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Health Risks and Nutritional Quality of Noodles Sold in Mumbai Markets: Proximate and Elemental Analysis

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ABSTRACT:

The study investigates the concentration of heavy metals and nutritional composition in noodle and taste maker samples from various markets in Mumbai and nearby districts. A tetramethylammonium hydroxide (TMAH)-assisted alkaline solubilization method was employed for trace element analysis. Elemental analysis was performed using graphite furnace atomic absorption spectroscopy (GFAAS) and flame atomic absorption spectroscopy (FAAS), with optimized instrumental parameters to mitigate matrix interference. The method's accuracy was validated through comparison with a conventional microwave-assisted acid dissolution method, showing no significant difference in results ($p > 0.05$). The concentrations of essential elements; Na, K, Ca, Fe and trace metals; As, Pb, Cr, Cd, Cu, Zn varied across noodle and tastemaker brands. Pb, and Cr were found in significant amounts, with varying potential health risks depending on the brand. Health risk assessment, based on Target Hazard Quotient (THQ), indicated that adult consumers are generally within safe exposure limits, while children face a higher risk due to their lower body weight and higher relative exposure. The Total Target Hazard Quotient (TTHQ) for children was 3.56 times higher than for adults, with certain brands exceeding the safety threshold, particularly for Cr and Pb. Proximate analysis revealed variations in moisture, protein, fat, carbohydrate, and energy content, with fat content and energy levels differing significantly across brands. This study highlights the importance of regular monitoring of heavy metal contamination in food products, particularly for children, and underscores the need for improved regulatory standards to ensure food safety.

Keywords: Noodle, Taste maker, elements, health risk assessment, proximate analysis

Introduction

Instant noodle is a favourite food among people of all ages. It is popular for its delicious taste, ease of preparation, affordable cost, longer shelf life, and versatility [1]. The ingredients for instant noodle manufacture are wheat flour, salt (1.5–2% based on wheat flour), and water. The steps followed in the manufacturing of noodles are; mixing wheat flour with water and salt using a mixer, rolling the dough into the noodle form, cutting the noodles and steaming in the chamber, cooling, chopping, and moulding the strands in the desired shape and size, dehydration of noodles in a fryer using oil and finally packed in polypropylene film [2].

The utilization of contaminated raw materials has been recognized as a significant cause of heavy metal contamination in food. Elements such as Cd, Pb, As, and Cr are toxic even in small amounts. Furthermore, these metals have the potential to accumulate in the body and can lead to irreversible harmful effects on individuals who consume such contaminated food. These effects may include serious health risks such as renal failure, liver damage, neurological impairment, cardiovascular diseases, and even death [3-5]. There is an increasing concern about the quality of noodles in several parts of the world.

Sample preparation is a crucial step for the analysis of food material as it contains more than 90% organic matter. The complexity of the matrix i.e. fats, proteins and carbohydrates pose difficulties in bring the sample in the solution form. Generally, microwave assisted (MWA) wet digestion method using various combinations of mineral acids and oxidising agents such as H_2O_2, perchloric acid etc. are used for destruction of the organic matrix releasing the metals into the solutions [4,6-7] followed by analysis by using spectrometric techniques, preferably, atomic absorption spectrometery (AAS), Inductively coupled plasma atomic emission spectrometry(ICP-AES) and inductively coupled plasma mass spectrometry(ICP-MS) [8-10].

Tetramethylammonium hydroxide (TMAH) is used to dissolve a variety of materials such as biological, environmental, and botanical samples for the determination of elements [11]. The dissolved samples can be easily introduced to instruments such as AAS, ICPOES, or ICP-MS by nebulization or autosampler. TMAH dissolution has several advantages over conventional microwave-assisted acid-based dissolution. It can be done at low temperatures, reduces the risk of analyte loss, and ensures complete dissolution of analytes from various matrices. This dissolution method is considered eco-friendly [12] and time efficient.

Mumbai's fast-paced lifestyle frequently drives residents to rely on quick meals such as instant noodles. Given this widespread consumption, it is crucial to ensure that these products are free from harmful contaminants. This study focuses specifically on analyzing the presence of heavy metals in various noodle brands, assessing their safety for consumption. By examining five commercial Indian brands (A, B, C, D, and E) and one imported brand (F), the research aims to highlight any potential health risks associated with heavy metal contamination in these popular instant foods. The study evaluates the potential human health risks associated with heavy metal exposure through noodle consumption, applying risk assessment methods such as Target Hazard Quotients (THQs) to determine the degree of health risk from such exposure.

Proximate analysis is a fundamental technique used to determine the basic nutritional composition of food products. In the context of instant noodles, this analysis typically measures key components such as moisture content, protein levels, fat content, and carbohydrates. By assessing these parameters, proximate analysis provides valuable insights into the nutritional profile of the noodles, helping consumers make informed dietary choices. Although this study primarily focuses on detecting heavy metals, understanding the proximate composition of the noodles can offer a comprehensive view of their overall nutritional quality. Consequently, proximate analysis was conducted using standard methods outlined by the Association of Official Analytical Chemists (AOAC, 2000) [13].

Materials and Methods

Instruments

All flame atomic absorption spectroscopy (FAAS) measurements were performed using a NovAA-800 spectrometer, while graphite furnace atomic absorption spectroscopy (GFAAS) measurements were conducted with a ZEEnit 650P (Analytik Jena, Germany). For the analysis of specific elements, elemental hollow cathode lamps were used for the following wavelengths: Na λ 589.0, K λ 766.5, Ca λ 422.7, Cr λ 357.9, Cu λ 324.7, Fe λ 248.3, Pb λ 253.3, As λ 193.7, and Zn λ 213.9 (Analytik Jena, Germany). The samples were ground using a MM 200 vibrating mill (Retsch, Germany), equipped with tungsten carbide chambers and balls. A Milli-Q water purification system (MERCK Millipore) was used to ensure the purity of the water used in the analysis.

Materials

Six different brands of noodle and tastemaker material, including five commercial brands manufactured in India (coded A, B, C, D, and E) and one imported brand manufactured in Singapore (coded F) was selected for this study. 10 packets of each brand were purchased from markets across Mumbai, Thane, Navi Mumbai, and the Raigad district.

Chemicals and Reagents

Suprapure nitric acid 65% (Merck, India), Suprapure H_2O_2 (Merck, India), Tetramethylammonium hydroxide (25% aqueous solution) (Sisco Research Laboratories Pvt. Ltd, India) were used for sample dissolution. Standard solutions of elements were prepared from Certipur ICP multi-element standard solution IV (1000 mg mL^{-1}) from Merck, India. All other reagents used were of analytical grade like cesium chloride, boric acid, sodium hydroxide, ethylenediaminetetraacetic acid, copper sulphate, sodium sulphate, sulphuric acid, hydrochloric acid, bromescresol green, methyl red, petroleum ether, n-hexane, and Kjeldahl Selenium Catalyst Tablets. The methodology was validated using CRM Whey powder IAEA-155 and CRM No.10-C, Rice flour unpolished.

All glassware's and falcon tubes and Teflon beakers were kept in 2% concentrated nitric acid for 24h before use. Sample preparation was carried out under Class ten laminar air flow benches in clean room.

Methodology

Sample preparation for trace metal analysis

The noodle and tastemaker materials were ground using an MM-200 vibrating mill (Retsch, Germany), which is equipped with tungsten carbide chambers and balls. The ground samples were then sieved through a mesh size of 60 (particle size < 250 µm) to obtain a homogenized and fine powder.

Microwave-Assisted Digestion

A 0.5 g sample of noodle powder and tastemaker powder was dissolved using a mixture of 3 mL nitric acid (HNO_3), 1 mL hydrogen peroxide (H_2O_2), and 4 mL deionized water, bringing the final volume to 8 mL. The vessels containing the samples were sealed and then subjected to the microwave digestion program, as detailed in Table 1.

After cooling, the digested samples were transferred to a 25.0 mL volumetric flask and diluted to the final volume with deionized water.

Alkaline solubilization with Tetramethylammonium hydroxide (TMAH)

Noodle powder, tastemaker powder, and certified reference materials (CRMs) (0.5g each) was taken in 50 mL Falcon tubes. To each tube, 5 mL of deionized (DI) water and 0.5 mL of 25% tetramethylammonium hydroxide (TMAH) were added. The mixtures were sonicated for 30 minutes, and then the volume was adjusted to 25 mL with DI water. The samples were diluted as needed for trace element analysis using FAAS and GFAAS, following the optimized parameters detailed in Table 2.

Risk Assessment Methodology

The Target Hazard Quotient (THQ) was calculated for each metal using the following equation:

$$THQi = \frac{Mc \times C_f \times IR \times Ef \times ED}{RfD \times BW \times Atn}$$

Where:

THQi= Target Hazard Quotient of individual metal ion, Mc= metal concentration (mg/Kg), Cf= the conversion factor, IR=the intake rate (g/day), RfD = the reference dose (mg/kg/day), BW = body weight (Kg), Ef= exposure frequency (days/year), ED = exposure duration (years). Atn = average exposure time. The RfD for each metal were sourced from established health guidelines [14-16]. These values represent the amount of a contaminant that is considered to be without risk of adverse health effects over a lifetime.

The total THQ (TTHQ) or hazardous index (HI) due to all hazardous elements under the investigation was calculated using the following equation to know the non-carcinogenic health effect associated with noodle consumption [17-19].

$$HI\ or\ TTHQ = \sum_{i=1}^{n} THQi$$

Potentially adverse effects are likely to be observed if HI > 1, while if HI ≤ 1, it is considered that adverse health effects are not likely [4, 15].

Proximate analysis

Standard methods from the Association of Official Analytical Chemists (AOAC 2000) [13] were employed for the analysis which involves determining key components of the samples i.e. moisture, ash, crude fat (ether extract), crude protein, and crude fiber. Protein content was assessed using the micro-Kjeldahl method, while fat was determined through ether extraction using the Soxhlet apparatus. Ash content was measured by ashing the sample in a furnace. The Weende method was used for estimation of crude fibres. Carbohydrate content, which includes sugars and starches, was calculated by difference using the formula:

$$\%\ \text{Carbohydrate} = 100 - (\%\text{Moisture} + \%\text{Fat} + \%\text{Ash} + \%\text{Crude fibre} + \%\text{Crude protein})$$

The energy was calculated using formula

$$\text{Energy} = 4 \times \text{protein} + 9 \times \text{fat} + 4 \times \text{carbohydrate}$$

Results and discussion

Sample preparation for trace element analysis

Alkaline solubilization of noodles and tastemaker

TMAH facilitates the breakdown of food matrices by hydrolyzing proteins, saponifying fats, and disrupting cellular structures. This process converts complex organic compounds into simpler, more soluble forms [11, 20].

Optimization of parameters for TMAH solubilisation

The amount of TMAH used in the preparation of noodle and tastemaker samples is crucial. It must be adequate to effectively solubilize the complex matrix of the samples. In the optimization process, 0.5 g of each noodle and tastemaker sample was weighed and initially wetted with 5 mL of deionized water. TMAH was then added to the samples at varying concentrations of 0.1% to 1%. The samples were subjected to sonication for 5 to 30 minutes, with the temperature varied from 27°C to 90°C in 10°C increments.

It was observed that a 0.5% V/V concentration of TMAH is sufficient for the solubilisation of the matrix, with analyte recovery ranging between 95-99%, as depicted in Figure 1. Sonication facilitates faster solubilisation and positively affects the recovery of elements, with an optimal sonication time determined to be 30 minutes. On the other hand, increased temperature negatively impacts the percentage recovery of elements due to matrix swelling; specifically, temperatures above 40ºC up to 90ºC on a water bath were found to be detrimental. Therefore, the optimized conditions for alkaline solubilisation of noodles and test samples are a 0.5% V/V TMAH concentration, 30 minutes of sonication, and at 27°C.

Optimization of Instrumental Parameters for GFAAS Analysis

A potential problem with the alkaline solubilised sample analysis in GFAAS is the interference from the matrix due to incomplete pyrolysis at recommended temperature program for aqueous matrix. The build-up of matrix in the graphite tube may also interfere with the background correction and even hinder the analyte determination because of the partial attenuation of the light beam. Therefore, the optimization of pyrolysis temperature, atomization temperature, and suitable chemical modifier is necessary to eliminate any matrix effect and ensure the accuracy and precision of the method.

Pyrolysis temperature and atomization temperature were optimized for noodle and tastemaker matrix in TMAH. These optimized pyrolysis and atomization temperatures (Table 2) were used for the analysis of elements in noodles, tastemaker, and CRMs. However, loss of signal was observed for As, Pb, and Zn, hence, 5µL of 0.1% $Pd(NO_3)_2$ was used as a modifier for these elements.

Optimization of process parameters for FAAS analysis

As per the literature, Na, K, Ca, and Fe are the major elements present in the samples. The samples were suitably diluted~20 to 200 times depending upon the calibration range of FAAS for these elements. TMAH solubilised samples were suitable for introduction into air acetylene flame [21-22]. The flow rate of the nebulizer was maintained at 5mL m^{-1}. The flow rate of air and acetylene was optimized to get maximum absorbance. 0.1% CsCl was added to the sample solution as an ionization buffer for the determination of Na and K.

$La(NO_3)_3$ is usually used as a releasing agent for Ca, however, due to the alkaline nature of TMAH, it got precipitated as $La(OH)_3$. Therefore, for Ca, 0.1M EDTA was used as a protecting agent. The standard addition calibration was applied to observe the matrix interference and compared with the aqueous calibration prepared in 0.1% HNO_3. It was observed that the slope of the standard addition calibration curve was better compared to the aqueous calibration curve. This may be due to the organic nature of TMAH used for preparing the samples which provides a reducing environment in the flame and eases atom formation.

Performance characteristics and validation of FAAS and GFAAS for TMAH assisted alkaline solubilization

The LOD and LOQ were calculated for each element based on 10 replicates of process blank measurement. The LOD and LOQ of each element in noodle and taste maker are presented in (Table 3). The accuracy of the method was established by comparing the mean of measurements (n=6) obtained from the TMAH alkaline solubilization method with the complete microwave-assisted acid dissolution method, the reference method. The t-values obtained were in the range of 0.03 to 1.92 against critical value t_{10} = 2.23 (P = 0.05) suggesting no significant difference in the values obtained from both method (Table 4).

Accuracy was further established by applying the developed method to Certified Reference Materials, IAEA-155 Whey powder and NIES No.10c Rice Flour. The results show recovery in the range of 88-113%. The results are depicted in Table 5a and Table 5b respectively.

The optimized proposed method was applied for determination of ten elements in 60 noodles samples of six different brands collected from various parts of Mumbai and nearby districts. The elemental concentration in 6 different brands is shown in Figure 2.

Comparison of Elemental analysis

The range of the metals concentrations in the noodle samples were (in mg/100g) Na 833-1473, K 200-361, Ca 51-288 (Figure 2 (i)), (in µg/g) Cu 2.45-13.56, , Zn 9.2-35.6, for Fe 6.3-90.7 (Figure 2 (ii)), (in µg/g) for As <0.007-0.053, Cr 0.05-0.38, Cd <0.008- 0.032 and Pb <0.016-2.22 (Figure 2 (iii)). The results of the metals concentrations in the tastemaker samples were (in mg/gm) Na 43-67, K 22-42, Ca 0.05-0.39 (Figure 2 (iv)), (in µg/g) Cu 2.16-21.97, Zn 5.5 - 45.4, Fe 4.0- 455 (Figure 2 (v)), (in µg/g) for As < 0.01-0.52, Cr <0.24-0.73, Cd <0.005, Pb <0.19-3.26 (Figure 2 (vi)).The descriptive statistic for noodle and taste maker is illustrated in Table 6a and Table 6b respectively.

Correlation between the elemental concentration in noodles and taste maker

The correlation coefficient of elemental concentrations in the noodle matrix can provide valuable insights into various aspects of food quality, safety, and composition. It can help identify contamination patterns and sources of contamination. A high correlation coefficient between heavy metals may indicate environmental contamination or shared sources of contamination, while a low or no correlation suggests localized or non-systematic contamination during manufacturing or packaging.

The correlation is better visualised through the heat map presentation of analyzed elements viz. Na, K, Ca, Cu, As, Cr, Cd, Zn, Fe, and Pb in noodle (Figure 3a) and for tastemaker (Figure 3b). The correlation coefficients range from -1 to 1, where values close to 1 indicate strong positive correlations, values around 0 indicate no correlation, and values close to -1 indicate strong negative correlations [23].

It was observed that a moderate to strong positive correlation between As and Fe was present in 4 out of the 6 brands of noodles. This finding supports the assertions made by geologists and agricultural scientists, that the presence of iron can influence the mobility and availability of arsenic in the environment [24] and subsequent entry into the food chain [25]. A moderate positive correlation was observed in Ca and Zn in all brands. The presence of Ca and Zn in food products like noodles can contribute to their nutritional value, making understanding their correlation important for dietary recommendations. Other correlations are very specific to the particular brand and cannot be generalised.

The correlation coefficient data for tastemaker was computed but there was no pattern of correlation of elements was observed. (Figure 3b)

Risk Assessment

The Target Hazard Quotient (THQi) for individual metals (As, Pb, Cr, Cd, Fe, Zn, and Cu) was calculated for both noodle and tastemaker (TM) samples for adult and child consumers. The results are depicted in Table 7. The rank order of heavy metals in noodles, based on THQi, for both adults and children, was Cr > Pb > As > Cu > Zn > Fe > Cd, while in TM samples, Cr, Fe, and As were found to be the most significant contributors compared to the other metals. The combined Total Target Hazard Quotient (TTHQ) for noodles and TM samples in adult consumers varied in the range of 0.149 to 0.376 across different brands. Brand B had the highest TTHQ at 0.376, while Brand E had the lowest at 0.149 for adult consumers. Meanwhile, the combined TTHQ for noodles and TM samples in children was approximately 3.56 times higher than in adults, varying in the range of 0.523 to 1.311. Brand B had the highest TTHQ at 1.311, while Brand E had the lowest at 0.523. This higher TTHQ in children is due to their lower body weight (BW), which increases their relative exposure to the metals.

The data presented in Table 7 indicates that for adults, the exposure to the metals present in these samples is within safe limits. However, there is still variability between brands. Brand B is showing higher cumulative toxicity, which warrants attention for potential long-term exposure.

The combined TTHQ as shown in Table 8, for children was significantly higher i.e. 3.56 times higher than the TTHQ for adults. In this case, Brand B exceeds the TTHQ threshold of 1 with a value of 1.311, which suggests a potential health risk for children who consume this product, as their exposure exceeds the safety threshold. This heightened risk for children is attributed to their lower body weight (BW). Since TTHQ is a function of body weight, children with lower body weight, will experience higher relative exposure to the same concentration of metals compared to adults. The fact that children face higher relative exposure to heavy metals compared to adults underscores the increased vulnerability of younger populations to environmental or dietary contaminants. Heavy metals such as Pb, As, and Cr are known to pose significant health risks to children, affecting their neurodevelopment, growth, and immune function. Exceeding a TTHQ of 1 suggests that the cumulative exposure to these metals may be unsafe and could lead to chronic health effects, especially for children who are still developing.

Proximate analysis

The proximate analysis of the nutrients namely, moisture, ash content, protein, fat and carbohydrate, in noodle of brands under investigation are shown in Figure 4. The moisture content of all samples ranges from 4.99% to 7.34%, which is relatively low. This is a good thing for shelf stability since lower moisture content generally means a longer shelf life [26]. Ash content varies from 1.55% to 5.45%. Ash content indicates the mineral content in the noodles, and higher ash content may suggest higher levels of minerals or impurities. In most samples, the ash content is within the normal range for noodles, suggesting good quality. Protein content ranges from 9.08% to 10.39% across the samples. Protein is an important nutritional component, contributing to the noodles' texture and nutritional value. Protein levels in all samples appear consistent, with no significant deviations from typical noodle formulations. Fat content varies from 12.55% to 22.73%, with some significant differences among the samples. Fat content plays a role in the texture, flavor, and energy density of the noodles. Samples with higher fat content (e.g., D. E, F) likely have a richer texture and higher calorie density. This variation might reflect different formulations or processing techniques (e.g., oil addition during frying). Carbohydrate content ranges from 58.1% to 68.3%, which is typical for pasta and noodles. Carbohydrates provide the bulk of the energy in noodle products. The carbohydrate levels are all in line with expectations for traditional noodle formulations, though there is some variation across the samples. The energy content ranges from 413 Kcal to 484 Kcal. This correlates closely with the fat and carbohydrate content, as both contribute significantly to the calorie count. Energy levels seem to be fairly consistent with the labelled values.

The proximate analysis indicates that the noodles are of good quality, with nutritional content close to expectations. The variations between the found and labelled values are relatively small and might be attributed to natural variations in ingredients or slight differences in the formulation. The differences in fat and energy levels across the samples suggest diversity in formulation, likely due to varying levels of oil or fat content, which could affect both texture and calorie content.

Conclusion

This study presents a comprehensive analysis of the trace element contamination and nutritional quality of various branded noodles available in Mumbai and its surrounding districts. The TMAH-assisted alkaline solubilization method provides aids in fast, green and reliable analysis of major and trace elements in noodle as well as in tastemaker. The elemental concentrations of metals such as As, Pb, and Cr varied significantly across different noodle and tastemaker brands, with potential health risks identified, particularly for children.

Health risk assessment, based on the Target Hazard Quotient (THQ), revealed that the adult consumers generally remain within safe exposure limits, while the exposure for children was notably higher, with certain brands exceeding the safety threshold for heavy metals like As Cr, and Pb. The Total Target Hazard Quotient (TTHQ) for children was significantly higher than for adults, emphasizing the increased vulnerability of younger populations to dietary contaminants.

The proximate analysis of the samples revealed variability in moisture, fat, protein, carbohydrate, and energy content, which reflects differences in processing methods and formulations. Some brands exhibited higher fat and energy levels, potentially influencing the nutritional value and overall quality of the products.

Overall, the findings highlight the need for continued monitoring of heavy metal contamination in processed foods, especially those consumed by children, and underscore the importance of regulatory measures to ensure food safety. The optimized TMAH-assisted method can serve as a reliable tool for routine analysis of food products, aiding in the assessment of both nutritional content and toxic element exposure, ultimately contributing to public health protection.

Declarations

The authors have no competing interest to declare.

References

1. N. Gulia, V. Dhaka, B.S. Khatkar, Instant Noodles: Processing, Quality and Nutritional Aspects. *Critical Reviews in Food Science and Nutrition* 54 no.10:1386–1399, (2014). https://doi.org/10.1080/10408398.2011.638227

2. I.S. Arvanitoyannis, A. Traikou, A comprehensive review of the implementation of hazard analysis critical control point (HACCP) to the production of flour and flour-based products. Critical Reviews in Food Science and Nutrition 45 no.5:327-70,(2005). https://doi.org/10.1080/10408390590967694

3. I.A. Charles, A.J. Ogbolosingh, I.U. Afia, Health risk assessment of instant noodles commonly consumed in Port Harcourt, Nigeria. Environmental Science and Pollution Research 25:2580–2587, (2018). https://doi.org/10.1007/s11356-017-0583-0

4. R.S. Thakur, A. Kumar, O. Lugun, N.G. Ansari, P. Satgur, T. Das, N. Gupta, D.K. Patel, Evaluation of heavy metal contaminants in prepared noodles: source allocation and health risk assessment. Environmental Science and Pollution Research 30: 25181–25192, (2023). https://doi.org/10.1007/s11356-021-17491-6

5. H. Abbasi, H. Shah, M. Mohiuddin, M. Elshikh, Z. Hussain, J. Alkahtani, W. Ullah, M. Alwahibi, A. Abbasi, Quantification of heavy metals and health risk assessment in processed fruits. Arabian Journal of Chemistry 13, no.12:8965-8978, (2020). https://doi.org/10.1016/j.arabjc.2020.10.020

6. L. Rastogi, A. Durga Prasad, K. Dash, S.J. Kumar, Development of a certified reference material for lead in noodles powder. Accreditation and Quality Assurance. 24:173–180. (2019). https ://doi.org/10.1007/s0076 9-018-01367 -3

7. S. Police, S. Maity, D.K. Chaudhary, C.K. Dusane, S.K. Sahu, V.A. Kumar, Estimation of trace and toxic metals in marine biota and associated health risk assessment in Thane Creek, Mumbai, India. Environmental Chemistry and Ecotoxicology 3:234–240, (2021). http://dx.doi.org/10.1016/j.enceco.2021.07.002

8. I. Muhammad, Analysis and Human Health Risk from Selected Heavy Metals in Common Instant Noodles. Biological Trace Element Research 198 no.1:339-343, (2020). https://doi.org /10.1007/s12011-020-02062-6

9. F.I.S. Kakoma, O.R. Awofolu, Contamination and Health Risk Assessment Of Instant Noodles By Heavy Metals From Commercial Outlets In Windhoek, Namibia. African Jounal of Food, Agriculture, Nutrition and Development 21 no.7: 18245-18260, (2021) https://doi.org/10.18697/ajfand.102.19700

10. D. Katyal, D. Chen, H. Kuo Analysis of lead, arsenic, and cadmium concentrations in instant noodles within the Canadian market. BCIT Environmental Public Health Journal 1-13, (2020). https://doi.org/10.47339/ephj.2020.167

11. U.M. Cerqueira, J.P. Alves, W.N. Santos, B. da Silva Pita, C. Novaes, S. Araújo, M. Bezerra, Recent applications of tetramethylammonium hydroxide (TMAH) in the sample preparation for elemental analysis by spectroanalytical techniques. Advances in Sample Preparation, 9:100104, (2024). https://doi.org/10.1016/j.sampre.2024.100104.

12. M.M. Melo, F.N. Ferreira, A.S. Luna, M.A. Langone, J.S. de Gois, Optimized Eco-friendly Sample Preparation Methods for Determining Major and Minor Elements in Cheeses by ICP OES. Food Analytical Methods 28:1-9, (2024). https://doi.org/10.1007/s12161-024-02648-z

13. AOAC, Official methods of Analysis, Association of official Analytical Chemistry, 15 th Edition. (2000).

14. United States Environmental Protection Agency, USEPA Electrokinetic and Phytoremediation in Situ Treatment of Metal-Contaminated Soil. (2000)

15. B. Tajdar-Oranj, N. Shariatifar, M. Alimohammadi, L. Peivasteh-Roudsari, G.J. Khaniki, Y. Fakhri, A. Mousavi Khaneghah, The concentration of heavy metals in noodle samples from Iran's market: probabilistic health risk assessment. Environmental Science and Pollution Research 25:30928-37, (2018). https://doi.org/10.1007/s11356-018-3030-y

16. C. Wong, S.M. Roberts, I.N. Saab, Review of regulatory reference values and background levels for heavy metals in the human diet. Regulatory Toxicology and Pharmacology 1 no.130:105122, (2022). https://doi.org/10.1016/j.yrtph.2022.105122

17. US Environmental Protection Agency (1992) Guidelines for exposure assessment-Risk Assess Forum. 57:22888–22938. EPA/600/Z-92/001

18. US Environmental Protection Agency (1996) Proposed guidelines for carcinogen risk assessment. Fed Regist 61no79:17960–18011

19. US Environmental Protection Agency (2011) Exposure factors handbook. EPA/600/R-:1–1466. EPA/600/R-090/052F

20. F.M. Adebiyi, R.O. Yoade, Thermodynamic study of the removal of heavy metal ions from heavy oils using tetramethyl ammonium hydroxide pentahydrate ionic liquid. Petroleum Research 7, no.4: 545-550, (2022). https://doi.org/10.1016/j.ptlrs.2021.12.010

21. J.P. Alves, U.M. da Mata Cerqueira, C.G. Novaes, W.N. Dos Santos, S.A. Araújo, M.A. Bezerra, Multivariate optimization of a goat meat alkaline solubilization procedure using tetramethylammonium hydroxide for metals determination using FAAS. Food Chemistry 15 no.362:130176, (2021). https://doi.org/10.1016/j.foodchem.2021.130176

22. D.C. da Silva, C.H. Chemim, L.Y. Togawa, F. Piechotcoski, E.R. da Rocha Watanabe, P.D. Leite, E. Sidinei, Determination of Zn and Mg in Milk Powder Samples Using Conventional and Alternative Sample Preparations and FAAS. Journal of Food Science and Engineering 9:171-173, (2019). doi: 10.17265/2159-5828/2019.05.002

23. A. Kumar, A. Kumar, S.K. Jha, Human health risk assessment of heavy metals in major carp (Labeo rohita) of Mahananda river in Northern India. Emergent Life Sciences Research 6:34-49, (2020). https://doi.org/10.31783/elsr.2020.613449

24. S. Park, S.H. Kim, H. Chung, J. An, K. Nam, Effect of organic substrate and Fe oxides transformation on the mobility of arsenic by biotic reductive dissolution under repetitive redox conditions. Chemosphere 1 no.305: 135431(2022). https://doi.org/10.1016/j.chemosphere.2022.135431

25. B. Arslan, M.B. Djamgoz, E. Akün, Arsenic: a review on exposure pathways, accumulation, mobility and transmission into the human food chain. Reviews of Environmental Contamination and Toxicology 243:27-51, (2017). DOI 10.1007/398_2016_18

26. S. Kavitha, R. Parimalavalli, Effect of Processing Methods on Proximate Composition of Cereal and Legume flours. J. Hum Nutr Food Sci 2(4): 1051, (2014).

Figure Captions

Fig. 1 Recovery of elements in percentage with varying concentration of TMAH

Fig. 2 Concentration of elements in Noodle (i). Na, K, and Ca in mg $100g^{-1}$; (ii). Fe, Zn, Cu in µg g^{-1}; (iii). As, Cr, Pb and Cd in µg g^{-1} and in Taste maker (iv). Na, K, and Ca in mg g^{-1}; (v). Fe, Zn, Cu in µg g^{-1}; (vi). As, Cr, Pb and Cd in µg g^{-1}

Fig. 3a Heat map representing Pearson's correlation analysis between elemental concentrations across various noodle brands

Fig.3b Heat map representing Pearson's correlation analysis between elemental concentrations across various brands of tastemakers

Fig. 4 Proximate composition (% w/w) of moisture, ash, protein, fat, and carbohydrate along with energy values (observed and labelled) in noodles

Fig. 5 Graphical presentation

Authors contribution

A: Sample collection, Methodology, Formal analysis; B: Conceptualization, Supervision for elemental analysis, Data curation, original draft preparation; C: Sample collection, Elemental analysis by AAS; D: Proximate analysis; E: Formal analysis and Supervision for proximate analysis; F: Supervision, Review and Editing.

Health Risks and Nutritional Quality of Noodles Sold in Mumbai Markets: Proximate and Elemental Analysis

FIGURES

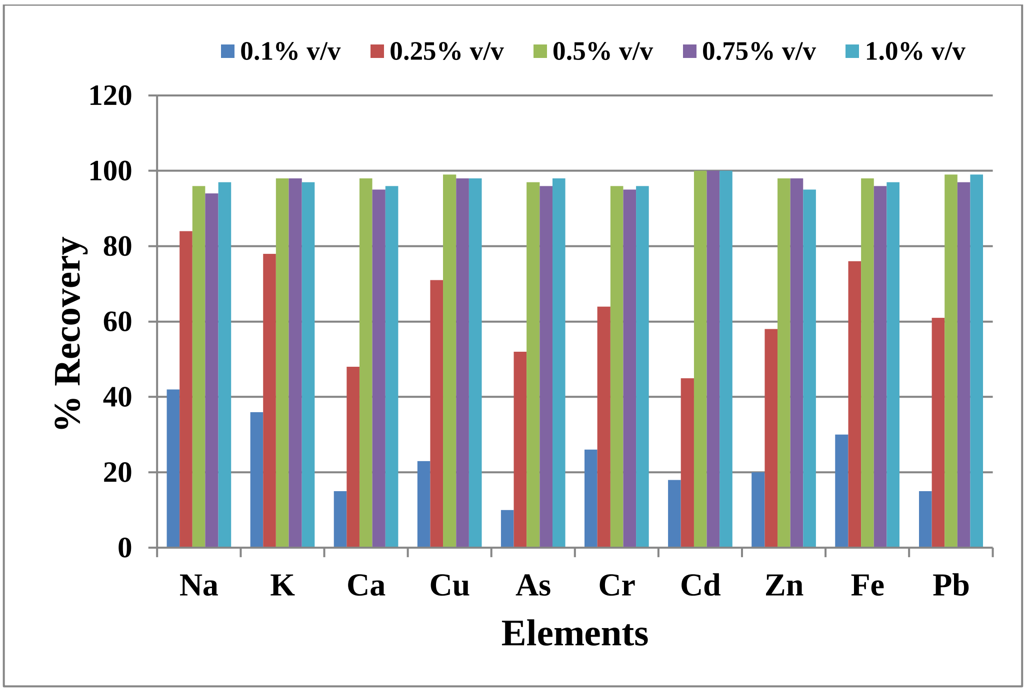

Fig. 1 Recovery of elements in percentage with varying concentration of TMAH

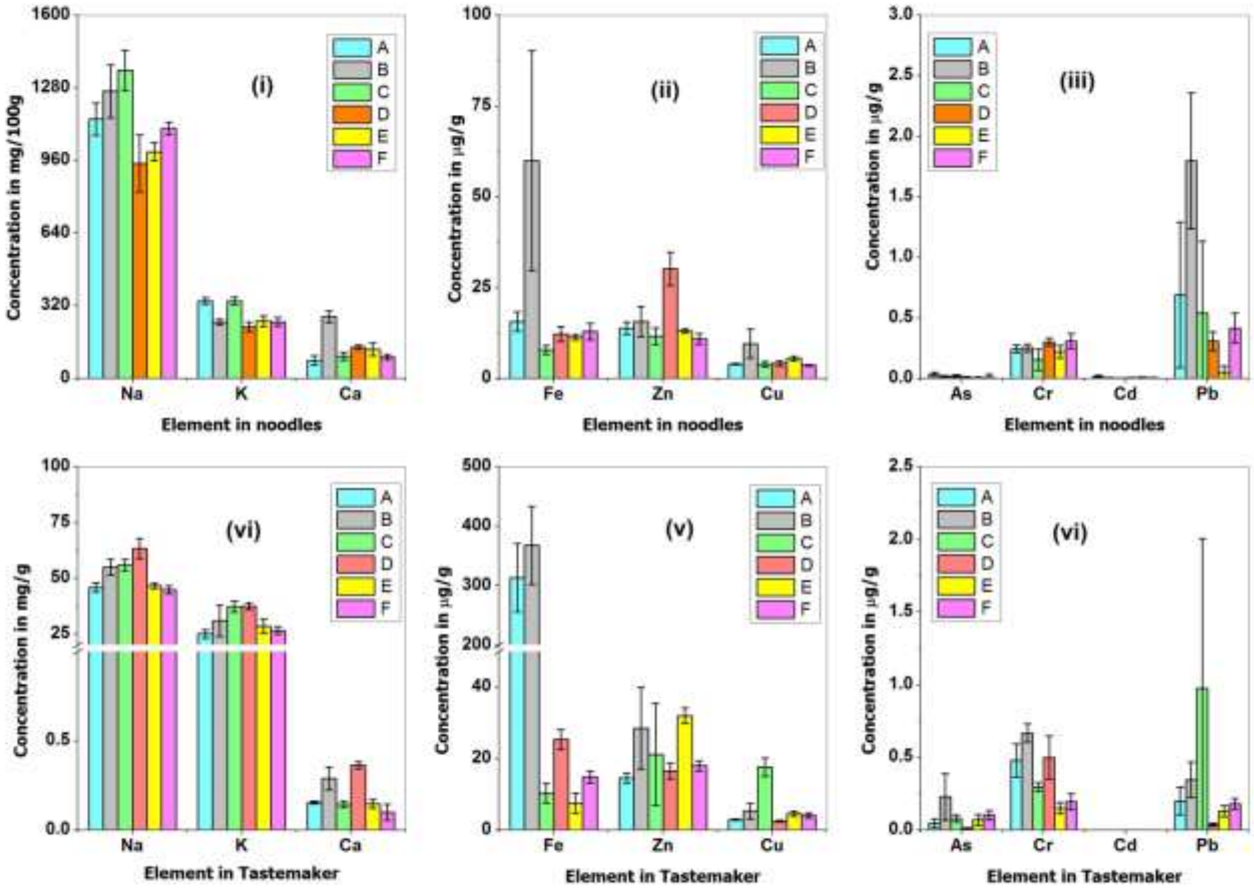

Fig. 2 Concentration of elements in Noodle (i). Na, K, and Ca in mg $100g^{-1}$; (ii). Fe, Zn, Cu in µg g^{-1}; (iii). As, Cr, Pb and Cd in µg g^{-1} and in Taste maker (iv). Na, K, and Ca in mg g^{-1}; (v). Fe, Zn, Cu in µg g^{-1}; (vi). As, Cr, Pb and Cd in µg g^{-1}

BRAND A

	Na	*K*	*Ca*	*Cu*	*As*	*Cr*	*Cd*	*Zn*	*Fe*	*Pb*
Na	1.0									
K	0.8	1.0								
Ca	-0.6	-0.8	1.0							
Cu	-0.1	0.2	-0.1	1.0						
As	0.3	0.5	-0.8	0.3	1.0					
Cr	0.2	0.4	-0.8	-0.2	0.7	1.0				
Cd	0.9	0.7	-0.6	0.0	0.6	0.3	1.0			
Zn	-0.5	-0.3	0.5	0.1	-0.7	-0.5	-0.8	1.0		
Fe	0.1	0.2	-0.6	0.1	1.0	0.8	0.5	-0.8	1.0	
Pb	0.7	0.6	-0.5	0.4	0.5	0.1	0.8	-0.6	0.4	1.0

BRAND B

	Na	*K*	*Ca*	*Cu*	*As*	*Cr*	*Cd*	*Zn*	*Fe*	*Pb*
Na	1.0									
K	0.3	1.0								
Ca	-0.2	0.5	1.0							
Cu	0.0	-0.9	-0.5	1.0						
As	-0.2	0.6	0.9	-0.4	1.0					
Cr	0.1	0.1	-0.6	-0.3	-0.4	1.0				
Cd	-0.4	0.0	0.2	-0.2	0.4	0.5	1.0			
Zn	0.1	0.0	0.6	0.2	0.6	-0.6	0.3	1.0		
Fe	0.7	-0.3	-0.5	0.7	-0.5	-0.1	-0.5	0.1	1.0	
Pb	-0.1	-0.6	-0.5	0.7	-0.1	0.2	0.3	0.1	0.5	1.0

BRAND C

	Na	*K*	*Ca*	*Cu*	*As*	*Cr*	*Cd*	*Zn*	*Fe*	*Pb*
Na	1.0									
K	0.5	1.0								
Ca	0.6	0.1	1.0							
Cu	0.6	0.3	0.9	1.0						
As	0.8	0.7	0.1	0.0	1.0					
Cr	0.4	-0.2	0.9	0.7	0.0	1.0				
Cd	-0.6	-0.1	-0.9	-0.7	-0.3	-0.9	1.0			
Zn	0.7	0.5	0.9	0.8	0.4	0.7	-0.7	1.0		
Fe	0.6	0.9	0.0	0.3	0.7	-0.3	0.0	0.4	1.0	
Pb	0.6	0.4	-0.3	-0.1	0.6	-0.3	0.0	-0.1	0.7	1.0

BRAND D

	Na	*K*	*Ca*	*Cu*	*As*	*Cr*	*Cd*	*Zn*	*Fe*	*Pb*
Na	1.0									
K	0.2	1.0								
Ca	0.8	-0.4	1.0							
Cu	-0.1	-0.7	0.3	1.0						
As	0.4	0.6	0.0	0.1	1.0					
Cr	0.7	0.7	0.2	-0.3	0.8	1.0				
Cd	0.1	0.4	-0.1	0.2	0.9	0.6	1.0			
Zn	0.8	-0.2	0.7	0.2	0.2	0.4	0.1	1.0		
Fe	-0.1	0.6	-0.6	-0.2	0.6	0.5	0.8	0.0	1.0	
Pb	-0.3	-0.9	0.2	0.6	-0.6	-0.9	-0.6	0.1	-0.6	1.0

BRAND E

	Na	*K*	*Ca*	*Cu*	*As*	*Cr*	*Cd*	*Zn*	*Fe*	*Pb*
Na	1.0									
K	0.3	1.0								
Ca	-0.3	-0.3	1.0							
Cu	-0.2	-0.2	-0.4	1.0						
As	0.7	0.7	-0.1	-0.6	1.0					
Cr	-0.9	-0.3	0.2	0.6	-0.8	1.0				
Cd	0.1	0.5	-0.1	0.0	0.1	0.2	1.0			
Zn	-0.2	0.3	0.4	0.1	0.0	0.4	0.9	1.0		
Fe	0.4	-0.5	0.4	-0.6	0.2	-0.6	-0.4	-0.3	1.0	
Pb	-0.6	0.0	-0.1	-0.3	-0.2	0.2	-0.5	-0.5	-0.2	1.0

BRAND F

	Na	*K*	*Ca*	*Cu*	*As*	*Cr*	*Cd*	*Zn*	*Fe*	*Pb*
Na	1.0									
K	0.1	1.0								
Ca	0.1	-0.2	1.0							
Cu	-0.6	-0.2	-0.6	1.0						
As	-0.1	-0.6	0.5	-0.5	1.0					
Cr	0.4	0.9	0.2	-0.4	-0.4	1.0				
Cd	-0.1	0.6	-0.5	0.2	-0.3	0.4	1.0			
Zn	-0.1	-0.7	0.5	0.0	0.3	-0.5	-0.9	1.0		
Fe	0.1	-0.6	0.1	-0.3	0.8	-0.6	0.0	0.1	1.0	
Pb	0.1	-0.1	-0.9	0.5	-0.5	-0.4	0.0	-0.1	-0.1	1.0

Fig. 3a Heat map representing Pearson's correlation analysis between elemental concentrations across various noodle brands

BRAND A

	Na	*K*	*Ca*	*Fe*	*Cu*	*As*	*Cr*	*Zn*	*Pb*
Na	1.0								
K	0.8	1.0							
Ca	-0.4	-0.7	1.0						
Fe	0.8	0.5	0.0	1.0					
Cu	0.3	0.4	-0.3	0.0	1.0				
As	-0.5	-0.1	0.1	-0.6	0.2	1.0			
Cr	-0.4	-0.2	0.1	-0.4	0.3	0.8	1.0		
Zn	0.1	0.2	-0.7	-0.1	-0.4	-0.2	-0.2	1.0	
Pb	-1.0	-0.8	0.3	-0.9	-0.3	0.5	0.3	0.0	1.0

BRAND B

	Na	*K*	*Ca*	*Fe*	*Cu*	*As*	*Cr*	*Zn*	*Pb*
Na	1.0								
K	0.1	1.0							
Ca	-0.7	-0.1	1.0						
Fe	-0.1	-0.1	0.3	1.0					
Cu	0.7	-0.3	-0.8	-0.2	1.0				
As	0.7	0.0	-0.3	0.5	0.6	1.0			
Cr	0.6	0.3	-0.8	-0.4	0.8	0.4	1.0		
Zn	0.7	0.1	-0.2	0.1	0.6	0.7	0.6	1.0	
Pb	-0.6	0.4	0.3	0.1	-0.8	-0.6	-0.6	-0.8	1.0

BRAND C

	Na	*K*	*Ca*	*Fe*	*Cu*	*As*	*Cr*	*Zn*	*Pb*
Na	1.0								
K	0.8	1.0							
Ca	0.7	0.8	1.0						
Fe	-0.2	-0.3	0.1	1.0					
Cu	0.8	0.5	0.4	-0.2	1.0				
As	0.1	0.2	0.4	0.9	-0.1	1.0			
Cr	0.5	0.4	-0.1	-0.8	0.6	-0.7	1.0		
Zn	-0.1	-0.6	-0.7	-0.1	0.4	-0.4	0.3	1.0	
Pb	0.5	0.8	0.6	0.3	0.3	0.6	0.1	-0.5	1.0

BRAND D

	Na	*K*	*Ca*	*Fe*	*Cu*	*As*	*Cr*	*Zn*	*Pb*
Na	1.0								
K	0.3	1.0							
Ca	0.1	0.3	1.0						
Fe	0.3	-0.6	-0.4	1.0					
Cu	0.2	1.0	0.4	-0.7	1.0				
As	-0.8	0.3	-0.3	-0.5	0.3	1.0			
Cr	-0.4	-0.1	0.6	0.1	0.0	0.1	1.0		
Zn	-1.0	-0.2	-0.1	-0.4	-0.2	0.8	0.4	1.0	
Pb	0.0	-0.8	-0.5	0.9	-0.7	-0.3	0.1	-0.1	1.0

BRAND E

	Na	*K*	*Ca*	*Fe*	*Cu*	*As*	*Cr*	*Zn*	*Pb*
Na	1.0								
K	0.0	1.0							
Ca	0.3	-0.9	1.0						
Fe	-0.1	0.3	-0.2	1.0					
Cu	-0.3	0.3	-0.6	-0.2	1.0				
As	0.4	-0.4	0.3	-0.5	0.5	1.0			
Cr	-0.4	-0.7	0.4	0.0	0.3	0.4	1.0		
Zn	0.3	0.6	-0.6	-0.5	0.4	0.2	-0.7	1.0	
Pb	0.1	-0.5	0.5	0.5	-0.3	0.1	0.2	-0.7	1.0

BRAND F

	Na	*K*	*Ca*	*Fe*	*Cu*	*As*	*Cr*	*Zn*	*Pb*
Na	1.0								
K	-0.1	1.0							
Ca	-0.2	0.1	1.0						
Fe	-0.5	0.2	-0.3	1.0					
Cu	0.4	-0.5	-0.7	0.2	1.0				
As	0.2	-0.4	-0.7	-0.1	0.2	1.0			
Cr	-0.9	0.4	0.4	0.6	-0.4	-0.6	1.0		
Zn	0.3	-0.1	-0.6	0.0	0.0	0.8	-0.6	1.0	
Pb	0.5	0.1	-0.3	-0.6	-0.1	0.6	-0.7	0.8	1.0

Fig.3b Heat map representing Pearson’s correlation analysis between elemental concentrations across various brands of tastemakers

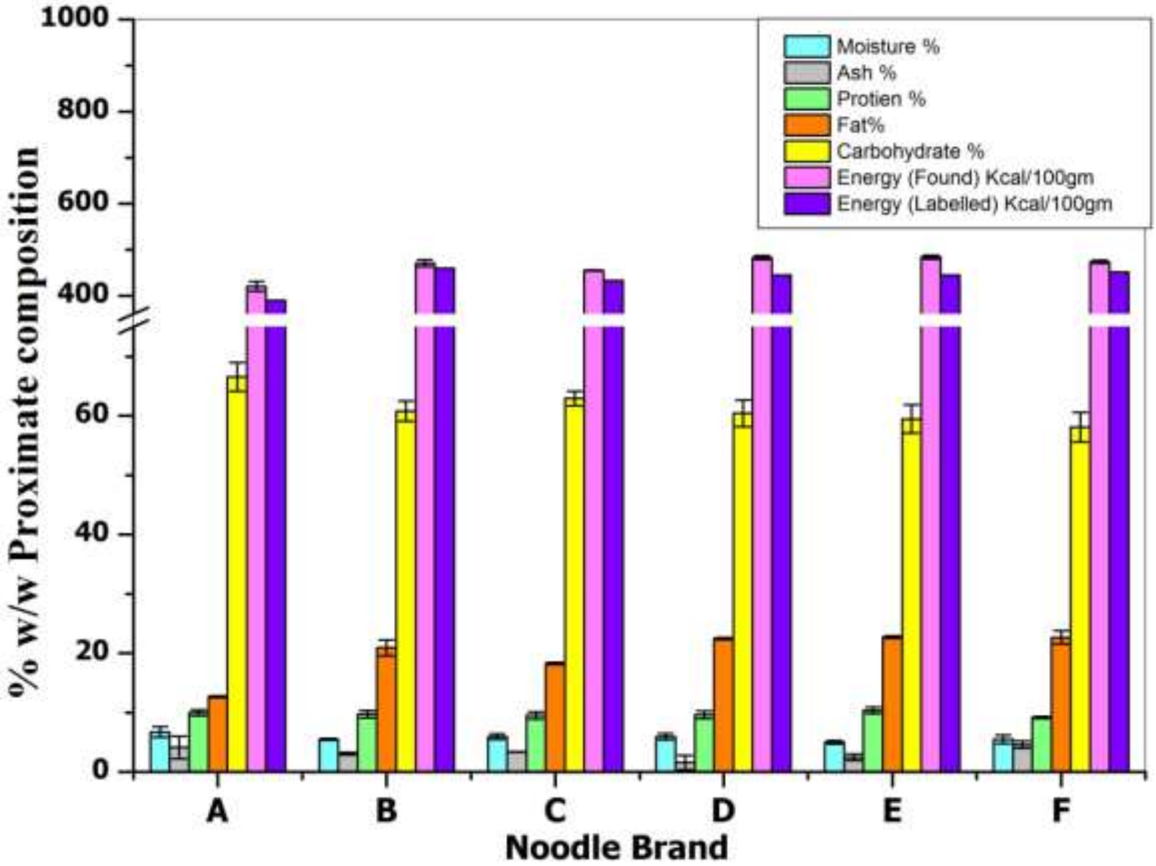

Fig. 4 Proximate composition (% w/w) of moisture, ash, protein, fat, and carbohydrate along with energy values (observed and labelled) in noodles

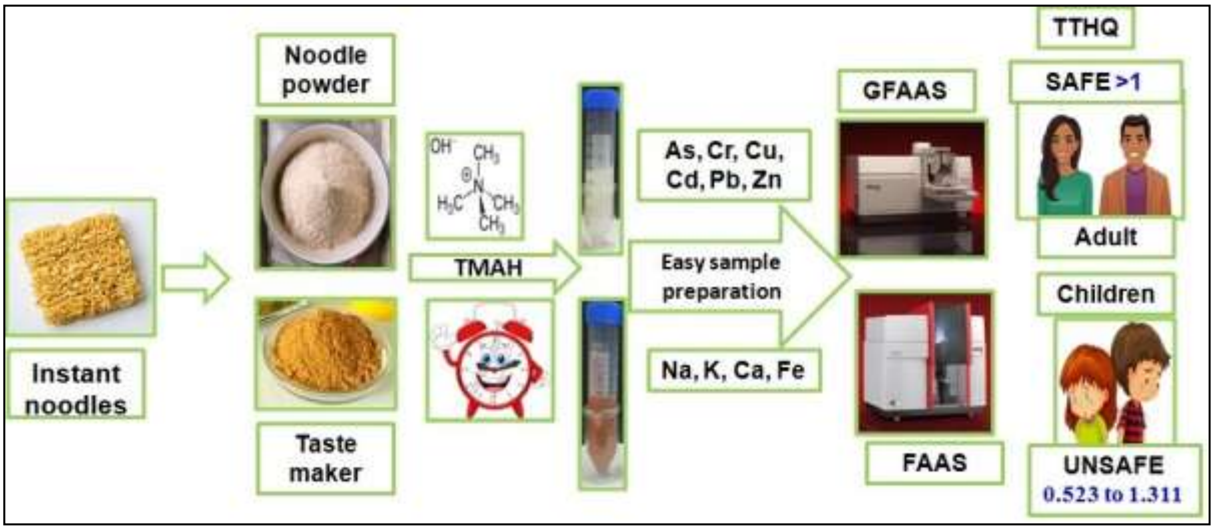

Fig. 5 Graphical presentation

Health Risks and Nutritional Quality of Noodles Sold in Mumbai Markets: Proximate and Elemental Analysis

Table 1 Operational parameters for microwave digestion of samples

Step	Time	Temp	Pressure	Power
Ramp	00:15:00	200^0C	45 bar	1000W
Hold	00:15:00	200^0C	45 bar	1000W
Cooling	00:30:00	45^0C	-	-

Table 2 Optimized parameters for AAS analysis

Element	Wavelength nm	Pyrolysis Temperature ^0C	Pyrolysis hold time s	Atomization Temperature ^0C	Modifier used
Cr	357.9	1100	300	2500	none
Cu	324.7	900	300	2300	none
Cd	228.8	300	300	1800	none
As	193.7	1100	300	2200	0.1% $Pd(NO_3)_2$
Pb	283.3	800	300	2100	
Zn	213.9	400	50	2000	
Na	589.0	Analyzed by FAAS Air- Acetylene flame			0.1% CsCl
K	766.5				
Ca	422.7				0.1M EDTA
Fe	285.2				none

Table 3 Performance characteristics of FAAS and GFAAS for TMAH assisted alkaline solubilization

	Noodles		Taste maker	
Elements	**LOD**	**LOQ**	**LOD**	**LOQ**
	mg/kg	**mg/kg**	**mg/kg**	**mg/kg**
Na	1.83	8	1.22	6.5
K	2.30	8.6	0.70	2.4
Ca	7.00	27	1.80	6.7
Fe	0.65	2.6	0.30	1.7
Cu	0.065	0.28	0.017	0.18
As	0.004	0.007	0.005	0.008
Cr	0.044	0.15	0.067	0.24
Cd	0.006	0.008	0.003	0.005
Zn	0.005	0.018	0.005	0.016
Pb	0.022	0.16	0.030	0.19

Table 4 Comparison of elemental concentrations in noodles using microwave assisted acid dissolution and TMAH solubilization.

Elements	**Microwave assisted acid dissolution *N=6**	**TMAH *N=6**	**%recovery**	**t-value**
	mg/100g	mg/100g		
Na	1305 ± 26	1262 ± 43	97	0.03
K	368± 1.8	360 ± 2.6	98	1.60
Ca	47± 1.6	51 ± 2.1	109	1.15
	mg/kg	mg/kg		
Cu	4.02± 0.13	3.99 ± 0.15	97	1.52

As	ND	Nd		
Cr	0.28± 0.08	0.26 ± 0.12	93	1.92
Cd	ND	ND		
Zn	11.4± 0.5	11.6 ± 0.8	102	0.45
Fe	20.2± 0.8	18.6 ± 1.6	92	1.00
Pb	1.83± 0.05	1.85 ± 0.2	101	0.94

*N=number of replicates

Table 5a Percentage recovery for IAEA-155 Whey Powder after TMAH solubilization

(CRM) IAEA-155 Whey powder (*N=3)			
Elements	Ref value (ug/g)	Obtained (ug/g)	%recovery
Cu	0.57 (0.46-0.63)	0.59	104
As	0.049 (0.016-0.083)	0.043	88
Cr	0.59 (0.51-0.66)	0.63	107
Cd	0.016 (0.012-0.020)	0.018	113
Zn	34.3 (32.8-35.7)	33.9	99
Fe	62 (50-74)	57	92
Pb	0.104 (0.071-0.136)	0.105	101

*N=number of replicates

Table 5b Percentage recovery obtained for CRM Rice Flour No 10C after TMAH solubilisation

CRM Rice Flour No 10C (*N=3)			
Elements	**Ref value**	**Obtained**	**%recovery**
	Wt%	**Wt%**	
K	0.275 ± 0.010	0.273 ± 0.032	99
	mg/kg	**mg/kg**	
Ca	95 ± 2	93.4 ± 5.0	98
Na	14 ± 0.4	13.8± 4	99
Cu	24.1 ± 0.3	24.3 ± 0.6	101
Fe	11.4 ± 0.8	10.8 ± 0.5	95
Zn	23.1 ± 0.8	23.8 ± 0.6	103
Cd	1.83± 0.06	1.86± 0.16	102

*N=number of replicates

Table 6a Descriptive statistics for Noodle

Element	Na	K	Ca	**Cu**	**As**	**Cr**	**Cd**	**Zn**	**Fe**	**Pb**
Noodles	Descriptive statistics									
	mg/100g			µg g^{-1}						
Mean	1135	276	135	5.10	0.013	0.25	0.007	15.9	20.0	0.63
Median	1116	256	112	4.09	0.010	0.25	0.005	12.9	12.2	0.39
Minimum	833	200	51	2.45	<0.007	0.05	<0.008	9.2	6.3	<0.16
Maximum	1473	361	288	13.56	0.053	0.38	0.032	35.6	90.7	2.22
1st quartile	1050	243	89	3.63	<0.007	0.22	0.008	11.3	10.2	0.24
3rd quartile	1262	325	141	5.01	0.020	0.29	0.009	16.0	15.7	0.59

Table 6b Descriptive statistics for Taste maker

Element	Na	K	Ca	**Cu**	**As**	**Cr**	**Cd**	**Zn**	**Fe**	**Pb**
Tastemaker	Descriptive statistics									
	mg/g			µg/g						
Mean	52	31	0.20	6.16	0.09	0.38	<0.005	21.8	123	0.31
Median	49	29	0.16	4.04	0.06	0.33	<0.005	18.6	20	0.19
Minimum	43	22	0.05	2.16	0.01	<0.24	<0.005	5.5	4	<0.19
Maximum	67	42	0.39	21.97	0.52	0.73	<0.005	45.4	455	3.26
1st quartile	46	26	0.14	2.92	0.03	<0.24	<0.005	15.1	12	<0.19
3rd quartile	57	36	0.27	5.10	0.11	0.56	<0.005	31.0	264	0.32

Table 7 Targeted Hazard Quotient (THQ) for trace and toxic metals and the Total Hazard Quotient (TTHQ) of noodle and corresponding Taste Maker (TM) brands for adults.

Adult	**A (THQ)**		**B (THQ)**		**C (THQ)**		**D (THQ)**		**E (THQ)**		**F (THQ)**	
Metal	**Noodle**	**TM**	**Noodle**	**TM**	**Noodle**	**TM**	**Noodle**	**TM**	**Noodle**	**TM**	**Noodle**	**TM**
As	0.034	0.002	0.010	0.011	0.020	0.004	0.010	0.000	0.002	0.003	0.010	0.005
Pb	0.051	0.001	0.134	0.001	0.040	0.004	0.023	0.001	0.004	0.000	0.031	0.001
Cr	0.079	0.008	0.083	0.011	0.050	0.005	0.099	0.005	0.073	0.002	0.102	0.003
Cd	0.004	0.000	0.003	0.000	0.001	0.000	0.001	0.000	0.003	0.000	0.001	0.000
Fe	0.007	0.007	0.025	0.008	0.003	0.000	0.005	0.000	0.005	0.000	0.005	0.000
Zn	0.014	0.001	0.016	0.001	0.011	0.001	0.030	0.001	0.013	0.002	0.011	0.001
Cu	0.029	0.001	0.071	0.002	0.029	0.007	0.031	0.002	0.041	0.002	0.027	0.002
TTHQ	**0.237**		**0.376**		**0.174**		**0.209**		**0.149**		**0.199**	

Table 8 Targeted Hazard Quotient (THQ) for trace and toxic metals and the Total Hazard Quotient (TTHQ) of noodle and corresponding Taste Maker (TM) brands for children.

Children	**A (THQ)**		**B (THQ)**		**C (THQ)**		**D (THQ)**		**E (THQ)**		**F (THQ)**	
Metal	**Noodle**	**TM**	**Noodle**	**TM**	**Noodle**	**TM**	**Noodle**	**TM**	**Noodle**	**TM**	**Noodle**	**TM**
As	0.117	0.008	0.035	0.040	0.069	0.014	0.035	0.002	0.007	0.012	0.035	0.017
Pb	0.179	0.003	0.468	0.005	0.140	0.013	0.081	0.004	0.013	0.002	0.109	0.002
Cr	0.277	0.028	0.289	0.039	0.173	0.017	0.347	0.017	0.254	0.009	0.358	0.012
Cd	0.016	0.000	0.005	0.000	0.003	0.000	0.004	0.000	0.009	0.000	0.004	0.000
Fe	0.023	0.023	0.089	0.027	0.012	0.001	0.018	0.001	0.017	0.001	0.019	0.001
Zn	0.048	0.003	0.054	0.005	0.040	0.004	0.105	0.005	0.045	0.006	0.038	0.003
Cu	0.101	0.004	0.249	0.007	0.101	0.023	0.108	0.005	0.142	0.006	0.094	0.005
TTHQ	**0.830**		**1.311**		**0.610**		**0.731**		**0.523**		**0.698**	