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Assessment of Heavy Metal Contaminants in Tomatoes Processed with Locally Fabricated Milling Machine

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ABSTRACT

Tomatoes are a staple food in many diets worldwide, often processed using locally fabricated milling machines in sub-Saharan Africa. However, these machines may introduce metal contaminants into tomato products, posing health risks. This study assesses the levels of heavy metals (Fe, Cu, Pb, Cd, Mg, Ca, Mn,) in tomatoes milled with locally fabricated machines. Samples were analysed using atomic absorption spectroscopy (AAS). The analysis showed that the detected metals from Tomatoes sourced from South (TSS) are Fe, Mg and Ca with concentration that varies between 8.08 to 27.44 mg/kg, 112.81 to113.46 mg/kg, 0.66 to 0.75 mg/kg respectively. While for Tomatoes sourced from the North (TSN), the metals detected are Fe, Cu, Pb, Mg, and Ca with concentration varying from 7.56 to 29.28 mg/kg,11.65 to 11.84 mg/kg, 0.011 to 0.08 mg/kg, 140.62 to142.54 mg/kg, and 0.5 mg/kg, respectively. Result of the analysis revealed that some contaminants might have been introduced during the milling process. Both carcinogenic and noncarcinogenic risk analysis revealed that adult and child exposure to risk is below minimal. The findings highlight the need for improved locally fabricated milling machine design and stricter food safety regulations to mitigate metal contamination.

Keywords: heavy metals, food safety, tomato milling, contamination, public health.

1.0 INTRODUCTION

Human are exposed to contaminants through consumption of vegetables such as tomatoes [1, 2]. Tomatoes constitute a source of necessary nutrients which includes bioactive compounds such as vitamin C, lycopene, lutein, macro-and microelements [3]. These compounds are considered to be of utmost importance to humans due to their valuable health benefits. Tomato (Lycopersicon esculentum), among all vegetables, is one the most widely grown and consumed vegetable in the world [4]. According to a report by the Food and Agriculture Organisation of the United Nations (FAO), tomatoes ranked as the most produced vegetable with an annual worldwide production output of 186 million metric tonnes in 2022 [5]. Nigeria with its annual output of 4.1 million tonnes is the second largest producer of tomatoes in Africa and the fourteenth largest producer in the world [6]. Tomato processing into paste for consumption is a vital economic activity in many regions of the world supporting livelihoods and food security. A common traditional method employed for this is the use of mortar and pestle or granite stones to grind the tomatoes. However, this method is laborious and time consuming. Locally fabricated grinding machines are therefore developed to solve this problem due to their affordability and accessibility. Though they are efficient in milling tomatoes into paste, the materials utilised in its fabrication are made from low quality materials that are prone to wear and corrosion [7]. Thus, there is a major risk of metal contaminants being introduced into the tomato products during their milling operation. These types of machines are developed to reduce the texture of food items into finer sizes. The mode of operation of the machine includes the rubbing of two discs, one stationary and the other rotating against one another. This generates wear and tear of the rubbing surfaces resulting in the introduction of contaminants into the food material [8]. Essentials and non-essentials metals are the two categories of heavy metals in existence with examples of non-essentials including metals such as lead, cadmium, tin, aluminium and arsenic. The essential minerals, however, constitute a set of important nutrients for living beings [2]. According to European parliament, regulation (EC) No. 1935/2004 ‘all materials and articles intended for direct or indirect contact with food must be sufficiently inert to prevent substances from being transferred to food in sufficient quantities to endanger human health or cause an unacceptable change in the composition of the food or deterioration in its organoleptic properties’ [9]. Therefore, materials that are not sufficiently inert might constitute health risk to humans if consumed. Apart from metal contaminants being introduced during food processing, [10] asserted that metal contaminants are also introduced into food through machinery, kitchen knives, pots, and pans or from particles of soil. Studies have also shown that contaminants find its way into tomatoes through contaminated polluted irrigation water and amended soil [11, 12]. Copper (Cu), Cobalt (Co), Iron (Fe), Iodine (I), Zinc (Zn), Manganese (Mn) are some of the essential nutritive elements needed by humans while the

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non-nutritive elements include Bromine (Br), Aluminium (Al), Chromium (Cr), Mercury (Hg), Nickel (Ni), Tin (Sn) together with Selenium (Se), Lead (Pb), Cadmium (Cd) which are known to have toxic effect even with a smaller amount of less than 10 mg/kg to 50mg/kg [13]. Recent studies have shown that potentially toxic elements (PTE) to humans and environment included Fe, Pb, Zn, As, Co, Cr, Cu, Cd, Mn, and Ni [14, 15, 16]. Such contaminants are mainly introduced to humans through inhalation or injection and can be accumulated in several organs of the human body; thereby resulting in undesirable side effects [17]. [18] examined contaminants in three types of tomatoes samples in mining communities in Nigeria. Inductive coupled plasma optical emission spectroscopy (ICP-OES) was used to identify six elements in the three tomatoes types. The results showed that Cr, Ni, and Cd concentrations are higher in all the varieties of Derica, UTC, and the Yowlings during the rainy season. [19] investigated heavy metal contents in tomatoes grown in Kano area, Nigeria using Atomic Absorption Spectrophotometer (AAS). The result of the work showed the concentration of Fe, Cr, Cd, Pb in the fruits tomatoes to be 0.0477 ppm, 0.0036 ppm, 0.1699 ppm, 0.0069 ppm, respectively. It was concluded that the heavy metal in the tomatoes is as a result of the effluent from the industries in the area where the tomatoes are grown. [20] evaluated the risk and effect associated with taking tomatoes grown with waste irrigation water. In the two locations selected for the study, it was found that the nutrients (N, P, K) of the soil and tomatoes reduce by a factor of 0.01 while the toxicity of the soil increases by a factor of 0.001. The Fe, Pb and Mn levels were found to be 5000.1mg/kg, 360 .7 mg/kg and 356.3mg/kg in the tomato fruits. This vehemently increases the daily consumption rate of heavy metals. Three varieties of organic and conventional tomatoes were examined for presence of heavy metals by [21]. Results showed that there is larger concentration of Ni, Cu, Zn, and Pb in the conventional tomatoes but there is no noticeable effect on the concentration of Cd, Co, Cr. There is therefore the risk of consuming PTEs through tomatoes as it is consumed on a daily basis. The current work is aimed at determining the level of PTEs in tomatoes introduced into milled samples of tomatoes as a result of milling process with locally fabricated milling machines and the possible consequence of consuming it.

2.0 METHODOLOGY

2.1 Materials

The materials used in this work include 5 kg of tomatoes from the north and 5 kg of tomatoes from the southern part of Nigeria, domestic milling machine, and milling disc from the same manufacturer, electronic weighing scales, measuring cylinder, bowls and stainless-steel stirrer, pestle, mortar.

2.2 Methods

Ripe tomatoes were selected for the investigation among the many types of vegetables because of their importance as one of the most widely consumed vegetables in Nigeria and throughout the world. They were bought from the local market in Zaria (11.12ºN, 7.73ºE), located in Kaduna State in the northern part of Nigeria, and the other set from Odo-Oba (8.053ºN, 4.14ºE) in Oyo State in the southern part of the country. The tomato samples were cleaned using distilled water to remove soil particles and other contaminants that might have adhered to the fruits. The clean fruits were then cut into pieces and sun-dried in a clean container. Ten grams of each sample of tomatoes were weighed using weighing machine (AE 945644, Adams equipment, South Africa) and put into beakers respectively. The beakers were arranged accordingly. The samples were then split into four: two samples from the south (TSS1 and TSS2) and two from the north (TSN1 and TSN2). One of each sample (TSS2 and TSN2) was ground using a locally developed milling machine, while the other (TSS1 and TSN1) was pounded using a pestle and mortar which serve as the control. Figures 1 and 2 show the two forms in which the grinding was done. Figure 3 shows a typical milling disc utilised in milling machines for the milling process.

Figure 1. Pestle and mortar

Figure 2. Locally Fabricated milling machine [22]

Figure 3. A typical milling Disc

One gram of the samples was then digested in 15 ml of HCl and 5 ml of HNO_3 with the mixture (3:1), and further heated at 80 °C using a hotplate in a fume cupboard until the fumes became colorless (Aqua Regia method). These transparent solutions were then filtered through Whatman No. 42 filter paper and diluted to 50 ml with deionized water to get the required concentrations.

An Atomic Absorption Spectrophotometer (AAS 240 FS, 21956, Varian, Germany) was used to determine the trace elements in the aliquots of the digested samples. The elements determined include iron (Fe – 248.3 nm), magnesium (Mg – 285.2 nm), lead (Pb – 283.3 nm), copper (Cu – 324.8 nm), cadmium (Cd – 228.8 nm), manganese (Mn – 279.5 nm), and chromium (Cr – 357.9 nm). Even before the elements were determined, the hollow cathode lamp used to determine a particular metal element was fixed. The fixed lamp supplies suitable light with its specific wavelength being set, which is used in determining a particular metal element and is changed successfully with other hollow cathode lamps to determine other elements. Each sample solution was introduced into the instrument by a nebulizer tubing that had been set for the analysis and later led to the burner tip, where atomization and evaporation of the solution took place. Table 1 shows the standard operating conditions for elemental analysis using AAS [2]. The standard limits of Potentially Toxic Elements (PTEs) in foods are given in Table 2.

Table 1: Standard operating conditions for elemental analysis using AAS

Elements	Wavelength (nm)	Lamp Current (mA)
Mg	285.2	4.00
Fe	248.3	5.00
Cu	324.8	4.00
Mn	279.5	5.00
Pb	283.3	10.00
Cd	228.8	4.00
Cr	357.9	7.00

Table 2: The Standard limits of PTEs in foodstuff

PTEs	Standard Limits (mg/kg)	References
Cd	0.1	[23]
Fe	15	[24]
Pb	0.1	[23]
Mn	2.3	[25]
Cu	10	[26]
Zn	30	[24]
Cr	1	[25]

2.3 Statistical Analysis of Metals

The mean concentration of the samples is determined by equation (1)

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (1)$$

where $\bar{x}$ is the mean concentration, n is the sample size and x_i the concentration

The Standard Deviation (SD) is given by equation (2)

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \quad (2)$$

The sample size is in triplicate (n = 3) and the results are expressed as mean ± standard deviation (SD). Statistical analyses are executed with IBM SPSS Statistics (Version 23.0, IBM Corp., Armonk, NY, USA). Statistical comparisons between two groups (TSS1 versus TSS2 and TSN1 versus TSN2) are conducted in Analysis of Variance (one-way ANOVA). The ANOVA decision rule imposed is that if $P < 0.05$, then there is significance difference however, if the P-value obtained is greater than 0.05 ($P > 0.05$) then there is no significant difference.

2.3 Health Risk Assessment Methodology

The health risk from the ingestion of PTEs through tomatoes is evaluated by determining the Average Daily Dose (ADDo) by employing the US Environmental Protection Agency (USEPA) model [27]. This is calculated using equation (3) [14, 28]:

$$ADDo = \frac{C \times IR \times EF \times ED}{BW \times AT}. \quad (3)$$

Where C = represents concentration of the metals in tomato (mg/kg)
IR = represents the ingestion rate (kg/day) where an average of 0.022 kg/day per person for tomato was assumed [29].
EF = Exposure frequency which is set at 365 days/year for daily consumption [28, 30].
ED = Exposure duration which is set at 70 years representing a lifetime exposure [28, 30].
BW = Average body weight which is set at 70 kg for an adult and 16 kg for adolescent [28, 30].
AT = Average Time in days = ED x 365 days = 70 x 365 days = 25,550 days.

2.3.1 Non-carcinogenic risk

To evaluate the noncarcinogenic risk of heavy metals, the Hazard Quotient (HQ) is employed as given in equation (4) [14, 28, 30, 31]:

$$HQ = \frac{ADD_O}{Ref} \quad (4)$$

where ADDo is the Average Daily Dose and Ref is the reference dose. $HQ < 1$ implies low risk to the population while $HQ \geq 1$ implies that the population is at noncancer risk [14, 28, 30, 31].

For prediction from many PTEs, the Hazard index (HI) is a combination of HQs and it gives an idea of the potential human noncancerous health risk when more than one heavy metal is consumed. It is given by equation (5) [14, 28, 31]:

$$HI = \sum HQ_i. \quad (5)$$

When $HI < 1$, then the exposed person or population will most likely not experience any adverse health effects. However, with $HI > 1$, the adverse effect may occur [14, 32].

2.3.2 Carcinogenic risk

The carcinogenic risk (CR) is given in equation (6) as [14, 33]:

$$CR = ADDo \times SF \quad (6)$$

Where CR is the cancer Risk, ADDo is the Average daily Dose (mg/kg-day) and SF is the slope factor $(mg/kg/day)^{-1}$ which links the mean exposure concentration to the increase in the probability of developing cancer [33].

The total cancer risk (TCR) is given by equation (7) [33]:

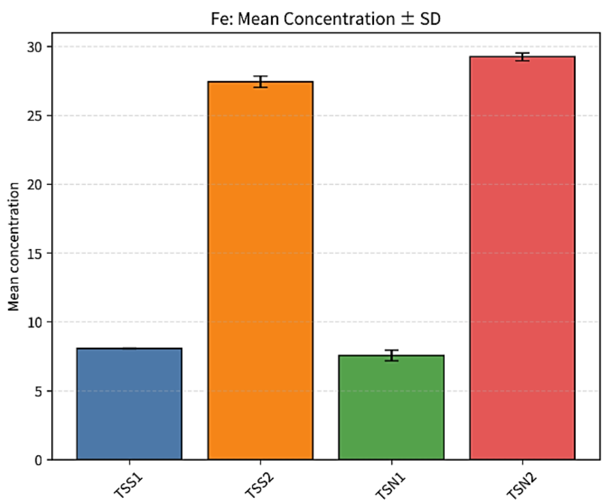
$$TCR = \sum_i^n ADDo \times SF_i \, ADD_O \quad (7)$$

According to US EPA, the acceptable carcinogenic risk ranges from 10^{-4} to 10^{-6} [33].

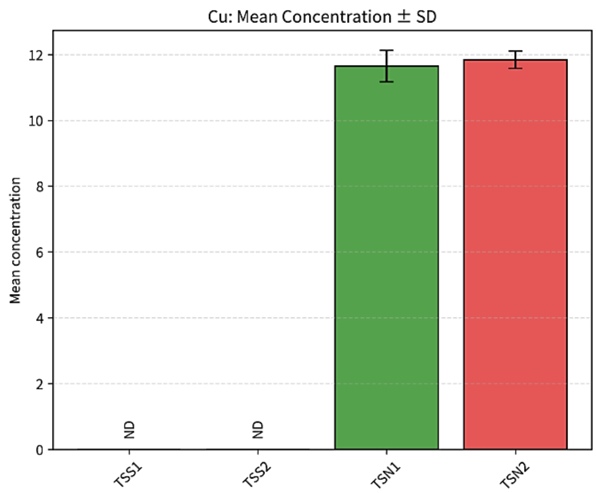
3.0 Results and Discussion

3.1 Results obtained from AAS

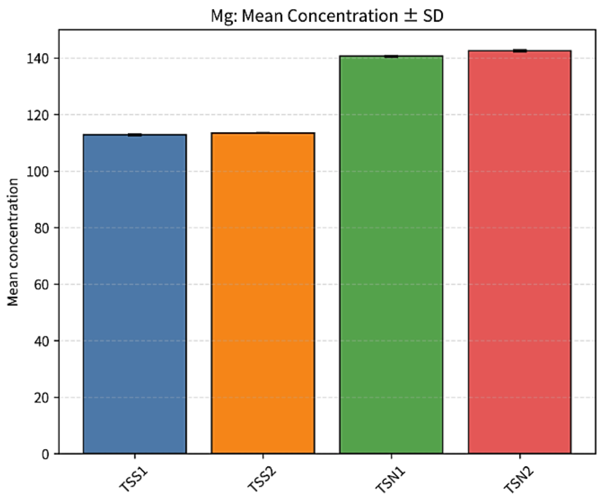
The results obtained from the use AAS to test the samples of tomatoes is given in Table 3. This involves three numbers of repetition with the average (mean) presented in standard deviation. Figures 4 (a), (b), (c), (d), (e), and (f) depict the mean concentration of Fe, Cu, Mg, Mn, Pb and Ca before milling (TSS1 and TSN1) and after milling (TSS2 and TSN2). In all the Figure 4 presented, the error bar represents the standard deviation. In all the graphs presented, there is a noticeable increase from before milling to after milling process.



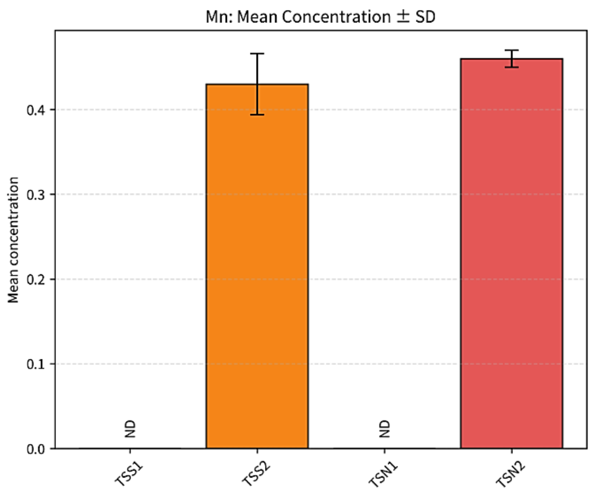
(a)


Cu: Mean Concentration ± SD
Mean concentration
0
2
4
6
8
10
12
ND
ND
TSS1
TSS2
TSN1
TSN2

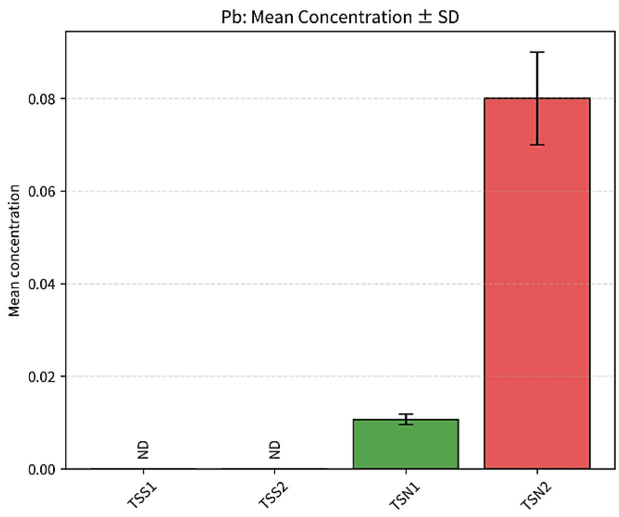
(b)


Mg: Mean Concentration ± SD
Mean concentration
0
20
40
60
80
100
120
140
TSS1
TSS2
TSN1
TSN2

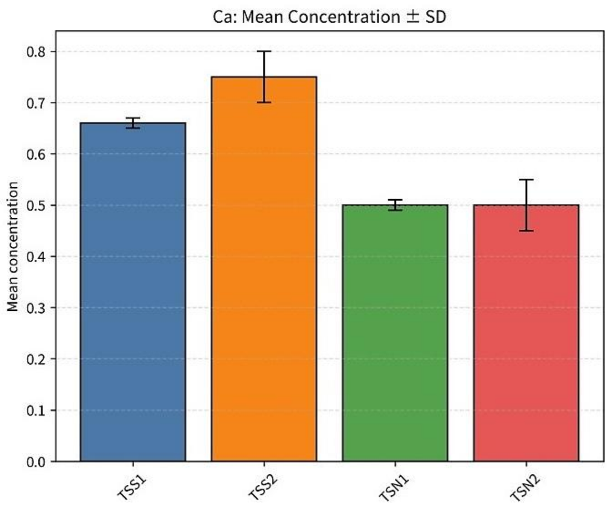
(c)


Mn: Mean Concentration ± SD
Mean concentration
0.0
0.1
0.2
0.3
0.4
ND
ND
TSS1
TSS2
TSN1
TSN2

(d)



(e)



(f)

. **Figure 4.** Plot of mean concentration and standard deviation for (a) Fe, (b) Cu, (c) Mg, (d) Mn, (e) Pb, and (f) Ca

Table 3: Mean Concentration and SD of Elements in Tomatoes sample from North and south

Metal	TSS1	TSS2	TSN1	TSN2
Fe	8.08 ± 0.02	27.44 ± 0.41	7.56 ± 0.39	29.25 ± 0.28
Cu	ND	ND	11.65 ± 0.48	11.84 ± 0.26
Mg	112.81 ± 0.32	113.46 ± 0.07	140.62 ± 0.33	142.54 ± 0.36
Ca	0.66 ± 0.01	0.75 ± 0.05	0.50 ± 0.01	0.50 ± 0.05
Mn	ND	0.43 ± 0.04	ND	0.46 ± 0.01
Pb	ND	ND	0.0107 ± 0.0012	0.0800 ± 0.0100

+ND: Not detected means below level that can be detected

3.1.1 Result of Statistical analysis

One way ANOVA is used to determine if there is significant difference between TSS1 and TSS2, and also between TSN1 and TSN2. The result is presented in Table 4.

Table 4: One-way ANOVA results for Significant difference between groups

Metal	Comparison	F	p-value	There is significant difference (p<0.05)
Fe	TSS1 vs TSS2	6567.93	1.39×10^{-7}	Yes
Fe	TSN1 vs TSN2	6075.63	1.62×10^{-7}	Yes
Cu	TSS1 vs TSS2	Not tested	Not tested	ND in both groups
Cu	TSN1 vs TSN2	0.37	0.5781	No
Mg	TSS1 vs TSS2	12.23	0.0249	Yes
Mg	TSN1 vs TSN2	46.08	0.0025	Yes
Ca	TSS1 vs TSS2	9.35	0.0378	Yes
Ca	TSN1 vs TSN2	0	1	No
Mn	TSS1 vs TSS2	Not tested	Not tested	TSS1 was ND
Mn	TSN1 vs TSN2	Not tested	Not tested	TSN1 was ND
Pb	TSS1 vs TSS2	Not tested	Not tested	ND in both groups
Pb	TSN1 vs TSN2	142.32	0.000283	Yes

+ND: Not detected means below level that can be detected

The ANOVA result showed that there is a significant difference between the values of element Fe for TSS1 versus TSS2, and it also showed a significant difference between the values of TSN1 versus TSN2. The result showed that for Mg, there is a significant difference between TSS1 versus TSS2, and TSN1 versus TSN2. There is also a significant difference only between the values Ca for TSS1 versus TSS2. For Pb, there is a significant difference between the value of TSN1 versus TSN2. However, there is no significant difference between the values of Cu for TSN1 versus TSN2. Also for Ca, there is no significant difference between the values of TSN1 and TSN2. There are some significant differences that could not be tested as a result of elements being Not Detected. These are TSS1 vs TSS2 for Cu, TSS1 vs TSS2 and TSN1 vs TSN2 for Mn, and TSS1 vs TSS2 for Pb.

3.1.2 Iron (Fe) concentration

For TSN2, Fe was found to be in the concentration of 29.25 mg/kg, while TSS2 was found to have a concentration of 27.44 mg/kg as shown in Tables 3 and 4. On the other hand, TSS1 and TSN1 have concentration of 8.08 and 7.56 mg/kg respectively, which is below the recommended dietary allowance (RDA). Fresh tomatoes are reported to contain an average of about 4.56-6.0 mg/100g of iron [34]. This may account for the size of its presence in both TSS1 and TSN1 which are pounded tomatoes with pestle and mortar (control). However, the difference in milled and pounded samples may be as a result of that introduced during milling process. Analysis shows that there is a significant difference between TSS1 vs TSS2, and between TSN1 vs TSN2.

3.1.3 Lead (Pb) concentration

The concentration of Pb in TSN2 was found to be 0.08 mg/kg and that of TSN1 was found to be 0.011 mg/kg as shown in Table 3. However, Pb was not detected in TSS1 and TSS2 according to Table 3. The Tomato samples of TSN1 and TSN2 level of concentration are well below WHO/FAO limits of 0.1 mg/kg [35]. However, care should be taken that this is not by any means exceeded. Effect of Pb poisoning in humans have been reported to cause neurotoxicity and undesirable effect on the nervous system even at very low dosage of exposure [36]. There is a significant difference between the values of TSN1 vs TSN2.

3.1.4 Copper (Cu) concentration

Although copper constitutes an essential micro-nutrient, its lack and unwarranted exposure can however have antagonistic effects on human health [37]. For TSN2, Cu was found to have a concentration of 11.84 mg/kg, while TSN1 had a concentration of 11.65 mg/kg as shown in Figure 3. Both TSS1 and TSS2 have no detected concentration of copper recorded. The slight variation in the concentration of TSN2 and TSN1 might be due to the intrusion during the processing. According to WHO, Cu has a daily intake of 50 µg/kg for an adult [38]. The concentration in TSN2 and TSN1 is relatively high, and the daily consumption of the tomatoes might result in health risk. However, there is no significant difference between TSN1 and TSN2.

3.1.5 Cadmium (Cd) concentration

Cadmium was found to be bind into cysteine-rich protein such as metallothionein [39]. After inducing hepatotoxicity in the liver, the cysteine-metallothionein complex travels to the kidney and accumulates in kidney tissue resulting in nephrotoxicity [40]. However, there was no concentration of Cd detected in all the samples of TSS1, TSS2, TSN1 and TSN2.

3.1.6 Chromium (Cr) concentration

There was no concentration of Cr detected in all the samples of TSS1, TSS2, TSN1 and TSN2.

3.1.7 Calcium (Ca) concentration

For the TSN1, Ca was found to have a concentration of 0.5 mg/kg, while TSS1 was found to have a concentration of 0.66 mg/kg. Also, TSS2 and TSN2 have a concentration of 0.75 and 0.5 mg/kg respectively. The concentration of calcium is relatively low in all samples considered for both the pounded and milled tomatoes. These low values of concentration of tomatoes respectively showed that both milled and pounded tomatoes are not affected by the two processes of pounding and grinding. There is a significant difference between TSS1 and TSS2 but the difference between TSN1 and TSN2 is not significant.

3.1.8 Magnesium (Mg) concentration

The metal was found to be in higher concentration for all samples with values of 140.62 and 142.54 mg/kg for TSN1 and TSN2 respectively. TSS1 and TSS2 have a concentration of 112.81 mg/kg and 113.46 mg/kg respectively. The difference of concentration for this metal in pounded and milled samples can be attributed to interferences which sometimes come to play and might lower the metal actual reading [13]. The difference between the values of TSN1 vs TSN2 is found to be significant. There is also significant difference between TSS1 and TSS2.

3.1.9 Manganese (Mn) concentration

The concentration of Mn found in TSN1 and TSS1 is found to be zero; however, TSN2 and TSS2 are found to contain 0.46 mg/kg and 0.43 mg/kg concentration respectively. Though it is an essential metal for the general well-being of humans, excess of it has been reported to result in neurological disorder because the maximum daily intake, according to National Academy of science, is supposed to be within 2-6mg/day [38]. The manifestation of 0.46 and 0.43 mg/kg in milled samples may be attributed to contamination by the milling machine during milling process.

3.1.10 Zinc (Zn) concentration

Although the recommended daily amount for Zinc is 8mg/day for women and 11 mg/day for men [41], it was not detected in both TSN1, TSN2, TSS1 and TSS2 samples.

3.2 Analysis of Concentration of Elements

The analysis revealed distinct regional differences. Tomatoes from Southern Nigeria (TSS1, TSS2) showed no detectable levels of Cu, Pb, Cd, Zn, or Cr. The Iron and Magnesium that they contain are among the main trace elements [42] and a lower risk of anemia was observed in people with large consumption of Fe and Mg. Manganese (0.43 mg/kg) available in TSS2 was introduced through the milling process. However, tomatoes from Northern Nigeria (TSN1, TSN2) contained detectable levels of Cu (11.65 and 11.85 mg/kg), and, critically, Lead (0.011 mg/kg and 0.08 mg/kg). The presence of Pb is a major concern due to its high toxicity. TSN2 and TSS2 also contained Manganese (0.43 and 0.46 mg/kg) which is probably introduced to Tomatoes through the milling process.

3.3 Average Daily Dose (ADDo) and Health Risk Implications

The ADDo was calculated for the key PTEs of concern: Lead (Pb) and Copper (Cu) in the Northern samples. The results are summarized in Table 5.

To contextualize the risk, the calculated ADDo values were compared with established reference doses (RfD) through HQ. The USEPA RfD for Pb is 3.6×10^{-3} mg/kg-day [31], for Cu, it is 4.0×10^{-2} mg/kg-day [32] and Mn, it is 1.4×10^{-2} mg/kg-day [28]. The RfD for Fe and Mg is not available in literature, so it could not be utilised to evaluate the health risk of the elements [14]. From Table 5, the ADDo for Cu in both adults and children varied from 4.49×10^{-3} mg/kg-day to 4.56×10^{-3} mg/kg-day for adults, and for a child = 1.97×10^{-2} mg/kg-day to 1.99

× 10^{-2} mg/kg-day. This is well below the RfD, which indicates that HQ<1 and implies a negligible non-carcinogenic risk from Cu intake. Also, from Table 5, the situation for Pb is shadier. The individual ADDo values are below the RfD, which also implies a value of HQ less than 1. Pb is a cumulative toxicant with no known safe exposure level [43]. The ADDo for a child consuming TSN1 (1.35 × 10^{-4} mg/kg-day) is particularly notable. Continuing exposure at this level, especially if it is combined with Pb consumption from other dietary and environmental sources like water and dust, could contribute to accumulated problem and constitute developmental risks to the child. This is in agreement with studies of [44] and [45] which highlighted the important health risks to children from the consumption of lead through food.

In the case of Mn, ADDo for TSS2 using equation (1) was evaluated to be 1.36 × 10^{-4} mg/kg-day for adult and 5.95 × 10^{-4} mg/kg-day for a child. The HQ of Mn for both adult and child was evaluated from equation (4) to be 9.71 × 10^{-3} and 4.25 × 10^{-2} respectively. However, the ADDo of Mn for TSN2 was evaluated using eq. (3) which is 1.45 × 10^{-4} mg/kg-day for adult and 6.33 × 10^{-4} mg/kg-day for child respectively. The HQ for both adult and child was evaluated from eq. (3) to be 1.04 × 10^{-2} and 4.25 × 10^{-2} respectively. HI is a summation of HQs as given in equation (5) and it gives an idea of the potential human noncancerous health risk when more than one heavy metal is involved. In this particular case, the metals under consideration are Pb, Cu and Mn.

Table 6 evaluates the HI from the summation of the HQs. HI is 1.33 × 10^{-1} for adult and 5.77 × 10^{-1} for child. In both cases, the value of HI<1, which implies that the exposed person or population will not experience any adverse health effects.

The carcinogenic risk (CR) of Pb is evaluated from equation (6). The carcinogenic Slope Factor for Pb = 0.00085 (mg/kg-day)$^{-1}$ [33]. Therefore, CR for Pb equals 2.62 × 10^{-8} for adult and 1.15 × 10^{-7} for child. Both of these values are below 10^{-6} threshold. This implies that the risk of cancer is minimal**.**

Table 5: Calculated ADDo and HQ for PTEs in TSN Tomatoes

Sample	PTE	Concentration (mg/kg)	ADDo Adult (mg/kg-day)	ADDo Child mg/kg-day)	HQ Adult	HQ Child
TSN1	Pb	0.08	3.08 × 10^{-5}	1.35 × 10^{-4}	8.55 × 10^{-3}	3.75× 10^{-2}
TSN2	Pb	0.011	4.23 × 10^{-6}	1.86 × 10^{-5}	1.18 × 10^{-3}	5.17 × 10^{-3}
TSN1	Cu	11.84	4.56 × 10^{-3}	1.99 × 10^{-2}	1.14 × 10^{-1}	4.97 × 10^{-1}
TSN2	Cu	11.65	4.49 × 10^{-3}	1.97 × 10^{-2}	1.12 × 10^{-1}	4.93 × 10^{-1}

Table 6: Evaluation of Hazard Index (HI) from HQ

Sample	PTE	Concentration (mg/kg)	ADDo Adult (mg/kg-day)	ADDo_Child (mg/kg-day)	HQ *Adult*	HQ *child*
TSN1	Pb	0.08	3.08 × 10^{-5}	1.35 × 10^{-4}	8.55 × 10^{-3}	3.75 × 10^{-2}
TSN1	Cu	11.84	4.56 × 10^{-3}	1.99 × 10^{-2}	1.14 × 10^{-1}	4.97 × 10^{-1}
TSN2	Mn	0.46	1.45 × 10^{-4}	6.33 × 10^{-4}	1.04 × 10^{-2}	4.25 × 10^{-2}
$HI=\sum HQ_i$	-	-	-	-	1.33 × 10^{-1}	5.77 × 10^{-1}

4. CONCLUSION

The study evaluated the level of PTEs in tomatoes and the quantity which was introduced into milled samples of tomatoes during milling process with locally fabricated milling machines and the possible consequence of consuming it. The iron content of the milled sample increased from the control of 7.56 mg/kg to 29.25 mg/kg for TSN, and the control of 8.08 mg/kg to 27.44 mg/kg of the milled for TSS. Analysis from ANOVA result showed that there is a significant difference between the values of element Fe for TSS1 versus TSS2, and it also showed a significant difference between the values of TSN1 versus TSN2 for Fe. The result showed that for Mg, there is significant difference between TSS1 versus TSS2, and TSN1 versus TSN2. There is also significant difference only between the values Ca for TSS1 versus TSS2. For Pb, there is significant difference between the value of TSN1 versus TSN2. The gradual accumulation of Pb in the body can cause undesirable effect. However, there is no significant difference between the values of Cu for TSN1 versus TSN2. Also, for Ca. there is no significant difference between the values of TSN1 and TSN2. Analysis of carcinogenic risk showed that the health risk through cancer is minimum. A small quantity of manganese was found in the milled samples of TSN2=0.46 mg/kg and TSS2=0.43 mg/kg, which is suspectedly introduced during milling process. From the study, it can be concluded that milling of tomatoes using the locally fabricated machines contributes to some metal contamination in the tomato products. To reduce this risk of contaminants from milling machines, it is recommended that the designers of such machines use food-grade stainless steel material in locally fabricated mills. Government agencies should enact better environmental regulations and enforce stricter food safety standards. There should be better education of the public on the risk of using locally fabricated milling machines and advice on safer processing alternatives.

AUTHORS CONTRIBUTION

Olalekan Tajudeen POPOOLA was in charge of Supervision, Conceptualization, Formal analysis, Review & Editing
Abdulkarim Baba RABIU was in charge of investigation how to get thematerials and Methodology
Hassan Kobe IBRAHIM was in charge of Review and Editing process.
Muhammed SANUSI was in charge of Methodology
Uthman Olanrewaju OJODU did the original draft and sourcing materials
Fatai AMBALI was in charge of Review and Editing
Muibat Adesola ADENIRAN was in cahrge of Methodology related to health, Data curation, Formal analysis

DECLARATION OF COMPETING OF INTEREST

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission, and declare no conflict of interest on the manuscript.

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