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Research Paper

Concentrations of Selected Metals and Non-Carcinogenic Health Risk Indices in Coffee Brands Available in Libyan Markets

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Abstract
Coffee can contain nutritionally essential and potentially harmful elements whose concentrations depend on origin, processing, and handling. This study determined chromium (Cr), zinc (Zn), copper (Cu), and iron (Fe) in seven packaged coffee brands purchased from markets in Al-Bayda, Libya, and estimated non-carcinogenic exposure associated with their consumption. Homogenized samples (0.500 g) were digested with concentrated nitric acid at 80 °C, diluted to 50 mL, and analyzed by atomic absorption spectrometry. Concentrations ranged from 0.555 to 0.807 mg/kg for Cr, 3.3336 to 4.4285 mg/kg for Zn, 0.032 to 0.946 mg/kg for Cu, and 3.619 to 4.190 mg/kg for Fe. A conservative screening assessment used the maximum measured concentration, an intake rate of 20 g dry coffee per day, a body weight of 70 kg, and complete transfer of each metal from ground coffee to the consumed beverage. The resulting estimated daily intakes were 0.000231, 0.001265, 0.000270, and 0.001197 mg/kg body weight/day for Cr, Zn, Cu, and Fe, respectively. The corresponding target hazard quotients were 0.000154, 0.00422, 0.00676, and 0.00171, giving a combined hazard index of 0.01284. All screening values were below 1, indicating a low likelihood of non-carcinogenic effects under the stated assumptions. However, this conclusion is preliminary because chromium speciation, metal transfer into brewed coffee, analytical quality-control data, and population-specific consumption patterns were not evaluated.

Keywords: coffee; atomic absorption spectrometry; chromium; zinc; copper; iron; estimated daily intake; hazard index

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I. Introduction

Coffee is one of the most widely consumed beverages and an economically important agricultural commodity. The two principal commercial species are Coffea arabica and Coffea canephora (robusta). In addition to caffeine and numerous organic compounds, roasted coffee contains mineral elements derived from the soil, irrigation water, agricultural inputs, processing equipment, and storage or packaging conditions. Elemental profiles therefore vary with geographical origin, species, cultivation practices, roasting, and analytical preparation [1&2]. Several metals have physiological roles at appropriate intake levels. Zinc and copper participate in enzyme function, while iron is essential for oxygen transport and cellular metabolism. Nevertheless, excessive exposure may disturb biological processes. Chromium requires particular care in interpretation because its toxicological behavior depends strongly on oxidation state; total chromium measurements do not distinguish nutritionally relevant Cr(III) from the more hazardous Cr(VI) [3&4].Data on metals in coffee sold in Libyan markets remain limited. The present study therefore aimed to determine Cr, Zn, Cu, and Fe in seven commercial coffee brands available in Al-Bayda and to conduct a screening-level assessment of potential non-carcinogenic exposure using estimated daily intake, target hazard quotient, and hazard index.

II. Materials and Methods

Sampling

Seven packaged coffee brands were purchased from local markets in Al-Bayda, Libya. The samples were assigned codes S1–S7, as listed in Table 1.

Table 1. Coffee brands included in the study

Sample code	Coffee brand
S1	Alaa Coffee
S2	Bala Coffee
S3	Turkish Coffee
S4	Krestta Coffee
S5	Masafi Coffee
S6	Al-Khaleg Coffee
S7	Amam Coffee

Sample Homogenization

Each coffee sample was ground, when necessary, with a clean mortar and pestle and thoroughly mixed to obtain a homogeneous fine powder before digestion.

Acid Digestion

A 0.500 g portion of each homogenized sample was transferred to a 100 mL Pyrex beaker. Concentrated nitric acid (5 mL) was added, and the mixture was heated with magnetic stirring at 80 °C for 1 h until a clear digest was obtained. After cooling, the digest was filtered through Whatman No. 42 filter paper into a 50 mL volumetric flask and diluted to the mark with deionized water.The heavy metals analysis was carried out after deigstion method used for different samples soil ,plant , water ,marine samples and others which carried out by different studies [5 – 55]

Instrumental Analysis

Chromium, zinc, copper, and iron were determined by atomic absorption spectrometry at the Central Laboratory of Omar Al-Mukhtar University, Libya. Results were expressed as milligrams of metal per kilogram of coffee (mg/kg). Because the source document did not report calibration characteristics, blanks, certified reference materials, recovery, precision, or detection limits, these items should be added before journal submission if the corresponding laboratory records are available.

III. Results and Discussion

Metal Concentrations

The measured concentrations of Cr, Zn, Cu, and Fe in the seven coffee samples are presented in Table 2 and Figure 1. The results are described as observed differences among samples; statistical significance cannot be inferred because replicate measurements and inferential statistical tests were not reported.

Table 2. Concentrations of selected metals in coffee samples (mg/kg)

Sample	Cr	Zn	Cu	Fe
1	0.654	3.3336	0.461	4.19
2	0.590	3.9526	0.197	4.025
3	0.555	4.1338	0.946	4.022
4	0.758	4.2171	0.681	3.996
5	0.730	4.2049	0.595	3.909
6	0.739	4.2666	0.288	3.928
7	0.807	4.4285	0.032	3.619

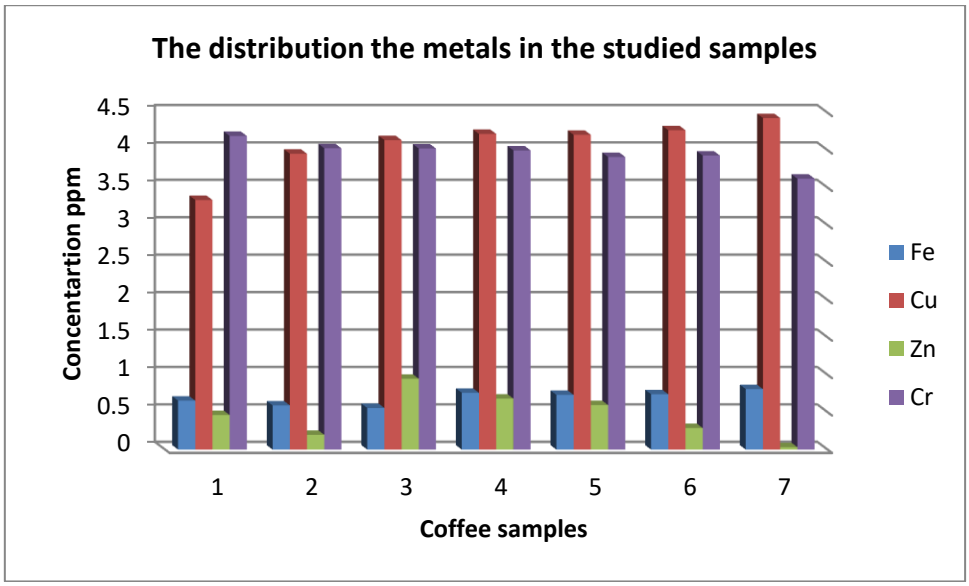


Figure 1. Distribution of Cr, Zn, Cu, and Fe concentrations among the seven coffee samples.

Chromium ranged from 0.555 mg/kg in S3 to 0.807 mg/kg in S7. Zinc ranged from 3.3336 mg/kg in S1 to 4.4285 mg/kg in S7. Copper showed the widest relative variation, from 0.032 mg/kg in S7 to 0.946 mg/kg in S3. Iron ranged from 3.619 mg/kg in S7 to 4.190 mg/kg in S1. Based on the arithmetic means, the overall concentration order was Zn (4.0767 mg/kg) > Fe (3.9556 mg/kg) > Cr (0.6904 mg/kg) > Cu (0.4571 mg/kg).The chromium results fall within the broad range reported in elemental studies of commercial coffee, but direct toxicological interpretation is limited by the absence of chromium speciation. The risk calculation below therefore uses the Cr(III) reference dose only as an explicit screening assumption; it must not be interpreted as evidence that all measured chromium was Cr(III). Zinc concentrations were relatively consistent among the seven brands. Comparable investigations have shown that coffee mineral profiles vary with origin and product type and that brewed coffee generally contributes only a small fraction of daily mineral intake [2]. Copper concentrations varied markedly across the samples, although all values were below 1 mg/kg. Because no replicate results or method-performance data were provided, the unusually low value in S7 should be confirmed by repeat analysis before attributing it to a genuine brand difference. Iron was the second most abundant measured element and displayed a narrow range across the brands. The measured concentrations are lower than values reported for some coffee products in the literature, illustrating the influence of geographical origin, coffee type, roasting, preparation, and analytical method [1&2]. Comparisons with regulatory limits should be made only against a clearly identified jurisdiction- and commodity-specific standard; the present findings alone do not establish regulatory compliance.

Non-Carcinogenic Health Risk Assessment

Potential chronic non-carcinogenic exposure was screened using the approach commonly applied in environmental health risk assessment. A reference dose (RfD) is a benchmark for daily exposure that is likely to be without appreciable risk over a lifetime, but values below an RfD should not be described as guaranteeing absolute safety [56].The following indices were calculated from the maximum measured concentration of each metal (a worst-case concentration scenario):

Estimated Daily Intake (EDI)

$$EDI_i = (C_i \times IR) / BW$$

Target Hazard Quotient (THQ)

$$THQ_i = EDI_i / RfD_i$$

Hazard Index (HI)

$$HI = \Sigma THQ_i$$

where C_i is the metal concentration in coffee (mg/kg), IR is the daily ingestion rate of dry coffee (kg/day), BW is body weight (kg), and RfD_i is the oral reference dose (mg/kg body weight/day).

Body weight (BW): 70 kg for an adult.

Ingestion rate (IR): 0.020 kg dry coffee/day (20 g/day).

Reference doses used for screening: Cr(III) = 1.5, Zn = 0.3, Cu = 0.04, and Fe = 0.7 mg/kg body weight/day.The assessment assumes that the total measured amount of each metal in 20 g of dry coffee is ingested. This is conservative because actual transfer into the beverage and retention in spent grounds were not measured. For total chromium, the Cr(III) RfD was applied only as a stated scenario because oxidation-state speciation was not performed.

Estimated Daily Intake

Using the maximum concentration measured for each metal, the EDI values were calculated as follows:

$$EDI = (Cmax \times 0.020\ kg/day) / 70\ kg$$

Cr: 0.000231 mg/kg/day; Zn: 0.001265 mg/kg/day; Cu: 0.000270 mg/kg/day; Fe: 0.001197 mg/kg/day.

Target Hazard Quotient

Dividing each EDI by its stated RfD produced the following THQ values:
Cr: 0.000154; Zn: 0.00422; Cu: 0.00676; Fe: 0.00171.

Hazard Index

The combined hazard index was calculated as the sum of the four THQs:

$$HI = 0.000154 + 0.00422 + 0.00676 + 0.00171 = 0.01284$$

Because each THQ and the combined HI were below 1, the screening assessment indicates a low likelihood of non-carcinogenic effects from the four measured metals under the selected exposure assumptions. The EDI values represent small exposures relative to the reference doses used in the calculation. Copper contributed the largest share of the HI (approximately 52.6%), followed by zinc (32.9%), iron (13.3%), and chromium (1.2%).A THQ below 1 suggests that the estimated exposure is lower than the selected reference dose. It is a screening result rather than proof of zero risk, and its reliability depends on the appropriateness of the concentration, intake rate, body-weight, chemical-form, and bioavailability assumptions. The assessment used the highest measured concentration for each metal, even though these maxima occurred in different brands. This provides a conservative combined scenario but does not represent exposure from any single sampled product. The HI of 0.01284 is well below 1. On the basis of the stated assumptions, combined exposure to Cr, Zn, Cu, and Fe from these coffee samples is unlikely to be of non-carcinogenic concern.Important limitations include the small market sample, absence of reported analytical quality-control parameters and replicate variability, lack of chromium speciation, use of dry-coffee ingestion rather than measured brewed-coffee concentrations, and absence of Libyan consumption and body-weight distributions. Future studies should analyze brewed infusions, report validated method performance, include toxic elements such as Pb and Cd, and assess exposure for both average and high consumers.

V. Conclusion

The seven coffee brands contained Cr, Zn, Cu, and Fe at measured concentrations of 0.555 – 0.807, 3.3336–4.4285, 0.032–0.946, and 3.619 – 4.190 mg/kg, respectively. Corrected screening calculations produced THQs between 0.000154 and 0.00676 and a combined HI of 0.01284. These values indicate a low potential for non-carcinogenic effects under the conservative assumptions used. Nevertheless, the study should be interpreted as a preliminary market survey rather than a definitive demonstration of regulatory compliance or absolute safety. Confirmatory work should incorporate replicate sampling, validated quality-control procedures, chromium speciation, and direct measurement of metal transfer into brewed coffee.Overall, the data provide a useful baseline for continued surveillance of elemental contaminants in coffee marketed in Libya and support the development of broader studies that better reflect local preparation practices and consumption patterns.

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