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Study of Measuring Heavy Metals in Some Leafy Vegetables

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Abstract;

This study was conducted to assess the concentration of heavy metals in some of the most consumed leafy vegetables in the Al-Jmail area of western Libya.

The heavy metals lead, cadmium, chromium, and copper were measured in some vegetables, including parsley, dill, and spinack. The values of cadmium in the parsley sample ranged from a maximum of 2.25 mg \litre to a minimum of less than 0.3 mg. For copper, the highest value was 2.46 mg/liter and the lowest was 2.2 mg/liter. As for lead, the highest value was 14.198 mg/liter and the lowest was less than 0.3 mg. The values for chromium were equal in four lod, being less than 0.05 mg/liter.

In the dill sample, the highest value for cadmium was 3.9 mg/liter, with the lowest value being less than 0.3 mg/liter. For copper, the highest value was 1.74 mg/liter and the lowest was less than 0.3 mg/liter. The highest value for lead was 15.5 mg/liter and the lowest was 10.6 mg/liter. The values for chromium were equal in all four directions, being less than 0.05 mg/liter.In the spinack sample, the highest value for cadmium was 0.75 mg/liter, with the lowest value being less than 0.5 mg/liter.

For copper, the highest value was 2.11 mg/liter and the lowest was 1.25 mg/liter. The values for lead were equal in all four directions, being less than 0.03 mg/liter. The values for chromium were also equal in four lod , being less than 0.05 mg/liter.The results showed that the concentrations of heavy metals (cadmium and lead) in the parsley and dill vegetable samples were above the permissible limits according to the World Health Organization specifications from 2001.

Keywords: Heavy metals, Cadmium, Lead, Chromium, Copper, Leafy vegetables, Parsley, Dill, Spinach, Al-Jmail, Western Libya, Contamination, WHO permissible limits.

المستخلص

أجريت هذه الدراسة لتقيم تركيز المعادن الثقيلة في بعض الخضروات الورقية الأكثر استهلاك في منطقة الجميل بالغرب الليبي حيث تم تقدير العناصر الثقيلة الرصاص والكادميوم والكروم والنحاس في بعض الخضراوات التي شملت البقدونس، الشبت ، السلك، حيث اظهرت تتراوح قيم عنصر الكادميوم في عينة البقدونس كانت اعلاهم 2.25ملي غرام / لتر وأقلهم أقل من 0.3 أما بالنسبة لعنصر النحاس كانت أعلي قيمة 2.46 ملي غرام / لتر وأقل قيمة 2.2ملي غرام \اللتر اما بالنسبة لعنصر الرصاص كانت اعلى قيمة 14.198ملي غرام / لتر واقل قيمة اقل من 0.3 لعنصر الكروم كانت القيم متساوية في الجهات الأربعة وهي اقل من 0.05

اما بالنسبة لعينة الشبت كانت اعلى قيمة لعنصر الكادميوم 3.9ملي غرام/ لتر وكانت اقل قيمة اقل من 0.3غرام / لتر اما بالنسبة لعنصر النحاس كانت اعلى قيمة 1.74غرام واقل قيمة اقل من 0.3 اما بالنسبة لعنصر الرصاص كانت اعلى قيمة 15.5 غرام/ لتر واقل قيمة 10.6 اما بالنسبة لعنصر الكروم كانت القيم متساوية في الجهات الأربعة وهي اقل من 0.05 غرام / لتر

اما بالنسبة لعينة السلك كانت اعلى قيمة لعنصر الكادميوم 0.75 غرام / لتر وكانت اقل قيمة اقل من 0.5غرام / لتر اما بالنسبة لعنصر النحاس كانت اعلى قيمة 2.11غرام / لتر واقل قيمة 1.25غرام / لتر اما بالنسبة لعنصر الرصاص كانت القيم متساوية في الجهات الأربعة وهي اقل من 0.03غرام / لتر اما بالنسبة لعنصر الكروم متساوية في الجهات الأربعة وهي اقل من 0.05 ملي غرام / لتر

توصلت الى أن تركيز العناصر الثقيلة (الكادميوم والرصاص) في عينات الخضار البقدونس والشبت كانت قيمها أعلى من الحد المسموح به طبقا مواصفات منظمة الصحة العالمية 2001

الكلمات المفتاحية :المعادن الثقيلة؛ الكادميوم؛ الرصاص؛ الكروم؛ النحاس؛ الخضروات الورقية؛ البقدونس؛ الشبت؛ السبانخ؛ الجمال؛ غرب ليبيا؛ التلوث؛ الحدود المسموح بها وفق منظمة الصحة العالمية

. Overall Framework of the Study ;

1-1 Introduction

Leafy vegetables are considered one of the most beneficial foods for human health, as these vegetables work to promote human health and protect against health problems that can negatively affect the body

Leafy vegetables are known for their distinctive dark green color and high content of nutrients such as vitamins A, K, E, and folic acid, as well as minerals such as calcium and potassium, in addition to fiber and other nutrients. This explains their many health benefits that they provide to the body, including supporting the immune system.

Leafy vegetables also contain some heavy metals, the presence of which in small quantities is required, but if these elements exceed their required limit, they become toxins that can have a negative and potentially harmful effect on human health (Myers, 2023).

Given the importance of leafy vegetables in a balanced healthy diet, they play an important role for pregnant and breastfeeding women due to their content of folic acid necessary for the proper growth of the fetus. They are also important for the elderly and athletes.

The term "heavy metals" refers to any metallic chemical element that has a relatively high density and is either non-toxic or toxic at low concentrations, and has negative effects on human, animal, and plant health. Examples of heavy metals include lead (Pb), cadmium (Cd), copper (Cu), and chromium (Cr). (Baptist Health, 2023).

They are natural elements in the earth's crust that cannot be decomposed or broken down to a small degree. Some heavy metals are necessary to maintain the metabolic process of the human body, but their presence at higher concentrations can lead to poisoning. Heavy metal pollution is considered one of the forms of environmental pollution resulting from human agricultural activity.

To maintain the quality of vegetables and ensure their safety, our study focuses on the effect of metals on leafy vegetables, specifically some leafy vegetables (parsley, dill, and spinack), by taking samples from different areas of the city of Al-Jamil and analyzing them in the laboratory (Al-Sadeem in Janzour and the Nuclear Research Center in Tajoura) and comparing the proportion of heavy metals in each type of the aforementioned vegetables

1-2- Problem statement :

The problem of the study lies in the extent of the impact of heavy metals on leafy vegetables, if present, and their effect on human health if they exceed the permissible limit set by the World Health Organization.

1-3-significance of the Study:

This study is interested in studying heavy elements in terms of their presence in leafy vegetables and their biological effects and their relationship to human health. Food is considered one of the main sources of human exposure to these elements,

1-4- Study Objectives:

1- The study aims to shed light on the dangers of heavy metals and the extent of their concentration in leafy vegetables.

1-6- Study Limits:

1- **Time limits**: The study begins in February 2024 and take a period of 3 to 6 months.
2- **Spatial limits:** in this study, samples were taken from four locations in different directions of the city of Al-Jamil, specifically from the east, west, north, and south. The sampling locations included Bir Al-Hilu in the east, Al-Makhrusa in the west, Al-Jamil in the north, and Abu Tina in the south. From each of these locations, three samples of each type of leafy vegetable—parsley dill and spinack—were collected, resulting in a total of 12 samples. The collected samples were subsequently analyzed at both the Al-Sadeem Laboratory and the Nuclear Research Center in Tajoura.

1-7- Study Methodology:

Analytical descriptive statistical approach Vegetable samples will be taken and a chemical analysis will be performed on them.

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Four heavy elements found in plants were used, and their results and proportions in each plant were detected. Their proportions varied from one plant to another, as the highest proportions were concentrated in the chard plant, followed by the dill plant, and the last was the heavy elements. As for the elements, the highest proportion was the nickel element in the plants subject to examination, followed by the lead element, and the last was the cadmium element, which had the lowest or almost non-existent proportions in the plants. As for the plant parts, the highest proportions were present in the soil and more in the soil of the chard plant, and the next were the leaves from the plant parts. As for the last, the leaves had the lowest proportions of heavy elements in the plants subject to examination

The Study's Theoretical Framework:

2-1 Leafy Vegetables

Leafy vegetables have been a cornerstone of human nutrition since ancient times. Their importance stems from their high nutritional value, as they are rich in essential vitamins, minerals, and dietary fiber, making them highly nutritious and low in calories. Consuming a diet rich in leafy vegetables can help prevent various diseases and boost the immune system. Leafy vegetables are also a significant source of folic acid, which helps reduce homocysteine levels. Additionally, they contain magnesium, selenium, and other compounds that support vascular health (Mann et al., 2015).

Picture (1): shows parsley leaves plant

2-2 Parsley

Parsley is a fundamental herb in the kitchen that can easily be incorporated into the diet, whether in cooking, salads, or as a garnish. Parsley is rich in essential nutrients, such as vitamins, minerals, and antioxidants, which give it a wide range of health benefits (Kooti et al., 2018).

2-2-1Benefits of Parsley

1) Digestive and Liver Health

Consuming parsley daily may support digestive health due to its role in supporting the liver. Parsley increases levels of glutathione, a key antioxidant in the liver. It has been shown to aid in liver tissue regeneration after damage caused by chronic diseases, as parsley stimulates bile production in the liver, which is necessary for fat digestion in the intestines (Mossalam k . et al., 2014).

2) Lowering Blood Sugar Levels

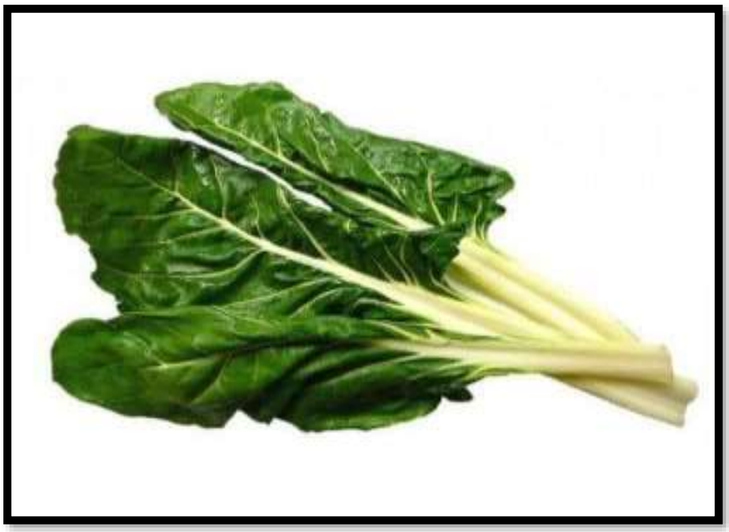
Parsley has been found to lower blood glucose levels and is used as an alternative treatment for type 1 diabetes in some countries (Sadeghzadeh et al., 2020)which helps lower blood pressure (Coutinho et al., 2015).

2-2-2 Potential Side Effects of Parsley

Parsley leaves and stems are generally safe and can be consumed without concern for toxicity. However, the seeds are more potent and contain essential oils that should be consumed carefully. The seeds can cause nausea, headaches, sun sensitivity, and liver and kidney damage. It is also recommended that pregnant women avoid consuming parsley to prevent premature labor, and nursing mothers should avoid it due to the risk of reducing milk production (Kooti et al., 2018).

2-3 spinack

Swiss chard (Beta vulgaris subsp. cicla) is a type of leafy vegetable that is rich in minerals, vitamins B and C, folic acid, and iron. Both the leaves and roots can be consumed, making it a versatile and nutritious addition to the diet (Rizvi et al., 2015).



Picture (2): shows chard leaves plant

2-3-Benefits of Swiss Chard

1) Lowering Blood Pressure

Swiss chard contains large amounts of vitamin K and nitrates, which help lower high blood pressure. Regular consumption of vegetables and fruits, including Swiss chard, is associated with numerous health benefits, such as reducing the risk of obesity, diabetes, and heart disease. It also improves skin appearance and increases energy levels (Liu et al., 2015).

2) Cancer Prevention

Swiss chard contains chlorophyll, which may help inhibit the effects of carcinogenic compounds produced when grilling or cooking certain foods at high temperatures. Additionally, it contains alpha-lipoic acid, an antioxidant that has been shown to reduce glucose levels, increase insulin sensitivity, and prevent oxidative stress changes in patients with diabetes **(Kanter et al., 2016).**

3) Bone Health

The adequate intake of vitamin K, found inspinack, is essential for improving bone health and preventing osteoporosis. Vitamin K enhances the protein structure of bones, improving calcium absorption and reducing the risk of fractures (Weaver et al., 2016).

2-3-2Potential Side Effects of Swiss Chard

Despite its many benefits, Swiss chard has some potential drawbacks. Its high vitamin K content makes it unsuitable for individuals taking blood-thinning medications, as vitamin K plays a significant role in blood clotting, which can interfere with the effectiveness of these medications (Furie & Furie, 2020).

2-4 Dill

Dill is an aromatic herb with green, fragrant leaves and a distinctive flavor. It is widely used in various dishes and is a key ingredient for those following a weight-loss diet. Dill is low in cholesterol and very low in calories, with 100 grams containing 2.1 grams of dietary fiber, which promotes satiety and reduces the frequency of eating (Sahib et al., 2013).

Picture (3): shows dill plant

2-4-1Benefits of Dill

1) Bone Health

Dill is rich in calcium, making it an important element in protecting against osteoporosis and loss of bone mineral density (Kooti et al., 2018).

2) Regulating Blood Sugar Levels

Dill has long been associated with diabetes management, as it helps regulate insulin levels. Studies indicate that dill may help reduce fluctuations in insulin levels in people with diabetes (Sahib et al., 2013).

3) Gas Relief

Dill acts as a carminative, preventing the accumulation of gas in the intestines and promoting its passage through the digestive system (Ali et al., 2017).

4) Antimicrobial Properties

Dill helps prevent microbial infections throughout the body, including those that can lead to open or small wounds on the skin (Sahib et al., 2013).

5) Diarrhea Treatment

Dill aids digestion and contains monoterpenes that eliminate germs in the body, helping treat diarrhea caused by microbial infections (Ali b.h. et al., 2017).

6) Oral Care

Dill seeds and leaves are natural breath fresheners and help eliminate microbial infections in the mouth. The antioxidants in dill reduce damage caused by free radicals in the gums and teeth (Ali et al., 2017).

2-4-2Potential Side Effects of Dill

Dill is generally safe, but in rare cases, it can cause side effects such as diarrhea, itching in the mouth, vomiting, throat swelling, and mild tongue swelling. It is also advisable to avoid dill during pregnancy and breastfeeding due to the lack of sufficient safety data (Kooti et al., 2018).

2-5 Heavy Metals

Heavy metals are elements with a density greater than five times that of water (5 mg/cm³). These metals are stable, meaning they are not metabolized in the human body and can accumulate, leading to toxicity. The most harmful heavy metals include mercury, lead, arsenic, and cadmium. These elements have no beneficial role in the body and are highly toxic, entering the body through inhalation, skin absorption, or ingestion of contaminated food. If the rate of entry exceeds the body's ability to eliminate them, they accumulate to dangerous levels, potentially affecting human health through direct consumption of contaminated fruits and vegetables (Tchounwou et al., 2012).

2-5-1 Properties of Heavy Metals

1) **Opacity**: Heavy metals are generally opaque, meaning they do not allow light to pass through. This property is significant in applications such as radiation shielding, where materials need to block harmful radiation effectively (Lenntech, 2023).
2) **Ductility and Luster**: Many heavy metals, such as gold and silver, possess high ductility, allowing them to be drawn into wires without breaking. Additionally, they often have a shiny luster, making them desirable for decorative applications and jewelry (Study.com, 2023).
3) **Electropositivity**: Heavy metals tend to be electropositive, meaning they readily lose electrons to form positive ions. This property is crucial in chemical reactions, particularly in the formation of alloys and in various industrial processes (Wikipedia, 2023).
4) **Thermal and Electrical Conductivity**: Heavy metals are known for their excellent thermal and electrical conductivity. This characteristic makes them essential in electrical wiring and electronic components, where efficient heat and electricity transfer is required (NCBI, 2014).

2-5-2Toxicity of Heavy Metals

1) Enzyme Disruption

Heavy metals form stable bonds with functional groups in enzymes, creating complexes that disrupt metabolic reactions (Jomova & Valko, 2011).

2) Cell Membrane Damage

Heavy metals accumulate on cell membranes, altering their structure and impairing or completely blocking the exchange of ions and essential organic molecules (Tchounwou et al., 2012).

For example, organic mercury compounds are neurotoxic, lead compounds harm the motor nervous system, arsenic is carcinogenic, and cadmium affects kidney function and neuropsychological health (Jomova . k. Valko.mo., 2011).

2-5-3 Heavy Metals studied in current study

1) Lead (pb):

Lead is one of the most dangerous environmental pollutants and has significant effects on human health, causing various modern diseases. Lead is one of the four metals with the highest risk to human health. It is a natural blue-gray metal found in small quantities in the Earth's crust and can be found in all parts of the environment due to human activities, such as fossil fuel burning, mining, and industrial processes (Needleman, 2004)

Picture (4): shows lead element

Health Effects of Lead:

- Disruption of hemoglobin synthesis and anemia.
- High blood pressure.
- Kidney tissue atrophy.
- Nervous system disorders and brain cell damage.
- Learning disabilities in children.
- Behavioral disorders in children (Needleman, 2004)

2) Cadmium (Cd)

Cadmium is one of the most dangerous heavy metals to human health due to its high toxicity to all living organisms. Cadmium enters the human body primarily through the food chain, especially from grains, fruits, and vegetables. Some plants, such as tobacco, can selectively absorb cadmium from the soil, leading to its accumulation in the tissues. When humans ingest cadmium in amounts exceeding the permissible limit, only about 5% is excreted, with the remainder accumulating in the liver and kidneys, where it is excreted very slowly. Cadmium is a potent carcinogen that enters the body through the respiratory system (Satarug et al., 2003).

Picture (5): shows cadmium element

Health Effects of Cadmium:

- Diarrhea, stomach pain, and vomiting.
- Osteoporosis and respiratory disorders.
- Cancer and infertility, DNA damage.
- High blood pressure and effects on heart muscle.
- Impaired kidney function leading to kidney failure (Satarug et al., 2003).

3) Copper (cu)

Copper is an essential nutrient that plays a vital role in many bodily functions, including promoting heart and bone health, supporting the nervous system, and maintaining healthy skin and hair. However, excessive copper intake can lead to health risks, including copper poisoning and negative effects on the kidneys and liver. Copper can be obtained from various dietary sources, including nuts, seeds, vegetables, fruits, meats, and fish. It is important to determine daily copper needs and balance intake to maintain good health (Gaetke et al., 2014).

Picture (6): shows copper elements

Health Effects of Excess Copper:

- Vomiting.
- Nausea.
- Diarrhea.
- Stomach pain.
- Changes in urine color (Gaetke et al., 2014).

4) Chromium(cr)

Chromium helps reduce triglyceride levels and increase good cholesterol. It also improves insulin sensitivity in people with type 2 diabetes and plays a significant role in how the body metabolizes proteins, carbohydrates, and fats. Chromium also supports cardiovascular health, weight loss, and brain function (Vincent, 2003).

Picture (7): shows chromium element

Health Effects of Excess Chromium:

- Stomach ulcers and disorders.
- Respiratory disorders.
- Weak immune system.
- Kidney and liver atrophy.
- Genetic material changes.

Lung cancer (Vincent, 2003)

Methodology;

3-1 Methodological Procedures

In this chapter, we will discuss the methodology followed in this project, including the identification of the research community and the selected sample, the scientific methods used during the data collection process, and the statistical methods employed in the analysis of the collected data.

3-2 Study Methodology

Since the aim of the project is to study the measurement of heavy metals in some types of leafy vegetables in the city of Al-Jmail, the researchers relied on a descriptive analytical approach due to its suitability for the nature and objectives of the research.

The following data were utilized:

3-2-1 Primary Data:

This consists of data found in scientific books, publications, journals, and previous research studies related to the research topic, aiming to benefit and enrich the research subject scientifically.

3-2-2 Chemical Analysis:

The necessary chemical analyses to fulfill the research requirements, which allow for the identification of heavy metal concentrations in the selected vegetables for this study, include the following elements: Cr, Pb, Cu, and Cd.

3-2-3 Research Sample

The study sample consisted of a collection of leafy vegetable samples from the city of Al-Jmail, specifically including parsley, dill, and chard. This study extended over the period from March to June 2024.

3-2-4- Materials and Methods

1- Laboratory Analyses:

The following devices were used to conduct all necessary tests for the study in both the Al-Sadeem Laboratory and the Nuclear Research Center in Tajoura, which included:

2- Tools Used:

- Automatic pipette (Micropipette) with a capacity of 100-1000 ml

- Beaker (pickar) with a capacity of 100 ml
- Standard flask with a capacity of 100 ml

Picture (8):Automatic pipette (Micropipette)

Picture(9):Standard flask with a capacity of 100 ml

Picture(10):Beaker (pickar) with a capacity of 100 ml

- Chemicals Used:

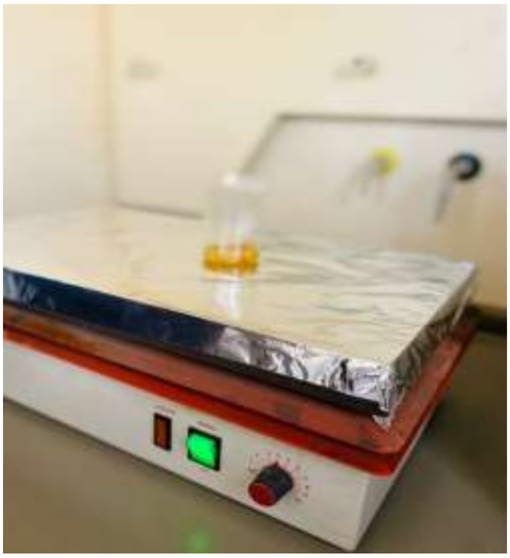
- Nitric acid (HNO3)
- Hydrogen peroxide (H2O2)

4- Devices Used:

- Sensitive balance
- Heating device
- Atomic absorption spectrometer

Picture (11):Sensitive balance

Picture (12):Atomic absorption spectrometer



Picture (13):Heating device

3-2-5 Samples Used:

(parsley, dill .spinack)

1- Sampling Stage:

Samples were taken from four locations in different directions of the city of Al-Jamil (East, West, North, South), and three samples of each type (parsley, dill .spinack) were collected from each direction, resulting in a total of 12 samples from the four locations.

- The first location was from the eastern part of Al-Jamil, an area called (Bir Al-Hilu).
- The second location was from the western part of Al-Jamil, an area called (Al-Makhrusa).
- The third location was from the northern part of Al-Jamil, an area called (Al-Jamil).
- The fourth location was from the southern part of Al-Jamil, an area called (Abu Tina).

2- Sample Preparation Stage:

In this stage, the sample is washed using distilled water to remove surface impurities, and then the sample is cut into small pieces to facilitate accurate weighing using the sensitive balance to determine its initial mass.

3- Sample Digestion Stage:

This stage is very important before analyzing heavy metals. Through digestion, heavy metals are dissolved and separated from organic molecules for measurement. After obtaining the specified weight on the sensitive balance, we add 5 ml of concentrated nitric acid (molarity 69.5) to the sample, then place the sample on the heating device and add hydrogen peroxide (30%) in increments until the sample becomes transparent, indicating the completion of the digestion process. After digestion, we filter the sample to separate solids from liquids and add distilled water to increase the sample volume to 100 ml.(Radwan et.l.,2006)

4- Heavy Metal Estimation Stage:

The analysis of the samples was conducted using the atomic absorption spectrometer at the Nuclear Research Center in Tajoura. The samples were returned to their original state, using the initial weight as a reference, and the device displayed the concentrations of each element.

3-3 Analysis of study samples :

The concentrations of lead, copper, chromium, and cadmium were measured using the atomic absorption spectrometer.

3-4 Analysis of Heavy Metal Concentrations in Parsley Samples

direction	Cd	Cu	Pb	Cr
e	2.25	2.17	14.198	0.05>
w	0.80	2.46	8.26	0.05>
n	0.50	2.30	8.00	0.05>
s	<0.30	2.20	<0.30	<0.05

3-5 Analysis of Heavy Metal Concentrations in Dill Samples

direction	Cd	Cu	Pb	Cr
e	2.37	1.74	10.60	0.05>
w	3.90	0.30>	12.55	0.05>
n	0.30>	0.70	15.50	0.05>
s	<0.30	0.85	15.10	<0.05

3-6 Analysis of Heavy Metal Concentrations in Chard Samples

direction	Cd	Cu	Pb	Cr
e	0.50>	1.25	0.03>	0.05>
w	0.50>	2.10	0.03>	0.05>
n	0.50>	1.80	0.03>	0.05>
s	0.75	2.11	<0.03	<0.05

3-7 Statistical Analysis Methods Used

The statistical methods employed in this study, which align with the nature of the research, are as follows:

- Arithmetic means and percentage difference ratios of the chemical analyses.
- One Way ANOVA test.
- Post Hoc Test and Tukey test.

4. Results and Discussion

In this chapter, all results obtained from the analyses related to the research topic will be presented, discussed, and analyzed to address the research hypotheses:

1. The extent to which the components of the vegetables under study conform to the specified standards for heavy metals.

Element (Cr)

Table (1): Descriptive Statistics for Element (Cr)

variable	Veg. type	Mean ± St.d
Cr	Parsley	**0.032 ± 0.013**
	Dill	**0.031 ± 0.009**
	Swiss chard	**0.338 ± 0.201**

Based on Table (1), the following can be observed:

- The concentration levels of element (Cr) under study for all three types of leafy vegetables are below the permissible limits, which are set at (1-2 mg/l) according to the standards of Codex Alimentarius. The following figure illustrates this.

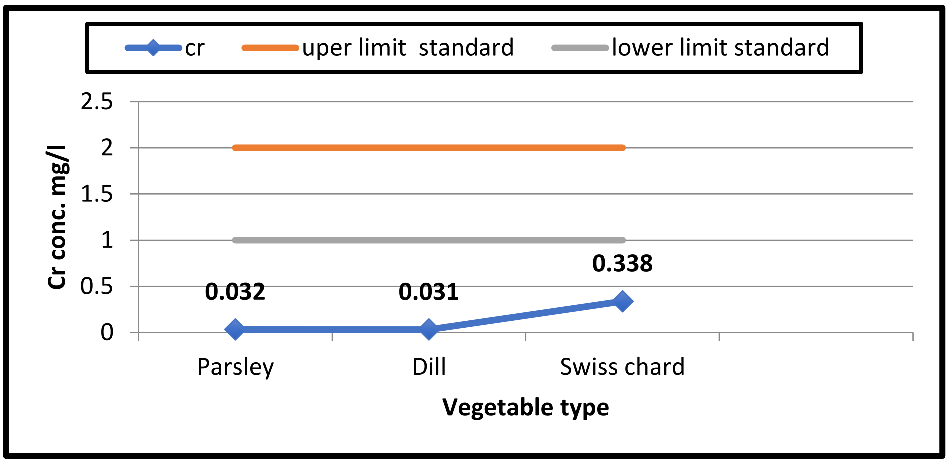


Figure (1) shows a comparison of element (Cr) concentration with the permissible limits.

Element (Pb)

Table (2): Descriptive Statistics for Element (Pb)

variable	Veg. type	Mean ± St.d
Pb	Parsley	**7.775 ± 1.497**
	Dill	**13.938 ± 1.026**
	Swiss chard	**1.497 ± 0.003**

Based on Table (2), the following can be observed:

- The concentration levels of element (Pb) under study for all three types of leafy vegetables are higher than the permissible limits, which are set at (0.3 mg/l) according to the standards of Codex Alimentarius. The following figure illustrates this.

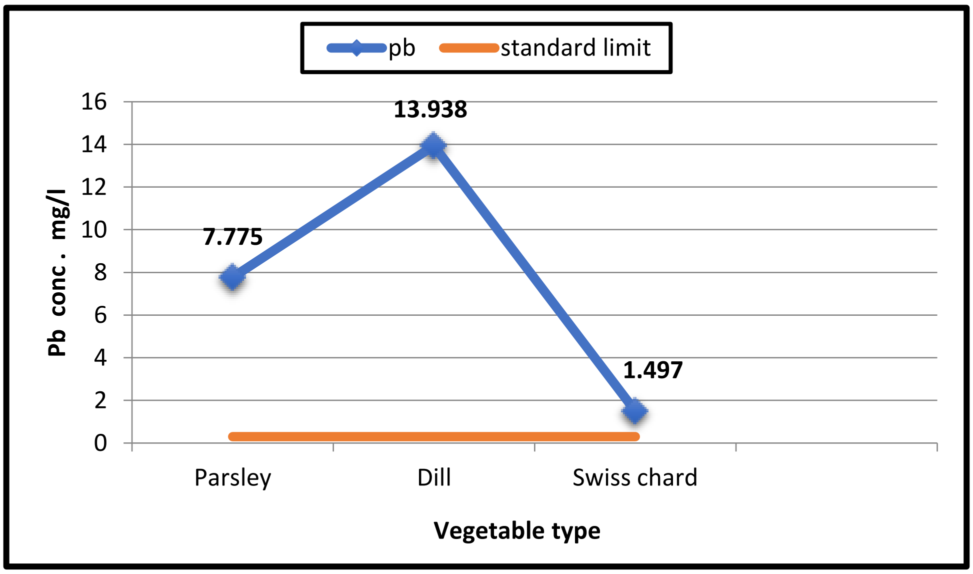


Figure (2) shows a comparison of element (Pb) concentration with the permissible limits.

Element (Cu)

Table (3): Descriptive Statistics for Element (Cu)

variable	Veg. type	Mean ± St.d
Cu	Parsley	2.168 ± 0.125
	Dill	1.633 ± 0.232
	Swiss chard	1.815 ± 0.403

Based on Table (3), the following can be observed:

- The concentration levels of element (Cu) under study for all three types of leafy vegetables are below the permissible limits, which are set at (10 mg/l) according to the standards of Codex Alimentarius. The following figure illustrates this.

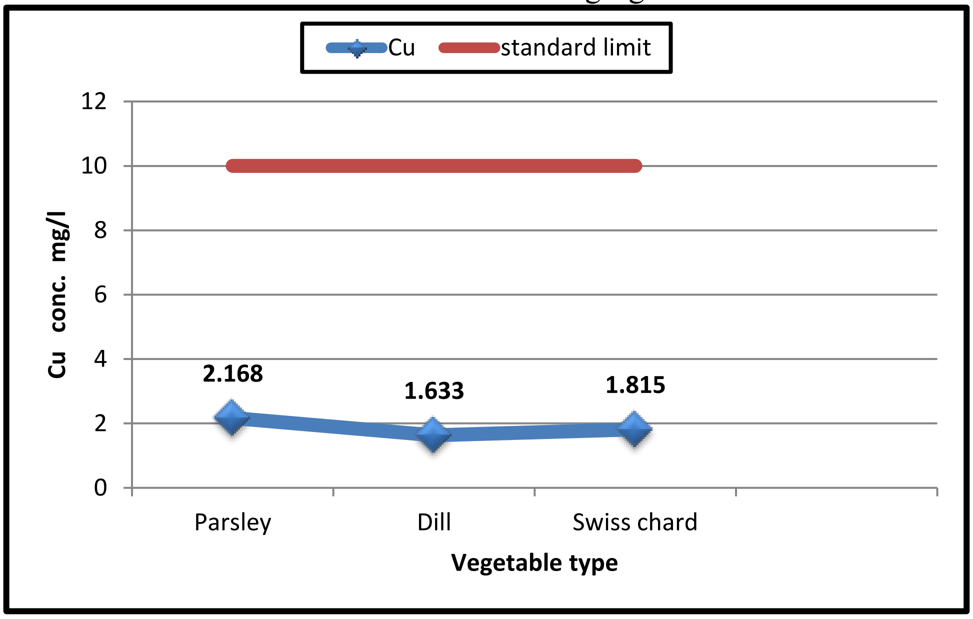


Figure (3) shows a comparison of element (Pb) concentration with the permissible limits.

Element (Cd)

Table (4): Descriptive Statistics for Element (Cd)

variable	Veg. type	Mean ± St.d
Cd	Parsley	0.638 ± 0.330
	Dill	2.575 ± 0.919
	Swiss chard	0.498 ± 0.176

Based on Table (4), the following can be observed:

- The concentration levels of element (Cd) under study for all three types of leafy vegetables are higher than the permissible limits, which are set at (0.2 mg/l) according to the standards of Codex Alimentarius. The following figure illustrates this.

- illustrates this.

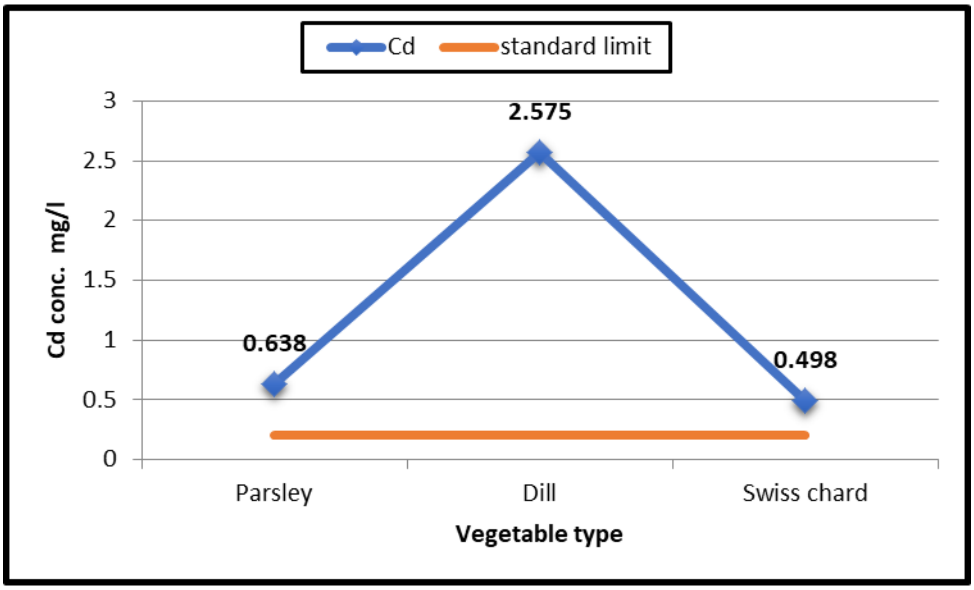


Figure (4) shows a comparison of element (Pb) concentration with the permissible limits.

There are no statistically significant differences at the significance level (0.05) in the average concentrations of heavy metals attributed to the type of leafy vegetable, as determined using the One-Way ANOVA statistical tool. The hypothesis can be rejected if the (P-Value ≤ α) when α=5%.

Measures of Central Tendency

Table (5) describes the measures of central tendency for the sample analyses.

Type	N	Mean mg/l	Mean ± St.d mg/l
Parsley	16	2.653	2.653± 0.832
Dill	16	4.544	4.544 ± 1.739
Swiss chard	16	0.667	0.667 ± 0.154

From the above table, it is evident that the average concentration of heavy metals under study in parsley was (2.263 mg/l) with a standard deviation of (0.832 mg/l), while the average concentration of these metals in dill was (4.544 mg/l) with a standard deviation of (1.739 mg/l).

In contrast, the average concentration of these metals in Swiss chard was (0.667 mg/l) with a standard deviation of (0.154 mg/l)

ANOVA Analysis Table

Table (6) shows the results of the ANOVA statistical analysis.

S.O.V	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	120.160	2	60.080	4.103	0.023*
Within Groups	658.909	45	14.642		
Total	779.069	47			

Significant at 5%*From the previous table, it is shown that the value (Sig = 0.023) is less than (0.05), indicating that there are statistically significant differences between the average concentrations of heavy metals attributed to the type of leafy vegetable, and that there is a different effect of each on the others.

Post Hoc Test Statistical Analysis

The Tukey statistical tool was used to identify the important differences between the average concentrations and their most relevant and impactful relationships. **Table (7)** shows the results of this analysis.

Table (7) shows the results of the Tukey statistical analysis.

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.
Parsley	Dill	-1.891	1.353	0.351
	chard	1.984	1.353	0.316
Dill	chard	3.875*	1.353	0.017*

Significant at 5%*Since the value (sig = 0.017) for the average concentrations of heavy metals in both Swiss chard and dill is less than (0.05), this indicates that there are significant statistical differences attributed to the type of leafy vegetable, highlighting which elements have a greater impact on human health. The statistical program (IBM SPSS 27) was used to determine this using the ANOVA analysis tool, which represents a statistical measure indicating the presence or absence of statistically significant differences between the average concentrations and identifying which are the most impactful, as follows:

Element Cr

Measures of Central Tendency

Table (8) describes the measures of central tendency for the analyses of the samples regarding element (Cr).

	Type	N	Mean mg/l	Mean ± St.d mg/l
Cr	Parsley	4	0.032	0.032± 0.0128
	Dill	4	0.032	0.032 ± 0.0085
	Swiss chard	4	0.338	0.338 ± 0.184

From the above table, it is clear that the average concentration of element (Cr) in parsley was (0.032 mg/l) with a standard deviation of (0.0128 mg/l), while the average concentration of element (Cr) in dill was (0.032 mg/l) with a standard deviation of

(0.0085 mg/l). In contrast, the average concentration of element (Cr) in Swiss chard was (0.338 mg/l) with a standard deviation of (0.184 mg/l).

ANOVA Analysis Table

Table (9) shows the results of the ANOVA statistical analysis for Cr.

S.O.V	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.249	2	0.125	9.189	0.007**
Within Groups	0.122	9	0.014		
Total	0.372	11			

Significant at 5%*From the previous table, it is shown that the value (Sig = 0.007) is less than (0.05), indicating that there are statistically significant differences between the average concentrations of the three types of leafy vegetable samples regarding the level of element (Cr), and that there is a different effect of each on the others.

Post Hoc Test Statistical Analysis

The Tukey statistical tool was used to identify the important differences between the average concentrations and their most relevant and impactful relationships. **Table (10)** shows the results of this analysis.

Table (10) shows the results of the Tukey statistical analysis for Cr.

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.
Parsley	Dill	0.0007	0.0823	1.000
	Swiss chard	-0.3055*	0.0823	0.012*
Dill	Swiss chard	-0.3062*	0.0823	0.012*

Significant at 5%*From Table (10), the results of the statistical analysis indicate that the value (sig = 0.012) is less than (0.05). Therefore, the level of element (Cr) has a significant effect across all study samples, with parsley ranking first, followed by Swiss chard, and then dill.

Element Pb

Measures of Central Tendency

Table (11) describes the measures of central tendency for the analyses of the samples regarding element (Pb).

	Type	N	Mean mg/l	Mean ± St.d mg/l
Pb	Parsley	4	7.775	7.775± 1.497
	Dill	4	13.938	13.938± 1.582
	Swiss chard	4	0.026	0.026± 0.003

From the above table, it is clear that the average concentration of element (Pb) in parsley was (7.775 mg/l) with a standard deviation of (1.497 mg/l), while the average concentration of element (Pb) in dill was (13.938 mg/l) with a standard deviation of (l 1.582 mg/l). In contrast, the average concentration of element (Pb) in Swiss chard was (0.026) with a standard deviation of (mg/l 0.003).

ANOVA Analysis Table

Table (12) shows the results of the ANOVA statistical analysis for Pb.

S.O.V	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	388.767	2	194.383	122.910	0.001**
Within Groups	14.234	9	1.582		
Total	403.000	11			

*Significant at 1%*From the previous table, it is shown that the value (Sig = 0.001) is less than (0.05), indicating that there are statistically significant differences between the average concentrations of the three types of leafy vegetable samples regarding the level of element (Pb), and that there is a different effect of each on the others.

Post Hoc Test Statistical Analysis

The Tukey statistical tool was used to identify the important differences between the average concentrations and their most relevant and impactful relationships. **Table (13)** shows the results of this analysis.

Table (13) shows the results of the Tukey statistical analysis.

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.
Parsley	Dill	-6.162**	0.889	0.001**
	Swiss chard	7.749**	0.889	0.001**
Dill	Swiss chard	13.912**	0.889	0.001**

*Significant at 1%*From Table (13), the results of the statistical analysis indicate that the value (sig = 0.001) is less than (0.05). Thus, the level of element (Pb) has a significant effect across all study samples.

Element Cu

Measures of Central Tendency

Table (14) describes the measures of central tendency for the analyses of the samples regarding element (Cu).

	Type	N	Mean mg/l	Mean ± St.d mg/l
Cu	Parsley	4	2.168	2.168± 0.125
	Dill	4	1.633	1.633± 0.232
	Swiss chard	4	1.815	1.815± 0.403

From the above table, it is clear that the average concentration of element (Cu) in parsley was (2.168 mg/l) with a standard deviation of (0.125 mg/l), while the average concentration of element (Cu) in dill was (1.633 mg/l) with a standard deviation of (0.232 mg/l). In contrast, the average concentration of element (Cu) in Swiss chard was (1.815 mg/l) with a standard deviation of (0.403 mg/l).

ANOVA Analysis Table

Table (15) shows the results of the ANOVA statistical analysis for Cu.

S.O.V	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.592	2	0.296	3.827	0.063
Within Groups	0.696	9	0.077		
Total	1.288	11			

From the previous table, it is shown that the value (Sig = 0.063) is greater than (0.05), indicating that there are no statistically significant differences between the average concentrations of the three types of leafy vegetable samples regarding the level of element (Cu).

Element Cd

Measures of Central Tendency

Table (16) describes the measures of central tendency for the analyses of the samples regarding element (Cd).

	Type	N	Mean mg/l	Mean ± St.d mg/l
Cd	Parsley	4	0.638	0.638± 0.247
	Dill	4	2.575	2.575± 0.919
	Swiss chard	4	0.498	0.498± 0.176

From the above table, it is clear that the average concentration of element (Cd) in parsley was (0.638 mg/l) with a standard deviation of (0.247 mg/l), while the average concentration of element (Cd) in dill was (2.575 mg/l) with a standard deviation of (0.919 mg/l). In contrast, the average concentration of element (Cd) in Swiss chard was (0.498 mg/l) with a standard deviation of (0.176 mg/l).

ANOVA Analysis Table

Table (17) shows the results of the ANOVA statistical analysis for Cd.

S.O.V	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.786	2	5.393	16.427	0.001**
Within Groups	2.955	9	0.328		
Total	13.741	11			

Significant at 1%

From the previous table, it is shown that the value (Sig = 0.001) is less than (0.05), indicating that there are statistically significant differences between the average concentrations of the three types of leafy vegetable samples regarding the level of element (Cd).

Post Hoc Test Statistical Analysis

The Tukey statistical tool was used to identify the important differences between the average concentrations and their most relevant and impactful relationships. **Table (18)** shows the results of this analysis.

Table (18) shows the results of the Tukey statistical analysis.

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.
Parsley	Dill	-1.937**	0.405	0.003**
	Swiss chard	0.140	0.405	0.937
Dill	Swiss chard	2.077**	0.405	0.002**

Significant at 1%

Since the values (sig = 0.003) and (sig = 0.002) for the average concentrations of element (Cd) in both Swiss chard and dill are less than (0.05), this indicates that there are significant statistical differences attributed to the type of leafy vegetable, and that they have a greater impact on health compared to parsley regarding the concentration of element

5. Results and Recommendations;

5-1 Conclusions

This study aimed to evaluate the concentrations of heavy metals (Cr, Pb, Cu, and Cd) in three types of leafy vegetables—parsley, dill, and Swiss chard—collected from various locations in the city of Al-Jamil. From the findings we concluded the following:

1. Element Concentrations:
    - The concentration levels of chromium (Cr) and copper (Cu) in all three types of leafy vegetables were found to be below the permissible limits established by the Codex Alimentarius, which indicates that these vegetables are safe in terms of these specific heavy metals.
    - Conversely, the levels of lead (Pb) and cadmium (Cd) in all three vegetable types exceeded the permissible limits. Specifically, the average concentration of Pb in dill was significantly high, while Cd levels in dill also posed a health risk.
2. Statistical Analysis:

- The One-Way ANOVA analysis revealed statistically significant differences in the concentrations of Pb and Cd among the different vegetable types, indicating that the type of vegetable affects the concentration of these heavy metals. The Tukey post hoc test further confirmed these differences, particularly highlighting the higher levels of Pb and Cd in dill compared to parsley and Swiss chard.

- There were no significant differences in the concentrations of Cu among the vegetable types, suggesting that all types of leafy vegetables contained similar levels of this metal.

3. Health Implications:

- The elevated levels of Pb and Cd in the studied vegetables raise concerns regarding food safety and potential health risks for consumers, particularly for vulnerable populations such as pregnant women, children, and the elderly.

5-2 Recommendations

Based on the conclusion of this study, the following recommendations are proposed:

1. Further research

   Additional studies should be conducted to explore the sources of heavy metal contamination in vegetables and to assess the long-term health effects of consuming contaminated produce

2. Public Awareness Campaigns:

   - Awareness campaigns should be initiated to educate consumers about the potential health risks associated with consuming vegetables that may contain high levels of heavy metals. This includes providing information on safe consumption practices and the importance of sourcing vegetables from reliable suppliers.

3. Agricultural Practices:

   - Farmers should be encouraged to adopt sustainable agricultural practices that minimize the risk of heavy metal contamination. This includes proper soil management, the use of organic fertilizers, and avoiding the use of contaminated water for irrigation.

4. Regular Monitoring:

- It is essential to implement regular monitoring and testing of heavy metal concentrations in vegetables, especially in areas where agricultural practices may lead to contamination. This will help ensure that food safety standards are maintained.

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