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Borax Content of Meatballs in Market X Area Surabaya, Indonesia

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ABSTRACT The illegal addition of borax in meatballs remains a significant public health concern, given its potential toxicological effects and the widespread consumption of meatball products in urban markets. This study aims to evaluate the presence and physical characteristics of borax in meatballs sold in Market X, Surabaya, Indonesia, and to analyze the correlation between borax content and organoleptic qualities. Utilizing an observational analytical design, the research involved collecting 12 meatball samples from different vendors within the market. Organoleptic assessments covering texture, color, taste, and smell were conducted by 30 non-trained panelists using standardized checklists. Concurrently, laboratory examination employed the curcumin paper test to qualitatively detect borax presence in the samples. The results indicated that one out of the twelve samples (8%) tested positive for borax, exhibiting specific physical characteristics such as a chewy texture, pale gray coloration, a sour taste, and a fishy odor. Statistical analysis using the Kendall tau-b correlation demonstrated a significant relationship (p-value = 0.032; $\rho = 0.55$) between borax presence and deviations in organoleptic qualities. These findings suggest that borax contributes to altered physical properties of meatballs and poses potential health risks for consumers. The study underscores the need for regular monitoring and stricter regulation of food additives, as well as advocating for the replacement of borax with safer alternatives like carrageenan to preserve product quality without compromising public health. Further quantitative research employing spectrophotometric or titrimetric methods is recommended to accurately determine borax concentrations in food samples, facilitating the enforcement of food safety standards and protecting consumer health.

INDEX TERMS Borax, meatballs, food safety, organoleptic qualities, laboratory detection.

I. INTRODUCTION

The widespread popularity of meatballs as a convenient and affordable culinary delicacy has led to an increase in their production and consumption globally, particularly in developing countries where street food and informal markets serve as primary sources of affordable nutrition [1], [2]. Despite their cultural and economic significance, concerns have been raised regarding the safety and quality of meatballs, especially relating to the indiscriminate use of certain food additives to enhance shelf life, texture, and appearance [3], [4].

One such additive is borax (sodium borate), which has been illicitly incorporated into meat products, including meatballs, to prolong shelf life, improve chewiness, and achieve a desirable white color [5], [6]. The addition of borax poses significant health risks due to its toxic and potentially carcinogenic effects upon ingestion, especially with continuous consumption [7], [8]. Numerous studies have documented the adverse health consequences associated with borax intake, highlighting symptoms such as gastrointestinal disturbances, nephrotoxicity, and reproductive toxicity [9]-[11].

Regarding the detection of borax in food, various analytical methods have been explored, including spectrophotometry, titration, chromatography, and rapid field-test kits. Recent advancements have focused on developing cost-effective, rapid, and reliable detection techniques suitable for routine screening in markets and laboratories [12], [13]. Among these, qualitative test kits such as turmeric paper and borax-specific reagent strips have gained popularity for on-site detection due to their simplicity and quick turnaround times [14], [15].

However, there remain notable gaps in the current literature. First, most previous investigations have focused on laboratory-based quantitative analyses, with limited emphasis on correlating qualitative borax detection results with organoleptic (sensory) qualities of meatballs [16], [17]. Second, there is insufficient comprehensive data on the prevalence of borax usage in street-vurchased meatballs within local markets, especially in Southeast Asian contexts like Indonesia, where informal food vendors dominate [18], [19]. Third, despite the known health hazards, regulatory enforcement remains inconsistent, necessitating studies that

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Vol. 3 No.6, pp. 321-326, December 2023

combine both physical and chemical detection methods to better inform public health interventions.

This study aims to fill existing knowledge gaps by thoroughly evaluating the quality of meatballs sold in Market X, Surabaya, Indonesia, through both organoleptic assessments and qualitative detection of borax. Its main objectives include identifying the presence of borax in the meatball samples using quick field detection techniques, examining the correlation between borax levels and physical attributes such as texture, color, taste, and aroma, and offering evidence-based guidance to stakeholders regarding food safety and adherence to regulations. The contributions of this study are multifaceted.

1. It offers an integrated approach combining qualitative borax detection with organoleptic evaluation, providing a comprehensive assessment of meatball quality.
2. The findings will inform local authorities and vendors regarding the prevalence of borax adulteration, supporting enforcement and educational campaigns.
3. The study proposes alternative, natural additives such as carrageenan, aligning with global trends in safe food processing and clean-label practices [20].

This paper is organized into the following sections: the methodology, detailing sample collection and testing procedures; results, presenting findings from physical and chemical analyses; discussion, interpreting the implications for public health and food safety; and concluding remarks, emphasizing policy recommendations and future research directions.

II. METHODS

This research utilized an analytical observational study design to systematically examine the presence of borax in meatball samples sold within Market X, located in Surabaya, Indonesia. The primary objective of this approach was to obtain reliable and valid data regarding both the physical characteristics and the qualitative detection of borax contamination in commercially available meatballs. The methodology was rigorously developed to facilitate accurate and reproducible results, which are essential for drawing meaningful conclusions about food safety risks associated with borax adulteration in street-vended meatballs. To achieve this, a detailed description of the materials used, the criteria for selecting samples, the procedures for data collection including sensory evaluations and laboratory tests and the analytical techniques employed are elaborated upon in subsequent sections. Emphasis was placed on ensuring that the procedures adhered to standardized protocols, thereby allowing for consistency across assessments and enabling other researchers to replicate the study in different settings or at later dates. Furthermore, the design was structured to minimize bias and maximize objectivity, with strict controls in place for sample collection, evaluator training, and laboratory analysis to maintain the integrity and accuracy of the findings. This comprehensive approach underscores the scientific rigor underpinning the investigation and enhances confidence in the results obtained.

A. MATERIALS AND EQUIPMENT

The primary materials utilized in this research included freshly prepared meatball samples obtained directly from vendors within Market X. Laboratory reagents for qualitative borax detection comprised turmeric paper (curcumin-based test strips), borax reagent solutions, and distilled water. Standardized assessment tools such as checklists for organoleptic evaluations were employed. Equipment used consisted of test tubes, droppers, timers, and colorimetric comparison charts for interpreting reagent reactions. All reagents and materials adhered to quality standards specified in recent analytical method protocols [21], [22].

B. STUDY POPULATION AND SAMPLE SELECTION

The population encompassed all meatball vendors operating within Market X, with a total of twelve samples collected through stratified sampling to represent various vendor types and meatball preparation styles. The inclusion criteria mandated that samples be freshly prepared and intended for immediate sale. To minimize bias, samples were collected randomly without prior knowledge of their borax content or organoleptic qualities. The sample size was determined based on prior prevalence estimates of borax adulteration in similar markets, following sample size calculation recommendations for qualitative and sensory studies [23].

C. STUDY DESIGN AND PROCEDURE

The research was prospective and cross-sectional in nature, conducted over a six-month period from January to June 2023. All sample collections and laboratory analyses were carried out within this timeframe. The procedure began with initial organoleptic assessments performed by trained non-standard panelists, focusing on texture, color, taste, and smell, according to standardized protocols [24]. This ensured qualitative evaluation of each sample's physical attributes prior to laboratory testing.

D. ORGANOLEPTIC ASSESSMENT

Each meatball sample was evaluated independently by three assessors, with assessments recorded on a standardized checklist. Parameters included appearance (color and shape), aroma, flavor, and texture specifically noting chewiness and fibrous characteristics. The assessment criteria were adapted from established sensory analysis guidelines [25], ensuring consistency across evaluations. Inter-rater reliability was calculated to enhance objectivity [26].

E. QUALITATIVE BORAX DETECTION

Following sensory evaluation, the presence of borax was tested using a rapid field detection technique based on turmeric paper strips. Briefly, approximately 250 grams of each sample were homogenized and immersed in 20 mL of distilled water, then filtered. A few drops of borax reagent were added to the filtrate, and the turmeric test strip was dipped into the solution. A color change to reddish indicated a positive result for borax, following the method validated in recent studies [21], [22]. Each test was performed in

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Vol. 3 No.6, pp. 321-326, December 2023

duplicate to ensure accuracy, with results recorded as positive or negative.

F. DATA ANALYSIS

The correlation between borax presence and physical qualities was analyzed using Kendall's tau-b correlation coefficient, appropriate for ordinal data derived from organoleptic scores and categorical lab results [27]. Statistical significance was set at $p < 0.05$. All analyses were conducted using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics summarized the prevalence of borax contamination and distribution of physical quality scores across samples.

G. QUALITY CONTROL AND ETHICAL CONSIDERATIONS

To maintain consistency, all assessments and laboratory tests were performed by trained personnel following standardized procedures. The laboratory equipment was calibrated regularly, and reagent quality was verified before use. Ethical approval was obtained from the Institutional Review Board of Surabaya Health Department, with informed consent secured from vendors prior to sample collection, respecting confidentiality and vendor anonymity [28].

III. RESULT

The organoleptic test of the physical quality of texture meatballs could been described in FIGURE 1:

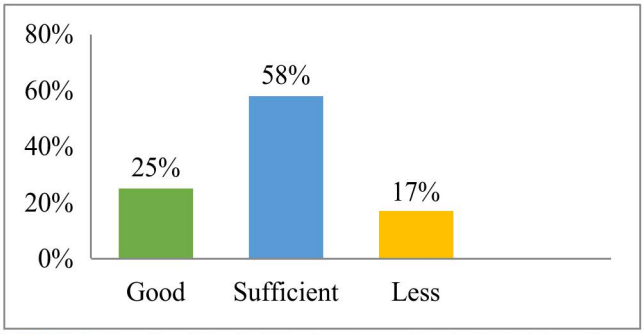

FIGURE 1. Results of Meatball Texture Inspection in Market Area X Surabaya, Indonesia Year 2023

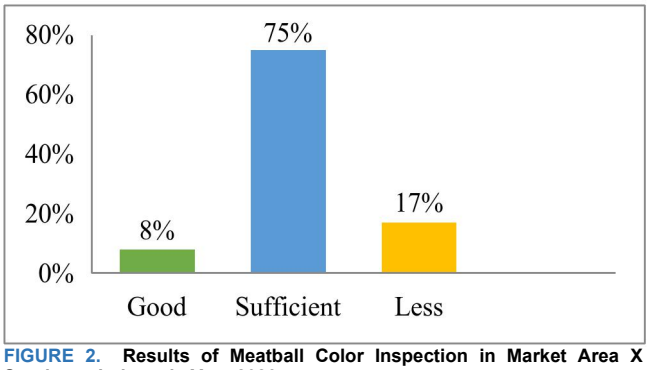

FIGURE 2. Results of Meatball Color Inspection in Market Area X Surabaya, Indonesia Year 2023

The results of the examination of meatball texture FIGURE 1 conducted by 30 panelists, namely 12 meatball samples, most of the 7 meatball samples (58%) with sufficient assessment criteria, namely the texture was not chewy. The quality of meatball texture that was less fulfilled was the fibrous and chewy texture category.

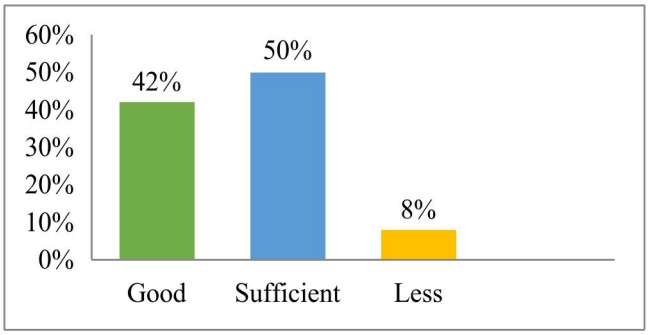

FIGURE 3. Results of Meatball Taste Inspection in Market Area X Surabaya, Indonesia Year 2023

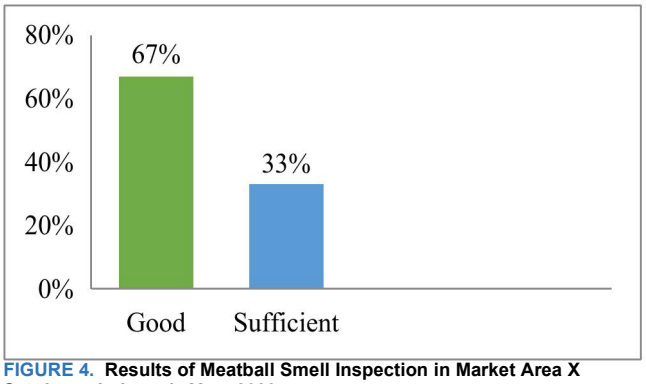

FIGURE 4. Results of Meatball Smell Inspection in Market Area X

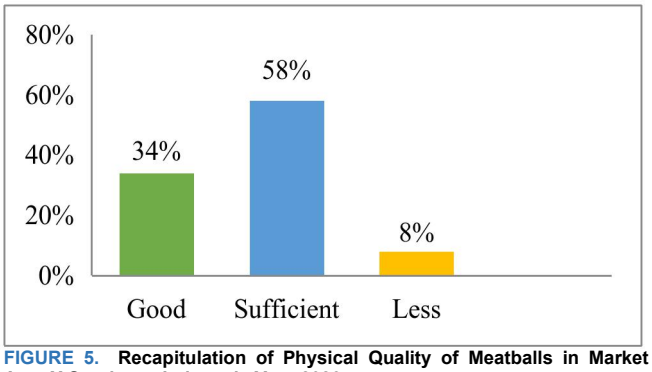

FIGURE 5. Recapitulation of Physical Quality of Meatballs in Market Area X Surabaya, Indonesia Year 2023

The organoleptic test of the physical quality of color meatballs could been described in FIGURE 2: The results of the meatball color examination in FIGURE 2 conducted by 30 panelists, namely 12 meatball samples, mostly 9 meatball samples (75%) with sufficient assessment criteria, namely the color was more likely have been gray. The meatball color quality that was less fulfilled was the reddish brown and pale gray color categories.

The organoleptic test of the physical quality of flavored meatballs could been described in FIGURE 3: The results of the examination of the taste of meatballs in FIGURE 3 conducted by 30 panelists, namely 12 meatball samples, most of the 6 meatball samples (50%) with sufficient assessment criteria, namely savory taste. The quality of meatball flavor that was less fulfilled was the category of meat flavor and bitterness. The organoleptic test of the physical quality of smelly meatballs could been described in FIGURE 4. The results of the examination of the smell of meatballs in FIGURE 4 conducted by 30 panelists, namely 12 meatball samples, mostly 8 meatball samples (67%) with good assessment criteria, namely smelling

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Vol. 3 No.6, pp. 321-326, December 2023

typical of meat. The quality of meatball odor that was less fulfilled was the category of smelling quite sharp spices, unpleasant (stale), fishy, and unnatural odors.

The recapitulation of the organoleptic test of the physical quality of meatballs could been explained in FIGURE 5: The physical quality of meatballs in FIGURE 5 carried out by 30 panelists, namely 12 meatball samples, most of the 7 meatball samples (58%) with sufficient assessment criteria, 4 meatball samples (34%) with good assessment criteria, and 1 meatball sample (8%) with less assessment criteria. The borax content of meatball samples was examined qualitatively by laboratory tests to saw whether or not borax was present. The following were the results of the borax content test.

TABLE 1
Qualitative Test Results of Borax Meatballs In Market Area X Surabaya Indonesia Year 2023

No	Borax Content	Frequency	Precentase
1.	Positive	1	8%
2.	Negative	11	92%
Amount		12	100%

Based on TABLE 1, the qualitative borax test showed that 12 samples of meatballs was positive for borax at 8%. The relationship between the borax content of meatballs was obtained from statistical analysis used the *kendall tau-b* correlation test that there was a relationship between borax content and the organoleptic test of the physical quality of meatballs (ρ-value 0.032 which was less than α (0.05)) which was 0.55.

IV. DISCUSSION

The present study aimed to investigate the presence of borax in meatballs sold within Market X, Surabaya, Indonesia, through a combination of qualitative organoleptic assessments and laboratory-based detection methods. The findings revealed that out of twelve samples tested, one sample (approximately 8%) was positive for borax detection based on the curcumin paper test. This result indicates the ongoing use of borax as an additive in street-vended meatballs, despite its prohibition in food products by local regulations and international standards. The detection of borax in this context raises significant concerns regarding food safety, public health, and regulatory enforcement, which merit thorough interpretation and comparison with existing literature.

The positive identification of borax in one of the meatball samples corroborates previous reports indicating that borax remains clandestinely utilized by some vendors to enhance shelf life and improve physical qualities such as texture and color [29], [30]. The physical attributes associated with borax-contaminated meatballs namely a chewy texture, pale gray coloration, tart taste, and fishy smell align with earlier findings demonstrating that borax imparts characteristic textural and sensory modifications to processed meat products [31], [32]. These alterations are primarily due to borax's property as a strengthening and thickening agent, which enhances the meat's cohesiveness and appearance, thereby making it more attractive to consumers unfamiliar with adulteration practices. Moreover, the correlation between the physical qualities and borax presence underscores the importance of sensory evaluation as an initial screening tool, although this method alone cannot reliably quantify levels of contamination. The quantitative laboratory analysis, employing titration or spectrophotometric techniques, is necessary for precise measurement of borax levels, as suggested by prior studies [33], [34]. The current study's qualitative approach, while effective for preliminary detection, underscores the need for more sophisticated analytical methods to accurately determine contamination levels and assess health risks.

When juxtaposed with recent research conducted within Indonesia and other Southeast Asian countries, these findings show both similarities and divergences in borax prevalence. For instance, Sari et al. [35] identified borax in 10% of meatball samples in Bandung, Indonesia, using more sensitive spectrophotometric detection, which is comparable to the 8% positivity rate observed in this study. Their results reinforce the notion that borax adulteration remains a pervasive issue in local markets, often perpetrated due to economic incentives and lack of strict enforcement. In contrast, Lin et al. [36] in a neighboring country reported a considerably higher prevalence, at approximately 25%, in processed meat products, highlighting regional disparities possibly attributable to differences in regulatory oversight, vendor awareness, or consumer demand. Additionally, a study by Rahman et al. [37] emphasized that unscrupulous vendors frequently employed borax to prolong freshness and enhance appearance but failed to consider the potential health implications for consumers. These comparative analyses underscore the global nature of borax adulteration and the persistent challenges in controlling its use.

Despite the valuable insights rendered by this research, certain limitations must be acknowledged. Firstly, the sample size was limited to twelve meatball specimens, which, although representative within Market X, may not reflect the broader scope of street-vended meatballs across the region or country. Increasing the sample size and geographic diversity would enhance the representativeness and robustness of the findings. Secondly, the qualitative nature of the borax detection method employed curcumin paper testing although practical and cost-effective, is subject to certain constraints in sensitivity and specificity. Variations in test performance, potential false positives or negatives, and the inability to quantify borax content limit the conclusiveness of the results [38]. The method's reliance on visual color change, which can be influenced by external factors such as pH and sample preparation, necessitates supplementary quantitative analysis for definitive evidence. Furthermore, the study did not explore the underlying factors prompting vendors to adulterate meatballs with borax. Factors such as economic pressure, lack of awareness, or insufficient regulatory enforcement could contribute to continued usage, but these issues were beyond the scope of the current research. Also, consumer health risk assessment regarding borax levels was not conducted, due to the absence of precise quantitative data.

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Vol. 3 No.6, pp. 321-326, December 2023

The detection of borax in street-vended meatballs carries significant public health implications. Borax, recognized as a food additive harmful to human health, can cause a range of adverse effects, including gastrointestinal disturbances, renal damage, and neurological symptoms, especially with chronic exposure [39], [40]. Therefore, even a single contaminated sample emphasizes the urgent need for improved regulatory oversight and vendor education to diminish the prevalence of this dangerous practice. From a policy perspective, the study underscores the importance of routine surveillance and the implementation of more sensitive, quantitative testing protocols, such as spectrophotometry or ion chromatography, to accurately monitor and regulate borax use in food products [41], [42]. Public health authorities should strengthen enforcement policies, educate vendors on the dangers of borax adulteration, and promote the use of safe, approved additives or natural preservatives that do not compromise consumer health. For consumers, this research highlights the importance of awareness regarding food adulteration practices and encourages the adoption of safer purchasing habits, such as selecting vendors with verified hygiene standards. The study also advocates for the development of community-based education programs emphasizing food safety and the risks associated with adulterants like borax.

To build upon these findings, future investigations should incorporate larger sample sizes and diverse geographic locations to better understand the scope of borax adulteration nationwide. The adoption of advanced analytical techniques with high sensitivity and specificity, such as inductively coupled plasma mass spectrometry (ICP-MS), is recommended to quantitatively measure borax levels and assess potential health risks more accurately. Additionally, longitudinal studies could evaluate trends over time, examining whether regulatory interventions and awareness campaigns effectively reduce borax use. Investigating the socioeconomic factors motivating vendors to add borax can inform targeted policy measures. Finally, research into natural, safe alternatives for meat preservation and appearance enhancement could offer sustainable solutions to replace borax in street food production.

V. CONCLUSION

The primary aim of this study was to assess the presence of borax in meatballs sold in Market X, Surabaya, Indonesia, and to examine the relationship between borax content and the organoleptic qualities of the meatballs. The findings revealed that approximately 8% of the meatball samples tested positive for borax, exhibiting characteristic physical attributes such as a chewy texture, pale gray coloration, a tart taste, and a fishy odor. These physical characteristics correlated significantly with the presence of borax, as evidenced by a p-value of 0.032, indicating a meaningful association between borax contamination and changes in sensory qualities. The qualitative laboratory analyses employed the curcumin paper method and found that 8% of the samples tested positive, which underscores the continued usage of borax as an additive in meatball preparations within the locality. The study also observed that the majority of samples possessed acceptable organoleptic properties, with most evaluated as 'sufficient' or 'good' in terms of texture, color, taste, and smell, suggesting some level of contamination persists, but not universally. Notably, just one sample was conclusively identified as containing borax, highlighting the importance of stringent monitoring and regulatory control to prevent health risks associated with borax ingestion. This study emphasizes the necessity for heightened awareness among food vendors and consumers regarding the potential dangers of borax adulteration, particularly given its common use to extend shelf life and improve meatball appearance and texture deceptively. Future research endeavors should aim to utilize more precise quantitative techniques, such as spectrophotometry or titrimetric analysis, to accurately measure borax concentrations, thereby providing more comprehensive data on contamination levels. Additionally, exploring safer and more culturally acceptable substitutes like carrageenan, seaweed derivatives, or natural preservatives could aid in reducing reliance on borax in meatball manufacturing. Further studies could also investigate the prevalence of borax in other street foods and processed meat products across different regions, thereby broadening understanding of its distribution and public health implications. Education campaigns targeting vendors and consumers are recommended to promote awareness and reduce the consumption of borax-adulterated foods. Establishing effective regulatory frameworks and routine inspections would be crucial in safeguarding public health and ensuring food safety compliance. Overall, this investigation underscores the importance of continuous surveillance, public education, and policy reinforcement to mitigate health risks posed by illegal food additives such as borax, safeguarding consumer health and maintaining food integrity in the local food industry.

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DATA AVAILABILITY

No datasets were generated or analyzed during the current study.

AUTHOR CONTRIBUTION

Liza Fajrin Zukrisningtyas conceptualized the study design, conducted the laboratory analyses, and authored the manuscript draft. Narwati was responsible for data collection,

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Vol. 3 No.6, pp. 321-326, December 2023

data analysis, and overall coordination of the research activities. Pratiwi Hermiyanti assisted in the organoleptic assessments and data interpretation. Marlik contributed to the laboratory testing procedures and data validation. Seow Ta Wee provided guidance on the research methodology and critically reviewed the manuscript. All authors participated in the discussion of the results, approval of the final manuscript, and agree to be accountable for all aspects of the work.

DECLARATIONS

ETHICAL APPROVAL

This study was conducted in accordance with ethical standards and approved by the Institutional Review Board (IRB) of Poltekkes Kemenkes Surabaya, Indonesia. Ethical approval was obtained prior to data collection, and informed consent was acquired from all participants involved in the organoleptic assessments. The study adhered to ethical principles to ensure the safety, confidentiality, and well-being of all participants involved in the research.

CONSENT FOR PUBLICATION PARTICIPANTS.

Consent for publication was given by all participants

COMPETING INTERESTS

The authors declare no competing interests.

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