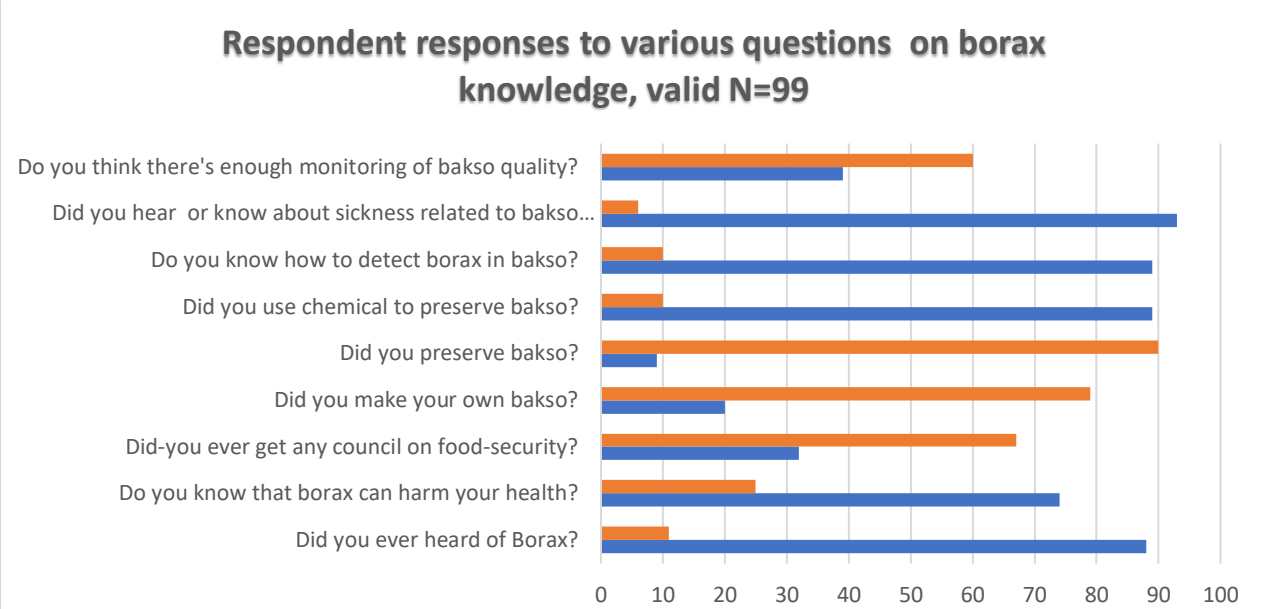
- Maliana/Bobonaro (40%) and Baucau (28.6%) are clear hotspots with exceptionally high contamination rates. Enforcement and education campaigns should be prioritized in these areas.
- Dili requires targeted action due to its high population density and the absolute number of contaminated samples (11 cases), which represents the largest public exposure risk.

4. Contextualizing with Previous Findings:

- Knowledge-Action Gap: This confirms the worst fears stemming from the previous finding of 91.3% unawareness of borax risks. This lack of knowledge clearly extends to other hazardous adulterants like formalin, and is being translated into dangerous practice.
- Trust-Safety Paradox: The high public trust in bakso (78.5%) is severely misplaced, as consumers in hotspots like Maliana have a nearly 1-in-2 chance of consuming a contaminated product.

Please take note that the sample sizes for some municipalities (e.g., Maliana n=5, Baucau n=7) are small. While the high percentages are strong indicators of a problem, the estimates for these specific regions are less precise and should be followed up with more extensive sampling.

3.1.3.3 Respondents feedback on various questions related to borax



	Did you ever heard of Borax?	Do you know that borax can harm your health?	Did-you ever get any council on food-security?	Did you make your own bakso?	Did you preserve bakso?	Did you use chemical to preserve bakso?	Do you know how to detect borax in bakso?	Did you hear or know about sickness related to bakso comsumption?	Do you think there's enough monitoring of bakso quality?
Yes	11	25	67	79	90	10	10	6	60
No	88	74	32	20	9	89	89	93	39

Figure 3. Responses of respondent to various questions, Valid N=99

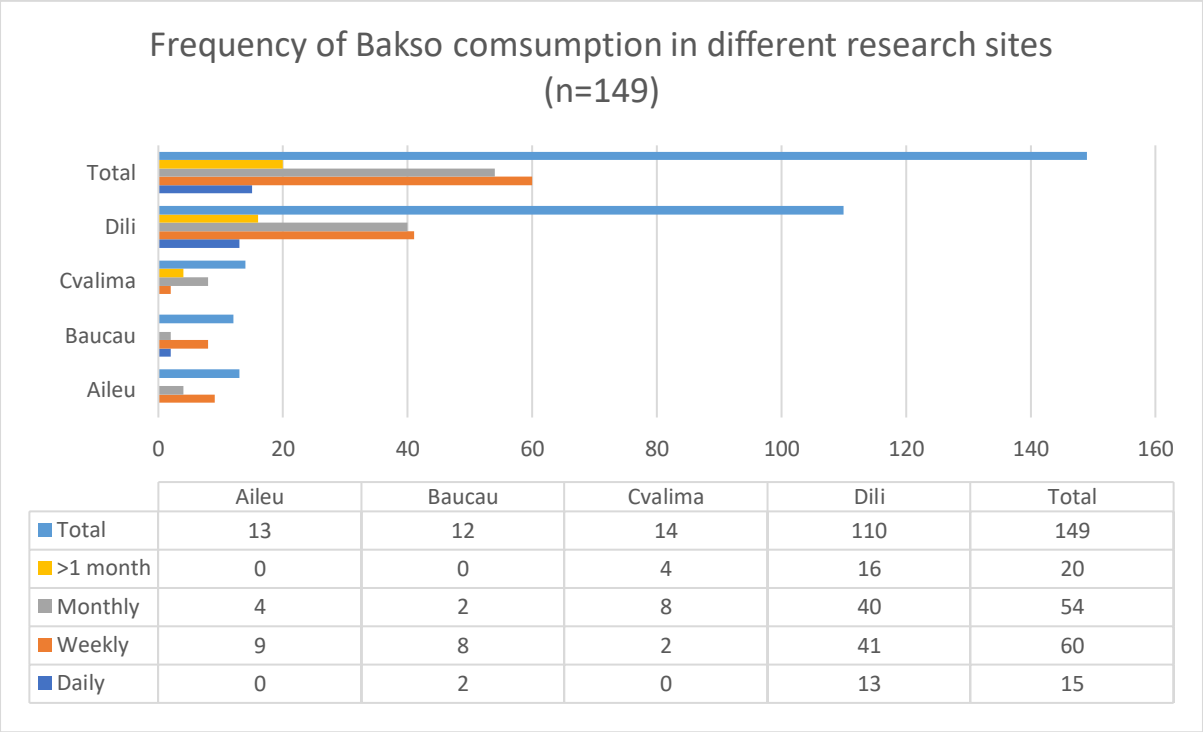
The findings from Figure 3:

- There's a very low level of awareness of what borax is among respondents. Only 11 people (11%) have heard of borax and 88 people (89%) have not heard of borax;
- Public education about the health dangers of borax is critically lacking. This is because only 25 respondents (25%) know that borax can harm health whereas 74 (75%) do not know the health risks;
- Positive sign, though there's still a third left out. 67 people (68%) have received counseling and 32 people (32%) have not;
- Homemade production is common, which increases the importance of food safety knowledge. 79 people (80%) make their own bakso and Only 20 (20%) do not;
- There is a concern: Some may use chemicals unknowingly or under-report. There are 90 (91%) do preserve bakso mostly using fridge and frezzer and only 10 (10%) admit to using chemicals to preserve it;
- Major gap in technical knowledge that increases consumer risk. Only 10 people (10%) know how to detect it. 89 (90%) do not;

- Alarming lack of health awareness. Only 6 people (6%) know about sicknesses caused by bakso consumption. 93 (94%) do not;
- Mixed perception, but many may trust current systems without full knowledge. 60 (61%) think monitoring is enough. 39 (39%) think it isn't.

3.1.4 Customers' perspective on borax contamination

3.1.4.1 Frequency of Bakso comsumption in different research sites (n=149)



	Aileu	Baucau	Cvalima	Dili	Total
Total	13	12	14	110	149
>1 month	0	0	4	16	20
Monthly	4	2	8	40	54
Weekly	9	8	2	41	60
Daily	0	2	0	13	15

Figure 4. Frequency of bakso comsumption in different research sites (n=149)

The Figure 4` above shows that:

1. Dili is overwhelmingly the largest sample group (110 out of 149 respondents, ~74%). This means the "Total" figures are heavily influenced by Dili's consumption patterns. Caution is needed when comparing regions directly due to the large sample size disparity.

2. Overall Consumption Pattern (Total):
    - Weekly consumption is the most common habit overall (60 respondents, ~40%).
    - Monthly consumption is the next most frequent (54 respondents, ~36%).

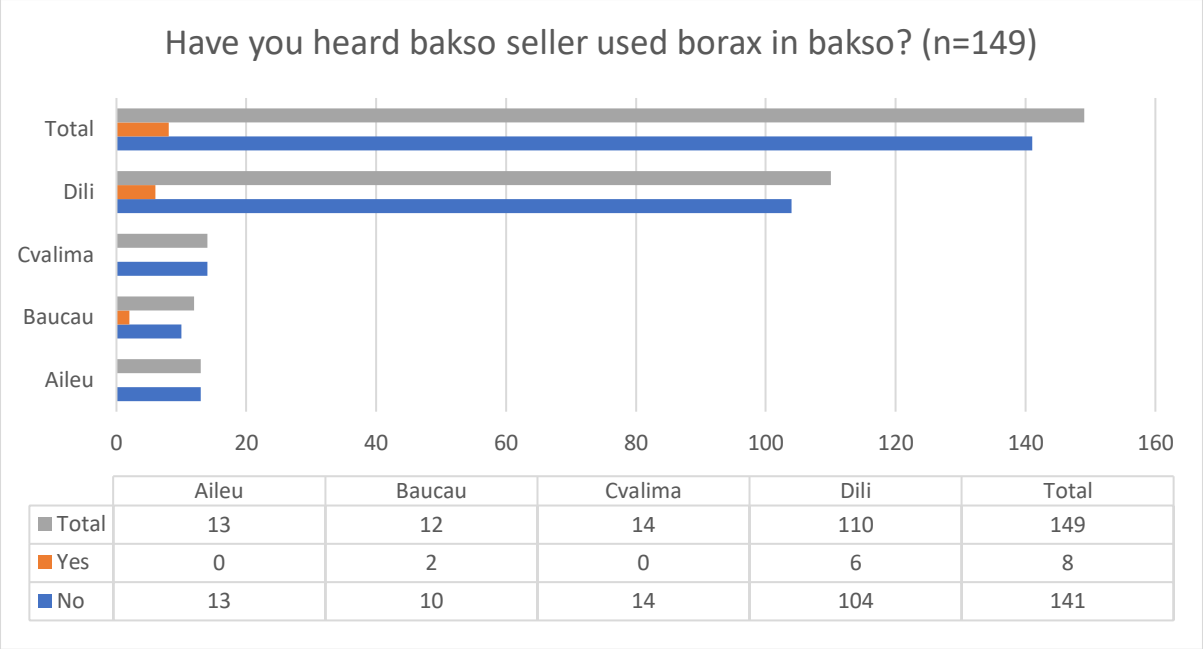
- Consumption less than monthly (>1 month) is less common (20 respondents, ~13%).
- Daily consumption is the least common overall (15 respondents, ~10%).

This can be interpreted that bakso is primarily a weekly or monthly food for most surveyed individuals, not a daily staple. Bakso is primarily a weekly or monthly food for most surveyed individuals, not a daily staple. Weekly consumption is the most common habit overall (60 respondents, ~40%). Monthly consumption is the next most frequent (54 respondents, ~36%). Consumption less than monthly (>1 month) is less common (20 respondents, ~13%). Daily consumption is the least common overall (15 respondents, ~10%).

Bakso is a regularly consumed food in the surveyed areas of Timor-Leste, primarily on a weekly or monthly basis. But significant regional variations exist:

- Aileu & Baucau: Consumption is frequent (at least monthly for all), with Aileu favoring weekly and Baucau having a notable daily minority;
- Covalima: Shows a distinct pattern with high monthly consumption but also the highest proportion of very infrequent consumers (>1 month) and no daily consumers;
- Dili: Represents the overall average pattern due to its large sample size, showing diverse habits but dominated by weekly/monthly consumption;
- Please note that the data Limitation: The extreme imbalance in sample sizes (Dili n=110 vs. others n=12-14) makes direct statistical comparison between regions difficult. The Dili data heavily influences the "Total" figures. Findings for Aileu, Baucau, and Covalima should be viewed as indicative of those specific small samples rather than definitive for the entire regions;
- In essence: While Bakso is generally consumed weekly or monthly across the surveyed sites, Covalima stands out with more infrequent consumption patterns, Baucau has a higher proportion of daily eaters, and Aileu/Baucau show no very infrequent consumers. The dominance of Dili's data shapes the overall total figures.

3.1.4.2 Consumer Awareness of Borax Use in Bakso (n=149)



	Aileu	Baucau	Cvalima	Dili	Total
Total	13	12	14	110	149
Yes	0	2	0	6	8
No	13	10	14	104	141

Figure 5. consumer awareness of borax use in bakso

The Figure shows that the overall Awareness is extremely Low:

- Only 8 respondents (5.4%) across all regions reported hearing about borax use in bakso;
- 141 respondents (94.6%) had no awareness of this practice, indicating a critical gap in food safety knowledge.

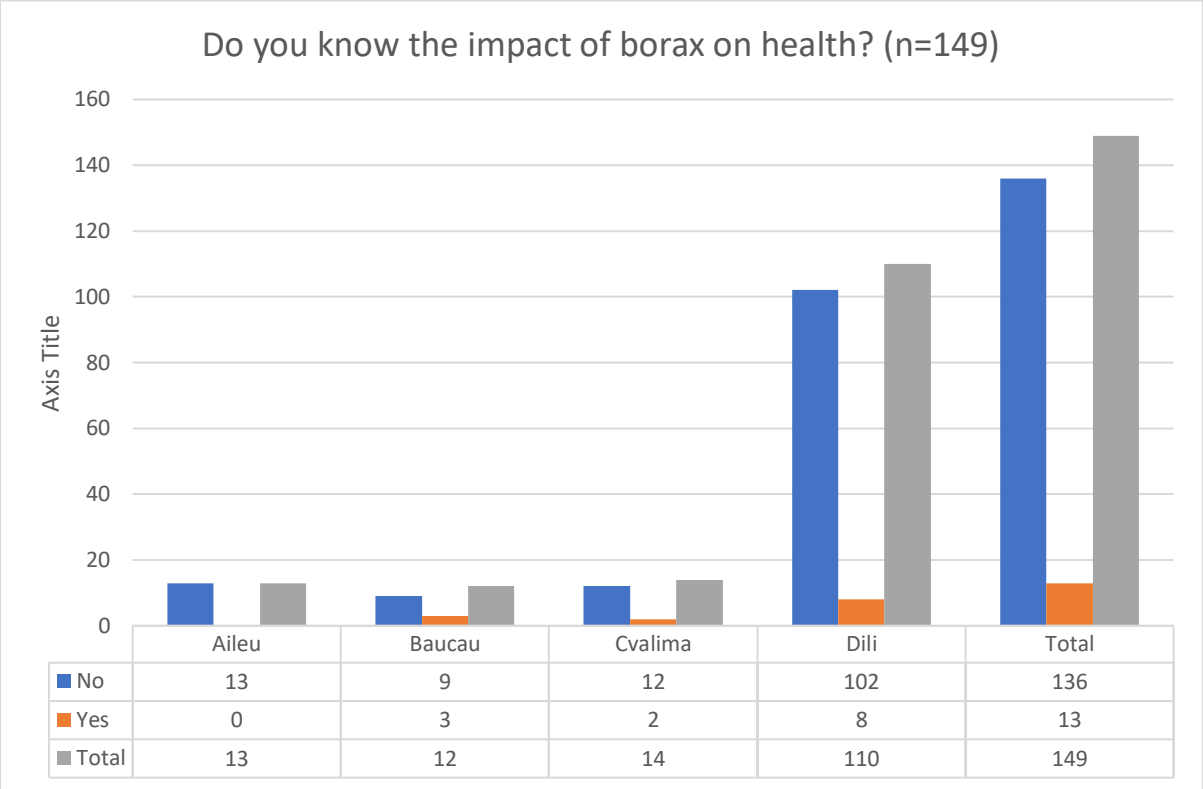
- Regional Disparities in Awareness:
  - Aileu & Covalima: Zero awareness (0/13 and 0/14 respondents, respectively);
  - Baucau: Minimal awareness (2/12 respondents, 16.7%);
  - Dili: Low absolute numbers (6/110 respondents, 5.5%) but drives the total due to sample size dominance.

- Urban-Rural Contrast:
  - Dili (urban center) shows marginally higher absolute cases of awareness (6 vs. Baucau's 2), but proportional awareness remains low (5.5%);
  - Rural municipalities (Aileu, Covalima) exhibit no reported awareness, suggesting potential information-access disparities.

Key Statistics for Reporting:

- Overall unawareness: 141/149 (94.6%);
- Highest awareness: Baucau (16.7%);
- Urban-rural awareness gap: Dili (5.5%) vs. Aileu/Covalima (0%).

3.1.4.3 Knowledge of Borax Health Impacts



	Aileu	Baucau	Cvalima	Dili	Total
No	13	9	12	102	136
Yes	0	3	2	8	13
Total	13	12	14	110	149

Figure 6. Knowledge of borax's impact on health

The Figure shows:

- Low Awareness: The vast majority of respondents (91.3%, 136/149) reported no knowledge of borax's health impacts. Only 8.7% (13/149) answered affirmatively;
- Critical Implication: This indicates a significant public health gap, as borax (a common industrial/chemical additive) poses risks (e.g., toxicity, organ damage) if misused. Lack of awareness may increase exposure vulnerability.

Regional Breakdown

- Dili: Highest absolute unawareness (102 "No" responses), representing 92.7% of its participants (102/110). As the largest cohort (110/149, 73.8% of total), Dili's low awareness disproportionately drives the aggregate result;

- Aileu: 100% unawareness (13/13). Though a small sample (13/149), unanimous lack of knowledge warrants targeted education;
- Baucau & Covalima: Baucau: 75.0% unaware (9/12), but highest relative awareness (25.0%, 3/12). Covalima: 85.7% unaware (12/14), with 14.3% (2/14) aware;
- Note: These regions show marginally better awareness than Dili/Aileu, but samples are small (Baucau: 12; Covalima: 14).

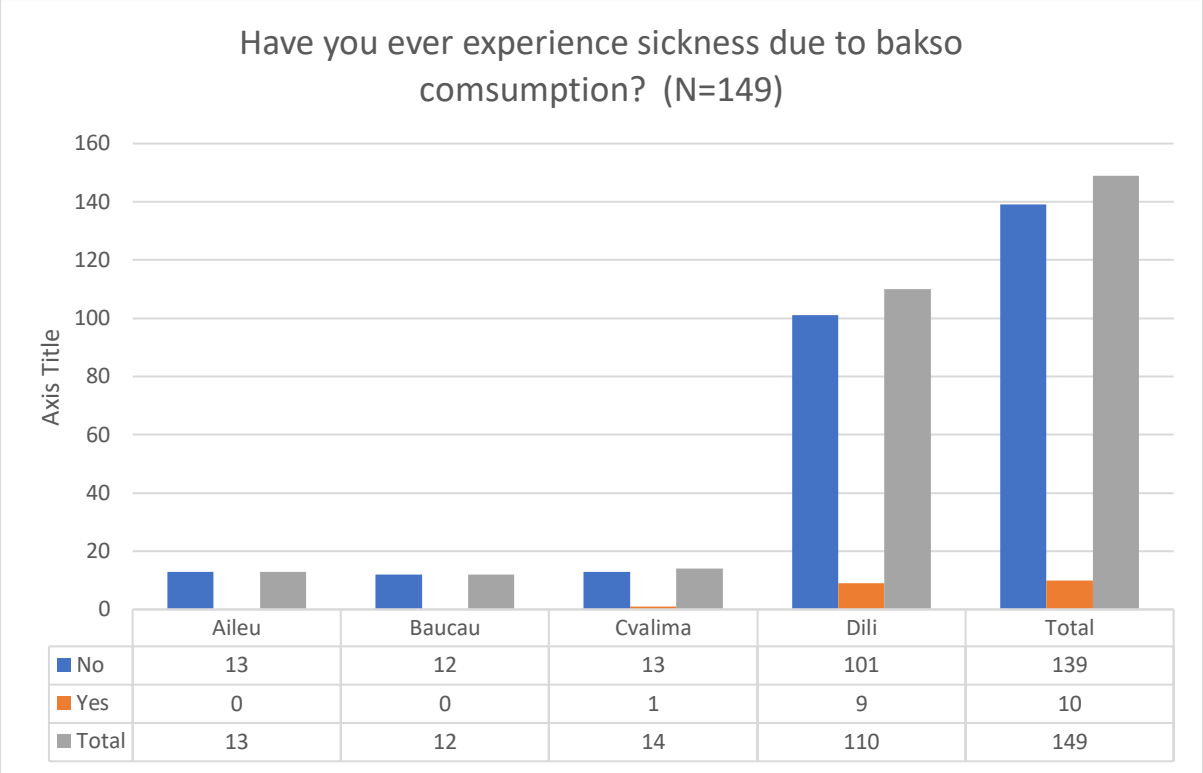
Statistical Notes

Data Limitations:

- Sample imbalance: Dili dominates (73.8% of responses), potentially skewing overall trends;
- Small subgroup sizes: Regional conclusions (especially Aileu/Baucau/Covalima) require caution. Chi-square tests for regional differences are unreliable with $n < 5$ in some "Yes" cells;
- Effect Size: The 91.3% unawareness rate is clinically significant for public health intervention, regardless of regional variability.

A survey of 149 participants across four regions revealed critical gaps in public awareness of borax's health impacts, with 91.3% (n=136) reporting no knowledge. Regional analysis highlighted uniformly low awareness in Dili (92.7% unaware, n=110) and Aileu (100%, n=13), while Baucau (75.0% unaware, n=12) and Covalima (85.7%, n=14) showed slightly higher but still insufficient awareness. The pronounced lack of knowledge underscores an urgent need for targeted public health campaigns, particularly in high-population urban centers (e.g., Dili) and rural areas (e.g., Aileu). Future work should address sample imbalances and explore socio-cultural determinants of awareness.

3.1.4.4 Experience of sickness due to bakso consumption



	Aileu	Baucau	Cvalima	Dili	Total
No	13	12	13	101	139
Yes	0	0	1	9	10
Total	13	12	14	110	149

Figure 7. Have you ever experienced sickness due to bakso consumption?

Analysis and Interpretation of Survey Results on Bakso-Related Sickness (N=149)

Overall Findings .

- Low Sickness Incidence: Only 6.7% (10/149) reported sickness after consuming bakso (meatballs), while 93.3% (139/149) experienced no adverse effects;
- Public Health Implication: Despite widespread consumption of bakso (a common street food), self-reported illness is rare. However, this may reflect underreporting (mild symptoms ignored) or genuinely low contamination rates.

Regional Breakdown:

Dili: Highest absolute cases (9 "Yes" responses), yet low relative incidence (8.2%, 9/110). As the largest cohort (73.8% of total), it drives the aggregate result.

Covalima: Highest relative incidence (7.1%, 1/14), though small sample size limits generalizability.

Aileu & Baucau: Zero reported cases (Aileu: 0/13, Baucau: 0/12). Note: Aileu's data shows formatting errors (duplicate "0" and "12" entries); assuming "0 Yes" and "13 Total" based on context.

Key Observations

Discrepancy with Borax Awareness: Contrasts sharply with prior data showing 91.3% unawareness of borax risks (often linked to bakso contamination). Possible explanations:

- Borax exposure may not cause immediate/recognized symptoms.
- Symptoms may be attributed to other causes (e.g., food poisoning).
- Genuine low contamination despite poor public awareness.

Regional Anomalies:

- Covalima's higher relative sickness rate (7.1%) warrants investigation into local food safety practices.
- Aileu/Baucau's zero cases could reflect safer supply chains or reporting bias.

Statistical Notes

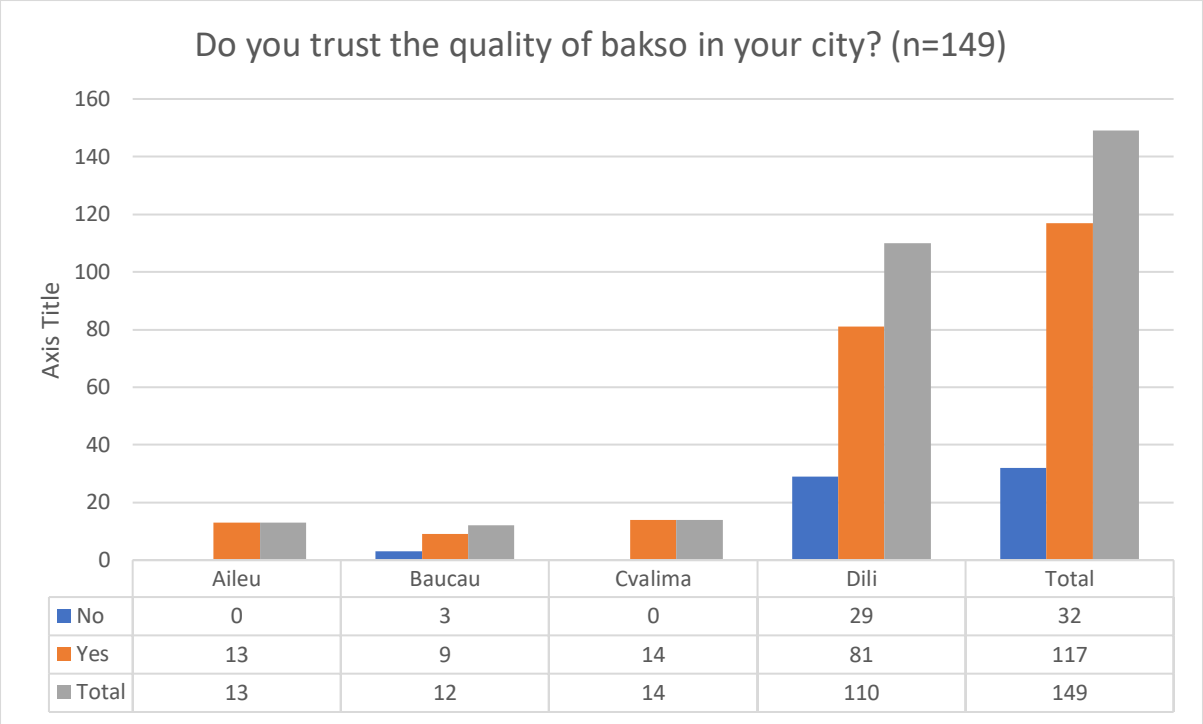
Data Limitations:

- Small "Yes" cohort (n=10 total) limits subgroup analysis (e.g., regional comparisons).
- Sample imbalance: Dili's dominance (n=110) may mask localized risks in smaller regions.
- Potential underreporting: Reliance on self-reported symptoms (recall bias, asymptomatic cases).
- Statistical Testing: Avoid chi-square tests due to sparse data (e.g., 80% of "Yes" cells have $n \leq 1$).

Survey data revealed low self-reported sickness after bakso consumption (6.7%, n=10/149), with no cases in Aileu (n=13) or Baucau (n=12), and marginal incidence in Covalima (7.1%, n=1/14) and Dili (8.2%, n=9/110). This contrasts sharply with high unawareness of borax risks (91.3% in prior data), suggesting underreported illness, misattribution of symptoms, or effective local food safety practices despite knowledge gaps. Targeted monitoring of bakso

supply chains—especially in Covalima and Dili—and clinical correlation of symptoms are recommended."

3.1.4.5 Trust the quality of bakso in your city (n=149)



	Aileu	Baucau	Cvalima	Dili	Total
No	0	3	0	29	32
Yes	13	9	14	81	117
Total	13	12	14	110	149

Figure 8. Do you trust the quality of bakso in your city? (n=149)

Overall Findings:

High Trust Dominates: 78.5% (117/149) trust the quality of bakso in their city, while only 21.5% (32/149) distrust it.

Key Implication: Despite low awareness of borax risks (91.3% unaware, per prior data) and isolated reports of sickness (6.7%), public confidence in bakso remains strong. This suggests:

- Cognitive Dissonance: Trust persists despite limited food safety knowledge.
- Cultural Acceptance: Bakso is deeply embedded in local food culture, potentially overriding safety concerns.

Regional Breakdown

- Dili: Lowest trust (73.6%, 81/110) and highest absolute distrust (26.4%, 29/32 of all "No" responses). Notable Discrepancy: Despite 8.2% reporting prior sickness (highest incidence), distrust is only moderate.

- Aileu & Covalima: 100% Trust (Aileu: 13/13; Covalima: 14/14). Paradox: Both regions had 100% borax unawareness and zero reported sickness. Trust may stem from cultural familiarity.
- Baucau: 25.0% Distrust (3/12), the highest relative distrust despite no prior sickness reports.

Key Observations

- Trust-Safety Mismatch: Regions with no reported sickness (Aileu, Baucau) show divergent trust patterns (100% vs. 75%). Dili's moderate distrust (26.4%) coexists with its high sickness incidence (8.2%).
- Urban-Rural Divide: Urban center (Dili) shows measurable distrust, while rural regions (Aileu, Covalima) report unanimous trust.
- Borax Awareness Gap: High trust persists despite near-universal unawareness of borax risks, implying consumers may not associate chemical hazards with bakso quality.

3.1.5 Health authorities' perspective on Borax contamination

To capture the professional health sector's perspective on borax-related risks, interviews were conducted with a total of 34 health staff from six distinct health institutions. The sample was designed to include professionals from various levels of the healthcare system. The largest number of respondents were from SMS-Covalima (n=8, 23.5%), followed by Hospital Regional Suai (n=6, 17.6%). An equal number of staff were interviewed from four other institutions: AIFAESA, HNGV, Hospital Aileu, and Hospital Regional Baucau (each n=5, 14.7%). This approach ensured that the gathered data on awareness and perspectives represented a diverse range of professional insights from across the regional health infrastructure.

Interviews were conducted with 34 health professionals from various disciplines to obtain a multidisciplinary perspective on the public health risks of borax. The sample was predominantly composed of medics (n=12, 35.3%), who constitute over a third of all respondents, reflecting their frontline role in patient care and diagnosis of potential chemical

poisoning. Nurses and public health professionals were equally represented (each n=6, 17.6%), providing crucial insights from clinical care and community health prevention strategies. Specialized scientific expertise was incorporated through microbiologists (n=4, 11.8%) and laboratory analysts (n=1, 2.9%), whose input is critical for understanding detection methods and toxicological effects. The inclusion of midwives (n=4, 11.8%) and a pharmacist (n=1, 2.9%) further broadens the perspective to include sensitive patient groups and pharmaceutical knowledge. This diverse composition ensures that the gathered opinions on borax awareness and its health implications are comprehensive, spanning clinical, analytical, and preventive public health domains.

Analysis of Health Professionals' Reports on Bakso-Related Illness. Health professionals reported observing patient illnesses linked to bakso consumption in a significant minority of cases. Among the 34 professionals interviewed, 7 (20.6%) confirmed they had encountered patients who had fallen ill after eating bakso, while the majority (79.4%, n=27) had not observed such cases.

The symptoms described by these health authorities are highly consistent with adverse reactions to chemical adulterants, particularly histaminergic reactions or toxicity. The reported symptoms can be categorized into two primary groups:

- Allergic/Histaminergic Reactions: Itchy skin, redness of skin, swollen face, and sweats. These are classic signs of a systemic allergic response, which can be triggered by substances like borax or formalin.
- Gastrointestinal Toxicity: Stomach ache, vomiting, and diarrhea. These are common symptoms of food poisoning and chemical toxin ingestion.
- Systemic Effects: Dizziness, which can indicate a broader neurological or systemic response to a toxin.

This clinical observation from frontline health workers provides crucial corroborating evidence for the laboratory findings of formalin contamination (16.5%). The symptomatology aligns with the known toxicological profiles of common food adulterants, offering a plausible biological explanation for the consumer-reported sickness and strengthening the conclusion that adulterated bakso poses a tangible and ongoing public health risk. The fact that one in five

health professionals reported encountering these cases underscores the practical clinical significance of the issue.

Analysis of Health Professionals' Perception of Population Awareness on Borax Risks. Health professionals were evenly divided in their assessment of public awareness regarding the risks of borax contamination in food. Precisely half of the respondents (50%, n=17) believed there is sufficient awareness of borax risks within the population, while the other half (50%, n=17) reported that there is insufficient awareness.

This lack of consensus among experts highlights significant uncertainty or variability in how the population's knowledge is perceived by healthcare providers. The fact that half of the professionals consider awareness to be inadequate aligns strongly with this study's core finding that 91.3% of vendors were unaware of borax's health impacts. This suggests a recognized gap in public knowledge among a substantial portion of those working on the front lines of public health.

The dichotomy in responses could be influenced by the professionals' specific roles, locations, or personal experiences. For instance, those who have treated patients with related symptoms might be more likely to perceive a lack of awareness. This split opinion underscores the critical need for systematic public education campaigns to ensure that risk awareness is uniform and widespread across the entire population, thereby mitigating reliance on potentially hazardous food additives.

Analysis of Health Professionals' Perceptions on Borax Control Measures. Health professionals demonstrated an overwhelming consensus regarding the inadequacy of current control measures against borax use in food. An absolute majority of respondents (97.1%, n=33) expressed that existing controls are insufficient, with 73.5% (n=25) stating they are outright inadequate and 26.5% (n=9) acknowledging they are adequate but require significant strengthening. Only one respondent (2.9%) considered controls to be adequate, though this response is not explicitly shown in the provided data and may be implied in the total.

This near-unanimous agreement highlights a critical gap in the regulatory framework and enforcement mechanisms aimed at preventing chemical adulteration in food products. The professionals' assessment aligns directly with this study's empirical findings of formalin

contamination in 16.5% of samples and widespread lack of awareness among vendors. The results underscore an urgent need for enhanced regulatory oversight, including more rigorous inspections, effective enforcement of food safety standards, and the implementation of targeted monitoring programs specifically designed to detect chemical adulterants like borax and formalin in the food supply chain.

These findings strongly support the necessity of implementing the multi-faceted interventions previously recommended by health professionals, including socialization campaigns, market controls, and chemical testing, to address this documented public health threat.

Analysis of recommended actions by health professionals. The recommended actions from health professionals for addressing chemical food contamination reveal a strong emphasis on education and proactive public health measures. A clear majority of professionals (52.9%, n=18) identified socialization (public education and awareness campaigns) as the primary necessary action, underscoring the critical need to inform vendors and consumers about the dangers of adulterants like borax and formalin. This aligns directly with the study's finding of a profound knowledge gap among vendors.

Beyond education, several professionals recommended specific regulatory and enforcement measures, including market control and inspections (8.8%, n=3), risk analysis and communication (2.9%, n=1), and direct actions such as communication with vendors and closing down non-compliant businesses (2.9%, n=1). The recommendation for testing of dangerous chemicals (2.9%, n=1) provides direct support for the laboratory methods used in this study and underscores the need for ongoing monitoring.

A smaller but notable segment of recommendations focused on consumer behavior and vendor practices, such as advising the public to avoid eating bakso (8.8%, n=3), eat healthy food (2.9%, n=1), and maintain personal hygiene (8.8%, n=3). A minimal proportion of respondents (5.9%, n=2) recommended taking no action, which may reflect resource constraints or a perception of the problem's scale.

Overall, the recommendations highlight a consensus among health professionals for a multi-faceted strategy that combines widespread education, robust regulatory enforcement, and chemical testing to mitigate the public health threat posed by chemical adulteration in food.

3.2 Discussion of Results

This study provides a comprehensive investigation into the safety of bakso (meatballs) in Timor-Leste, combining survey data, laboratory analyses, organoleptic tracking, and expert interviews. The findings highlight a major public health risk driven by a critical knowledge-practice gap, consumer deception, and the widespread use of chemical adulterants. Importantly, while previous concerns centered on borax, this study demonstrates that the current hazard is the deliberate adulteration with formalin.

3.2.1 Laboratory Findings

Laboratory analysis of 103 meatball samples revealed no evidence of borax (0%), but formalin contamination was detected in 16.5% (n=17). This makes formalin, not borax, the primary adulterant in the studied markets. The presence of formalin, a known toxin and carcinogen (IARC, 2012; Tang et al., 2009), explains the inconsistency between consumer unawareness of borax and the reports of illness (6.7%, Figure 7). The contamination rate of 16.5% (Table 4) represents a quantifiable public health threat requiring urgent regulatory intervention.
Geographical analysis identified Bobonaro (40%) and Baucau (28.6%) as hotspots, while restaurants (18.3%) and supermarkets (22.2%) were the highest contamination sources. Mobile sellers, in contrast, had no positive samples in this study (Table 4). Although sample sizes outside Dili were small, these findings warrant immediate follow-up investigations.

3.2.2 Organoleptic Observations

Organoleptic tracking revealed that formalin serves as a temporary but powerful preservative. On Day 1, 82.4% of contaminated samples still appeared 'Good,' deceiving consumers into perceiving them as fresh and safe. However, spoilage eventually emerged by Day 3 (23.5% spoiled), showing that formalin only delays microbial activity rather than preventing it. This creates a dangerous disconnect between sensory quality and biological safety. Consumers relying on sight or smell are unable to detect formalin, making vigilance ineffective (Wirawan & Dewi, 2021).

3.2.3 Consumer Awareness and Trust

Survey data revealed that 94.6% of consumers were unaware of borax adulteration risks, with rural areas (Aileu, Covalima) showing complete lack of knowledge (Figure 5). Despite this, trust in bakso quality was high (78.5%, (Figure 7), including 100% trust in Aileu and Covalima. Yet laboratory data confirmed contamination in these areas, illustrating a profound mismatch between perception and reality. Self-reported sickness remained low (6.7%) (Figure 7), likely underestimating true health impacts as formalin-related illness may be misattributed to common foodborne diseases.

3.2.4 Vendor Practices and Supply Chain Vulnerabilities

Analysis of vendor practices (n=89) showed that 82.0% produce bakso in-house using locally purchased meat, while only 18.0% use pre-processed products (Figure 2). Formalin contamination rates were nearly identical across both groups (18.4% vs. 18.8%, Table 7), indicating systemic risks throughout the supply chain. Limited refrigeration access incentivizes the illegal use of preservatives like formalin, as observed in other LMICs (Rahaman et al., 2018; Shaltout et al., 2019).

3.2.5 Health Professional Perspectives

Health professionals provided expert validation of these findings. About 20.6% had treated patients with symptoms consistent with chemical toxicity (dermatological, gastrointestinal, systemic) following bakso consumption (Section 3.1.5). Nearly all (97.1%) considered regulatory controls inadequate, and half believed the public lacked sufficient knowledge. Their recommendations emphasized urgent education campaigns, stronger inspections, chemical test kits, and capacity building among healthcare providers.

3.2.6 Thematic Integration

Three central themes emerge from this study:

A. Knowledge–Practice Gap: While consumers were largely unaware of borax risks, laboratory findings confirmed that borax is absent but formalin is prevalent. This shift highlights a substitution toward a more dangerous chemical;

B. Consumer Trust vs. Chemical Hazard: High consumer confidence persists despite laboratory-confirmed risks. Formalin's deceptive organoleptic effects directly explain this paradox.
C. Supply Chain Vulnerabilities: Contamination occurred both in in-house production and pre-processed supply chains, indicating that interventions must be multi-level, targeting vendors, suppliers, and regulators.

4 Conclusions and Recommendations

4.1 Conclusions

This study concludes that the most urgent food safety risk in Timor-Leste's bakso market is not borax, as initially assumed, but the deliberate adulteration with formalin. Formalin creates an invisible and dangerous hazard that consumers cannot detect through appearance or smell, while widespread vendor knowledge gaps and weak regulatory oversight allow the practice to persist.

In relation to the study's hypotheses, the findings clearly support the Null Hypothesis (H0): borax was absent in all tested meatball (bakso) samples, indicating that borax is not currently a significant public health threat in Timor-Leste. Conversely, the Primary Hypothesis (H1), which anticipated borax presence at significant levels, was not supported. Instead, the study uncovered a substitution hazard-the widespread use of formalin as the primary adulterant. This outcome underscores the importance of laboratory confirmation, as relying solely on assumptions about borax risks would have overlooked the more pressing danger posed by formalin adulteration.

This research successfully addressed its original objectives. Laboratory analysis confirmed the absence of borax in all sampled meatballs from Dili and the selected municipalities (Aileu, Baucau, Bobonaro, Covalima), thereby directly meeting the primary aim of detecting borax contamination. Sampling across multiple points of sale-restaurants, supermarkets, mobile sellers, and shops-ensured comprehensive coverage and revealed that the main adulteration risk now lies with formalin, not borax. Interviews with vendors, customers, and shop owners provided valuable insights into awareness and practices, exposing widespread unawareness of chemical risks and misplaced consumer trust. The purchase of bakso samples as ordinary customers further guaranteed the reliability of the findings, showing that the products analyzed reflected their true market status. Overall, the study not only met its objectives but also revealed an unexpected but urgent shift in food safety risks from borax to formalin.

4.2 Recommendations

1. **Expand the Focus of Public Health Campaigns:** Shift awareness campaigns from borax alone to a broader spectrum of chemical adulterants, including formalin and other illegal additives. Public messages must emphasize that good appearance, texture, or taste does not necessarily indicate food safety.
2. **Strengthen Systematic Food Safety Surveillance:** Equip the new Food Quality and Safety Testing Laboratory to conduct routine, nationwide screening not only for formalin but also for borax and other high-risk chemicals. Develop a long-term monitoring plan that integrates multiple food categories beyond *bakso*.
3. **Adopt Gold-Standard Analytical Methods:** Implement internationally recognized, gold-standard laboratory tests—such as spectrophotometric or chromatographic techniques—for both borax and formalin detection. This will enhance the accuracy, reliability, and comparability of test results, ensuring that national findings meet global food safety benchmarks.
4. **Prioritize Vulnerable Populations:** Tailor education campaigns and regulatory protections for children, pregnant women, and individuals with chronic illnesses, who are most at risk from cumulative exposure to adulterants.
5. **Enhance Regulatory Enforcement and Monitoring:** Provide municipal health inspectors and food safety authorities with rapid test kits for on-the-spot screening of both formalin and borax. Increase inspection frequency at high-risk vendor types (e.g., restaurants, supermarkets) and in municipalities with prior detections (e.g., Bobonaro, Baucau).
6. **Build Vendor Capacity and Promote Safe Alternatives:** Train *bakso* producers and vendors in safe food handling, emphasizing the health and legal consequences of chemical adulteration. Promote access to refrigeration and other safe preservation technologies as alternatives to illegal additives.
7. **Integrate Food Safety into National Health Systems:** Establish a formal surveillance and reporting system for suspected foodborne chemical poisoning. Link laboratory findings, clinical reports, and regulatory enforcement to ensure a coordinated national response.
8. Ultimately, this study shows that while borax was absent in the samples tested, the emergence of formalin as a hidden adulterant-and the possibility of other illegal additives—signals a broader food safety crisis in Timor-Leste. Protecting public health

will require not only addressing formalin but also building a resilient, systematic monitoring framework that can detect and prevent the full spectrum of chemical risks in the national food supply.

5 References

Aiadkaeo, N., Rianglaem, T., Lila, P., Pin-ngam, S., Saeyang, N., Jongrattanamongkon, S., Kunchanaroj, P., & Kasikitkonkun, K. (2022). A Case study: An Investigation of Borax in Meatball Products Sold in Bangkok, Thailand. *International Journal of Research Publications*, *110*(1), 414–419. https://doi.org/10.47119/ijrp10011011020223945

Ali, A., Khan, S. R., & Hussain, R. (2020). Assessment of Borax and Formalin Adulteration in Meat Products Sold in Karachi, Pakistan. *Pakistan Journal of Agricultural Sciences*, *57*(5), 1375-1382.

Amaral, A. C., Carvalho, R. D. de, Fernandez, S. S. A., Gomes, G. S., & Mendonça, L. (2025). Formalin (CH2O) Contamination in Seafood and Frozen Meat Imported into Timor-Leste. *Food Science and Technology*, *13*(1), 1–14. https://doi.org/10.13189/fst.2025.130101

Carvalho, R. D. de, Amaral, A. C., Fernandez, S. S. A., Gomes, G. S., & Mendonça, L. (2023). *Final report: Formalin (CH2O) Contamination in Seafood and Frozen Meat Imported* (Issue December). https://journal.unhas.ac.id/index.php/hajas/article/download/6409/3986/0

CEPAD-TL. (2017). *Timor-Leste Strategic Review: Progress and Success in Achieving the Sustainable Development Goal 2*. https://www.tl-cepad.org/wp-content/uploads/2018/07/progress-and-success-in-achieving-the-sustainable-development-goal-2-english.pdf?utm_source=chatgpt.com

Cirino, E. (2023). *2*. https://www.healthline.com/health/is-borax-safe#safety

Codex-alimentarius. (2018). *Timor-Leste: a strong national food control system to ensure safe food consumption*. https://www.fao.org/fao-who-codexalimentarius/news-and-events/news-details/es/c/1105255/

Codex-Alimentarius. (2023). *General Standard for Food Additives (GSFA) Online Database. CXS 192-1995. Codex Alimentarius International Food Standards.* . FAO/WHO. https://www.fao.org/gsfaonline/additives/index.html

Dili-weekly. (2017, February 1). Tests show some supermarket food contaminated by formalin. *The Dili Weekly*. https://thediliweekly.com/2017/02/01/tests-show-some-supermarket-food-contaminated-by-formalin/

El-Nabawy, S. M., El-Nabawy, A. M., & Hassan, M. A. (2017). Detection of Borax Residues in Meat and Meat Products in Assiut City, Egypt. *Assiut Veterinary Medical Journal*, *63*(155), 124–130.

Firmansyah, D., Pramajati, G., Sumiatun, S., & Sarlita Kartiani, B. (2024). Turmeric Extract Bioindicator in Identification of Borax Compounds in Meatballs. *JUPE : Jurnal Pendidikan Mandala*, *9*(2), 524. https://doi.org/10.58258/jupe.v9i2.7074

FSQD. (2018). *Food Safety Information System (FoSIM) Annual Report 2018*.

Gemantari, B. M., Fatmayanti, B. R., & Ramadhan, L. (2024). Identification of Borax in Meatball Skewer Snacks in East Lombok. *Jurnal Farmasi & Sains Indonesia*, *7*(1), 60–64. https://doi.org/10.52216/jfsi.vol7no1p60-64

Girmay, G., G/her, M., & Kiros, A. (2020). Assessment of Borax and Other Chemical Adulterants in Meat and Meat Products in Mekelle City, Tigray, Ethiopia. *Ethiopian Journal of Health Sciences*, *30*(5), 787–794.

Harimurti, S., Bariroh, I. H., Setiyawan, A., Ratna Indah Permatasari, Putri, F. D., & Fajriana, L. Y. (2020). Identification of the spread of borax use in meatball skewers in Bantul district, special region of Yogyakarta. *Jurnal Farmasi Sains Dan Komunitas (Journal of Pharmaceutical Sciences and Community)*, *17*(2). https://doi.org/https://doi.org/10.24071/jpsc.002369

Hossain, M., Akhtar, S., & Anwar, M. (2019). Detection of Adulterants in Meatball Samples from Different Areas of Dhaka City, Bangladesh. *International Journal of Food Contamination*, *6*(1), 5.

IARC. (2012). Chemical Agents and Related Occupations. A Review of Human Carcinogens. In *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans* (Vol. 100). https://www.ncbi.nlm.nih.gov/books/NBK304416/

ILO. (2016). *Food Hygiene & Preparation Guesthouse Operators Tourism Training Module 2*. ILO. https://www.timorleste.tl/wp-content/uploads/formidable/4/4-Hygiene-and-Food-Preparation-Module-2-Manual-English.pdf

Khairiyati, L., Waskito, A., Marlinae, L., & Nur, A. (2023). Borax Risk Assessment in Meatball That Circulating Around Vocational School Darussalam Martapura. *Journal of Environment and Earth Science*, *13*(9), 1–8. https://doi.org/10.7176/jees/13-9-01

KT. (2017, February). Noodle makers shut over borax. *Khmer Times*. https://www.khmertimeskh.com/12219/noodle-makers-shut-over-borax/

Lestari, D., Tristiana, Y., & Mardiana, M. (2021). Identification of Borax Content in Meatballs Circulating in the Jambi City. *Jurnal Akademika Kimia, 10*(1), 37–41.

NTIS. (1983). Health Hazard Evaluation Report MHETA 80-109, US Borax and Chemical Corp., Boron, California. *Govt Reports Announcements & Index (GRA&I), Issue 21, 1997*. https://www.cdc.gov/niosh/hhe/reports/pdfs/80-109.pdf

Poison-Control. (2025). *Borates, Borax, and Boric Acid: Are They Safe?* Poison Control-National Capital Poison Centre (NCPC). https://www.poison.org/articles/borates

Pongsavee, M. (2009). Effect of borax on immune cell proliferation and sister chromatid exchange in human chromosomes. *Journal of Occupational Medicine and Toxicology*, *4*(1), 1–6. https://doi.org/10.1186/1745-6673-4-27

Rahaman, M. M., Razzak, M. A., & Khan, M. M. (2018). Formaldehyde and health: a systematic review of the literature on human exposure to formaldehyde and its associated health effects. *Asian Pacific Journal of Environment and Cancer*, *1*(1), 29-38.

Rahim, S., Dukalang, F. I., & Abas, A. S. (2022). Examination of hazardous food additives (Borax) in meatballs in the city of Gorontalo. *Journal of Health, Tecnology and Science (JHTS)*, *1*(3), 72–81. https://journals.ubmg.ac.id/index.php/JHTS/article/download/1045/317/

Rahma, D. A., Sari, E. M., & Nurfajriah, S. (2023). Identifikasi kandungan boraks pada bakso yang beredar di pasar tradisional Kecamatan Tambun Selatan. *Journal of Research and Education Chemistry*, *5*(1). https://doi.org/https://doi.org/10.25299/JREC.2023.vol5(1).12502

Rohani, S., Rosita, Y., Vina Pramayastri, & Lutfiah Hafidzah. (2023). Borax analysis with spectrophotometry on meat bakso of frozen food that sold in modern markets and traditional markets in Palembang. *International Journal of Ecophysiology*, *5*(1), 19–35. https://doi.org/10.32734/ijoep.v5i1.12342

Saputro, A. H., & Fauziyya, R. (2021). Analisis kualitatif boraks pada bakso dan mi basah di Kecamatan Sukarame, Sukabumi dan Wayhalim. *Jurnal Ilmiah Farmasi Farmasyifa*, *4*(1). https://doi.org/https://doi.org/10.29313/JIFF.v4i1.7067

Sari, I. P., Yanti, F. A., Saefullah, D. I., & Yunianto, B. T. (2021). Identification of borax in meatballs at Bandung City, Indonesia. *Journal of Sustainability Science and Technology*, *1*(1), 44–51. https://www.academia.edu/84837232/Identification_of_borax_in_meatballs_at_Ciroyom_Market_Bandung_City_Indonesia

Shaltout, F. A., El-Toukhy, A. M., & Ahmed, H. A. (2019). Study of the use of formalin in the preservation of meat and fish. *Journal of Advanced Veterinary Research, 9*(3), 87–91.

Sogbesan, O. A., Ogori, A. F., & Igyor, M. A. (2019). Assessment of Borax and Other Additives in Processed Meat Products in Sokoto Metropolis, Nigeria. *Asian Food Science Journal, 12*(1), 1–7.

Tabassum, K., Memi, A. A., Sultana, N., Reza, A. W., & Barman, S. D. (2019). Food and formalin detector using machine learning approach. *International Journal of Machine Learning and Computing*, *9*(5), 609–614. https://doi.org/10.18178/ijmlc.2019.9.5.847

Tang, X., Bai, Y., Duong, A., Smith, M. T., Li, L., & Zhang, L. (2009). Formaldehyde in China: Production, consumption, exposure levels, and health effects. *Environment International, 35*(8), 210–1224.

Tatoli. (2021). *TL should stablish a National Quality Control Laboratory for food*. TATOLI - Agencia Nacional de Timor-Leste. https://en.tatoli.tl/2021/08/26/tl-should-stablish-a-national-quality-control-laboratory-for-food/19/

Tatoli. (2025). *AIFAESA to, set up Food Quality and Safety Testing Laboratory*. https://en.tatoli.tl/2025/01/15/aifaesa-to-set-up-food-quality-and-safety-testing-laboratory/12/

TL-UN. (2022). *Consolidating resources and multi-sectoral action for better nutrition in Timor-Leste*. https://timorleste.un.org/en/199982-consolidating-resources-and-multi-sectoral-action-better-nutrition-timor-leste?utm_source=chatgpt.com

Wardati, Nur'aini, & Hadi, A. . (2019). Uji Kandungan Natrium Aluminat (Boraks) dalam bakso di Kecamatan Sangatta Utara. *Journal of Animal Science*, *2*(2), 165.

WHO. (2018). *Timor-Leste becomes 188th Codex member*. https://www.who.int/southeastasia/activities/timor-leste-becomes-188th-codex-member?utm_source=chatgpt.com

Wirawan, I. M. A., & Dewi, N. P. S. R. (2021). Consumer perception and willingness to pay for food safety attributes: A review. *IOP Conference Series: Earth and Environmental Science, 733*(1), 012121.

Yoshida, M., Tokiyasu, T., Watabiki, T., Ueda, M., & Ishida, N. (1991). Study on the histochemical staining of boric acid. *1991*, *45*(5–6), 416–422. https://pubmed.ncbi.nlm.nih.gov/1725792/#article-details

Zachawerus, A. C., Sulistiawati, S., & Qurnianingsih, E. (2023). Investigation of Borax in Meatball Products Sold in Bengkalis, Riau. *JUXTA: Jurnal Ilmiah Mahasiswa Kedokteran Universitas Airlangga*, *14*(2), 89–93. https://doi.org/10.20473/juxta.v14i22023.89-93

6 Appendixes

6.1 Declaração de Consentimento para Participação na Pesquisa

Título da Pesquisa:
Identificação da presença de bórax em almôndegas (bakso) vendidas em Timor-Leste: Riscos para a saúde pública e segurança alimentar

Pesquisadores Responsáveis:

A/Prof. Acacio Cardoso Amaral	**:**	**Investigador principal**
Apt. Stefany S.A. Fernandez, M.Si	**:**	**Membro**
Lourenca Mendonca	**:**	**Membro**
Drh. Nicodemos Bores Lonai, SKh	**:**	**Membro**
Drh. Silvia Correia, SKh	**:**	**Membro**

Objetivo da Pesquisa:
Esta pesquisa tem como objetivo identificar a presença de bórax no bakso comercializado na cidade de Dili e avaliar os possíveis riscos para a saúde pública e a segurança alimentar. As informações coletadas serão utilizadas exclusivamente para fins científicos e acadêmicos.

Procedimentos:
Se você concordar em participar, responderá a um questionário com perguntas sobre o consumo e a venda de bakso, seu conhecimento sobre o uso de bórax e sua percepção sobre os riscos à saúde. A participação é voluntária e levará aproximadamente [tempo estimado] minutos.

Confidencialidade e Anonimato:
Todas as informações fornecidas serão mantidas em sigilo e utilizadas apenas para esta pesquisa. Os dados serão analisados de forma agregada, sem identificação individual dos participantes.

Direitos do Participante:
Sua participação é voluntária, e você pode se recusar a responder qualquer pergunta ou encerrar a entrevista a qualquer momento, sem necessidade de justificativa.
Não haverá riscos diretos para você ao participar desta pesquisa.
Se você tiver dúvidas sobre esta pesquisa, pode entrar em contato com os responsáveis pelo estudo pelo e-mail [inserir e-mail] ou telefone [inserir número].

Declaração de Consentimento:
[ ] Eu li e compreendi as informações acima. Concordo voluntariamente em participar desta pesquisa.

Nome do Participante:……. ……..
……..
Assinatura: …….
…….

Data: ……./……./2025

Pesquisador Responsável:
Nome: ……
……
Assinatura: ……
…….

6.2 Formulário De Consentimento É Para Entrevistados Menores De Idade[1]

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO PARA RESPONSÁVEIS LEGAIS

Título da Pesquisa:
Identificação da presença de bórax em almôndegas (bakso) vendidas em Timor-Leste: Riscos para a saúde pública e segurança alimentar
Pesquisadores Responsáveis:

A/Prof. Acacio Cardoso Amaral	**:**	**Investigador principal**
Apt. Stefany S.A. Fernandez, M.Si	**:**	**Membro**
Lourenca Mendonca	**:**	**Membro**
Drh. Nicodemos Bores Lonai, SKh	**:**	**Membro**
Drh. Silvia Correia, SKh	**:**	**Membro**

1. Introdução
O (A) senhor(a) está sendo convidado(a) a autorizar a participação de seu (ua) filho(a) ou dependente nesta pesquisa, que tem como objetivo identificar a presença de bórax no bakso comercializado em Dili e avaliar os possíveis riscos para a saúde pública e segurança alimentar.
Antes de decidir, é importante que leia atentamente este documento e esclareça todas as suas dúvidas com os pesquisadores responsáveis.
2. Procedimentos da Pesquisa
Se autorizado, seu(ua) filho(a) responderá a perguntas sobre seus hábitos de consumo de bakso e seu conhecimento sobre segurança alimentar. A participação é voluntária e levará aproximadamente [tempo estimado] minutos.
3. Riscos e Benefícios
Não há riscos diretos à saúde do(a) participante.
A pesquisa pode contribuir para conscientização sobre segurança alimentar e influenciar políticas públicas para melhorar a qualidade dos alimentos.
4. Confidencialidade e Anonimato
Todas as informações serão mantidas em sigilo, utilizadas exclusivamente para esta pesquisa e analisadas de forma agregada, sem identificação dos participantes.
5. Direitos do Participante e do Responsável
A participação é voluntária e pode ser interrompida a qualquer momento, sem necessidade de justificativa.
O responsável pode solicitar esclarecimentos e retirar o consentimento a qualquer momento.

Caso tenha dúvidas, entre em contato com os pesquisadores pelo e-mail [acacio.amaral@ipb.edu.tl] ou telefone [+670 77813154].
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6. Declaração de Consentimento
Eu, _____, responsável legal por _____, declaro que:
[ ] Li e compreendi as informações acima. Autorizo a participação de meu(ua) filho(a)/dependente nesta pesquisa.

[1] Menor de idade significa os inquiridos cuja idade é inferior a 18 anos

Nome do Responsável: _____
Assinatura: _____
Data: ……../……/2025

7. Declaração do Pesquisador
Eu, _____, responsável pela condução da pesquisa, confirmo que esclareci todas as informações ao responsável legal e estou à disposição para eventuais dúvidas.
Nome do Pesquisador: _____
Assinatura: _____
Data:…… /……/2025

6.3 Questionnaires

1. Questionnaire for bakso sellers

Aim: To identify sellers' knowledge about the use of borax and their food handling practices.

1.1.1 General Data:
1. Name (optional):
2. Age:
3. Sex:[ ] Male [ ] Female
4. How long have you been selling bakso? [ ] Less than 1 year [ ] 1-5 years [ ] More than 5 years
5. Where do you buy the ingredients for bakso?
1.1.2 Knowledge of food safety:

6. Have you ever heard of borax being used in food? [ ] Yes [ ] No
7. Do you know that borax can be harmful to health? [ ] Yes [ ] No
8. Have you ever received any advice on food safety? [ ] Yes [ ] No
1.1.3 Production practices:

9. Do you make the bakso yourself or buy it ready-made? [ ] I make it [ ] I buy it ready-made
10. How do you preserve the bakso before selling it?
11. Do you use any chemicals to preserve or improve the texture of the bakso? [ ] Yes [ ] No (If yes, which?)
12. Do you know how to tell if a bakso contains borax? [ ] Yes [ ] No

1.1.4 Risk perception:

13. Have you ever heard of health problems related to bakso consumption? [ ] Yes [ ] No
14. Do you think there is sufficient supervision of the quality of bakso? [ ] Yes [ ] No

2. Questionnaire for Bakso Consumers

Aim: To assess the frequency of consumption and consumers' perception of the food safety of bakso.

1.2.1 General Data:

15. Age:
16. Sex: [ ] Male [ ] Female
17. How often do you eat bakso?
[ ] Daily [ ] 1-2 times a week [ ] 1-2 times a month [ ] Rarely
18. Where do you usually buy bakso?

1.2.2 Perception of food safety:

19. Have you heard that some vendors use borax in their bakso? [ ] Yes [ ] No
20. Do you know the health risks that borax can cause? [ ] Yes [ ] No
21. Have you ever had health problems after consuming bakso? [ ] Yes [ ] No (If yes, what symptoms?)

22. Do you trust the quality of the bakso sold in the city? [ ] Yes [ ] No (Why?)
23. What do you think the authorities should do to guarantee the food safety of bakso?

3 Questionnaire for Health Professionals

Objective: To understand the relationship between consumption of bakso with borax and reported health problems.

1.3.1 General Data:

24. Specialty: [ ] Doctor [ ] Pharmacist [ ] Nutritionist [ ] Other
25. Length of experience in the area: [ ] Less than 5 years [ ] 5-10 years [ ] More than 10 years

1.3.2 Perception of the Effects of Borax:

26. Have you ever seen patients with symptoms that could be related to the consumption of contaminated bakso? [ ] Yes [ ] No

27. What symptoms are most common in cases of borax poisoning?
28. Do you think there is sufficient awareness of the risks of borax in the population? [ ] Yes [ ] No
1.3.3 Professional recommendations:

29. What measures would you recommend to reduce the risks associated with consuming adulterated bakso?

30. Do you believe that the controls on the use of borax in food are adequate? [ ] Yes [ ] No