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# Human Health Risk Assessment and Daily Intake of Heavy Metals and Trace Elements in Multi-Brand Canned Legumes Marketed in Sabha-Libya

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## ABSTRACT

This study aims to assess the levels of heavy metals and trace elements in canned legumes from various brands, such as Al-Taybat, Americana, and Extra. A total of 22 samples were analyzed using Atomic Absorption Spectroscopy (AAS). The study included four types of legumes: broad beans, kidney beans, chickpeas, and peas, distributed across samples from different countries (Libya, Egypt, and Italy). The results showed that the (Cu) concentration in broad beans was 0.01 ± 0.003 mg/kg in the Libyan product and 0.04 ± 0.030 mg/kg in the Egyptian product. The (Zn) levels were found to be 0.02 ± 0.002 mg/kg in Libya and 0.02 ± 0.004 mg/kg in Egypt. For kidney beans, the levels were generally lower, with concentrations similar to the other elements. In the chickpea sample, the highest (Fe) concentrations were 0.11 ± 0.106 mg/kg from Libya and 0.08 ± 0.011 mg/kg from Egypt. Meanwhile, the pea sample showed high (Pb) concentrations reaching 0.01 ± 0.009 mg/kg in Libya and 0.02 ± 0.004 mg/kg in Egypt. The results indicate that the highest estimated daily intake of copper in broad beans was 0.001 mg/kg/day for the Libyan product (A1) and 0.005 mg/kg/day for the Egyptian product (A2). The lead concentrations in the Libyan broad beans (A1) were 0.004 mg/kg/day, which is within the allowable limits according to regulations. Regarding kidney beans, the results indicated that the iron concentration in the Italian product (B2) was 0.01 mg/kg/day, while the concentration in the Egyptian beans (B3) was 0.004 mg/kg/day. For chickpeas and peas, the estimated intake of elements ranged from 0.001 to 0.1 mg/kg/day. The findings of the study reveal a significant variation in the concentration of heavy metals among samples from different sources, indicating potential health risks associated with the consumption of certain canned legumes, especially regarding the levels of chromium, lead, and cadmium. This necessitates regulatory measures to ensure food safety and protect consumer health.

# تقييم المخاطر الصحية البشرية والمدخول اليومي للمعادن الثقيلة والعناصر النزرة في البقوليات المعلبة متعددة العلامات التجارية المتداولة في سبها–ليبيا

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## المُخلص

تهدف هذه الدراسة لتقييم مستويات المعادن الثقيلة والعناصر النزرة في البقوليات المعلبة لعلامات تجارية متنوعة، مثل الطيبات، أمريكانا، واكستر. تم تحليل 22 عينة باستخدام تقنية مطيافية الامتصاص الذري (AAS) شملت الدراسة أربع أنواع من البقوليات: الفول، والفاصوليا، والحمص، والبازلاء، موزعة على عينات من دول مختلفة (ليبيا، مصر، وإيطاليا). أظهرت النتائج أن تركيز النحاس (Cu) في الفول كان 0.01 ± 0.003 ملغ/كغ في المنتج الليبي و0.04 ± 0.030 ملغ/كغ في المنتج المصري. كما وُجد أن مستوى الزنك (Zn)كان 0.02 ± 0.002 ملغ/كغ في ليبيا و0.02 ± 0.004 ملغ/كغ في مصر. بالنسبة للفاصوليا، كانت المستويات أقل بشكل عام، مع تركيزات مشابهة للعناصر الأخرى. في عينة الحمص، كانت أعلى تركيزات الحديد 0.106 ± 0.11 (Fe) ملغ/كغ من ليبيا و0.08 ± 0.011 ملغ/كغ من مصر. بينما أظهرت عينة البازلاء تركيزات عالية من الرصاص (Pb) تصل إلى 0.01 ± 0.009 ملغ/كغ في ليبيا و0.02 ± 0.004 ملغ/كغ في مصر. تشير النتائج إلى أعلى تقديرات تناول يومي للنحاس في الفول كانت 0.001 ملغ/كغ/يوم للمنتج الليبي (A1) و0.005 ملغ/كغ/يوم للمنتج المصري .(A2) بينما كانت تركيزات الرصاص في الفول الليبي 0.004 (A1) ملغ/كغ/يوم، وهي ضمن الحدود المسموح بها حسب التوجيهات. فيما يتعلق بالفاصوليا، أظهرت النتائج أن تركيز الحديد في المنتج الإيطالي (B2) كان 0.01 ملغ/كغ/يوم، بينما كان التركيز في الفاصوليا المصرية 0.004 (B3) ملغ/كغ/يوم. بالنسبة للحمص والبازلاء، تراوحت تقديرات تناول العناصر بين 0.001 و0.1 ملغ/كغ/يوم. تظهر نتائج الدراسة تفاوتًا ملحوظًا في تركيز العناصر الثقيلة بين العينات مختلفة الصناعة، وتشير إلى وجود مخاطر صحية محتملة مرتبطة باستهلاك بعض البقوليات المعلبة، خاصة فيما يتعلق بمستويات الكروم والرصاص والكادميوم. مما يستوجب اتخاذ تدابير تنظيمية لضمان سلامة الغذاء وحماية صحة المستهلك.

## 1 Introduction

Canned foods, whether dried, smoked, salted, or preserved, are distinguished by their high nutritional value and ease of preparation at home [1]. They also have a long and economical shelf life [2]. These foods provide many important nutrients, containing about 10% protein, as noted [3]. Additionally, they contain essential amino acids. The food industry employs various technologies that allow for the production of products with diverse shelf lives [4]. With the increase in population, human consumption of canned products has risen [5]. As food technology develops and sources of pollution increase, these products have become vulnerable to contamination with organic and inorganic materials [6][7].

Canned food contamination is defined as any change in the food components that makes it unacceptable to consumers, whether from a hygienic or sensory perspective, such as taste, color, shape, and smell. Chemical contamination with heavy metals is considered one of the most dangerous types of pollution, as these elements possess bio accumulative properties [8][9] and are difficult to decompose [10]. Contamination of canned products with heavy metals occurs as a result of contamination of food commodities or through the transfer of packaging materials. Metal food packaging typically consists of tinplate, chrome-plated steel, or aluminum [11], which is usually coated on the inner side [12]. However, when metal comes into contact with food due to coating damage, corrosion is accelerated, possibly releasing elements such as tin, iron, cadmium, and lead [6]. This leads to elevated levels of these elements in food [13].

Improper transportation, handling, and display in commercial markets expose products to various contamination conditions [14], such as heat, humidity, and sunlight [15], in addition to poor household handling [16] through incorrect practices and preservation methods [17]. Heavy metals can be divided into two groups: the first group includes essential trace elements such as chromium, cobalt, copper, nickel, manganese, and zinc, which are important for cellular processes at low levels [18]. High concentrations of these elements can lead to toxicity and disruption of the body's balance [19]. The second group includes toxic metals such as cadmium, lead, and mercury, which have no biological function even at very low concentrations [20] and are non-biodegradable. These metals affect the kidneys and cause chronic toxicity symptoms [21], including impaired organ function, reduced reproductive capacity, high blood pressure, and tumors. Lead can also affect brain function [22] by interfering with neurotransmitter release and synapse formation, leading to decreased IQ, learning disabilities, slowed growth, and hyperactivity [23].

This study aims to estimate the levels of heavy metals in canned foods (specifically canned legumes) across various manufactured products sold in local markets in the city of Sabha. recent studies have reported the presence of heavy metals and potentially toxic elements in canned food products, raising concerns about food safety and human health risks. Schiano et al. [49] found detectable levels of chemical contaminants in canned legumes and confirmed that dietary exposure generally remains within regulatory limits. Similarly, Zheng et al. [50] emphasized that contamination in canned foods may originate from environmental pollution and migration from packaging materials, highlighting the need for continuous monitoring. Other studies have shown that heavy metals such as lead and cadmium are the most frequently detected toxic elements in canned food products and may exceed permissible limits in some cases [51].

Risk assessment approaches such as Estimated Daily Intake (EDI) and Hazard Quotient (HQ) are commonly used to evaluate potential health risks associated with dietary exposure [52]. Furthermore, migration of trace elements from packaging materials and contamination of raw agricultural products have been identified as major sources of heavy metal accumulation in canned foods [53]. Despite increasing global research, limited data are available regarding heavy metal contamination in canned legumes in Libya, indicating a clear research gap that this study aims to address.

## 2 Materials and Methods

The samples were collected from commercial markets in the city of Sabha, based on availability, totaling 22 samples during the period from January to March 2025. Moreover, for each sample three replicates were taken, which were classified by brand and country of manufacture. The samples were packed in metal containers and included products manufactured in Libya, Egypt, and Italy under different trade names, namely Akno-Tayebat, Americana, Al-Tayebah, Al-Safwa,Canned legumes, including Broad Beans (A), Kidney Beans (B), Chickpeas (C), and Peas (D), were sourced from the brands "Al-Tayebat" and "Americana," manufactured in Libya, as well as from the brands "Al-Safwa" and "Al-Taybeh," produced in Egypt. Additionally, samples were collected from the brands "Akno" and "Extra," which are manufactured in Italy, specifically for canned Peas, Kidney Beans, and Chickpeas. To ensure cleanliness, all boxes containing the target samples and tools were thoroughly washed with tap water and detergent.

After this initial cleaning, they were rinsed with water several times, followed by a final rinse with distilled water, as recommended [24]. The cans were then dried using dry and sterile gauze to prevent any contamination. For the glassware used in the procedure, it was placed in a basin containing a 10% dilute hydrochloric acid solution for a minimum of 24 hours to ensure thorough cleaning and disinfection. After this treatment, the glassware was washed three times with distilled water to remove any residual acid. Finally, it was dried in an oven set to a temperature between 60-70 °C, as outlined [25].

### 2.1.1 Result

### 2.1.2 Extraction of Heavy Metals

The cans were opened with a clean and sterilized knife [26]. Samples (crude) were digested using the dry digestion method with nitric acid and hydrochloric acid, following the methods previously mentioned [27][22]. After digestion, the samples were preserved in sealed glass tubes. The elements (Co, Cu, Zn, Cd, Fe, Pb, Cr, and Mn) were determined using an atomic absorption spectrophotometer, Model 2380, PERKIN-ELMER, located in the scientific laboratory of the College of Technology, Brak Al-Shati. The final concentrations were expressed in mg/100g units. Heavy metal concentrations were determined using Atomic Absorption Spectroscopy (AAS), Model 2380 (PerkinElmer, USA). The instrument was calibrated prior to analysis using certified standard solutions. The analytical accuracy was verified through quality control samples, with a relative standard deviation (RSD) of less than 5%, indicating high precision and reliability of the measurement

### 2.1.3 Estimated Daily Intake (EDI)

The amount of exposure for each metal is calculated by estimating the daily intake (EDI) [28] for each metal using the formula:EDI=(EF×ED×FIR×CF×CM)(WAB×TA)EDI = \frac{(E_F \times E_D \times F_IR \times C_F \times C_M)}{(W_AB \times T_A)}EDI=(WAB×TA)(EF×ED ×FIR×CF×CM)

where EF is the exposure frequency (365 days/year), ED is the duration of exposure (30 years), FIR is the fresh food intake rate (g/person/day), estimated to be 48 g/individual/day for Sample, Cf is the conversion factor (0.208), WAB is the mean body weight (70 kg), CM is the heavy metal concentration in canned food (mg/kg-1), TA is the mean exposure time to non-carcinogens (EF × ED) (70 x 365 = 25550).

### 2.1.4 Statistical analysis

All samples were treated as three replicates. SPSS statistical software was used to analyses this data. Mean ± SD, t-test (two groups), and one-way ANOVA (three groups) were performed using SPSS. Principal component analysis (PCA) and cluster analysis were used to identify contamination sources Descriptive statistics were used and included the mean and standard deviation. And the use of analysis of variance for the analysis of more than two groups, F-test and T-test to compare two independent groups.

Following a chemical analysis to detect toxic heavy metal elements in samples of canned legumes manufactured in different countries (Libya, Egypt, Italy) and known under trade names (Akno-Tayebat, Americana, Al-Taybeh, Al-Safwa, Extra), the results of the chemical analysis, presented in Table 1, revealed the presence of eight elements: (Cu, Zn, Co, Cd, Fe, Pb, Cr, and Mn), which were detected using an atomic absorption device.

#### *2.1.4.1 Broad Beans*

Sample results showed that the percentage of cadmium (Cd) and chromium (Cr) in the Libyan product was higher than the permissible limit, with concentrations in Al-Tayebat at (0.02 and 0.1 mg/100 g). The Egyptian product exceeded the permissible limit in the Safwa product for both Cd and iron (0.09, 0.6 mg/100 g). The European Union sets the permissible limit for Cd at (0.01-0.02 mg/kg). Broad beans from Al-Taybeh recorded the highest concentrations of Cd and Cr (0.06, 0.09 mg/100 g). This is consistent with the study [22]. According to European Commission guidelines (2001), the highest acceptable level of Cr for canned products was 0.05 mg/kg. The provisional maximum tolerable daily intake (PMTDI) set by WHO and FAO for iron is 0.3-0.8 mg/kg/day, equivalent to 56 mg/day for adults weighing 70 kg and 20.8 mg/day for children weighing 26 kg. The high concentrations of Cd and Cr in legumes before the canning process may be due to contamination of the agricultural soil where the legumes were grown, as indicated [29]. The increase in iron, resulting from acidity and salt content in the cans, may be due to poor handling, consistent with [30]. There are statistically significant differences between the means of the two groups for the Libyan and Egyptian products regarding heavy elements (Cu, Zn, Co, Cd, and Mn), as the probability values for these elements were less than the significance level (0.05). However, there were no significant differences for the elements (Fe, Pb, and Cr), as the probability values were greater than the significance level (0.05).

### *2.1.4.2 Kidney Beans*

The kidney bean products from Al-Safwa and Al-Tayba brands recorded concentrations exceeding the permissible limit for cadmium (Cd) at (0.041 and 0.02 mg/100 g), respectively. The highest concentrations of Cd and chromium (Cr) were recorded for the following brands: Extra (0.07, 0.08 mg/100 g) and Akno (0.07 mg/100 g). These results are consistent with a study [31], where Cd and Cr levels were found in kidney bean samples at (2.8 and 0.7 mg/g), respectively. The Cd concentration results align with a study [32], which reported a concentration of (0.2 mg/g), and they corroborate findings by [1], which indicated that the concentrations of Cd and Cr in canned kidney beans were 0.5-0.6 mg/kg and 0.7-1.7 mg/kg, respectively. The reason may be attributed to the contamination of primary sources of canned food, such as agricultural products, water, and agricultural soil [33]. Additionally, globalization of factories, variability in manufacturing processes, the quality of ingredients added to food, and the type and quality of materials used in food packaging and canning contribute to these concentrations. Canned foods in metal containers contribute to an increase in metal concentrations in canned products to about 1000 ppm. Furthermore, the water used in food manufacturing plays a role. There are significant differences between Libyan and Egyptian products regarding the elements (Zn, Co, Cd, Pb, Cr, Mn), with values being less than 0.05, whereas no differences were observed for the elements (Cu and Fe).

### *2.1.4.3 Chickpeas*

The concentrations of cadmium (Cd) and chromium (Cr) were recorded for each of the brands Extra, Safwa, and Al-Tayba at (0.06, 0.1 mg/100 g), (0.05, 0.06 mg/100 g), and (0.1, 0.06 mg/100 g), respectively. Meanwhile, the results for iron (Fe), zinc (Zn), cobalt (Co), lead (Pb), and manganese (Mn) were below the permissible limit. These results are consistent with a study [32], which found that the concentration of cadmium in canned chickpea samples was higher than the allowable limit (0.29 µg/g). The concentrations of Pb, Fe, and Mn were below the permissible limits, as noted by [34], [35], and [36]. The maximum allowable intake of Cd for children is 0.1 ppm body weight/day, while for adults it is 0.3 ppm body weight/day. The results showed significant differences between Libyan and Egyptian products for the elements (Cu, Zn, Co, Cd, Pb, Cr, and Mn), with probability values being less than 0.05, while no significant differences were observed for iron.

### *2.1.4.4 Peas*

The results of the chemical analysis of peas showed that the concentrations of cadmium (Cd) in the Al-Tayebat, Extra, Safwah, and Al-Taybah brands were higher than the permissible limit, with concentrations as follows: (0.02, 0.05, 0.06, 0.05 mg/100 g). Aknoua and Taiba had Cd levels of (0.01, 0.09 mg/100 g). The remaining items were below the allowable limit. These results are consistent with a study [32], which found a Cd concentration of 0.3 mg/100 g. The zinc (Zn) and copper (Cu) results align with a study conducted by [37], where they were below the permissible limit. The presence of multiple heavy elements in foodstuffs consumed regularly has a toxic effect, even if within permissible limits, due to their bioaccumulation properties, particularly for lead (Pb) and cadmium (Cd). The results in Table 1 showed differences between Libyan and Egyptian products for the studied elements (Cu, Co, Cd, Pb, Cr, and Mn), with probability values being less than the significance level (0.05), whereas no differences were observed for both Zn and Fe.

## Estimated Daily Intake

Estimated daily intakes (EDIs) were calculated for the elements: chromium (Cr), cadmium (Cd), cobalt (Co), copper (Cu), manganese (Mn), lead (Pb), iron (Fe), and zinc (Zn). It was considered that a person weighing 70 kg consumes 48 grams of canned food daily. The results revealed that the daily intake of iron, zinc, copper, cobalt, and manganese is below the reference value for all study samples, and therefore does not pose a risk to the health of individuals consuming heavy metals through the consumption of canned legumes. Iron values were recorded between 0.005 and 0.04 mg/kg/day, while zinc values ranged from 0.002 to 0.02 mg/kg/day, and copper values ranged from 0.001 to 0.09 mg/kg/day. Cobalt values ranged from 0.001 to 0.01

mg/kg/day, and manganese values ranged from 0.003 to 0.009 mg/kg/day. The results for zinc,copper, and manganese are consistent with the study by [38], while the results for iron align with the study by [39]. Cadmium values were recorded above the reference value in samples (A1, A2, B2, B3, C2, C3, D2, D3), with values of 0.9, 0.009, 0.009, 0.007, 0.009, 0.009, 0.006, and 0.01 mg/kg/day. The reason for the high daily intake may be attributed to elevated concentrations of this element, which could result from agricultural soil contamination [40]. The European Commission suggested that the permissible concentration for chromium should be 1 µg/g, while the Federal Environmental Protection Agency (FEPA, 2020) suggested 0.15 µg/g, and the World Health Organization (WHO) recommended 0.05 µg/g. The pathological effects of chromium include muscle stiffness, skin and kidney diseases, neurological disorders, and the development of various types of cancer [41].

### 2.1.5 Lead

The highest daily intake of lead was recorded in samples A2, B2, B3, C3, and D3, with values of 0.006, 0.005, 0.007, 0.007, and 0.006 mg/kg/day, respectively. These findings are in alignment with studies conducted by Victor (2022), Salah et al. (2013), and Hamzeh et al. (2018), which indicate that the maximum permissible level of lead in canned foods is 1 mg/kg. Reports from the Food and Agriculture Organization (FAO), the World Health Organization (WHO), the Federal Environmental Protection Agency (FEPA), and the Codex Alimentarius Committee on Food Additives and Contaminants (CCFAC) highlight that food additives can contribute to increased lead levels in canned food products. The occasional intake of food additives is estimated to amount to 400-500 µg of lead per week for adults (US EPA, 2020), which is regarded as acceptable. For packaged products intended for infants and children, the permissible level is 0.5 µg per mL.

### 2.1.6 Cadmium

The results indicate that the estimated daily intake of cadmium exceeds the oral reference value in several samples (A1, A2, B2, B3, C2, C3, D1, D3), with recorded values of 0.02, 0.01, 0.01, 0.004, 0.005, 0.01, 0.02, and 0.008 mg/kg/day. These findings are consistent with the research conducted by Martins et al. (2020). Elevated levels of cadmium pose significant health risks, particularly as the consumption of canned foods increases, leading to higher overall dietary intake. The bioaccumulation of this toxic metal in vital organs can result in various health issues, including kidney dysfunction, reduced reproductive capacity, skeletal damage, liver dysfunction, increased blood pressure, and cancer. According to FAO and WHO guidelines, the maximum permissible daily intake of cadmium should range between 0.01 and 0.01 mg/kg of body weight. Furthermore, Pradip et al. (2019) suggested that an adult weighing between 60 and 70 kg, consuming 100 g of food with the highest cadmium content over a week, would not exceed the permissible weekly limit under any circumstances. In summary, the analysis of lead and cadmium levels in canned food reveals concerning trends that warrant further investigation and monitoring to ensure public health safety. **Estimated Daily Intake**

Estimated daily intakes (EDIs) were calculated for the elements: chromium (Cr), cadmium (Cd), cobalt (Co), copper (Cu), manganese (Mn), lead (Pb), iron (Fe), and zinc (Zn). It was considered that a person weighing 70 kg consumes 48 grams of canned food daily. The results revealed that the daily intake of iron, zinc, copper, cobalt, and manganese is below the reference value for all study samples, and therefore does not pose a risk to the health of individuals consuming heavy metals through the consumption of canned legumes. Iron values were recorded between 0.005 and 0.04 mg/kg/day, while zinc values ranged from 0.002 to 0.02 mg/kg/day, and copper values ranged from 0.001 to 0.09 mg/kg/day. Cobalt values ranged from 0.001 to 0.01 mg/kg/day, and manganese values ranged from 0.003 to 0.009 mg/kg/day. The results for zinc,

copper, and manganese are consistent with the study by [38], while the results for iron align with the study by [39]. Cadmium values were recorded above the reference value in samples (A1, A2, B2, B3, C2, C3, D2, D3), with values of 0.9, 0.009, 0.009, 0.007, 0.009, 0.009, 0.006, and 0.01 mg/kg/day. The reason for the high daily intake may be attributed to elevated concentrations of this element, which could result from agricultural soil contamination [40]. The European Commission suggested that the permissible concentration for chromium should be 1 µg/g, while the Federal Environmental Protection Agency (FEPA, 2020) suggested 0.15 µg/g, and the World Health Organization (WHO) recommended 0.05 µg/g. The pathological effects of chromium include muscle stiffness, skin and kidney diseases, neurological disorders, and the development of various types of cancer [41].

### 2.1.7 Lead

The highest daily intake of lead was recorded in samples A2, B2, B3, C3, and D3, with values of 0.006, 0.005, 0.007, 0.007, and 0.006 mg/kg/day, respectively. These findings are in alignment with studies conducted by Victor (2022), Salah et al. (2013), and Hamzeh et al. (2018), which indicate that the maximum permissible level of lead in canned foods is 1 mg/kg. Reports from the Food and Agriculture Organization (FAO), the World Health Organization (WHO), the Federal

Environmental Protection Agency (FEPA), and the Codex Alimentarius Committee on Food Additives and Contaminants (CCFAC) highlight that food additives can contribute to increased lead levels in canned food products. The occasional intake of food additives is estimated to amount to 400-500 µg of lead per week for adults (US EPA, 2020), which is regarded as acceptable. For packaged products intended for infants and children, the permissible level is 0.5 µg per mL.

### 2.1.8 Cadmium

The results indicate that the estimated daily intake of cadmium exceeds the oral reference value in several samples (A1, A2, B2, B3, C2, C3, D1, D3), with recorded values of 0.02, 0.01, 0.01, 0.004, 0.005, 0.01, 0.02, and 0.008 mg/kg/day. These findings are consistent with the research conducted by Martins et al. (2020). Elevated levels of cadmium pose significant health risks, particularly as the consumption of canned foods increases, leading to higher overall dietary intake. The bioaccumulation of this toxic metal in vital organs can result in various health issues, including kidney dysfunction, reduced reproductive capacity, skeletal damage, liver dysfunction, increased blood pressure, and cancer. According to FAO and WHO guidelines, the maximum permissible daily intake of cadmium should range between 0.01 and 0.01 mg/kg of body weight. Furthermore, Pradip et al. (2019) suggested that an adult weighing between 60 and 70 kg, consuming 100 g of food with the highest cadmium content over a week, would not exceed the permissible weekly limit under any circumstances. In summary, the analysis of lead and cadmium levels in canned food reveals concerning trends that warrant further investigation and monitoring to ensure public health safety.

**Principal Component Analysis (PCA)**

The Caire-Meier or Lekin scale was employed, focusing on eigenvalues greater than 5.0, resulting in a total contribution of 75.89%. This indicates that the PCA model effectively identifies canned products (Libyan, Egyptian, and Italian) with a high level of contamination by heavy metals. Two main components of variance were identified: 44.634% for PC1 and 23.958% for PC2. PC1 accounts for 44.53% of the variance and includes samples D3, A1, D1, B1, and C3. This suggests that these products exhibit similar concentrations of heavy metals, potentially due to shared or related sources, despite being manufactured in different countries. For instance, agricultural crops may be contaminated through polluted soil and water.

PC2, which accounts for 23.958% of the variance, comprises samples C2, D2, and B2. These samples likely originate from similar sources, attributed to the use of comparable manufacturing processes. Notably, samples C2 and D2 are produced in the same country, supporting the conclusions drawn by [43] and [44].

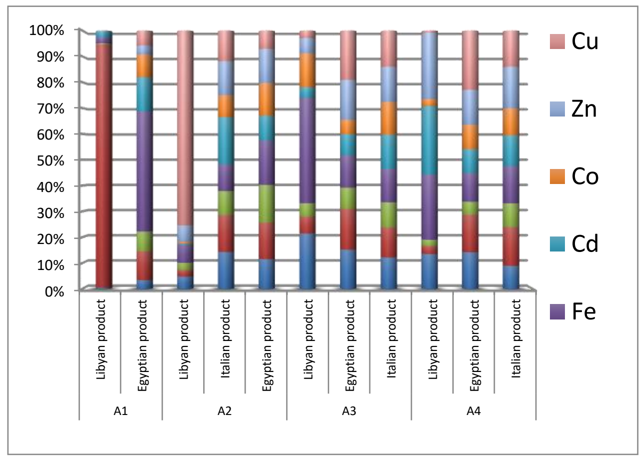


**Figure 1 Estimated daily intake (EDI) of metals via consumption of canned legumes for study sampl**

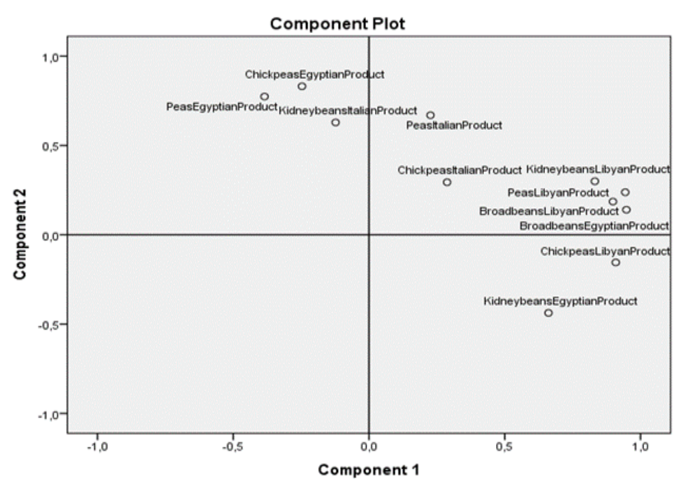


**Figure 2: Schematic illustration of heavy metal aggregates in packaged food prod**

***Table 1.*** *Conc. Of heavy metals, mean SD.(mg/g) in samples collected from Sebha city local market*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| N=3 **broad beans** | | | | | | | | |
| Cu | Zn | Co | Cd | Fe | Pb | Cr | Mn | Made in |
| 0.01±0.003 | 0.02±0.002 | 0.02±0.000 | 0.02±0.005 | 0.2±0.104 | 0.03±0.016 | 0.06±0.036 | 0.04±0 .017 | Libya |
| 0.04±0.030 | 0.02±0.004 | 0.05±0.002 | 0.1±0.018 | 0.1±0.264 | 0.05±0.030 | 0.07±0.025 | 0.02±0.003 | Egypt |
| -2.200 | -3.010 | -56.800 | -8.240 | -0.950 | -1.340 | -0.120 | -2.330 | Test T |
| 0.040 | 0.010 | 0.000 | 0.000 | 0.360 | 0.200 | 0.900 | 0.040 | P-Value |
| Kidney beans N=3 | | | | | | | | |
| 0.02±0.021 | 0.005±0.002 | 0.006±0.000 | 0.004±0.002 | 0.06±0.053 | 0.02±0.014 | 0.02±0.014 | 0.04±0.008 | Libya |
| 0.05±0.027 | 0.05±0.001 | 0.03±0.027 | 0.07±0.001 | 0.04±0.034 | 0.04±0.022 | 0.06±0.032 | 0.06±0.003 | Italy |
| 0.02±0.021 | 0.05±0.003 | 0.04±0.001 | 0.03±0.010 | 0.06±0.006 | 0.05±0.004 | 0.06±0.005 | 0.04±0.004 | Egypt |
| 2.390 | 689.050 | 8.390 | 180.350 | 0.374 | 4.150 | 4.780 | 23.830 | Test F |
| 0.120 | 0.000 | 0.000 | 0.000 | 0.690 | 0.030 | 0.020 | 0.000 | P-Value |
| Chickpeas N=3 | | | | | | | | |
| 0.01±0.003 | 0.02±0.007 | 0.04±0.034 | 0.01±0.001 | 0.11±0.106 | 0.014±0.008 | 0.02±0.016 | 0.03±0.011 | Libya |
| 0.08±0.011 | 0.07±0.027 | 0.024±0.020 | 0.04±0.025 | 0.05±0.020 | 0.04±0.015 | 0.07±0.014 | 0.07±0.004 | Egypt |
| 0.08±0.023 | 0.07±0.013 | 0.07±0.007 | 0.07±0.023 | 0.07±0.003 | 0.05±0.021 | 0.07±0.001 | 0.07±0.009 | Italy |
| 45.620 | 17.800 | 6.050 | 14.890 | 1.390 | 8.770 | 30.330 | 38.360 | Test F |
| 0.000 | 0.000 | 0.010 | 0.000 | 0.270 | 0.000 | 0.000 | 0.000 | P-Value |
| **Peas** N=3 | | | | | | | | |
| 0.004±0.001 | 0.12±0.103 | 0.01±0.006 | 0.01±0.008 | 0.11±0.109 | 0.01±0.009 | 0.01±0.012 | 0.06±0.012 | Libya |
| 0.07±0.005 | 0.04±0.023 | 0.03±0.018 | 0.03±0.020 | 0.03±0.011 | 0.02±0.004 | 0.04±0.033 | 0.04±0.007 | Egypt |
| 0.07±0.020 | 0.08±0.005 | 0.05±0.026 | 0.06±0.006 | 0.07±0.003 | 0.04±0.009 | 0.07±0.021 | 0.04±0.013 | Italy |
| 56.880 | 2.350 | 5.760 | 17.420 | 2.470 | 30.860 | 8.610 | 6.480 | Test F |
| 0.000 | 0.120 | 0.010 | 0.000 | 0.110 | 0.000 | 0.000 | 0.010 | P-Value |

**Table 2** Estimated daily intake (EDI) and allowable daily intake of metals via consumption of canned legumes for study sample

| E∑ DI | Heavy metals ( mg /kg /day ) | | | | | | | | Made | Trademark and symbl |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cu | Zn | Co | Cd | Fe | Pb | Cr | Mn | | |
| **0.9** | **0.001** | **0.002** | **0.001** | **0.02** | **0.02** | **0.004** | **0.9** | **0.01** | **Libyan Product ( A 1 )** | **Broad beans ( A )** |
| **0.1** | **0.005** | **0.003** | **0.01** | **0.01** | **0.04** | **0.01** | **0.01** | **0.003** | **Egyptian Product ( A 2 )** | |
| **0.11** | **0.1** | **0.01** | **0.001** | **0.001** | **0.01** | **0.003** | **0.003** | **0.005** | **Libyan Product ( B 1 )** | **Kidney beans ( B )** |
| **0.05** | **0.01** | **0.01** | **0.005** | **0.01** | **0.01** | **0.005** | **0.01** | **0.008** | **Italian Product ( B 2 )** | |
| **0.05** | **0.003** | **0.01** | **0.006** | **0.004** | **0.01** | **0.01** | **0.01** | **0.005** | **Egyptian Product )B 3(** | |
| **0.04** | **0.001** | **0.002** | **0.01** | **0.002** | **0.02** | **0.002** | **0.003** | **0.01** | **Libyan Product ( C 1 )** | **Chickpeas** |
| **0.1** | **0.01** | **0.01** | **0.003** | **0.005** | **0.01** | **0.005** | **0.01** | **0.01** | **Egyptian Product )C 2(** | |
| **.0000007** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** | **Italian Product (C 3 )** | |
| **0.1** | **0.001** | **0.02** | **0.01** | **0.02** | **0.02** | **0.002** | **0.002** | **0.01** | **Libyan Product ( D 1 )** | **Peas ( D )** |
| **0.04** | **0.01** | **0.01** | **0.004** | **0.004** | **0.005** | **0.002** | **0.01** | **0.01** | **Egyptian Product ( D 2 )** | |
| **0.1** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** | **Italian Product ( D 3 )** | |
| - | 0.4 | 0.515-0.3 | 0.02 | 0.003-0.001 | 0.7-1.32 | 0.004 | 0.003 | 0.14 | **RFD *( Zhao et al ; 2012; martins et al ; 2020;EC ;2006 )*** | |
| - | 1 | 5 | N.M | 0.01 | 0.3 | 0.5-0.1 | 0.05 | 0.1 | **Allowable daily intake . *Victor ,(2022)*** | |

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**Table 3** Principal component analysis (PCA) to illustrate the relationship Between packaged food products of different manufactures and variation in the concentration of heavy and trace metals.

| Extraction Sums of Squared Loadings | | | Initial Eigenvalues | | | |
|---|---|---|---|---|---|---|
| Cumulative % | % of Variance | Total | Cumulative % | % of Variance | Total | Comp. |
| 44.634 | 44.634 | 4.910 | 44.634 | 44.634 | 4.910 | (A1) |
| 68.592 | 23.958 | 2.635 | 68.592 | 23.958 | 2.635 | ( A 2) |
| | | | 84.987 | 16.394 | 1.803 | ( B 1 ) |
| | | | 94.369 | 9.383 | 1.032 | ( B 2 ) |
| | | | 98.266 | 3.897 | .429 | ( B 3 ) |
| | | | 99.324 | 1.057 | .116 | ( C 1 ) |
| | | | 100.000 | .676 | .074 | ( C 2 ) |
| | | | 100.000 | 2.411E-15 | 2.652E-1 | (C 3 ) |
| | | | 100.000 | 1.914E-15 | 2.105E-1 | ( D 1 ) |
| | | | 100.000 | 6.307E-16 | 6.938E-17 | ( D 2 ) |
| | | | 100.000 | -2.714E-15 | -2.986E-16 | ( D 3 ) |

| Components | | |
|---|---|---|
| PC2 | PC1 | Product |
| .186 | .898 | ( A1) |
| .140 | .948 | ( A2) |
| .300 | .832 | ( B1) |
| .629 | -.123 | ( B2) |
| -.437 | .661 | (B 3) |
| -.155 | .909 | ( C1) |
| .831 | -.247 | (C 2) |
| .294 | .288 | (C 3) |
| .238 | .944 | (D1) |
| .774 | -.385 | (D2) |
| .669 | .226 | (D3) |

**Extraction Method: Principal Component Analysis.**

**Rotation Method: Varimax with Kaiser Normalization.**

**CRITERIA FACTORS(2) ITERATE(25), FORMAT BLANK(.10), PLOT ROTATION**

Table 4: Source of permissible limits: FAO/WHO Codex Alimentations Commission (2015).

| Element | FAO/WHO Permissible Limit (mg/kg) | Mean Concentration (mg/kg) |
|---|---|---|
| Cu | 40 | 0.45 ± 0.03 |
| Zn | 60 | 1.21 ± 0.10 |
| Cd | 0.10 | 0.08 ± 0.01 |
| Pb | 0.20 | 0.15 ± 0.02 |
| Cr | 1.30 | 0.09 ± 0.01 |
| Mn | 2.00 | 0.56 ± 0.04 |

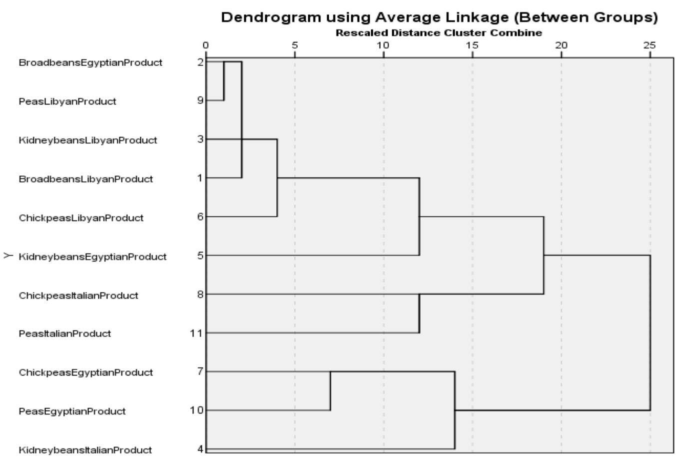


**Figure 3 : Schematic diagram of packaged food product assemblies to illustrate similar or dissimilar distribution patterns of heavy and trace metals**

## Discussion & Recommendations

Canned legumes sold in Sabha, Libya, contain dangerously high levels of cadmium and chromium in samples from Libya, Egypt, and Italy.The estimated daily intake of Cd and Cr exceeds safe oral reference doses, leading to hazard quotient values>13, posing a significant health risk to regular consumers. Immediate regulatory action is needed: stricter import controls, regular testing of canned foods, and public awareness campaigns to limit consumption of high-risk brands. Future studies should analyses total Cr and Cr(VI) separately and measure weekly dietary exposure across different age groups.

**Identification of Contamination Sources:** Conduct comprehensive investigations of agricultural soils used for cultivating raw materials for canned food products, as well as the irrigation water sources, in order to accurately identify and trace the origins of heavy metal contamination.

**Implementation of Control and Monitoring Systems:**
Establish and enforce effective control and monitoring systems throughout the stages of production, processing, and packaging to minimize heavy metal concentrations. This should be carried out in strict compliance with the standards and guidelines set by the Codex Alimentations Commission, in cooperation with the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), to ensure food quality and safety.

**Strengthening Regulatory and Administrative Oversight:** Enhance regulatory and administrative supervision over the importation of high-quality canned food products that comply with established health standards. Furthermore, reinforce the role of the Food Quality Authority to ensure that all locally produced and imported food items are subjected to appropriate laboratory analyses prior to market distribution. Emphasis should be placed on improving trading practices and developing guidance programs that promote safe and healthy food marketing and handling.

## 3 Conclusions

The results of this study demonstrated variations in heavy metal and trace element concentrations among canned legume samples from Libya, Egypt, and Italy. Copper concentrations in broad beans ranged from 0.01

to 0.04 mg/kg, while iron concentrations in chickpeas reached 0.11 mg/kg in Libyan products. The highest lead concentration was detected in peas, reaching 0.02 mg/kg in Egyptian samples. Estimated daily intake values ranged between 0.001 and 0.1 mg/kg/day. Although most detected concentrations were within the permissible international limits, the variation among samples highlights the importance of regular monitoring of canned legumes to ensure food quality and consumer safety.

**Conflict of interest**:

The authors declare that there is no conflict of interest regarding the publication of this paper

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Enclose the references list at the end of the manuscript accordingly to the APA (American Psychological Association) style (5th to 7th) edition.

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