African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 8, Issue 2, 2025 (pp. 52-74) www.abjournals.org

ASSESSMENT OF NUTRITIONAL QUALITY AND HEAVY METAL CONTAMINATION IN SOME VEGETABLES FROM THE MEZAM DIVISION, NORTHWESTERN REGION OF CAMEROON: HEALTH RISK IMPLICATIONS

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Cite this article:

Alakeh, M. N., Ngeneform, N. Y., Cornelius, T. (2025), Assessment of Nutritional Quality and Heavy Metal Contamination in Some Vegetables from the Mezam Division, Northwestern Region of Cameroon: Health Risk Implications. African Journal of Agriculture and Food Science 8(2), 52-74. DOI: 10.52589/AJAFS-RDQHUOJB

Manuscript History

Received: 2 Apr 2025

Accepted: 7 May 2025

Published: 30 May 2025

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ABSTRACT: *Vegetables are vital for nutrition, yet their nutritional quality and heavy metal content related to agricultural practices remain underexplored in the Mezam Division (MD), Northwest Region of Cameroon. This study aimed to identify prevalent agricultural practices related to soil amendments and pest management, and assess the carcinogenic effects of four commonly consumed vegetables: carrot (Daucus carota ssp. sativa), cabbage (Brassica oleracea), leek (Allium ampeloprasum), and tomatoes (Solanum lycopersicum), which were grown in three localities within the MD. A semi-structured questionnaire was used to gather information on farmers' practices, whereas standard analytical methods were used to assess proximate composition, vitamin C content and heavy metal concentrations. Health risk assessments have investigated estimated daily intake (EDI), hazard index (HI), and target cancer risk (TCR) models. The results revealed no significant differences ($P > 0.05$) in proximate composition among vegetables from the different localities. The moisture content and carbohydrate content ranged from 84.032±25% to 94.750±0.23% and from 1.990±0.52% to 12.279±2.82%, respectively. The crude fibre content ranged from 1.133% to 2.685%, and the ash content ranged from 0.416±0.01% to 1.706±0.04%. The protein and vitamin C contents varied from 0.713±0.061% to 1.484±0.21% and from 5.090±0.12% to 44.900±0.06%, respectively. Chromium (0.557 to 1.318 mg/kg), cadmium (0.942 to 1.885 mg/kg), and lead (1.552 to 2.154 mg/kg) exceeded the FAO/WHO limits. HI indicated a noncarcinogenic risk greater than unity, and the TCR values surpassed the 1×10^{-4} threshold, suggesting that long-term consumption poses cancer risks. The results of this study underscore the need for improved agricultural practices and monitoring of heavy metal contamination in vegetables to safeguard public health in the Mezam Division.*

KEYWORDS: Vegetables, nutritional quality, heavy metals, health risk assessment, Mezam division and agricultural practices.

Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

INTRODUCTION

Vegetables are essential components of the human diet, providing vital nutritional elements necessary for the maintenance of optimal health. In numerous regions globally, vegetables constitute a significant portion of human dietary intake and are integral to human nutrition (Fonge et al., 2021). They serve as important sources of vital vitamins, including A, B1, B6, B9, C, and E, as well as key minerals such as calcium, iron, potassium, zinc, and copper (Butnariu, 2014). Additionally, vegetables contribute dietary fiber and phytochemicals, including phenolic compounds, flavonoids, and bioactive peptides (Dias & Ryder, 2011). The rising global emphasis on healthy living has led to an increased consumption of fruits and vegetables, which are frequently consumed in their raw or lightly cooked forms (Feroz et al., 2013). Acknowledging the significance of vegetables in a nutritious diet, various health organizations and associations, including the United States Food Pyramid, advocate for the intake of 3–5 servings of vegetables daily (World Health Organization, 2016; Fonge et al., 2021). The nutritional composition of vegetables, coupled with the growing recognition of their health benefits, has established them as a fundamental component of balanced and health-promoting diets worldwide.

Mezam Division (MD) is situated in the North West region of Cameroon, where the local population primarily relies on agriculture for their livelihoods, particularly in the cultivation of vegetables. This division is recognized as one of the major producers of vegetables, including carrot (*Daucus carota*), cabbage (*Brassica oleracea*), leek (*Allium ampeloprasum*), celery (*Apium graveolens*), onion (*Allium cepa*), and Irish potatoes (*Solanum tuberosum*), among others, within Cameroon (Pouokam et al., 2017). The agricultural output from MD is not only consumed locally within the Northwest Region but is also distributed to other regions, including the West, Southwest, and Centre, as well as to neighboring countries in the Central African Economic and Monetary Community (CEMAC) zone, such as Gabon, Equatorial Guinea, the Republic of Congo, Chad, the Central African Republic, and Nigeria (Amawa et al., 2015; Bidogeza et al., 2016). Consequently, any compromise in the quality and safety of the vegetables produced in this region could have significant health implications for a substantial portion of Central Africa. Furthermore, the difficulties associated with securing extensive agricultural land for vegetable cultivation have resulted in the repeated use of the same plots of land for prolonged periods. The ever-increasing demand for vegetables has prompted farmers to seize the opportunity for year-round cultivation. This practice of excessive farming leads to the depletion of vital soil nutrients necessary for optimal plant growth, compelling farmers to depend on soil amendments to maintain production levels and enhance vegetable yields (Amawa et al., 2015). Moreover, rapid industrialization and development have contributed to the introduction of hazardous heavy metals into the environment via air, soil, water, and ultimately, plants (Kumar et al., 2019). Additionally, agrochemicals, including fertilizers, pesticides, and herbicides, have been identified as potential sources of heavy metal contamination, often being misapplied, particularly in developing nations.

Agricultural practices, including the indiscriminate use of fertilizers and pesticides by vegetable growers and poor water quality, characterize vegetable production in most parts of Cameroon, including the MD (Fonge et al., 2021). These agricultural practices may have a great impact on the quality and safety of vegetables consumed not only in MD but also throughout Central Africa. Several studies have been conducted in other parts of the world to assess the health risk associated with exposure to carcinogenic heavy metals from the

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consumption of vegetables (Mahfuza et al., 2017; Zahfardazeh et al., 2018). Similar studies have been conducted in Nigeria (Orish et al., 2012; Berniah & Christian, 2020; Onyedikachi et al., 2021) to assess the heavy metal exposure risk associated with the consumption of indigenous vegetables. Most studies carried out in MD are limited to characterizing agricultural soils and determining farmers' agricultural practices without examining the impact of these practices on food safety. The quality and safety of vegetables in relation to agricultural practices in MD have not been adequately assessed, although Fonge et al. (2021) carried out a study on the assessment of heavy metal exposure risk associated with the consumption of cabbage and carrot grown in Santa. This study was limited to only the Santa Subdivision and two vegetables. This study aimed to identify the most prevalent agricultural practices used in vegetable cultivation, particularly soil amendment and pest management; assess the proximate and vitamin C compositions; determine the levels of carcinogenic heavy metals (cadmium, lead, and chromium) present in four selected vegetables (tomato, cabbage, leek and carrot) grown in three localities (Tubah, Bamenda III and Santa) in the MD; and assess cadmium, lead and chromium-related carcinogenic and non-carcinogenic health risks associated with the consumption of the selected vegetables grown in these three localities.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Mezam Division, which is located in the Northwest Region (N.W.R.) of Cameroon. The region is geographically located within the western highlands of the nation, positioned between latitudes 5°40' and 7°50' north and longitudes 9°80' and 11°51' east of the Greenwich Meridian. It encompasses a total surface area of 1,841.45 km² and it had a population of 524,127 according to the 2017 census (Mukete et al., 2021). Administratively, the area is divided into seven subdivisions: Bamenda I, Bamenda II, Bamenda III, Bafut, Bali, Santa, and Tubah (Mamoudou et al., 2016) (Fig 1).

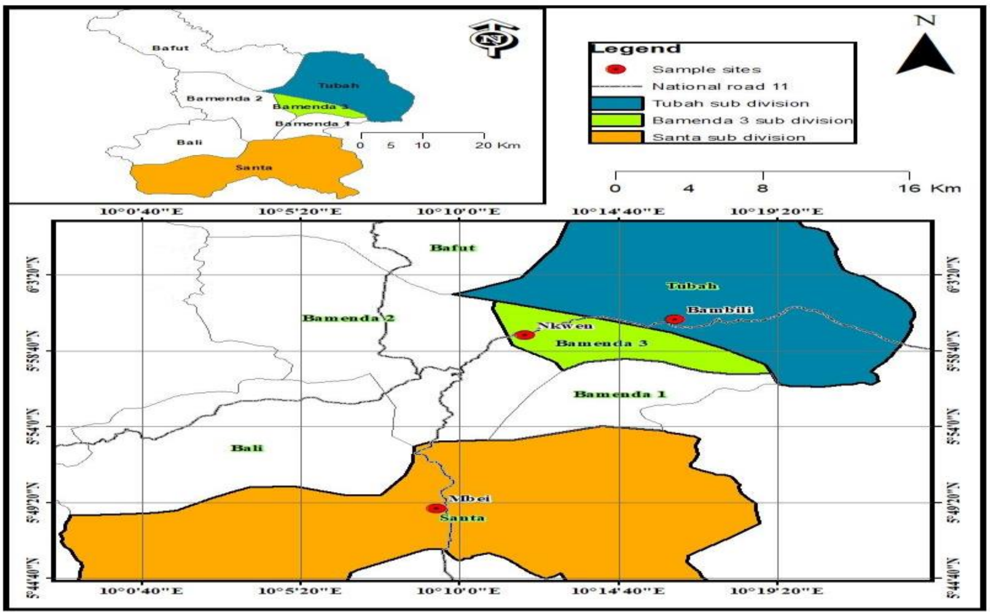

Fig. 1: Location and layout of sample sites in the Mezam Division, N.W.R., Cameroon

Article DOI: 10.52589/AJAFS-RDQHUOJB
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Inventory of the study area and administering questionnaire

To investigate the prevalent agricultural practices in terms of fertilizer and pesticide applications by vegetable farmers, as well as their knowledge of the adverse effects of agrochemicals, a cross-sectional study was conducted in the Mezam division. Seventy-five farmers were randomly selected from the three subdivisions within Mezam for the survey. A semi-structured questionnaire was designed and used to collect information on the farmers' current agricultural practices, including the types and frequencies of fertilizer and pesticide applications, the reasons for using these agrochemicals, and their perceptions of the potential impacts on the environment and human health. The questionnaire also assessed the farmers' knowledge and awareness of the adverse effects of excessive or improper use of agrochemicals, such as risks to consumer health. This questionnaire was administered at random through face-to-face interviews and friendly discussions with the selected farmers.

Sample Collection

Vegetable samples were collected from three subdivisions in Mezam, Tubah (Bambili), Bamenda III (Nkwen) and Santa (Mbei), on the basis of the classification of plants according to their edible parts (Table 1).

Table 1: The different vegetables studied

Common name	Scientific name	Family	Part used
Tomato	*Solanum lycopersicum*	Solanaceae	Fruit
Leeks	*Allium ampeloprasum*	Amaryllidaceae	Stem
Cabbage	*Brassica oleracea*	Brassicaceae (Cruciferae)	Leaves
Carrot	*Daucus carota*	Apiaceae (Umbelliferae)	Root

Each subdivision was considered a study site. At each study site, farms with monocropping systems were selected for sampling carrots, leeks, cabbage and tomatoes. The global positioning system (GPS) coordinates of all the farms were recorded via GPS Waypoint version 3.12 (Table 2). A one-kilogram sample of each vegetable was obtained at the point of optimum maturity, and each sample was collected in triplicate. The samples were placed in labelled polythene bags and immediately transferred to the laboratory for preservation and analysis.

Table 2: Study sites with their coordinates and descriptions

Study site	Sample	Longitude	Latitude	Description
Mbei	Tomatoes and Leeks	10° 9'31.02"E	5°49'9.45"N	Agricultural area and farms located on a slope of 0-2% surrounded by other vegetable farms.
	Cabbage	10° 9'10.05"E	5°48'44.20"N	
	Carrots	10° 9'3.89"E	5°48'58.60"N	
Nkwen	Carrots	10°11'48.00"E	5°59'44.57"N	

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	Cabbage and Leeks	10°10'44.52"E	5°59'35.32"N	Farms surrounded by garden egg, celery and nightshade farms and approximately 2 km from the main road.
	Tomatoes	10°11'24.00"E	5°59'41.61"N	
Bambili	Carrots and Cabbage	10°14'43.98"E	5°56'55.42"N	Farms located on a slope of 0-3% 4 km from lake Bambili surrounded by a ranch and potatoes farm.
	Tomatoes and Leeks	10°15'11.53"E	5°59'28.39"N	Vegetable farm located about a kilometer away from the main road leading to Bambili palace surrounded by a stream and an African nightshade farm.

Sample Preparation and Analytical Procedures for the Determination of the Proximate and Vitamin C Compositions

The vegetable samples were properly washed under flowing tap water and then reduced to appropriate sizes via a stainless-steel knife to facilitate analysis. The proximate compositions of the vegetable samples were analysed for moisture, ash, protein, fibre and fat contents via the AOAC protocol (AOAC, 2016). The carbohydrate contents of the vegetable samples were determined via subtraction (Ajenu et al., 2016).

Determination of Moisture Content

Five grams of the homogenized sample was placed in a previously weighed aluminum can, and the weight of the can plus sample was recorded. The mixture was then placed in a drying oven and heated at 105 ℃ for 24 h to a constant weight, after which it was removed and cooled in a desiccator for approximately 10 minutes.

$$\text{Moisture (\%)} = \frac{weight\ of\ H2O\ in\ sample}{weight\ of\ sample} \times 100 \tag{1}$$

$$\text{Moisture (\%)} = \frac{(weight\ of\ wet\ smple + can) - (weight\ of\ dry\ sample + can)}{(weight\ of\ wet\ sample + can) - (weight\ of\ can)} \times 100 \tag{2}$$

Determination of Ash Content

Two grams of each sample was placed into previously weighed crucibles and reweighed. The sample was then placed in a muffle furnace and burnt at 550 ℃ for 3 hours until whitish gray ash formed, ensuring that the sample was free of carbon. The crucibles were transferred to a desiccator and allowed to cool at room temperature, after which their weights were measured. The weight of the ash was then calculated via Equation 3.

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Ash content (%) = $\frac{weight\ of\ ash}{sample\ weight} \times 100$ (3)

Weight of ash =$weight\ of\ crucible + ash - weight\ of\ empty\ crucible$

Weight of sample = (weight of crucible + fresh sample)– (weight of empty crucible)

Determination of the Crude Fibre Content

Two grams of sample was weighed and placed in a conical flask, 200 mL of 0.128 M sulfuric acid was added, and the mixture was boiled under reflux for 30 minutes. The boiled sample was then washed several times with hot water to remove all the acid. The mixture was filtered to trap the remaining particles, which were placed in a conical flask, and 200 mL of 0.313 M sodium hydroxide was added. A few drops of n-octanol were added as antifoaming agents, and the mixture was boiled again for 30 minutes. After boiling, the mixture was washed again with hot water and filtered through watt-man filter paper. The particles collected were dried in an oven (ROYAL CAREUK-DNP-9022A) at 105 ℃ for 3 hours. After drying, the residue was weighed to obtain the weights of the ash and fibres. The dried residue was charred in a muffle furnace (SUPERTEK-SN-1035) at 550 ℃ for 3 hours to burn off the fibre, and the remaining ash in the crucible was weighed again. The crude fibre content of the sample was calculated via Equation (4).

Crude fibre (%) $= \frac{weight\ of\ fibre}{weight\ of\ sample} \times 100$ (4)

where:

Weight of fibre = (weight of ash + fibre) – weight of ash

Determination of Crude Fat Content

A Soxhlet extraction unit was set up with a reflux condenser. A clean 250 mL round bottom flask was half filled with 350 mL of n-hexane and fixed into the extraction unit (boiling point 68-69 ℃). Two grams of each sample was wrapped in Whatman filter paper and gradually lowered into the thimble of the extractor. Fat was extracted for 6 hours using hexane. After evaporating the solvent, the samples were dried to a constant weight in an oven at 105 ℃ for 3 hours. The samples were cooled in a desiccator and weighed to determine the amount of fat extracted. The crude fat content was calculated via Equation (5).

Crude fat content (%) = $\frac{weight\ loss\ (w2-w3)}{Sample\ weight\ (w1)}$×100 (5)

where:

W_1 = *Weight of sample*

W_2 = *Weight of sample + filter paper before drying*

W_3 = *weight of sample + filter paper after drying*

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Determination of Crude Protein Contents

Two grams of each sample was weighed and placed in a Kjedal digestion flask, and 0.7 g of copper sulfate catalyst + 7 g of potassium sulfate was added to increase the temperature of the reaction medium. Twenty milliliters of concentrated sulfuric acid was added to the flask, and the mixture was boiled at 350 ℃ until a clear digest was obtained. During the digestion step, protein in the form of nitrogen was converted to ammonium sulfate.

$$\text{Protein} \xrightarrow[\text{Heat,catalyst}]{\text{H2SO4}} (NH_4)_2SO_4$$

After digestion, the digest was diluted with distilled water to 100 mL. Ten milliliters of the digest was taken and placed in a distillation flask, and 50 mL of 40% sodium hydroxide was added to neutralize the acid, followed by the addition of 50 mL of distilled water for dilution. By doing so, the ammonium sulfate was converted to ammonia gas.

$$(NH_4)_2\ SO_4 + 2NaOH \longrightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

The resulting ammonia was distilled into 30 mL of 4% boric acid.

$$NH_3 + H_3BO_3 \longrightarrow NH_4 + H_2BO_3^-$$

The borate ion produced during distillation, which is proportional to the amount of nitrogen in the sample, was titrated with standardized 0.1 N hydrochloric acid using methyl red as an indicator, which changes from yellow at the beginning of the titration to orange at the end point.

$$H_2BO_3^- + H^- \longrightarrow H_3BO_3$$

The protein content of the sample was then calculated as follows:

$$\text{Protein content (\%)} = \text{Nitrogen content (N \%)} \times \text{Sample factor} \times \text{Dilution factor } (F_2) \qquad (6a)$$

where

The sample factor, e.g., wheat, is 5.7. Most other food samples are 6.25

The dilution factor was 10. (10 mL was taken from the 100 mL digest to distil; therefore, the dilution factor in this case was 100/10 =10.)

$$\text{Nitrogen content (N \%)} = \frac{V1\ x\ n1\ x\ F1\ x\ MWn}{Sw\ x\ 10} \qquad (6b)$$

where:

S_w is the weight of the sample

V_1 is the titre volume of 0.1 N HCL used

F_1 is the acid factor, which is 1 (because HCL is a monoprotic acid)

MWn is the molecular weight of nitrogen, which is 14.007

n_1 is the normality of HCL, which is 0.1.

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www.abjournals.org

Determination of Carbohydrate Content

Carbohydrate % = *100 - %(protein+ash+crude fibre+fat+moisture)* (7)

Determination of Ascorbic Acid Content in Vegetables

The ascorbic acid content of the selected vegetables was determined via the 2,6-dichlorophenol indophenol (DCPIP) titration method described by Rao and Deshpande (2006). Five milliliters of the ascorbic acid working standard (500 µg/5 mL) and 10 mL of 4% oxalic acid were pipetted into a 100 mL conical flask. The contents in the flask were titrated against the dye solution (V_1) until the appearance of a pale pink color that persisted for a few minutes. Five milliliters of the test sample was similarly titrated against the dye solution (V_2). The ascorbic acid content present in the test samples was determined via Equation 8.

$$\text{Amount of ascorbic acid (mg/100 g)} = \frac{500\ x\ V2\ x\ 25\ x\ 100}{V1\ x\ 5\ x\ 5} \quad (8)$$

where

500 = µg of standard ascorbic acid taken for titration

V_1 = volume of dye consumed by 500 µg of standard ascorbic acid

V_2 = volume of dye consumed by 5 mL of test sample

25 = corresponds to total volume of the extract

100 = ascorbic acid content/100 g of sample

5 = weight of sample taken for extraction and

5 = volume of the test sample taken for titration.

Preparation of Vegetable Samples for Heavy Metal Analysis

The vegetable samples were reduced to the appropriate size using a stainless-steel knife to facilitate dehydration. The chopped samples were subjected to dehydrator drying for approximately 24 h at 70°C. The dehydrated samples were crushed via a porcelain mortar and pestle and sieved through a 2 mm sieve. The powder obtained was packaged in transparent airtight plastic cups at room temperature to prevent moisture ingression prior to being transported to the Research Unit of Soil Analysis and Environmental Chemistry (RUSAEC), University of Dschang, for digestion and metal analysis.

Digestion and Metal Analysis

One gram of each sample was weighed, placed into a porcelain crucible and calcined in a Carbolite Eurotherm muffle furnace at a temperature of 450 °C for 2 hours to obtain ash. The ash was then digested with 10 mL of 1 N nitric acid. The mixture obtained was gently heated on a hot plate and stirred occasionally for approximately 30 minutes. The solution was allowed to cool, filtered through Whatman filter paper into 50 mL volumetric flasks and diluted to the mark with distilled water. The Pb, Cr and Cd contents in the samples were determined via standard volumetric and spectrophotometric analytical techniques (Pauwels et al., 1992).

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Determination of Health Risk

The health risk associated with the consumption of the selected vegetables was assessed by determining the estimated daily intake, target hazard quotient, hazard index and target cancer risk from the heavy metal concentrations obtained.

Noncarcinogenic Health Risk Assessment

Estimated Daily Intake (EDI)

The estimated daily intake (mg/person/day) of each studied metal was determined from the concentration of the metal in the plants via Equation (9):

$$\text{EDI} = \frac{C \times IR \times EF \times ED}{BW \times AT} \times 10^{-3} \tag{9}$$

where

C is the metal concentration (mg/kg dry weight)

IR is the average food (vegetable) consumption rate in the study area (220 g/person/day)

EF is the exposure frequency (365 days/year)

ED is the exposure duration or life expectancy of an adult (65 years), equivalent to the average lifetime

BW is the reference body weight for an adult (70 kg)

AT is the average exposure time over 65 years (23,725 days)

The value of 10^{-3} *is the unit conversion factor (Bambara* et al.*, 2023; Agbor* et al.*, 2024).*

Target Hazard Quotient (THQ)

The target hazard quotient (THQ) was used to assess the noncarcinogenic health risk (noncarcinogenic human toxicity) to humans who consume vegetables contaminated with heavy metals. The THQ values for the population consuming these vegetables were calculated via Equation (10).

$$THQ = \frac{EDI}{RfD} \tag{10}$$

where

EDI is the estimated daily metal intake of the population in mg/day/kg of body weight;

RfD is the value of the oral reference dose (mg/kg/day) for each metal of interest.

If the calculated THQ value is < 1, it indicates that consumption of vegetables is presumed safe, and if the THQ value is > 1, it indicates potential health risk due to the consumption of products with increasing probability as consumption increases (Bambara et al., 2023).

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Hazard Index (HI)

The hazard index characterizes the risk to the health of individuals linked to the accumulation of heavy metals in the same vegetable (Bambara et al., 2023). The hazard indices (HIs) of the studied metals were calculated via Equation (11).

$$HI = \sum THQ \quad (11)$$

Carcinogenic Health Risk Assessment

Target cancer risk (TCR)

The cancer risk (CR) in humans due to the ingestion of potentially carcinogenic heavy metals was estimated via Equation (12). The target cancer risk (TCR) resulting from the ingestion of heavy metals, which can cause cancer depending on the exposure dose, was subsequently calculated via Equation (13).

$$CR = EDI \times CPS0 \quad (12)$$

$$\sum_{i=1}^{n} CR_i\,; i = 1, 2, 3, \dots n \quad (13)$$

where

EDI is the estimated daily metal intake of the population in mg/day/kg body weight

CPS0 is the oral cancer slope factor in mg/kg day^{-1}

n is the number of heavy metals considered for the cancer risk calculation (Bambara et al.*, 2023).*

Data Analysis

Statistical analysis was conducted via SPSS v.20 for Windows and Statgraphics. The analysis involved ANOVA to assess overall differences between groups and t tests to compare means between specific pairs of groups, all at a 5% level of significance. The results were visualized via graphs and tables generated with SPSS v.20 for Windows. The health risk index was also used to analyse the data generated from heavy metal concentrations in vegetables.

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RESULTS AND DISCUSSION

Agricultural Practices

Information on Individuals' Farming Practices, Management and Crop Preparation

Information on individuals' farming practices and crop management practices is presented in Table 3.

Table 3: Information on individual farming practices, management and crop preparation

		Frequency/% of respondents
Vegetable type	Leafy	44.00
	Stem	23.00
	Root	14.00
	Fruit	19.00
Cultivation purpose	Sale	24.00%
	Consumption by family	20.00%
	Sale and family consumption	53.38%
Use of same farmland	Yes	78.46%
	No	21.54%
Soil amendment used	Organic only	21.54%
	Biofertilizer	3.08%
	Chemical fertilizer only	3.08%
	Chemical and organic fertilizers	72.31%
Fertilizer type	Urea	37.70%
	N.P.K	53.46%
	Phosphate	9.84%
Pest and disease management	Chemical pesticides	70.77%
	Crop rotation	20.00%
	Biological control	3.08%
	All.	6.15%
Pesticides used	Penncozeb	63.04%
	Balear	8.70%
	Mancozan super	28.26%

Forty-four (44) respondents cultivated mostly leafy vegetables, twenty-three respondents cultivated mostly stem vegetables, and fourteen and nineteen respondents cultivated both root and fruit vegetables, respectively. A total of 53.38% of these respondents cultivated these vegetables mostly for home consumption and sale purposes, whereas 20% and 24% cultivated these vegetables for the sole purpose of family consumption and sales, respectively. Five of every ten respondents (78.46%) cultivated these vegetables on the same piece of land repeatedly and relied on soil amendments to improve soil fertility and increase crop yield. The use of both organic and inorganic fertilizer (72.31%) was the most prevalent practice in terms of fertilizer use in the Mezam division, followed by the use of only organic fertilizer (21.54%),

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and only approximately 7% of the respondents used chemical fertilizer. This result is comparable to that of Fonge et al. (2021), who assessed the heavy metal exposure risk associated with the consumption of cabbage and carrot grown in a tropical savannah region and reported that 98% of respondents used both organic and inorganic fertilizers. Mbu et al. (2019), while conducting a study on the intricacies of organic and chemical fertilizer application on arable land crop production in Cameroon, reported that 94% of farmers used both organic and inorganic fertilizers and stated that such results occurred because the integrated use of organic and inorganic fertilizer has been recommended for sustainable agriculture in Cameroon. Most of the respondents practicing the integrated use of both organic and inorganic fertilizers could employ practices similar to those of other farmers since most farmers tend to copy what works best for other farmers to achieve maximum yields.

Knowledge of Heavy Metal Awareness

The results pertaining to heavy metal awareness are presented in Table 4.

Table 4: Knowledge pertaining to heavy metal awareness

		Frequency	Percentage
Farmland location	Waste disposal	05	7.35
	Agricultural	58	85.29
	Industrial	02	2.94
Safety measures during chemicals application	Yes	63	96.92
	No	02	3.07
Frequency of chemicals application	Monthly(+)	49	100
Awareness of HM risk to human health	Yes	55	84.62
	No	10	15.38

Most of the respondents had basic knowledge of the adverse effects of heavy metals on the environment, human health and vegetable quality. The highest percentage of the respondents (85.29%) cultivated these vegetables in agricultural areas, and a minority of the respondents cultivated them in waste disposal and industrial areas. A total of 96.92% of the respondents who used chemicals in vegetable cultivation applied safety measures and followed the manufacturer's instructions when these chemicals were applied. One hundred percent of respondents who used chemicals applied these chemicals within a time interval of one month and above.

Nutrient and Heavy Metal Concentrations in Vegetables

Proximate Composition of Vegetables

The proximate composition and vitamin C contents of cabbage, tomato, leek and carrot are presented in Table 5. No significant differences ($P > 0.05$) were detected in the proximate and vitamin C contents among some vegetables from the different subdivisions.

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Sample	Moisture*	Ash*	Protein*	Fat*	Carbohydrate*	Fibre *	VitaminC (mg/100 g)
$T_{cabbage}$	91.765±1.20[a]	0.898±0.04[c]	0.713±0.061[a]	0.952±0.01[a]	5.448±1.22[a]	1.154	39.580±0.32[a]
$S_{cabbage}$	90.916±0.01[a]	0.481±0.09[ab]	0.994±0.38[a]	0.974±0.01[a]	5.980±0.72[a]	1.174	37.331±0.09[a]
$N_{cabbage}$	90.709±0.28[a]	0.416±0.01[a]	0.973±0.19[a]	0.949±0.02[a]	5.114±0.33[a]	1.175	39.271±0.11[a]
$O_{cabbage}$	90.155±1.00[a]	0.564±0.01[b]	0.937±0.08[a]	0.714±0.06[b]	5.988±0.33[a]	1.190	44.900±0.06[b]
T_{tomato}	94.750±0.23[a]	0.899±0.06[a]	1.021±0.08[a]	1.668±0.22[a]	2.262± 0.29[a]	1.140	11.022±0.12[a]
T_{omato}	94.711±0.82[a]	0.878±0.06[a]	0.995±0.00[a]	1.678±1.68[a]	1.990±0.52[a]	1.143	12.061±0.50[a]
S_{tomato}	93.648±0.18[a]	0.813±0.03[a]	0.998±0.03[a]	1.699±1.70[a]	2.174±0.18[a]	1.133	11.990±0.22[a]
T_{leek}	84.132±0.73[a]	1.196±0.11[a]	1.484±0.21[a]	0.744±0.02[a]	5.842±0.81[a]	2.103	11.900±0.46[a]
S_{leek}	83.667±1.00[a]	1.229±0.48[a]	1.102±0.16[a]	0.726±0.01[a]	5.592±1.14[a]	2.176	12.021±0.51[a]
N_{leek}	84.032±0.25[a]	1.195±0.02[a]	1.162±0.21[a]	0.746±0.02[a]	5.421±0.70[a]	1.982	11.891±0.00[a]
O_{leek}	87.597±1.06[b]	1.214±0.02[a]	1.857±0.41[b]	0.325±0.04[b]	6.643±0.38[a]	2.685	12.728±0.03[a]
T_{carrot}	84.112±0.94[a]	1.486±0.34[a]	0.942±0.01[a]	0.290±0.34[a]	11.939±0.73[a]	1.168	5.990±0.00[a]
S_{carrot}	84.288±0.94[a]	1.706±0.04[a]	0.926±0.02[a]	0.272±0.43[a]	11.843±0.92[a]	1.170	5.271±0.31[a]
N_{carrot}	86.356±2.41[a]	1.679±0.32[a]	0.937±0.01[a]	0.214±0.00[a]	12.279±2.82[a]	1.176	5.090±0.12[a]

Table 5: Proximate composition of vegetables

*The same letters indicate no significant differences: T = Tubah, N = Nkwen, S = Santa, and * indicates the percentage of the parameter measured in the vegetable.*

The moisture content of the cabbage ranged from 90.155 ± 1.00 (organic) to 91.765 ± 1.20% (Tubah). There was no significant difference in the moisture content of cabbage among the different study sites or among the different soil amendment types. The dietary fibre content of cabbage ranged from 1.154 to 1.190% (organically cultivated cabbage). The protein content recorded in cabbage ranged from 0.713 ± 1.20 (Tubah) to 0.994 ± 0.08% (organic). The protein content in cabbage from Tubah was significantly lower than that in the other cabbage samples, with no significant difference recorded between cabbage from Santa China, Nkwen and the organically cultivated cabbage. The fat content in cabbage ranged from 0.714 ± 0.06 (organic) to 0.952 ± 0.01% (Tubah). The fat content in the organically cultivated cabbage was significantly lower than that in the other cabbage samples.

The carbohydrate content of the cabbage samples ranged from 5.448 ± 1.22 (Tubah) to 5.988 ± 0.33% (organic), with no significant difference ($p>0.05$) recorded between the cabbage samples. The ash content of cabbage ranged from 0.416 ± 0.01 (Santa) to 0.898 ± 0.04% (Tubah), with significant differences recorded between the cabbage samples, except for the cabbage from Santa China, whose ash content was not significantly different from that of the cabbage from Nkwen and the organically cultivated cabbage. This result is comparable to the results obtained by Ashfaq et al. (2018), who performed a “compositional analysis of Pakistani green and red cabbage” and recorded similar values. This result could be attributed to the use of the same cultivars of cabbage (Ashfaq et al., 2018). The vitamin content of cabbage recorded in this study ranged from 37.331 ± 0.09 to 44.900 ± 0.06 mg/100 g. The vitamin C content in organically cultivated cabbage was significantly greater than that in the other cabbage samples.

The moisture content of the carrots ranged from 84.112 ± 0.94 to 86.356 ± 2.41%. There was no significant difference ($p > 0.05$) in the moisture content of carrots from the three different study sites. The dietary fibre content found in carrots was recorded to be within the range of 1.168 (Tubah) to 1.176% (Nkwen). The protein content of the carrots ranged from 0.926 ± 0.02 to 0.942 ± 0.01%. The ash content recorded in carrots ranged from 1.679 ± 0.32% (Nkwen) to

Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

2.486 ± 0.34% (Tubah). No significant difference was observed in the ash content of the carrot samples from the three different study sites. The carbohydrate content of the carrots ranged from 11.843 ± 0.92 (Nkwen) to 12.279 ± 2.82% (Tubah), with no significant difference recorded among the different carrot samples. This result closely aligns with those obtained by Ajenu et al. (2021) in a study titled comparative evaluation of the proximate and micro nutritional benefits of pawpaws, carrots, turmeric and coconut. The vitamin C content of the carrots ranged from 5.090 ± 0.12 to 5.990 ± 0.00 mg/100 g, with no significant differences recorded. This result disagrees with the value of 7.2 mg/100 g recorded by Ajenu et al. (2021) but is similar to the value of 5.6 mg/100 g obtained by Hussain et al. (2016). This variation in results could be linked to the method used for the vitamin C analysis.

The moisture content of the tomatoes ranged from 93.648 ± 0.18 (Santa) to 94.750 ± 0.23% (Tubah). There was no significant difference in the moisture content of tomatoes from the different study sites. In tomatoes, dietary fibre ranged from 1.133% (Santa) to 1.143% (Nkwen). The protein content of the tomatoes ranged from 0.995 ± 0.00 (Tubah) to 1.021 ± 0.08% (Santa Cruz). There was no significant difference in the protein content of the tomatoes collected from the three study sites. The fat content recorded in the tomatoes ranged from 1.668 ± 0.22 (Tubah) to 1.699 ± 1.70% (Santa Cruz), with no significant difference among the tomato samples. The carbohydrate content recorded in tomatoes ranged from 1.990 ± 0.52 (Nkwen) to 2.262% (Tubah), with no significant difference recorded. The ash content ranged from 0.813 ± 0.03 to 0.899 ± 0.06%, with no significant difference recorded in the tomato samples from the three study sites. This result is comparable to the results obtained by Abdullahi et al. (2016), who determined the proximate, mineral and vitamin compositions of fresh and canned tomatoes. The vitamin C content of the tomatoes ranged from 11.022 ± 12 to 12.06 ± 0.58 mg/100 g. This value disagrees with the findings of Abdullahi et al. (2016), who reported a value of 5.71 mg/100 g.

The moisture content of the leaves ranged from 83.667 ± 1.00 (Nkwen) to 87.597 ± 1.06% (organic). The moisture content in the organically cultivated leaves was significantly greater than that in the leaves from the three study sites. The dietary fibre in the egg ranged from 1.982% (Tubah) to 2.685% (organic). The protein content of the leaves ranged from 1.102 ± 0.16 (Tubah) to 1.857 ± 0.41% (organic). The protein content in the organically cultivated leeks was significantly greater than that in the other leek samples. The fat content in the leaves ranged from 0.325 ± 0.04 (organic) to 0.746 ± 0.07% (Nkwen). The fat content of organically cultivated leeks was significantly lower than that of the other vegetables. The carbohydrate content recorded in the leeks ranged from 5.421 ± 070 (Tubah) to 6.640 ± 0.38 g/100 g. No significant difference was detected in the carbohydrate content between the organically cultivated leeks and the leek samples from the three study sites. The ash content ranged from 1.195 ± 0.02 to 1.229 ± 0.48%. The vitamin C content of the leaves ranged from 11.891 ± 0.00 to 12.728 ± 0.03 mg/100 g.

Heavy Metal Concentrations in Vegetables from the Sampling Sites

Tubah Subdivision

The heavy metal concentrations in vegetables from Tubah are presented on Fig. 2. The concentration of Cr in the studied vegetables in Tubah ranged from 0.531 mg/kg in leeks to 1.387 mg/kg in cabbage, with a cruel concentration of 0.863 mg/kg, whereas the FAO/WHO standard limit was 2.3 mg/kg. The highest concentration of cadmium (1.237 mg/kg) was

Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

recorded in leeks, and the lowest concentration (0.675 mg/kg) was recorded in carrots. The cruel concentration of cadmium in all four vegetables was 0.942 mg/kg, compared with the FAO/WHO standard limit of 0.2 mg/kg. The lead concentration was highest in tomato (2.899 mg/kg) and lowest in carrot (0.675 mg/kg), with a peak concentration of 2.154 mg/kg, compared with the FAO/WHO standard limit of 0.3 mg/kg.

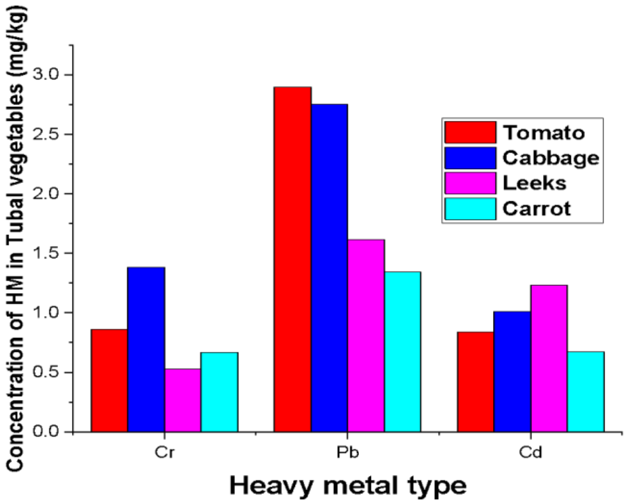

Fig. 2: Heavy metal concentrations in vegetables from Tubah

Nkwen Subdivision

The results of the heavy metal analysis indicated that the concentration of cadmium ranged from 0.531 mg/kg in tomato and carrot to 1.143 mg/kg in leeks, with a peak concentration of 0.820 mg/kg. The highest concentration of chromium (0.636 mg/kg) was recorded in cabbage, and 0.531 mg/kg was recorded in carrots, leeks and tomatoes, with a final concentration of 0.557 mg/kg. The lead concentration in vegetables ranged from 1.429 mg/kg in tomatoes to 2.672 mg/kg in carrots. The recorded lead concentration was 1.931 mg/kg (Fig. 3).

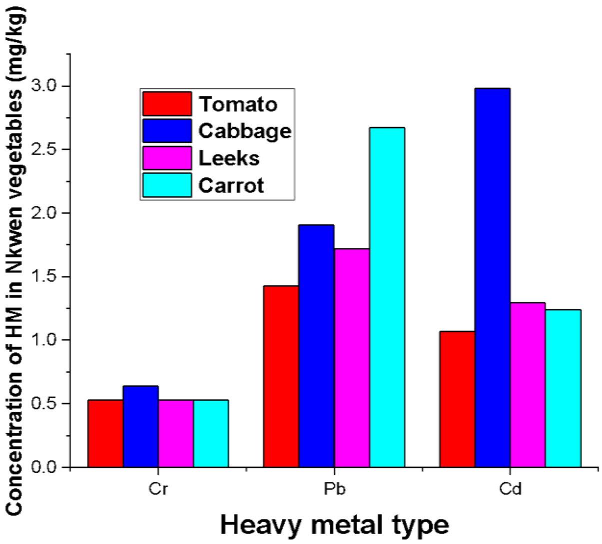

Fig. 3: Heavy metal concentrations in vegetables from Nkwen

Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 8, Issue 2, 2025 (pp. 52-74)
www.abjournals.org

Santa Subdivision

The heavy metal concentrations in vegetables from Santa are presented on Fig. 4. The highest concentration of chromium (1.143 mg/kg) was recorded in cabbage, and the lowest concentration (0.531 mg/kg) was recorded in carrot and tomato plants, with a concentration of 0.820 mg/kg. The cadmium concentration ranged from 0.899 mg/kg in carrots to 4.103 mg/kg in leeks, with a peak concentration of 1.855 mg/kg. The lead concentration was greatest (2.010 mg/kg) in carrots and lowest (1.036 mg/kg) in leeks, with an average concentration of 1.615 mg/kg.

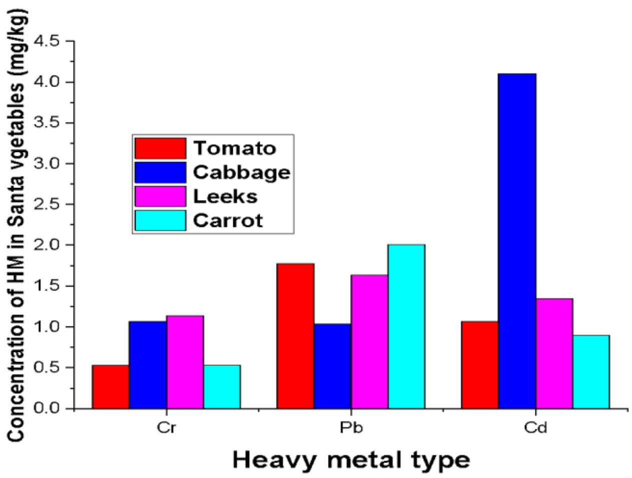

Fig. 4: Heavy metal concentrations in vegetables from Santa

Organically Grown Carrot and Leek Samples

The results of the analysis revealed that cabbage presented the highest concentrations (1.96 mg/kg, 1.760 mg/kg, and 1.630 mg/kg) of chromium, cadmium and lead, respectively. Leeks reported the lowest concentrations (0.670 mg/kg, 1.284 mg/kg and 1.240 mg/kg) and average concentrations of chromium, lead and cadmium of 1.318 mg/kg, 1.52 mg/kg, and 1.430 mg/kg, respectively (Fig. 5).

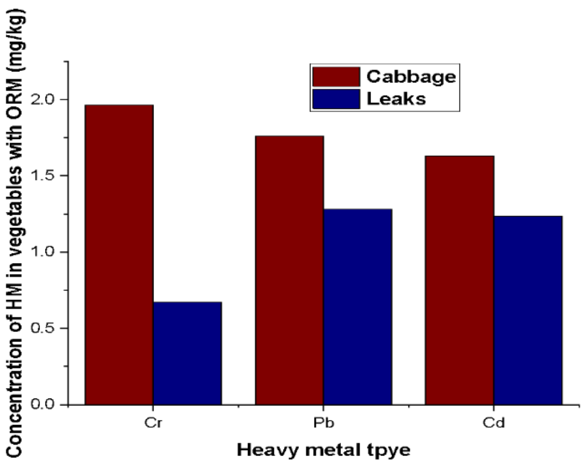

Fig. 5: Heavy metal concentrations in organic samples
(HM = heavy metal, ORM = organic)

Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

Chromium (Cr) is a trace element that plays a critical role in the metabolism of carbohydrates, fats, and cholesterol, and is essential for the proper functioning of various hormones and enzymes at specific concentrations (up to 200 mg/day). However, prolonged exposure to chromium can lead to hepatic and renal damage, as well as the development of organic diseases, including cancers of the lungs, nasal passages, stomach, and intestines, in addition to dermatitis (Bambara et al., 2023). The concentration of chromium in vegetables from the three subdivisions ranged from 0.557 mg/kg in vegetable samples from Nkwen to 1.318 mg/kg in organically cultivated vegetables. The chromium concentrations in vegetables cultivated in MD were lower than the FAO/WHO permissible standard limit of 2.3 mg/kg, implying that these vegetables are safe from chromium contamination. This result is similar to those obtained by Fonge et al. (2021), who reported a value of 1.5 mg/kg in carrot and cabbage in the tropical savannah region and suggested that such results could be because chromium has a relatively high transfer factor from the soil to the vegetable. Kolawole et al. (2022), who reported an average chromium concentration of 0.566 mg/kg in vegetables grown on roadside farms in Farin-Lamba, Jos South Local Government Area, Plateau State, Nigeria, suggested that the results could be because different vegetables have different absorption rates for different heavy metals, thus accounting for the different concentrations in different vegetables. The chromium concentration being within the permissible standard level could be because chromium is not a heavy metal in most agrochemicals, such as fertilizers used in the cultivation of these vegetables.

The crude Pb concentration in vegetables obtained from MD was within the range of 1.552 mg/kg in organically cultivated vegetables to 2.154 mg/kg in vegetables collected from Tubah. The lead concentrations in the vegetable samples were higher than the FAO/WHO permissible standard limit of 0.3 mg/kg. This result is comparable to those of Bambara et al. (2023), Kolowale et al. (2022) and Fonge et al. (2021). Bambara et al. (2023) and Kolowale et al. (2022) suggested that the elevated levels of lead detected in all vegetable samples may be linked to contaminants present in irrigation water, agricultural soil, or fertilizers, as well as pollution originating from highway traffic and industrial facilities situated in proximity to the sampled locations. The significant concentration of lead in these vegetables may be attributed to the metal's low transfer factor and mobility rate, which facilitates its uptake from the soil and accumulation in the edible portions of the plants. Lead (Pb) is a highly toxic heavy metal that can be ingested through the consumption of contaminated vegetables, potentially resulting in severe adverse effects on the liver, kidneys, vascular system, and immune system. Furthermore, the consumption of vegetables cultivated in areas with high lead contamination, such as those in the MD region, may also contribute to neurological and psychiatric disorders (Bambara et al., 2023).

Cadmium is classified as a nonessential heavy metal that exhibits significant toxicity, even at minimal concentrations. Its exposure has been associated with the development of learning disabilities and hyperactivity in children (Hunt, 2003; Bahiru et al., 2019). The vegetable samples collected from MD had a cadmium concentration within the range of 0.942 mg/kg in vegetables from Tubah to 1.885 mg/kg in vegetables from Santa China. The cadmium concentrations in these vegetables were above the FAO/WHO permissible standard limit of 0.2 mg/kg. This result is comparable to that of Bahiru et al. (2019) and suggested that the high concentration of Cd in vegetables might be due to the use of pesticides, fertilizer, and municipal and industrial sewage effluents. Cadmium is more soluble than other heavy metals, thereby making it highly available for plant uptake as well as having a low transfer factor (Bahiru et

Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

ISSN: 2689-5331

Volume 8, Issue 2, 2025 (pp. 52-74)

al., 2019). Cadmium is also a common heavy metal in urea and NPK fertilizers (Fonge et al., 2021). This could suggest a cause of the high cadmium concentration in these vegetables.

Health Risk Assessment

Estimated Daily Intake (EDI)

The estimated daily intake (EDI) of cadmium (Cd), chromium (Cr), and lead (Pb) from the consumption of vegetables was calculated on the basis of their concentrations and consumption rates, as presented in Table 6.

Table 6: Estimated daily intake of metals

Vegetable	EDI Cr	EDI Pb	EDI Cd
T_{tomato}	2.336E-04	2.336 E-04	2.282 E-04
$T_{cabbage}$	3.755 E-04	3.755E-04	2.738 E-04
T_{leek}	1.438 E-04	4.371 E-04	1.825 E-04
T_{carrot}	1.816 E-04	3.643 E-04	2.890 E-04
S_{tomato}	1.438 E-04	4.820E-04	3.651 E-04
S_{cleek}	3.093 E-04	4.428 E-04	1.110 E-03
$S_{lcabbage}$	2.903 E-04	2.802 E-04	2.434 E-04
S_{carrot}	1.438 E-04	5.4362E-04	2.890 E-04
N_{tomato}	1.438 E-04	3.867 E-04	8.062 E-04
$N_{cabbage}$	1.721 E-04	5.156 E-04	3.497 E-04
N_{leek}	1.438 E-04	4.652 E-04	3.346 E-04
N_{carrot}	1.436 E-04	7.230 E-04	4.411 E-04
$O_{cabbage}$	5.315 E-04	4.764 E-04	3.346 E-04
O_{leek}	1.18 E-04	3.475 E-04	4.200 E-04
Total Daily intake	3.138 E-03	6.994 E-03	5.83E-03
Maximum Tolerable Daily intake (MTDI/mg/kg)	0.003	0.0036	0.001

S = Santa, T = Tubah, N = Nkwen, O = organic

The total daily intake was 3.130E–03 mg/day for Cr, 6.994E–03 mg/day for Pb, and 5.582E–03 mg/day for Cd. Notably, the daily intake of chromium exceeded the tolerable daily intake (TDI) recommended by the FAO/WHO, while the intakes of cadmium and lead also surpassed the acceptable limits. Consequently, consuming carrots, tomatoes, leeks, and cabbage cultivated in Mezam may pose health risks associated with these heavy metals. These results are similar to those obtained by Edogbo et al. (2020) and Bambara et al. (2023).

Target Hazard Quotient (THQ)

The target hazard quotient (THQ) of Cr was within the range of 0.479–1.771. The THQ of Cd ranged from 0.183 to 1.110, with the highest value recorded in cabbage from Santa China. The lead THQ values ranged from 0.080 to 0.228, and the highest target hazard quotient was observed in tomatoes from Tubah. The chromium TQH values in cabbage from Tubah, leeks from Santa and organically grown leeks were greater than unity; thus, the consumption of these vegetables can cause chromium-related diseases.

Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

The hazard indices (HIs) of heavy metals (Cd, Cr and Pb) in vegetables from Mezam were between 0.877 and 2.350. This result is comparable to that of Bambara et al. (2023), who reported values of 0.8036 to 2.71 in the Loumbila area of Burkina Faso. The highest value of HI was observed in organically cultivated leeks. The HIs for Cd, Cr and Pb in T1, T2, S2, S3, N2, N4, O2 and O3 were 1.23, 1.73, 2.16, 1.52, 1.52, 1.02, 2.35 and 1.04, respectively. The HIs for Cr, Cd and Pb were greater than 1 (HI > 1), as shown in Table 7.

Table 7: Target hazard quotient and hazard index

S	T1	T2	T3	T4	S1	S2	S3	S4	N1	N2	N3	N4	O2	O3
HI	**1.23**	**1.74**	**0.94**	**0.89**	**0.91**	**1.52**	**2.16**	**0.88**	**0.879**	**1.53**	**0.96**	**1.02**	**2.35**	**1.04**

S = Vegetable sample, HI = hazard index, T = Tubah, N = Nkwen, S = Santa, O = organic, t = tomato, 2 = cabbage, 3 = leek and 4 = carrot.

Thus, the consumption of tomatoes and cabbage from Tubah, cabbage and carrot from Nkwen, leeks and cabbage from Santa, and organically cultivated leaks and cabbage are at risk to the local population of MD.

Target Cancer Risk (TCR)

The target cancer risk (TCR) values for cabbage, carrots, tomatoes, and leeks from Tubah, Santa, and Nkwen are presented in Table 8.

Table 8: Target cancer risk

Vegetable	**TCR**
T1	**3.546E-03**
T2	**4.300E-03**
T3	**5.095E-03**
T4	**2.832E-03**
S1	**4.411E-03**
S3	**5.634E-03**
S2	**1.680E-02**
S4	**3.723E-03**
N1	**4.410E-03**
N2	**1.218E-02**
N3	**5.324E-03**
N4	**5.098E-03**
O3	**6.887E-03**
O2	**5.113E-03**

T = Tubah, N = Nkwen, S = Santa, O = Organic, 1 = Tomato, 2 = Cabbage, 3 = Leek and 4 = Carrot.

Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

The target cancer risk for cadmium ranges from 2.738E-03 to 1.666E-02, exceeding the threshold of 1×10^{-4}. These findings indicate a potential risk for cancer related to cadmium consumption from vegetables in Mezam. In contrast, the TCR values for chromium and lead fell between 7.188E-05 and 1.546E-04 and between 2.954E-06 and 6.669E-06, respectively. These TCR values for Cr and Pb are within the safe threshold of 1×10^{-4}, suggesting that the population is at low risk for cancer related to these metals.

Overall, the TCRs for Cd, Cr, and Pb from the consumption of vegetables in the MD range from 2.832E-03 to 1.680E-02. All the studied vegetables presented TCR values for Cd, Cr, and Pb above the threshold of 1×10^{-4}, indicating a potential risk for cancer. This result is similar to that obtained by Bambara et al. (2023).

CONCLUSION

The objective of this study was to assess vegetable quality, quantify selected carcinogenic heavy metals and determine the health risk associated with the consumption of vegetables grown in these localities in relation to the agricultural practices farmers put in place when cultivating these vegetables. The most prevalent agricultural practice in terms of soil fertility management in these three localities is the integrated use of both organic and inorganic fertilizers applied at different stages of cultivation and in terms of pest management; the most prevalent practice is the use of chemical pesticides. The approximate composition and vitamin C content of these selected vegetables revealed a well-rounded nutrient profile, and the vitamin C levels corresponded with established guidelines. The cadmium and lead contents in these selected vegetables were higher than the FAO/WHO permissible standard limits, whereas the chromium concentration in the vegetables was within safe limits. The health risk assessment results revealed a hazard index greater than one for most of the selected vegetables, indicating exposure to non-carcinogenic diseases related to lead, cadmium and chromium. The target cancer risk was greater than the threshold of 1×10^{-4}, indicating that long-term consumption of these vegetables may result in the development of Cd-, Pb- and Cr-related cancers. Tomatoes, leeks, carrots and cabbage from these three localities in MD have very good proximate compositions and vitamin C contents, but their safety is compromised by the presence of heavy metals.

ACKNOWLEDGMENTS

We are grateful to the farmers in the three selected areas in Mezam Division for responding to the questionnaire by providing valuable information on farming practices. We are also grateful to the technicians of RUSAEC, FASA_Dschang_Cameroon for assisting in laboratory analyses.

FUNDING

This research did not receive any funding and was self-sponsored.

Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

AUTHORS' CONTRIBUTIONS

Mofor Nelson Alakeh: Conception, fieldwork approval, supervision at all stages and correction of draft manuscript.

Nuikweshi Yvette Ngeneform: Conception, methodology, carried out fieldwork, writing, production of draft manuscript.

Tsamo Cornelius: Conception, methodology, fieldwork approval, supervision at all stages and review of draft manuscript.

DATA AVAILABILITY STATEMENT

Data, related materials and calculations tools are available and can be provided by the corresponding author (nelsonmofor@yahoo.com) upon request.

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Article DOI: 10.52589/AJAFS-RDQHUOJB
DOI URL: https://doi.org/10.52589/AJAFS-RDQHUOJB

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