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Studies on the medical safety of botanical medicines: Novel toxic metals and microbial contamination approach

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Abstract: The utilization of herbal therapies is increasing globally, prompting investigations into the health complications that may arise from drug side effects. A total of 160 herbal medicines (HMs), were used for this study, and their toxic heavy metal content, microbial load and dielectric properties were evaluated. The results obtained revealed that the crude HMs exhibited a greater proportion of heavy metals, microorganisms and a higher dielectric constant (ε′) value, in comparison to the refined HMs. Particularly, the powdered HMs contained high heavy metals and microbial contaminations. For the unrefined powders, HM samples exceeded the safety limits of cfu/g $\leq 10^5$, approved by World Health Organization for herbal medications. Regarding the electrical properties, the ε′ for the crude unrefined HMs ranged from 9.19 to 92.67; while the refined HMs ε′ values varied from 7.35 to 39.15. The hazard index (HI) analysis showed that unrefined HMs have higher non-carcinogenic toxicity than refined ones, with children facing serious health risks as their HI values surpass 1. Crude heavy metal consumption increases a child's risk of developing cancer. This research's findings highlighted the importance of consistent monitoring of herbal products, as heavy metals can accumulate, resulting in toxicity after prolonged use of these drugs.

Keywords: Drug safety, heavy metals, medicinal herbs, microbial contamination, public health practice

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INTRODUCTION

The increasing global health issues are closely associated with anthropogenic activities such as pollution, urbanization, lifestyle patterns, and self-medication (Ellwanger *et al.*, 2023). Millions of people die annually, from non-communicable diseases (NCDs), and diseases that could be prevented (WHO, 2024). In numerous low- and middle-income nations, challenging economic conditions and distrust in conventional treatments drive patients to seek herbal remedies (Okaiyeto and Oguntibeju, 2021; Wu *et al.,* 2022; Lima *et al.,* 2023). Herbal medicine (HM) is an extract derived from plant products, which has nutritional and therapeutic benefits (WHO, 2008; AJerohoet *al*., 2018; Amir *et al*., 2023). Globally, around $60 billion is spent annually on herbal medications, often used without proper prescriptions, risking under-dosing or overdosing challenges (Barkat *et al*., 2021; Wu *et al*., 2022). Overdosing can cause drug toxicity, leading to serious health problems, including neurological damage, kidney problems and liver issues (Picot *et al.,* 2022; Antar *et al.,* 2023).

Herbal medicines fall into two main types: crude herbal medicines, which are not registered by the Food and Drug Administration (FDA), and refined herbal medicines, which are FDA-registered (Muyumba *et al.,* 2021). They come in creams, soaps, powders, water-extracted liquids and ethanol-extracted liquids forms (de Sousa *et al*., 2020). Some herbal medicine practitioners assert their products are registered; however, they lack the rigorous testing and safety evaluations of pharmaceuticals (Hassen *et al*., 2022; Mssusa *et al*., 2023). These medicines often contain various toxic substances, including heavy metals, benzene, formaldehyde, cyanogenic glycosides, ephedrine, phytates, tannins, and pyrrolizidine alkaloids, as well as pathogens (Quan *et al.,* 2020; Lis-Cieplak *et al*., 2024).

Herbal medicines are widely sold and consumed globally, and in most cases, these products lacks adequate regulations and clinical evidence to support their public

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safety and efficacy (AJeroho *et al*., 2018; Okaiyeto and Oguntibeju, 2021; Hassen *et al*., 2022). Though certain HMs have high efficacy managing protracted ailments, materials used for their production may contain harmful substances and pathogens (Okaiyeto and Oguntibeju, 2021; Jităreanu *et al.,* 2023). Alghamdi *et al.* (2023) reported that some herbal drugs can interfere with conventional drugs, resulting in life-threating side effects. Likewise, improper formation tends to reduce the efficacy and public health safety of herbal products (Hassen *et al*., 2022; Wang *et al*., 2023; Balkrishna *et al.,* 2024). Furthermore, HMs' electrical properties can be correlated to their parent materials' physicochemical characteristics (Brini *et al*., 2017; Schafer and Lerner, 2022).

Although numerous studies have investigated the effectiveness of herbal therapies, there has been relatively little comprehensive research conducted on the potential health hazards associated with these herbal treatments. It is now paramount to conduct an in-depth examination of the health risks associated with herbal medicines. Therefore, this study combines many aspects such as microbial load, heavy metal contamination, and electrical properties, to evaluate the public health safety of herbal products. Information obtained from this study will proffer possible solutions, to health risks allied to HMs consumption.

MATERIALS AND METHODS

Sample size and sampling technique

To accomplish the goals of this study: 40 powders, 40 water-based extracts, 40 ethanol-based extracts, 20 creams and 20 soaps samples, were randomly selected from Saudi Arabia. Among the sampled specimens, 20 powders, 20 ethanol- based extracts, 5 creams and 5 soaps samples were refined products (certified by Food and Drugs Administration), while the remaining samples were from local/crude unrefined sources. The medicines were placed in coded glass bottles, placed in dark containers at ambient temperature (25±3ºC), and promptly taken to the laboratory for analysis. The study was conducted from January 2024 to October 2024.

Chemicals, reagents and instruments

The chemicals used for this research were of the analytical grade procured from Fisher Scientific (Thermo Fisher Scientific, America). The Atomic absorption spectrometry (AAS) system used for the heavy metals analysis was purchased from Fisher Scientific Ltd.

Determination of heavy metals

The metals (cadmium "Cd", arsenic "As", lead "Pb", chromium "Cr", nickel "Ni", copper "Cu", zinc "Zn" and mercury "Hg") levels in the herbal samples were determined, by employing the appropriate ASTM approved procedures (ASTM D1971-16, 2021). 10 mL or its equivalent of each HM, was digested with 50 mL of a prepared mixture, that contained concentrated HNO_3 and H_2O_2, mixed at a ratio of 4:1. A temperature of 100±5ºC was used for the digestion until a clear product was achieved. The digested specimen was cool to room temperature (25±4ºC), sieved, and diluted to 100 mL using deionized water (Uguru *et al.,* 2023). Thereafter, elemental contents of the digested sample as measured, by using atomic absorption spectrophotometer (AAS) system. The detection limits of elements were 1, 3, 1, 2, 3, 1 and 3 ppb, for Cd, Pb, Cr, Hg, Cu, Ni, As and Zn, respectively.

Microbial population

The microbial evaluation of the herbal materials was conducted in accordance with standard strategies (WHO, 2007). After the incubating period, the colony-forming units per gram (cfu/g) were computed, through multiplication of the mean colonies quantity by the dilution factor, and the total bacterial count (TBC) and total fungal count (TFC) population documented.

Electrical properties

The HMs dielectric constant (ε′) levels were determined at 1 MHz frequency, though the processes employed by these authors (Hong *et al*., 2024; Šegatin *et al*., 2020). The ε′ value was calculated through the formula shown in Equation 1.

$$E' = \frac{Cps}{kc} \qquad 1$$

Where Cps = sample parallel capacitance corrected for 'stray' capacitance, and Kc = average cell constant (Šegatin *et al*., 2020)

Health risk assessment

The oral absorption (ingestion) method assessed the serious internal health risks of heavy metal exposure in humans, focusing solely on herbal products extracted with powder, water, and ethanol during evaluation (Luo *et al.,* 2021).

Daily intake dose (EDI)

The EDI was calculated through Equation 2.

$$BDI = \frac{C \times IR}{BW} \qquad 2$$

Where C = metal level in the herbal preparations, IR = mean daily ingestion rate and was taken to be 20 g/person/day (Meseret *et al*., 2020), BW = individual body weight, which was taken to be 25 kg for children and 75 kg for adults (Uguru *et al*., 2023), CF = conversion factor from g/person/day to mg/person/day, and it was 0.001.

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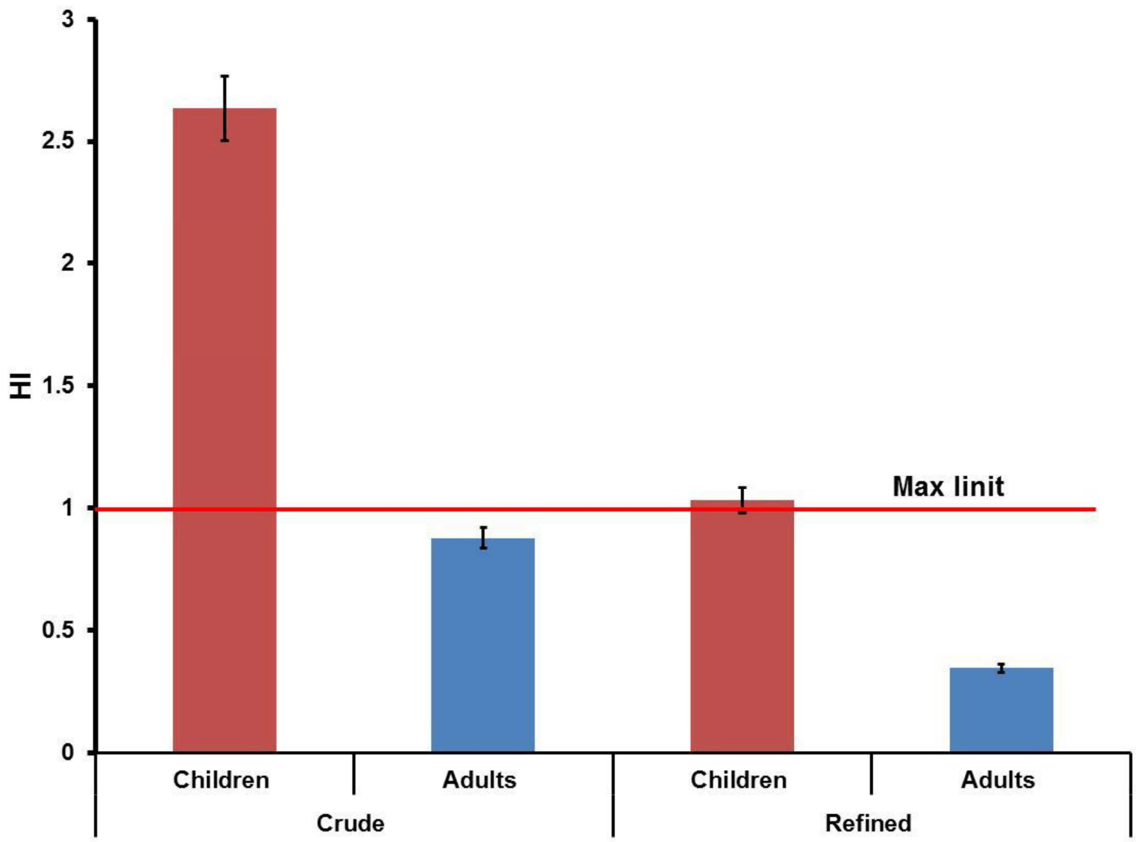

Fig. 1: The HI values of the herbal medicines

Table 1: Heavy metals levels in the herbal medicines (mg/kg)

Metal		Powder	Water	Ethanol	Cream	Soap	WHO*
Cd	L	0.772^{b}±0.929	0.760^{b}±0.779	0.675^{a}±0.758	0.681^{a}±0.893	0.651^{a}±0.754	0.3
	R	0.142^{c}±0.248	ND	0.104^{b}±0.171	0.044^{a}±0.058	0.063^{a}±0.079	0.3
Pb	L	0.968^{c}±1.353	0.848^{b}±1.066	0.764^{a}±0.919	0.951^{c}±1.083	0.733^{a}±1.053	10
	R	0.317^{c}±0.459	ND	0.215^{b}±0.322	0.092^{a}±0.119	0.093^{a}±0.126	10
Cr	L	0.737^{d}±0.831	0.567^{b}±0.649	0.462^{a}±0.411	0.579^{b}±0.638	0.615^{c}±0.726	2
	R	0.201^{c}±0.349	ND	0.133^{b}±0.240	0.139^{b}±0.161	0.069^{a}±0.116	2
As	L	0.406^{c}±0.487	0.446^{d}±0.435	0.346^{a}±0.376	0.362^{b}±0.446	0.350^{a}±0.402	10
	R	0.236^{c}±0.370	ND	0.180^{b}±0.257	0.014^{a}±0.018	0.017^{a}±0.022	10
Ni	L	1.419^{c}±1.468	1.185^{d}±1.170	1.038^{a}±1.068	1.315^{c}±1.164	1.140^{b}±1.113	NA
	R	0.055^{b}±0.088	ND	0.040^{a}±0.061	0.073^{c}±0.057	0.053^{b}±0.058	NA
Hg	L	0.194^{c}±0.257	0.183^{b}±0.229	0.148^{a}±0.208	0.182^{b}±0.231	0.178^{b}±0.219	1.0
	R	0.036^{b}±0.045	ND	0.025^{a}±0.031	0.054^{c}±0.045	0.027^{a}±0.045	1.0
Cu	L	10.698^{d}±8.981	8.962^{b}±6.883	7.887^{a}±6.233	9.159^{c}±6.262	8.893^{b}±7.039	20
	R	8.753^{c}±6.981	ND	5.671^{b}±4.121	4.917^{a}±4.340	5.365^{b}±5.113	20
Zn	L	13.495^{d}±9.889	10.629^{b}±6.73	11.380^{c}±6.803	10.967^{b}±8.751	9.855^{a}±7.906	50
	R	10.132^{c}±6.737	ND	7.252^{a}±3.937	7.883^{b}±3.860	7.586^{b}±3.927	50

L = Crude HMs, R = Refined HMs, ND = not determined, WHO* = (WHO, 2007), Mean ± standard deviation, NA = not available, for same metal and HM type- columns with the same common letter (superscript) indicate that they are not significantly differ at p ≤0.05 using DMRT,

Table 2: Estimated Daily Intake (mg/kg/day) and HQ values of the heavy metals

	EDI (mg/kg/day)				HQ			
	Crude		Refined		Crude		Refined	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
Cd	5.89E-04	1.96E-04	9.84E-05	3.28E-05	5.89E-01	1.96E-01	9.84E-02	3.28E-02
Pb	6.88E-04	2.29E-04	2.13E-04	7.09E-05	4.91E-01	1.64E-01	1.52E-01	5.07E-02
Cr	4.71E-04	1.57E-04	1.34E-04	4.45E-05	1.57E-01	5.24E-02	4.45E-02	1.48E-02
As	3.19E-04	1.06E-04	1.66E-04	5.55E-05	1.06	3.55E-01	5.55E-01	1.85E-01
Ni	9.71E-04	3.24E-04	3.80E-05	1.27E-05	4.86E-02	1.62E-02	1.90E-03	6.33E-04
Hg	1.40E-04	4.67E-05	2.44E-05	8.13E-06	7.00E-02	2.33E-02	1.22E-02	4.07E-03
Cu	7.35E-03	2.45E-03	5.77E-03	1.92E-03	1.84E-01	6.12E-02	1.44E-01	4.81E-02
Zn	9.47E-03	3.16E-03	6.95E-03	2.32E-03	3.16E-02	1.05E-02	2.32E-02	7.73E-03

Table 3: The CR and TCR values of the toxic metals

Metal	Unrefined		Refined	
	Children	Adults	Children	Adults
Cd	2.24E-04	7.46E-05	3.74E-05	1.25E-05
Pb	5.85E-06	1.95E-06	1.81E-06	6.03E-07
Cr	2.36E-04	7.85E-05	6.68E-05	2.23E-05
As	4.79E-04	1.60E-04	2.50E-04	8.32E-05
Ni	8.16E-04	2.72E-04	3.19E-05	1.06E-05
		TCR		
	Children	Adults	Children	Adults
	1.76E-03	5.87E-04	3.88E-04	1.29E-04

Table 4: Microbial population of herbal medicines ($x10^4$cfu/g)

State		Bacteria	Fungi	WHO*
Powder/dried	Crude	28.93^d±39.60 (0.2-152)	25.09^c±32.36 (0.3-135)	cfu/g ≤ 10^5
	Refined	9.95^b±3.38 (0-51)	9.18^a±9.86 (0-38)	cfu/g ≤ 10^5
Liquid - WE	Crude	19.36^b±27.45 (0.06-106.82)	12.84^a±19.97 (0.04-84.8)	cfu/g ≤ 10^5
Liquid - EE	Crude	14.77^d±20.65 (0.05-81.05)	9.60^c±14.37 (0.03-62.75)	cfu/g ≤ 10^5
	Refined	3.25^b±4.94 (0-18.26)	2.04^a±2.64 (0-11.97)	cfu/g ≤ 10^5
Cream	Crude	14.19^d±18.79 (0.05-76.86)	11.25^c±14.69 (0.17-64.98)	cfu/g ≤ 10^5
	Refined	2.57^a±2.39 (0.02-8.67)	3.05^b±2.90 (0.01-12.86)	cfu/g ≤ 10^5
Soap	Crude	8.80^d±8.70 (0.04-41.54)	6.49^c±6.81 (0.09-28.19)	cfu/g ≤ 10^5
	Refined	2.43^a±2.61 (0.05-10.17)	2.67^b±2.76 (0.03-11.25)	cfu/g ≤ 10^5

WE ~ Water extracted, EE ~ Ethanol extracted, Mean ± standard deviation and range in parentheses, rows having the same common letter (superscript) specify that they are significantly similar (p ≤0.05) using DMRT, * ~ WHO Standards (WHO, 2007).

Table 5: The HMs dielectric properties

State	Level	Dielectric constant
Powder/dried	Crude	50.29^h±9.43 (34-69)
	Refined	39.15^g±8.21 (27-55)
Liquid – WE	Crude	92.67^i±7.82 (78-106)
Liquid – EE	Crude	32.14^f±7.09 (24-52)
	Refined	24.05^e±5.71 (18-41)
Cream	Crude	20.76^d±4.92 (14-34)
	Refined	15.85^c±4.91 (9-27)
Soap	Crude	9.19^b±3.33 (4-16)
	Refined	7.35^a±2.76 (4-13)

Mean ± standard deviation and range in parentheses; rows sharing similar superscript letter designate no significant differences (p ≤ 0.05) according to DMRT.

Non-carcinogenic risk

The hazard quotient (HQ) and hazard index (HI) of the metals were computed using Equations 3 and 4.

$$HQ = \frac{EDI}{RfD} \quad 3$$

$$HI = \Sigma HQ \quad 4$$

Where RfD = Reference dose, with Cd, Pb, Cr, As, Ni, Hg, Cu and Zn values of 0.001, 0.0014, 0.003, 0.0003, 0.02, 0.002, 0.04 and 0.3 $mgkg^{-1}day^{-1}$, respectively (Meseret *et al.*, 2020; Uguru *et al.*, 2024).

Carcinogenic risk

The carcinogenic risk values were calculated using Equations 5 and 6 (Uguru *et al.*, 2023).

$$CR = EDI \times CSF \quad 5$$

$$TCR = \Sigma CR \quad 6$$

Where CSF= cancer slope factor (oral) for the PTMs - Cd (0.38), Pb (0.0085), Cr (0.5), As (1.5) and Ni (0.84) (Uguru*et al.*, 2023).

DATA ANALYSIS

The data obtained from this research were analyzed through Analysis of variance by employing SPSS software (version 22). Additionally, the average results were separated using the Duncan's Multiple Range Test (DMRT) at 5% significant level ($p \leq 0.05$). All the tests were conducted in triplicates.

RESULTS

Heavy metals content

The results of the heavy metals concentrations for HMs are presented in table 1. It was observed that there were significant differences among the mean values of the different herbal products (table 1). Notably, Zn recorded the maximum concentration in the local powdered, refined powdered and water-solvent extracted botanical medicines, with values of 13.495, 10.132 and 10.629 mg/kg, respectively. Similarly, it was noted that in the crude ethanol extracted, refined ethanol extracted, unrefined soap, and refined soap herbal medicines, zinc still maintained the maximum concentration, with an average value of 11.380, 7.252, 9.855 and 7.586 mg/kg, respectively. Additionally, the results revealed that the unrefined cream (pomade) and refined herbal cream medicines, exhibited the highest zinc concentrations, with a mean value of 10.967 and 7.8832 mg/kg, respectively.

Health risk assessment

Non - carcinogenic risk

Table 2 presents the EDI and HQ values of the PTMs investigated in this study. For the crude herbal products, the EDI values ranged from 4.67 $x10^{-5}$ to 9.47 $x10^{-3}$ mg/kg/day, while for their refined counterparts, the EDI values varied from 8.13 $x10^{-6}$ to 6.95 $x10^{-}3$ mg/kg/day. The HQ values depicted that the crude products ranged from 1.05 $x10^{-2}$ to 1.06, while the refined products HQ values varied between 6.33 $x10^{-4}$ and 5.55 $x10^{-1}$. Similarly, the HI results presented in fig. 1 revealed that HI values for the crude HMs were 2.635 and 0.878 for children and adults, respectively; while for the refined HMs, the values for the children and adults were 1.031 and 0.344, respectively.

Carcinogenic risk

The calculated CR and TCR results of the PTMs evaluated in this study are presented in table 3 shows that in the crude HMs, the CR values ranged from 5.85 $\times10^{-6}$ to 8.16 $\times10^{-4}$ for children and 1.95 $\times10^{-6}$ to 2.72 $\times10^{-4}$ for adults. Then in the refined HMs, the CR values varied from 1.81 $\times10^{-6}$ to 2.50 $\times10^{-4}$ and 6.03 $\times10^{-7}$ to 8.32 $\times10^{-5}$ for the children and adults, respectively. Additionally, the total carcinogenic risk (TCR) results depicted that the TCR values for the children and adult for unrefined HMs were 1.76 $\times10^{-3}$ and 5.87 $\times10^{-4}$, respectively. However, in the refined HMs, it was noted that the TCR values for the children and adult categories were 3.88 $\times10^{-4}$ and 1.29 $\times10^{-4}$, respectively.

Microbial load

The results of the microbial population in the herbal medications are presented in table 4. It was observed that the TBC and TFC in the HMs varied from 2.43 $x10^4$ to 28.93 $x10^4$cfu/g, and from 2.04 $x10^4$ to 25.09 $x10^4$cfu/g, respectively. The crude HMs exhibited higher microbial levels compared to the refined products, which can be attributed to the higher hygienic procedures strictly adopted during refined products preparation and packaging unit operations (de Sousa *et al.*, 2020; Alharbi *et al.*, 2024).

Electrical properties

The results of the dielectric constant (ε′) are presented in table 5. It was noted that the dielectric constant varied widely among the medical products. The ε′ values of the herbal materials studied varied between 7.35 and 92.67, which is an indication of wide electrical behavior of the herbal mediations.

DISCUSSION

Heavy metals concentration

This research has established that the refined HMs recorded lower metals levels. This situation can be correlated with effective refining and storage operations (Kandić *et al.*, 2023; Hu *et al.,* 2024). Fascinatingly, the results revealed that apart Cd concentration degree in the crude powder herbal product, the concentrations of the remaining heavy metals, regardless of the HMs nature were below the World Health Organization approved maximum allowable limits for metals. Notably, most HMs tend to have higher Cd levels, as earlier buttressed and published by these researchers (AJeroho *et al.*, 2018; Kandić *et al.*, 2023; Bhalla and Pannu, 2020).

The mean Hg levels recorded in this study were lower than those reported by Bhalla and Pannu (2020), higher than the findings of Kandić *et al.* (2023), and within the range of values obtained by Wu *et al.* (2022). Also, the Pb concentrations obtained for this study were smaller than the values reported by Wu *et al.* (2022) and Meseret (2020). However, the Cr, Zn and Cu concentrations observed in this study were below the WHO maximum limits (Cr = 2 mg/kg, Cu = 20 mg/kg, Zn = 50 mg/kg). The presence of toxic heavy metals in the HMs may be related to environmental pollution in the area, where the herbal plants thrived or during the production processes (Wu *et al.,* 2022; Uguru *et al.*, 2023; Asiminicesei *et al.*, 2024).

Toxic metals like Pb, As, Cd, and Hg, noted in significant levels in this study, are deemed hazardous by the US Agency for Toxic Substances and Disease Registry (ATSDR) (ATSDR, 2019). Long-term Cd exposure can cause issues in cancer, kidneys, lungs, and renal tract (Uguru *et al.,* 2023). Chronic As exposure is linked to cancer diseases; Hg toxicity affects kidney and the nervous system; while Zn toxicity can lead to mucormycosis (Bhalla and Pannu, 2020; Yao *et al.,* 2024).

Health risk assessment

The calculated health hazards associated with the HMs consumption indicated that the medications are largely safe for human ingestion. Generally, the EDI values indicate that the refined medicines pose lower health risks, aligning with the findings reported by Kandic` *et al.* (2023). Except for arsenic in children, human exposure to heavy metals poses no significant health risks, since hazard quotient values exceeded 1 in all age groups. The high Pb and As HQ values documented in this research are similar to the findings of Wu *et al.* (2022) and Kandic´ *et al.* (2023), indicating that great concern should be given to contamination by these metals in phytomedicines. Furthermore, the HI results (table 2) indicated significant non-cancerous health risks for children exposed to these phytomedicines, as their HI values exceeded 1 for both crude and refined forms (USEPA, 1986; Uguru *et al.*, 2023). This study's findings align with those of Meseret *et al.* (2020) and Kandić *et al.* (2023), highlighting the dangers of toxic metal contamination in herbal medicines. The close proximity to the critical threshold of 1 necessitates urgent attention to mitigate potential heavy metal toxicity risks (Yang *et al.*, 2021).

This study's Carcinogenic risk results outcome revealed that the refined HMs exhibited lower carcinogenic risks compared to their unprocessed counterparts. This aligned with previous authors (Yang *et al.*, 2021 and Wu *et al.*, 2022) reports, which stipulated that refining processes tend to reduce the toxicity and carcinogenic potentials of HMs. This research's TCR values revealed that intake of these crude HMs posed serious carcinogenic health risks to the children, as the TCR values were below 1.00 x10^{-4}. According to World Health Organization, TCR values below 1.00 × 10^{-4} is considered dangerous and carcinogenic (Uguru *et al.*, 2024). The study's outcomes have highlighted the potential health hazards associated with crude biomedicines.

Microbial load

The pathogenic evaluation results depicted that the TBC and TFC population in most of the un-refined herbal medicines exceeded the safe borders (cfu/g ≤ 10^5) approved by the WHO for herbal medications (WHO, 2007). This shows that un-refined biomedicines have a lot of health complications, observation aligning with previous reports of these scientists (Yesuf *et al.*, 2016; de Sousa *et al.* 2020). Remarkably, the microbial populations obtained in this investigation, were comparatively less than outcomes reported by Yesuf *et al.* (2016), regarding HMs in Ethiopia.

Additionally, the pathogenic levels detected in the refined biomedicines, might be caused by cross contamination, primarily due to insanitary (de Sousa *et al.*, 2020; Ekeleme *et al.,* 2024; Alharbi *et al.*, 2024). Furthermore, ethanol's antiseptic characteristics can be attributed to the lower pathogenic growth observed mostly in the ethanol based biomedicines formation (Gonelimali *et al.*, 2018). The large microbial population thieving in the crude HMs, will reduced their efficacy, and can also results in adverse health challenges (Yesuf *et al.*, 2016).

Electrical properties

Interestingly, this research's verdicts illustrated that most herbal drugs have substantial dielectric properties, which will affects their efficiency. Lesser dielectric constant identified in the refined products, may be attributed to the lower impurities they have. Dielectric properties can alter drugs absorption and dissemination rates; and higher ε′ tends to increases the possibilities of adverse drugs side effects (Hong *et al.*, 2024). The elevated ε′ recorded from water based products, can be linked to water's polarity, which increases solubility and mobility of bioactive compounds (Brini *et al.*, 2017).

Furthermore, the ε′ of the biomedicines appraised in this study, were lower than Abdul *et al.* (2018) findings; however, they aligned with Hong *et al.* (2024) and Lahane (2016) reports. The discrepancies noted among the dielectric properties values - as obtained by various researchers, might be linked to environmental factors, processing approaches, moisture content, and the machines settings (Kandić *et al.*, 2023. According to Abdul *et al.* (2020), dielectric constant of materials is highly dependent on the frequency used for the measurement, and lower frequency tends to produce higher ε′ values. Dielectric constant has been identified as an indispensable factor that is employed to identify drugs safety.

CONCLUSION

The increasing demand for alternative medications has spawned considerations, regarding their efficacy and health implications. This research was conducted to assess the safety of herbal medicines (HMs), and to propose solutions to their limitations. The microbiological, heavy metals and electrical properties of biomedical drugs were measured in harmony with standard approaches. Interestingly, the laboratory outcomes depicted that crude herbal drugs posed serious health implications. The results further shown that, the refined herbal medications have lower toxic metals concentrations, pathogenic loads, and dielectric constant (ε′) values. Notably, the crude HMs microbial loads, surpassed the WHO's approved maximum limits for drugs safety. The findings highlighted that refined HMs, cannot be directly correlated to either non-carcinogenic or carcinogenic diseases, which portrays their safeness. Findings of this study have underscored that caution should be taken, when taking unregistered biomedicines, and consistent monitoring of herbal drugs formulation and medication. Also, children should be given special attention when administering herbal medications.

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Conflict of interest
There are no conflict of interest.

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