International Journal of Medical Toxicology & Legal Medicine Volume 28, No. 1, 2025
e-ISSN: 0974-4614
p-ISSN: 0972-0448
https://doi.org/10.47059/ijmtlm/V28I5/005

Levels of Some Heavy Elements in Corn and Some Product

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Received: 13.11.2024 Revised: 16.12.2024 Accepted: 14.01.2025

ABSTRACT
Ten heavy elements (Cd, Pb, Hg, Cr, Ni, Al, Mn, Co, Cu, Mg) in raw corn from four different Iraqi governorates were collected, boiled, oil extraction and corn bread made were examined by atomic absorption spectrophotometer (AAS) after wet digestion. The results showed that the levels of elements (Cd, Pb, Hg, Cr, Ni, Al, Mn, Co, Cu, Mg) were at average 0.047, 0.313, 0,0016, 1.317, 67.401, 9.825, 66.975, 13.763, 10.078 and 502.75 mg/kg in raw corn, 0.154, 0.165, 0.0585, 1.143, 1.154, 15.278, 44.603, 6.395, 4.395 and 916 mg/kg in boiled corn,0.026, 4.025, 0.0038, 2.2, 0.525, 0.683, 0.855, 1.888 , 2.848 and 9.903 mg/kg in the extracted oil and 0.49, 7.402, 0.0045, 2.4, 1.748, 21.613, 6.597, 0.838, 1575 and 852.25 mg/kg in corn bread, respectively. The results also showed a decrease in the levels of Pb, Cr, Ni, Mn, Co and Cu in boiled corn, and Pb, Ni, Al, Mn, Co, Cu and Mg in the extracted oil and Ni, Mn, and Co in corn bread, while, increase the elements Cd, Hg, Al and Mg in boiled corn and Cd, Hg and Cr the extracted oil and Cd, Pb, Hg, Cr, Al, Cu and Mg in corn bread. The results showed that the levels of Cd, Pb, Cr, Ni, Co and Cu exceeded the permissible limits according to the Codex Alimentarius Commission, which indicates contamination of corn grown in Iraq, which is reflected in the health of humans or animals that feed on it.

Keywords: Corn, Heavy elements, Boiled corn, Corn oil, Corn bread, atomic absorption.

1. INTRODUCTION
Corn (Zia mays L.) is a staple crop with nutritional value and profound economic importance. It is the third most important cereal after Wheat and Rice. It can be used as food for humans or animals as fodder and as a raw material for industrial production (Groote et al., 2002), (Al-Rawie ,2022). It is a source of B vitamins (thiamine, niacin) in addition to essential nutrients such as pantothenic acid. It plays a vital role in the metabolism of fats, carbohydrates and proteins into energy. Corn is a source of fiber and provides iron and folic acid, which are important for increasing the production of red blood cells. Antioxidants and phenols also contribute to the prevention of liver diseases. Its content of vitamin A, C and beta-carotene which is important for maintaining healthy skin(Abdi et al. 2022). Corn contains oil that helps lower cholesterol and prevent heart disease. It contains a large amount of unsaturated fatty acids derived from glycerol alcohol such as oleic, linoleic, stearic and palmitic acids, which help lower harmful cholesterol, reduce strokes and heart attacks and prevent atherosclerosis. It also plays an important role in energy and structural components and helps absorb fat-soluble vitamins (Mukhametov et al., 2020). Food contamination is the abnormal presence of any external factor in food that can endanger human health or life. Heavy elements contamination is a type of chemical contamination that is very dangerous to humans, especially when exposed to it for a long time, accumulates and is unable to biodegrade, such as cadmium, lead and mercury (Reyes et al. 2016). The development of industry, increase in industrial development and the excessive use of chemicals in agriculture such as pesticides (Othman & Kakey, 2021), fertilizers and manure, increase in vehicle traffic especially Lead which those plans can absorb from soil (Al-Rubaie &Al- Owaidi,2022), water(Sultan et al., 2018) and air(Mahdi & Omran, 2021), in addition to the natural human activity. Contamination can also occur during manufacturing processes such as grinding (Kumar et al.,2019), oil extraction (Gonzalez-Torres et al.,2023), baking (Ghasemi et al.,2022), cooking (Mohammed,2023) and packaging (Abu-Almaaly, 2019) . Regulatory authorities around the world have set maximum permissible limits for heavy elements in food products due to the serious repercussions of heavy metal contamination and maintain food safety. Therefore, it I important to implement comprehensive strategies to mitigate these risks associated with heavy metals to protect public health and ensure the continuity of food production system. The current study aimed to measure and identify the levels of contamination with heavy

metals Cd, Pb, Hg, Cr, Ni in corn crops grown in Iraq and extent to which these metals are transferred to its products during processing.

2.MATERIALS AND METHODS

Metals (Cd, Pb, Hg, Cr, Ni, Al, Mn, Co, Cu, Mg) stock solution with 1000 mg. L^{-1}. HNO3, H2SO4 and HCIO4 were obtained from Merck Co. (Darmstadt, Germany). A mixed of standard solution was prepared at the concentration of 100 µg. kg^{-1}, and working the solutions were also prepared by diluting the stock solution with deionized water, all the plastic and glassware were cleaned by soaking in dilute HNO3 and rinsed with distilled water.

2.1. Sample Collection

Sixty samples of corn were collected from different regions of Iraq (Baghdad, Diyala, Wasit, Babil) from the 2022-2023 planting season about 3000g for each sample, they also included samples of corn products available in local markets (commercial corn bread, frozen and canned corn, popcorn) then:

1- boil 200g of each sample of raw corn in 1000ml of hot tap water with 1%rock salt was added for ½ hr. then filtered.

2- roasting 1000g of raw corn samples at 100°c, then extracting the oil at 70°c using a home oil press (made in China). the oil percentages were calculated and were (4.8, 4.2, 5.5, 5.0) for samples C1, C2, C3, C4 respectively, then placed in plastic containers until analysis.

3-corn bread was made from whole corn flour using (2cups corn flour, 2.5cups of water, 1tablespon of baking powder, salt and olive oil).

4-all samples (except oil) were dried at 90°c for 24hr., then ground and placed in polyethylene bags until analysis.

2.2. Sample Preparation and Laboratory Tests

About 15 ml of 5:1:1 tri-acid mixture (70%high purity HNO3, 65%HCIO4 and 70% H2SO4) was added to the beaker containing 1 g dry sample (Allen et al.,1986). The mixture was subjected to digest at 80ºc until the transparent solution appeared. After cooling, the digested samples were filtered using Whitman no.42 filter paper and poured into the Teflon bottle. The filtration was diluted to 50ml with deionized water. This bottled solution of samples was used for analyzing heavy metals by Shimadzu AA- 7000 Atomic Absorption Spectrophotometer, and concentration calculated on dry weight basis in mg.kg^{-1}.

2.3. Statistical Analysis

To compare the groups, a one-way of variance (ANOVA) was employed. Post – hoc analysis, including Fisher's Least Significant Differences (LSD) test and Duncan's test, were conducted at an Additionally, paired sample t-test were utilized for comparisons between the two groups. All statistical analyses and graphical representations were performed using IBM SPSS Statistics version 28, Microsoft Excel version 2019, and R version, with a significance threshold set at 0.05.

3. RESULT AND DISCUSSION

3.1. Cadmium (Cd)

Figure (1) shows the levels of Cd in corn and some of its products, Cd was recorded in whole corn flour, ranging between (0.019-0.121) mg/kg the highest level 0.121mg/kg was recorded in C2 corn samples, while the lowest level were recorded in C1samples which 0.019mg/kg.it showed that the levels of Cd in all corn samples under study was within the permissible limits except for C2 sample according to FAO/WHO (Codex,2019), which was 0.1mg/kg, statistical analysis showed significant difference($p<0.05$) between Cd levels in different corn samples. The results of the present study were consistent with(Kacalkova et al. ,2014) he reported that the level of Cd in corn was (0.09-0.12) mg/kg, (Babatunde & Emeka-Oha, 2015) reported the level of Cd was between (0.1118-0.1214) mg/kg, while(Akenga et al.,2017) report that the level of Cd was 0.03mg/kg in maize grown in various land of Uasin Gishu county/Kenya,(El-Hassanin et al. ,2022) reported that Cd level was (0.00-0.10) mg/kg in corn grains irrigated with river water (Nile), (0.076-0.112) mg/kg irrigated with industrial wastewater and (0.038-0.063) mg/kg irrigated with sewage water, (Sharma &Bisla,2019) recorded Cd level was 0.2mg/kg in corn flour collected from Bareilly markets/India. Our result was less than (Adekiya et al., 2018) as the Cd level reached (1.5-4.60) mg/kg, (Afolayan& Hassan, 2017), as they mentioned that Cd level reached 39.879 mg/kg and(Zhou et al, 2020) 0.21 mg/kg in corn grains grown in southwest China. Cd levels increased after boiling corn and ranged about (0.123-0.241) mg/kg, the highest was recorded in C2 samples and were (0.241) mg/kg, while the lowest in C3 samples were (0.123) mg/kg, the high Cd level may be due to the use of tap water and salt, which may contaminate. Statistical analysis showed the existence of a significant difference($p<0.05$) between samples. After oil extraction, Cd level recorded ranged (0.015-0.04) mg/kg, the highest level was recorded in C3 and were (0.04) mg/kg, the lowest in C1and were (0.015) mg/kg. it seems that extraction of oil led to a decrease in Cd levels in C1 and C2, these results are consistent with(Lee et al.,2019), who stated that oil extraction process leads to decrease Cd level in the resulting oil compared to what is found in the seeds, while the levels increased in C3 and C4 samples, statistically there were a significant difference (p<0.05) between samples. The results of the current study were higher than (Pehlivan et al., 2008) who reported that Cd level in corn oil reached 0.0012 mg/kg, , while (Mohammed et al.,2019) reported Cd levels were (0.02-0.14) mg/kg in corn oil produced in (Jorden, Morocco, Algeria) countries, and(Taghizadeh et al.,2020) that were (0.098-0.1) mg/kg in corn oil that produced in Iran. Cd is one of the most toxic heavy metals, along with Lead and Mercury. Humans have contributed to its spread through mining and

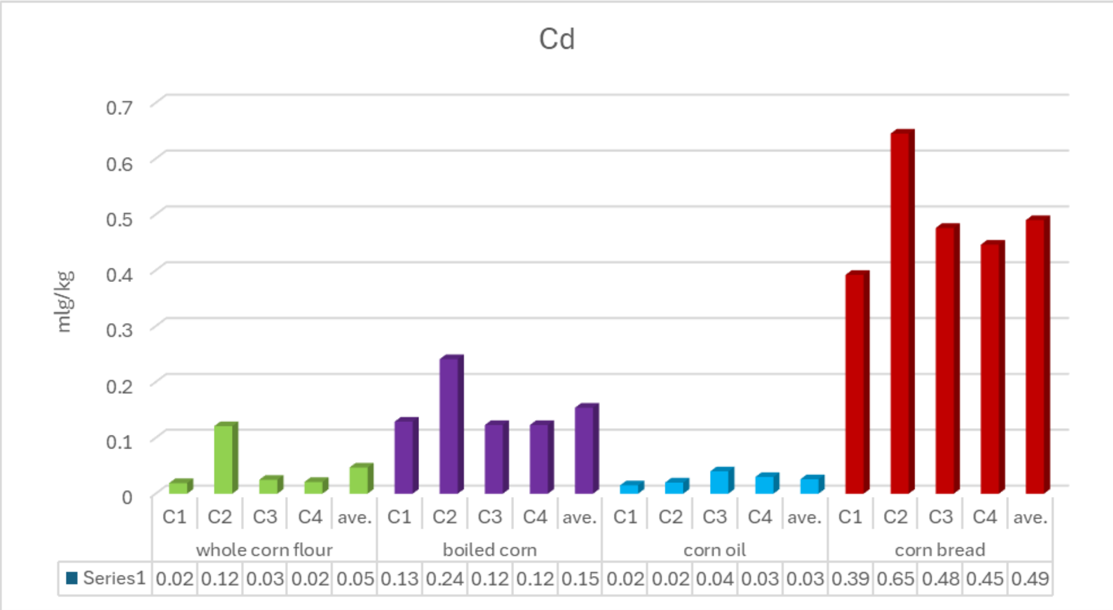

Figure 1: levels of Cd in corn and some of its products.

metallurgy activities. In the production and processing sector of edible vegetable oils, its presence may have arisen from the organic solvents used in the extraction process, which must meet a series of safety requirements to control the presence of Cd in the final product and avoid consumer exposure to these metals. The absence of specific regulations for the presence of Cd in edible vegetable oils, the chosen comparative standard was the most restrictive standard value for the rest of metals. Therefore, the standard value 0.1 mg/kg was adopted as a maximum presence of Cd in edible vegetable oils (Gonzales-Torres et al.,2023). Therefore, based on the above, the results of our research on Cd con. were below this mentioned limit and the resulting oil does not pose any danger to the individual consumer.

3.2. Lead (Pb)

Figure (2) shows the levels of Pb in corn and some of its products, Pb in whole corn flour recorded values ranging between (0.21-0.44) mg/kg, the C2 sample recorded the highest level of 0.44 mg/kg, while the lowest level was recorded in the C1 sample and was 0.21 mg/kg, and the results showed that Pb in all corn samples exceeded the permissible limits (0.2) mg/kg according to Codex Alimentarius Commission FAO/WHO(Codex 2019), and the statistical analysis showed a significant difference (P<0.05) between the first sample and the rest of the samples, while there is no significant difference between the three samples C4, C3, C2(P value = 0.01303*, F = 3.504). The results of the current study were close to (Sharma & Bisla,2019) reported that the Pb level was 0.3 mg/kg in corn flour available in the markets of Bareilly/India,(Akenga et al.,2017) recorded Pb values ranged between (0.382-0.285) mg/kg in three regions in Kenya/Uasin Gishu, (El-Hassanin et al.,2022) was report about (ND-0.04) mg/kg for corn irrigated with river water (Nile), (0.26-0.39) mg/kg for corn irrigated with wastewater, (0.52-0.55) mg/kg for corn irrigated with industrial wastewater (industrial effluent) , (Al-Trbany et al.,2024) was reported 0.52 mg/kg in yellow corn flour in Egypt, (Adekiya et al.,2018) reported (0.90-2.5) mg/kg in corn and (Afolayn & Hassan ,2017) record 38.114 mg/kg.

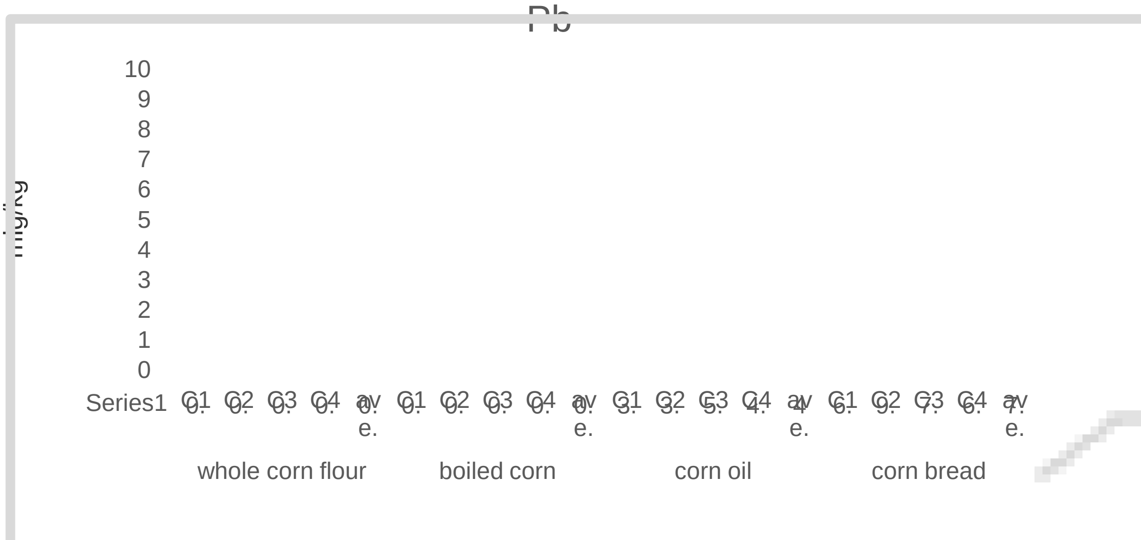

Figure 2: levels of Pb in corn and some of its products.

After boiling corn, Pb recorded levels ranging (0.141-0.215) mg/kg, the highest levels were recorded in the C2 sample and was 0.215 mg/kg, while the lowest were recorded in the C4 sample and was 0.141 mg/kg, the results showed that the levels were within permissible limits except for the C2 sample, and the statistical analysis showed a significant difference ($P<0.05$) between samples (P value = 0.0237*, F=3.183). After oil extraction, Pb recorded ranging (3.1-5.4) mg / kg in the oil, meaning that the oil extraction process led to a high level of Pb in the resulting oil and all of them were higher than the permissible limits (0.08) mg / kg according to FAO/WHO (2019), and the statistical analysis showed a significant difference ($P<0.05$) (P value = 0.0264*,F=2.993), The results of the current study are higher than the findings of(Zhu et al.,2011)he record (0.009-0.019) µg/g, while, (Taghizadeh et al.,2020) reported about (0.099-0.1) mg/kg in corn oil. In corn bread, Pb recorded levels ranging between (6.157-9.241) mg/kg, the highest level was recorded in C2 sample and amounted to 9.241 mg/kg, while the lowest were recorded in C4 sample at 6.157 mg/kg. The results showed an increase in Pb levels after the cornbread manufacturing process. These results are consistent with (Abeb & Chandravanshi,2017), that Pb levels were reported to be (0.31-2.59) mg/kg in raw corn and (1.55-3.41) mg/kg in corn bread.

3.3 Mercury (Hg)

Figure (3) shows the levels of Hg in corn and some of its products, Hg recorded levels ranging between (0.001-0.0022) mg / kg, the highest level were recorded in C3 sample and amounted to 0.0022 mg / kg, while the lowest values were recorded in C2 sample and amounted to 0.001 mg / kg, and the results showed that the levels of Hg in the whole corn flour samples did not exceed the permissible limit of (0.02) mg /kg according to the USDA (NHMRC,1987)., and statistical analysis showed no significant difference between Hg levels in different corn flour samples (P value = 0.0993, F = 1.038). The results of the current study were lower than those reported by (Sharma & Bisla,2019) reported about of 0.2 mg/kg in corn flour available in the Indian market.

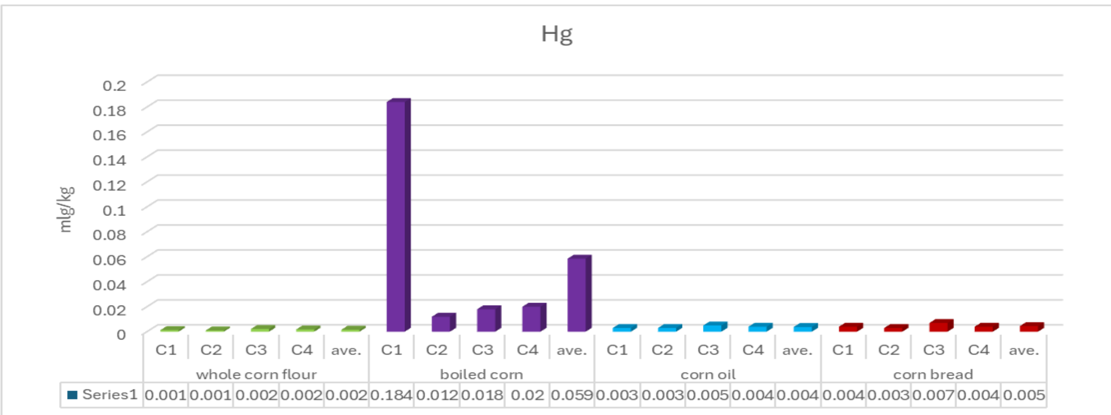

Figure 3: levels of Hg in corn and some of its products.

The results showed after boiling corn high levels of Hg in the corn samples under study, Hg recorded level ranging between (0.012-0.184) mg / kg, and the highest were recorded in the C1 sample and amounted to 0.184 mg / kg, while the lowest were recorded in the C2 sample and amounted to 0.012 mg / kg, and the results showed that the levels of Hg exceeded the permissible limit in the C1 corn samples. Only, the statistical analysis showed a significant difference (P<0.05) between the levels of Hg in boiled corn samples (P value = 0.0236*, F = 3.448). After oil extraction, Hg in the oil recorded ranging between (0.003-0.005) mg / kg, the highest was recorded in the C3 sample and amounted to 0.005 mg / kg, while the lowest was recorded in the C1 and C2 sample and was 0.003 mg / kg, the statistical analysis showed that there was no significant difference (P>0.05) between levels in corn oil samples (P value = 0.1872, F = 1.449). in corn bread, the Hg recorded ranging (0.003-0.007) mg/kg, the highest were recorded in the C3 sample and amounted to 0.007 mg/kg, while the lowest were recorded in the C2 sample and amounted to 0.003 mg/kg, and the statistical analysis showed that there was no significant difference (P>0.05) between the Hg levels in corn bread samples (P value = 0.0803, F=1.819).

3.4. Chromium (Cr)

Figure(4) shows the levels of Cr in corn and some of its products, Cr in whole corn flour recorded values ranging (0.728-1.701) mg/kg, the highest were recorded in C1 samples and amounted to 1.701 mg/kg, while the lowest were recorded in the C2 sample and amounted to 0.728 mg/kg, and the results showed that the level of Cr in corn samples exceeded the permissible limit of 1.0 mg/kg according to FAO/WHO (2016) Except for the C2 sample, the statistical analysis showed a significant difference (P<0.05) between Cr levels in corn flour samples (p value=0>0193*, F=3.444), the results of the current study were higher than(El-Hassanin et al.,(2022) was reported (0-0.15) mg/kg in corn irrigated with river water (Nile), (0.5-0.79) mg/kg for corn irrigated with industrial wastewater, (0.47-0.66) mg/Kg for corn irrigated with wastewater,(Khan et al.,2015) record (0.08-0.38) mg/kg, and(Al-Trbany et al.,2024) reported 0.5 mg/kg in corn grains/Egypt, and less than(Oladejo et al.,2017) that record 2.809 mg/kg, and (Awokunmi et al.,2014) reported Cr at 30.231 mg/kg.

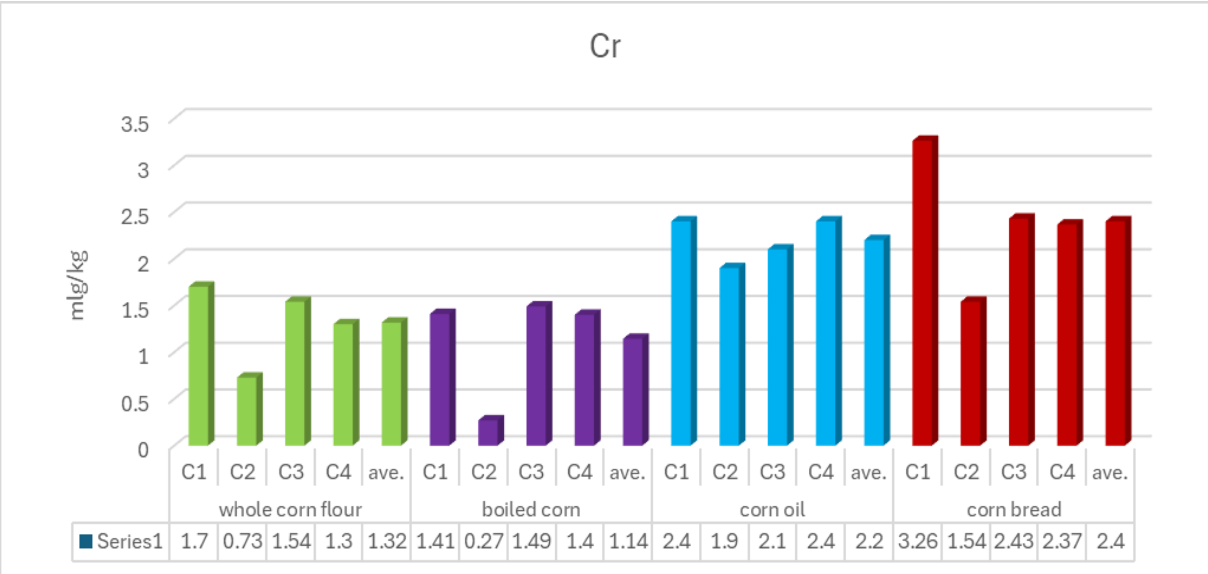

Figure 4: levels of Cr in corn and some of its products.

In boiled corn, Cr recorded ranging (0.27-1.49) mg/kg, the highest were recorded in the C2 sample and amounted to 0.27 mg/kg, while the lowest were recorded in the C3 sample and amounted to 1.49 mg / kg, that is, there was a decrease in the Cr level after boiling corn, except for the C4 sample, it was observed that the con. was to 1.4 mg / kg after it was 1.3 mg /kg before boiling, and the statistical analysis showed a significant difference (p<0.05) in the con. of Cr between different corn samples (P value = 0.0276*, F = 2.942). Cr recorded in oil ranging (1.9-2.4) mg / kg, the highest were recorded in the C1 and C4 sample and were 2.4 mg / kg, while the lowest were recorded in the C2 sample and amounted to 1.9 mg / kg, and it seems that the oil extraction process led to the transfer and high level of Cr in the oil, and the statistical analysis showed a significant difference (p<0.05) between the levels of Cr in different oil samples (P value=0.0254*, F=2.792). Cr in corn bread recorded ranging (1.54-3.263) mg / kg, the highest were recorded in the C1 sample and were 3.263 mg / kg, while the lowest were recorded in the C2 sample and amounted to 1.54 mg / kg, and it seems from the results that the manufacturing process has led to a rise in Cr levels in the resulting bread, the statistical analysis showed a significant difference (p<0.05) between levels in the bread samples (P value=0.0212*, F=3.334), these

results are consistent with(Abeb & Chandravanshi,2017), they revealed that the level of Cr was (0.17-1.58) mg/kg in raw corn and (0.81-1.65) mg/kg in corn-produced bread.
According to the report of the International Agency for Research on Cancer (IARC) in 2018, Cr is classified in the first group of carcinogens, Cr(III) is present in the earth's crust and its presence can increase from the release of the metal by industries to the soil, groundwater and air, as many metals are discharged into the waterways to oxidize to the hexagonal Cr known for its water-soluble and highly toxic Cr (Kumar et al.,2019)

3.5. Nickel (Ni)
Figure (5) shows the level of Ni in corn and some of its products, Ni recorded ranging (42.1-80) mg/kg, the highest were recorded in C4 samples and amounted to 80 mg/kg, while the lowest were recorded in C2 samples and amounted to 42.1 mg/kg, the results of the current study were much higher than the permissible limit for the presence of Ni in cereals (0.1) mg/kg according to Codex Alimentarius Commission. FAO/WHO (Codex 2016), and statistical analysis showed a significant difference ($p<0.05$) between concentrations in whole corn flour samples (P value=0.0273*, F=2.938). The results of the current study were higher than the findings of(Kacalkova et al.,2014) they reported Ni level ranged (0.94-1.12) mg/kg in corn grains,(El-Hassanin et al.,2022) was reported (0.14-0.51) mg/kg in corn grains irrigated with river water (Nile) , (1.63-2.06) mg/kg in corn irrigated with industrial wastewater and (0.81-1.57) mg/kg in corn irrigated with wastewater,(Al-Trbany et al.,2024)recorded 0.53 mg/kg,(Zhou et al.,2020) with 0.3 mg/kg in corn grains grown in southwest China, and(Adekiya et al.,2018) with (1.33-6.0) mg/kg in corn grains grown in gold mining sites, as the waste resulting from the extraction of gold contains large amounts of minerals and may seep in an uncontrolled manner into the surrounding environments through water or atmospheric sedimentation on the bark and parts of the plant or dispersion by the wind in England and Wales. Ni recorded a significant decrease in levels after boiling corn, and ranged (0.54-1.75) mg / kg, the highest were recorded in the C3 sample and was 1.75 mg / kg, while the lowest were recorded in the C2 samples and was 0.54 mg / kg, the results indicate that a large amount of Ni can be eliminated during the process of boiling corn to reach the permissible limit for the presence of Ni in corn, and the statistical analysis showed a significant difference ($p<0.05$) between Ni level in different samples (P value=0.0376*, F=3.384).

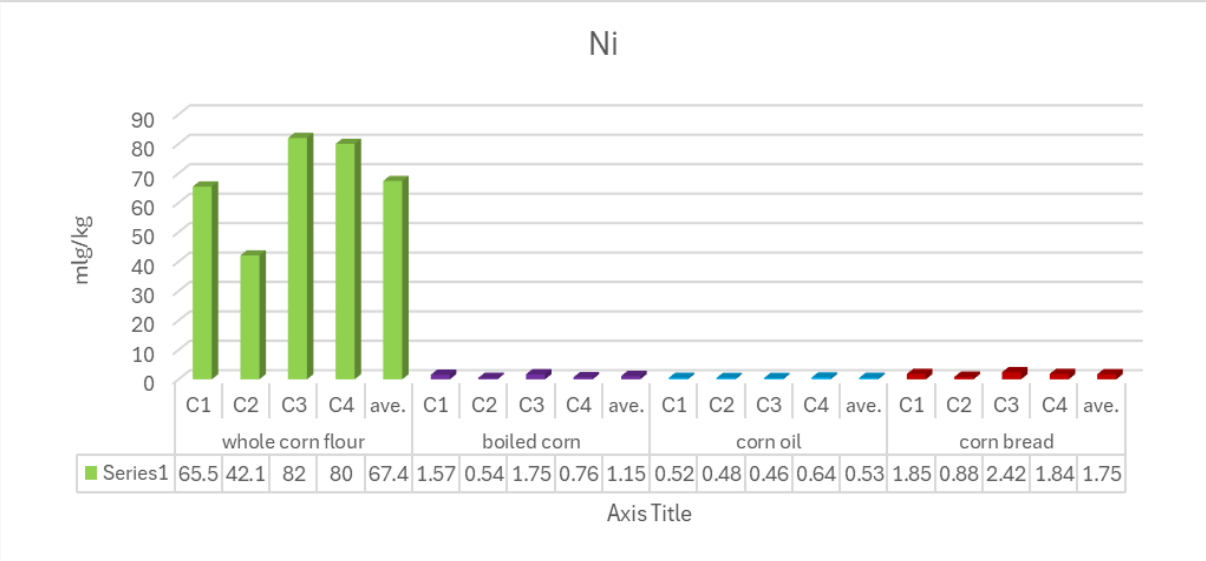

Figure 5: levels of Ni in corn and some of its products.

Ni also recorded a decrease after oil extraction, its ranged (0.46D-0.64) mg/kg, the highest were recorded in C4 samples and was 0.64 mg/kg, while the lowest were recorded 0.46 mg/kg in C3 samples, according to (Kowovlewska et al.,2005) the permissible limit is 0.2 mg/kg, for Ni level in oil exceeded the permissible limit, and the statistical analysis showed that there was no significant difference ($p>0.05$) between levels. The results of the current study were higher than (Zhu et al.,2022) reported as it revealed that the Ni level was 0.031 mg/kg in corn oil. In corn bread, Ni recorded ranging (0.877-2.42) mg / kg, the highest were recorded in the C3 samples and was 2.42 mg / kg, while the lowest were recorded in the C2 samples and was 0.877 mg / kg, and the statistical analysis showed a significant difference ($P<0.05$) between the Ni levels in different bread samples (P value = 0.0274*, F = 3.737). Ni has an important vital role for plants and affects metabolic activities and the transfer of electrons for photosynthesis and chlorophyll biosynthesis because some enzymes contain nickel, and humans need it to activate some enzymes, but, exceeding the permissible limits may lead to toxic damage to humans, its toxicity arises by increasing Reactive Oxygen Species (ROS) , and the formation of tumors, especially the lung and breast, as it has been described as one of the metal estrogens, and acute toxicity symptoms appear in the form of headache, dizziness and irregular beats Heart and severe visual and psychiatric disorders (Kumar et al.,2019)

3.6. Aluminum (Al)

Figure (6) shows the level of Al in corn and some of its products, Al recorded ranging (8.9-10.7) mg / kg, the highest was recorded in the C1 sample and was 10.7 mg / kg, while the lowest was recorded in C3 sample and was 8.9 mg / kg, and the results showed that the level of the Al was within the permissible limits of 2 mg / kg body weight / week according to JECFA (2011) , the statistical analysis showed a significant difference ($p<0.05$) between Al levels (P value=0.0291*,F=2.994), The results of the current study were higher than reported by (Sharma and Bisla,2019), which revealed that the level of Al was 1.2 mg/kg in corn flour.

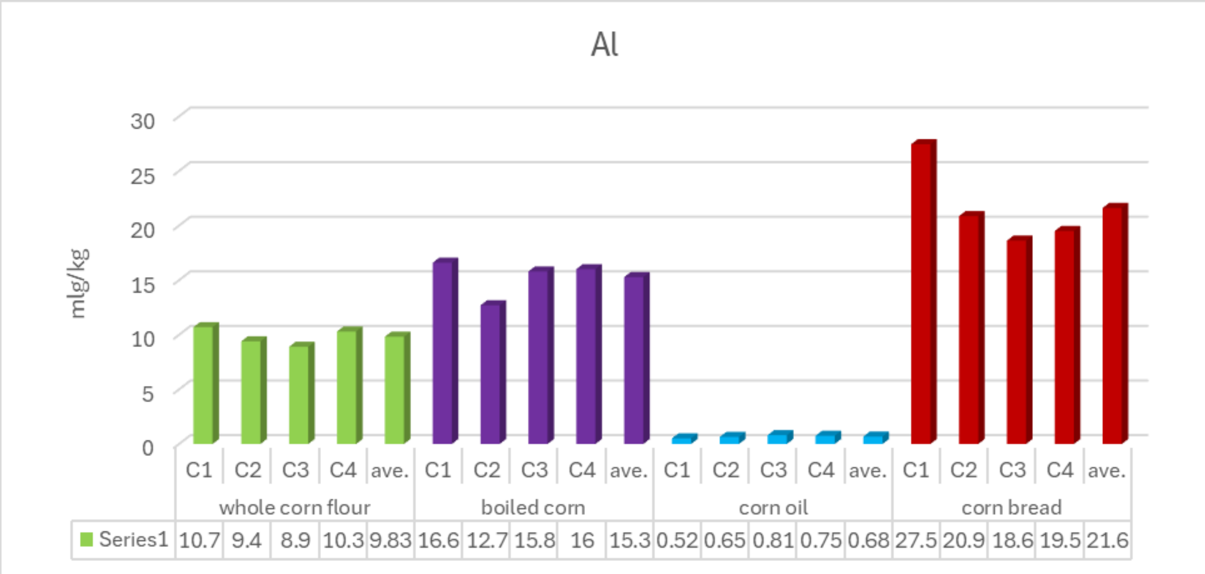

Figure 6: levels of Al in corn and some of its products.

After boiling corn, Al recorded an increase in levels and ranging (12.7-16.6) mg / kg, the highest was recorded in C1 sample and was 16.6 mg / kg, while the lowest was recorded in C2 sample and was 12.7 mg / kg, the statistical analysis showed a significant difference ($p<0.05$) in different corn samples (P value = 0.0256*,F=3.442). in oil, Al recorded a decrease in levels and ranged (0.52-0.81) mg/kg, the highest were recorded in C3 sample and were 0.81 mg/kg, while the lowest value were recorded in C1 sample and were 0.52 mg/kg, the statistical analysis showed that there was no significant difference ($p>0.05$) between Al levels in the different oil samples (P value = 0.0964*,F=1.882). The results are consistent with (Lee et al.,2019) where it was revealed that metals (Al, As, Cd, Pb) have decreased significantly in oils by extracting them and metals can be transferred to oil by (1.1-32.5)%, (0-27.3)%, (0.9-20.0)%, (1.7-23.9)% respectively, and heavy metal was transferred from seeds to oils by (rate) less than 10% through the process of extracting oil by pressure or solvents. in corn bread, Al recorded high increasing ranging (18.62-27.45) mg/kg, the highest were recorded in C1 sample and were 27.45 mg/kg, while the lowest were recorded in C3 sample and were 18.62 mg/kg, the statistical analysis showed that there was no significant difference ($p>0.05$) between Al levels in produced bread samples (P value = 0.0765, F = 1.877). It is noted from the results that level of Al increased in the bread produced, which is expected, as it allows the addition of Al to the bread as a leavening agent such as aluminum phosphate – sodium acidic, so the bread can contain high concentrations of Al.

3.7. Manganese (Mn)

Figure (7) shows the level of Mn in corn and some of its products, Mn in corn recorded ranging (22.9-90.0) mg / kg, the highest was recorded in C3 sample and was 90 mg / kg, while the lowest was recorded in C2 sample and was 22.9 mg / kg, the results showed that the level of Mn in corn did not exceed the permissible limits of 500 mg / kg according to FAO/WHO (2001), the statistical analysis showed a significant difference between Mn levels ($p<0.05$) in different corn samples. The results of the current study were higher than the findings of (Hongxing & Yu-Kui,2011) Mn level of 4.40 mg/kg, (Abeb & Chandravnshi,2017) with Mn (0.52-3.98) mg/kg.(Hicsonmez et al.,2012) reported Mn level of 8.4 mg/kg, and(Al-Trbany et al.,2024) Mn detected in corn was 7.2 mg/kg. Mn in boiled corn recorded a decrease in levels and ranged (5.92-60.73) mg / kg, the highest was recorded in C3 sample and was 61.73 mg / kg, while the lowest was recorded in C2 sample and was

5.92 mg / kg, the statistical analysis showed a significant difference (p<0.05) between Mn levels in different corn samples (p value = 0.0366*, F=3.637).

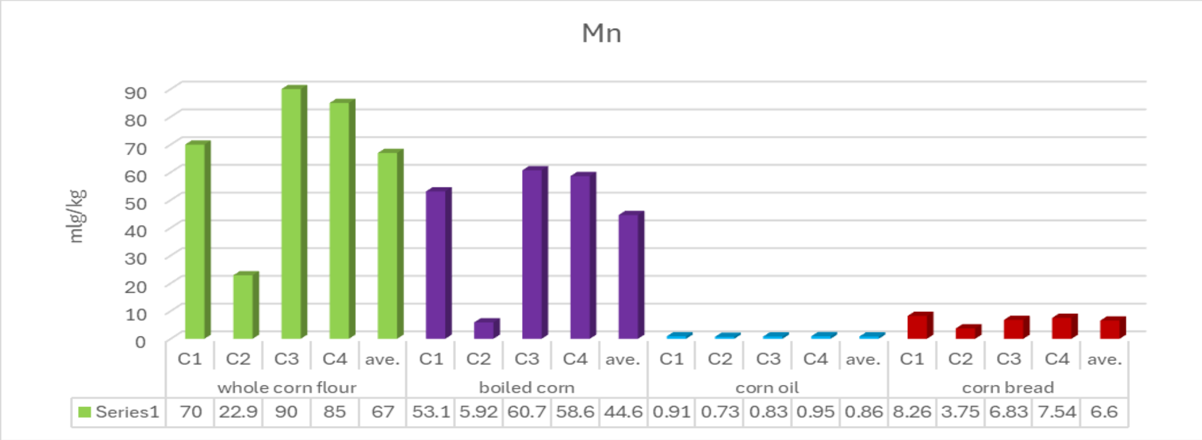

Figure 7: levels of Mn in corn and some of its products.

Mn recorded a decrease in level after oil extraction, and its ranged (0.73-0.95) mg / kg, the highest were recorded in C4 sample and was 0.95 mg / kg, while the lowest were recorded in C2 sample and were 0.73 mg / kg, the statistical analysis showed that there was no significant difference (p>0.05) between the Mn levels in the different oil samples (P value = 0.0794, F = 1.395). The results of the current study were higher than (Zhu et al.,2011) Mn level was revealed to be an average of 0.327 mg/kg in corn oil consumed in China. Mn in corn bread recorded ranging (3.753-8.263) mg / kg, the highest were recorded in C1 sample and were 8.263 mg / kg, while the lowest were recorded in C2 sample and were 3.753 mg / kg, the statistical analysis showed a significant difference (p<0.05) between Mn levels in corn bread samples (P value = 0.0272*, F = 2.475). The results of the current study are consistent with (Abeb and Chandravanshi,2017) was revealed that Mn level in raw corn was (1.04-3.98) mg/kg, while it was (0.52-2.83) mg/kg in corn bread.

3.8. Cobalt (Co)

Figure (8) shows the level of Co in corn and some of its products, Co in corn recorded ranging (5.05-20) mg/kg, the highest was recorded in C3 sample and was 20 mg/kg, while the lowest was recorded in C2 sample and was 5.05 mg / kg, through these results the Co levels in corn exceeded the permissible limits of 0.03 mg / kg according to FAW/WHO (2016), the statistical analysis showed a significant difference between Co levels (p<0.05) in different samples (P value = 0.0384*, F=3.948), the results of the current study were higher than those of (Akenga et al.,2017) as it revealed that the Co level was (0.037-0.045) mg/kg in corn grains, (Adekiya et al.,2018) with level (0.7-2.78) mg/kg, and(Al-Trbany et al.,2024) revealed that Co level were 0.5 mg/kg in yellow corn flour. Co after boiling corn recorded a clear decrease and its ranged (1.97-8.25) mg / kg, the highest was recorded in C1 sample and was 8.25 mg / kg, while the lowest was recorded in C2 sample and was 1.97 mg / kg, the statistical analysis showed a significant difference (p<0.05) between Co levels in different corn samples (P value = 0.039 *, F = 3.942).

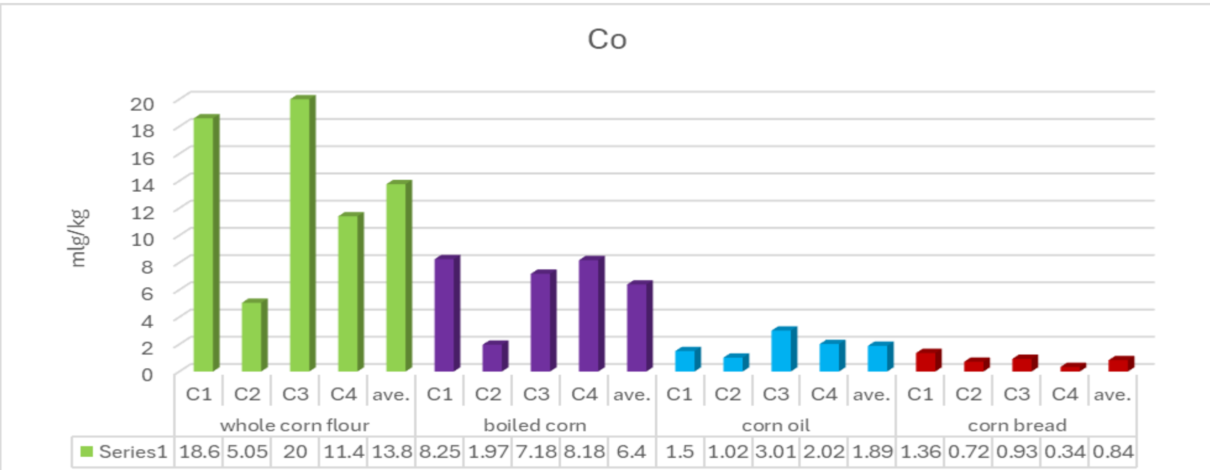

Figure 8: levels of Co in corn and some of its products.

Co in corn oil recorded ranging (1.02-3.01) mg/kg, the highest were recorded in C 3 sample and was 3.01 mg/kg, while the lowest were recorded in C2 sample and were 1.02 mg/kg, the statistical analysis showed a significant difference ($p<0.05$) between Co levels in different oil samples (P value = 0.0244*, F=2.295). in corn bread Co recorded ranging (0.34-1.36) mg/kg, the highest were recorded in C1 sample and were 1.36 mg/kg, while the lowest were recorded in C4 sample and were 0.34 mg/kg, the statistical analysis showed a significant difference ($p<0.05$) between Co levels in different bread samples. (Abeb and Chandravanshi,2017) revealed that Co in corn bread amounted to (0.34-0.75) mg/kg, and (0.41-0.49) mg/kg in raw corn, meaning that Co in corn bread can be less or more than its level in raw corn, and this can depend on the method of work and the materials involved in the industry

3.9. Copper (Cu)

The figure (9) shows the level of Cu in corn and some of its products, as Cu recorded ranging (8.02-13.5) mg / kg and recorded its highest level in C1 sample and was 13.5 mg / kg, and recorded the lowest in C4 sample and was 8.02 mg / kg, the results showed that Cu level in C1 and C2 samples were higher than the permissible limit according to the Codex Alimentarius Commission FAO/WHO (Codex 2016).) of 10 mg/kg, while the C3,C4 samples were below the permissible limit, the statistical analysis showed a significant difference ($P<0.05$) between Cu levels in different corn samples (P value = 0.0383*, F = 2.944), the results of the current study were approach with(Adekiya et al.,2018) he revealed that the presence of Cu in corn was an average of (18.12) mg / kg and values ranging between (8.10-33.80) mg / kg, and the results were higher than reported by(Al-Trbany et al.,2024) as it was reported that Cu was (2.08) mg / kg in yellow corn flour, and (El-Hassanin et al.,2022) revealed that Cu con. was (0.23-0.71) mg/kg in corn irrigated with river water (Nile), (1.77-2.73) mg/kg in corn irrigated with industrial wastewater and (1.69-2.51) mg/kg in corn irrigated with wastewater, and less than reported by (Mu et al.,2013) (20.576) mg/kg were reported in corn grains. Cu after boiling corn recorded a decrease and its ranged (4.12-4.51) mg / kg and the highest were recorded in C3 sample and was 4.51 mg / kg, and the lowest were recorded in C2 sample and was 4.12 mg / kg, the results showed that the process of boiling corn led to a decrease Cu level below the permissible limit, the results of the statistical analysis showed that there was no significant difference between the cons. ($P>0.05$) (P value = 0.1676, F=1.042).

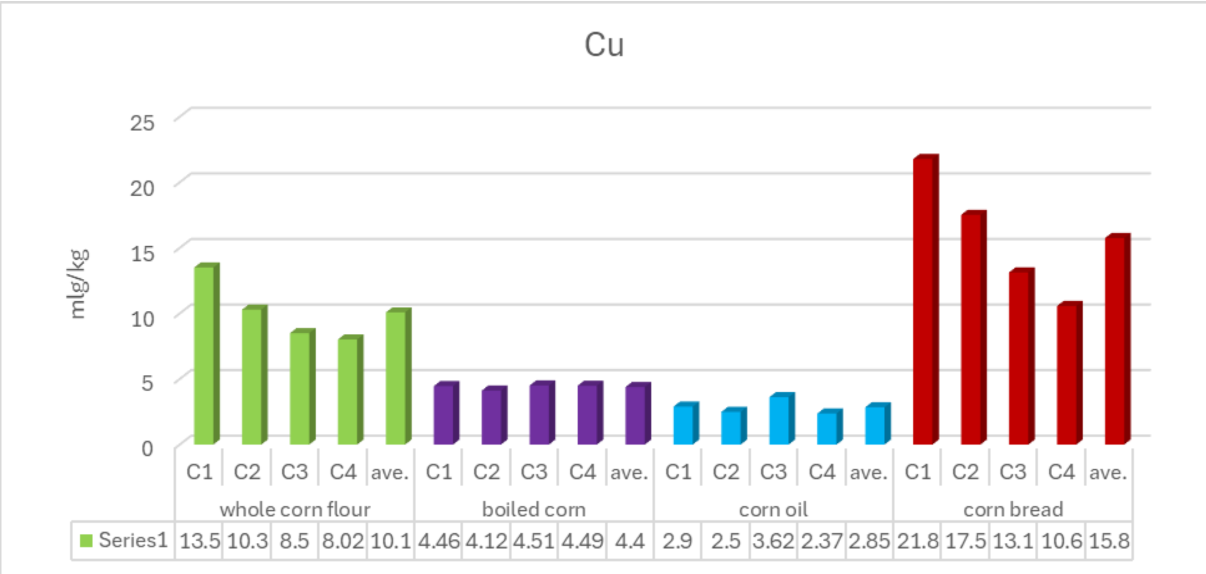

Figure 9: levels of Cu in corn and some of its products.

Cu in the extracted oil recorded ranging (2.37-3.62) mg/kg, the highest were recorded in C3 sample and was 3.62 mg/kg, while the lowest were recorded in C4 sample and were 2.37 mg/kg, according to FAO, there are recommendations for maximum Cu levels (because there is no specific international legislation for copper) that should not be exceeded in different oils, 0.1 mg/kg for fats and oils, Cu level in oil have exceeded the permissible limit, the statistical analysis showed a significant difference ($p<0.05$) between Cu levels in oil samples (P value=0.0384*, F=2.742), the results of the current study were higher than what(Zhu et al.,2011) recorded (0.021) mg/kg in corn oil. In corn bread produced, Cu recorded ranging (10.57-21.78) mg/kg, the highest were recorded in C1 sample and was 21.78 mg/kg, the lowest were recorded in C4 sample and was 10.57 mg/kg, the statistical analysis showed a significant difference ($P<0.05$) between the Cu levels in samples of the bread produced (P value=0.0232*, F=2.731), the results showed high of Cu in corn bread , this is consistent with (Abeb & Chandravanshi,2017) , revealed that Cu level in raw corn was (0.04-1.32) mg/kg, while it was (0.05-3.12) mg/kg in corn bread.

3.10. Magnesium (Mg)

Figure (10) shows the level of Mg in corn and some of its products, Mg recorded ranging (236-798) mg / kg, the highest were recorded in C2 sample and was 798 mg / kg, while the lowest were recorded in C1 sample and was 236 mg / kg , the results showed that Mg level were within the permissible limits according to the nutrient database of the USDA (NHMRC,1987) of 2390 mg / kg, the statistical analysis showed a significant difference ($p<0.05$) between Mg levels in different corn samples (p value = 0.0283*, F = 2.944),(Abeb & Chandravanshi,2017) revealed that Mg in raw corn was (388-400) mg/kg, while as (378-401) mg/kg in bread, and (Musa Özcan,2006) revealed that Mg level in corn/Turkey was 1154 mg/kg, (Olu et al.,2013) at (248-321) mg/kg, while (Padovani et al.,2007) was reported that Mg was at 200 mg/kg in raw corn based on dry weight.

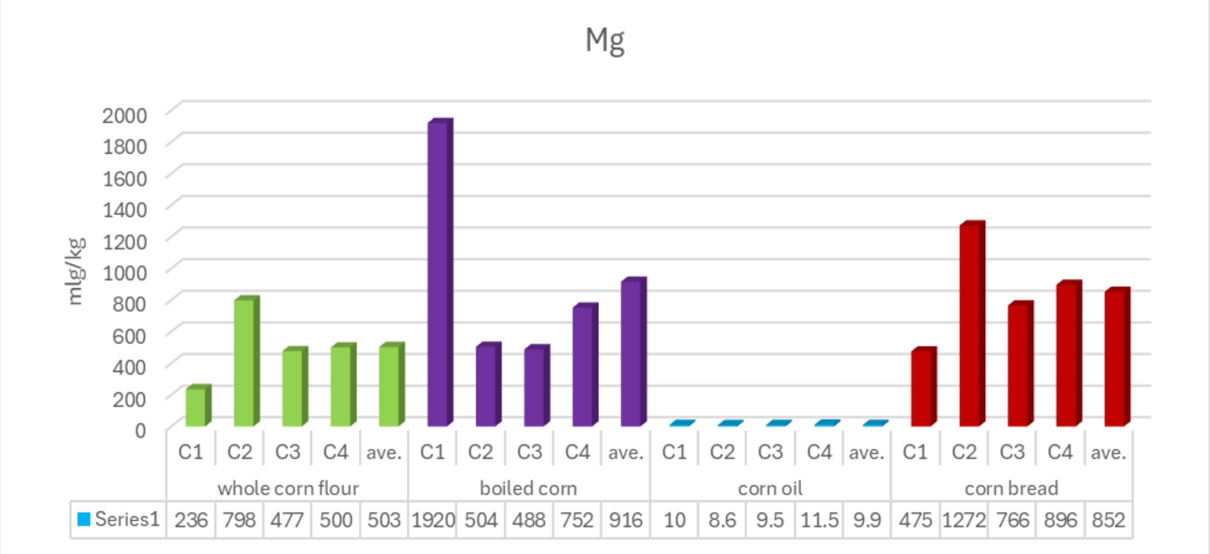

Figure 10: levels of Mg in corn and some of its products.

Mg recorded after boiling ranging (488-1920) mg / kg, the highest was recorded in C1 sample and was 1920 mg / kg, while the lowest was recorded in C3 sample and was 488 mg / kg, the statistical analysis showed a significant difference ($P<0.05$) between Mg levels in boiled corn. in the extracted oil, Mg recorded a significant decrease in levels and ranged between (8.6-11.5) mg / kg, the highest were recorded in C4 sample and was 11.5 mg / kg, while the lowest was recorded in C2 sample and was 8.6 mg / kg, the statistical analysis showed that there was no significant difference between Mg levels ($P>0.05$) in oil samples. Mg was recorded in the corn bread increased in levels and ranged between (475-1272) mg / kg, the highest were recorded in C2 sample and was 1272 mg / kg ,while the lowest were recorded in C1 sample and was 475 mg / kg, the results show that the C2 sample exceeded the permissible concentration of 1000 mg / kg in bread FAO/ WHO(2011) quoted from (Khodaei et al.,2023), the statistical analysis showed a significant difference ($p<0.05$) between Mg levels in corn bread product.

4. CONCLUSION.

Ten heavy elements (Cd, Pb, Hg, Cr, Ni, Al, Mn, Co, Cu, Mg) in raw corn from four different Iraqi governorates, boiled, oil extracted, and corn bread made and examined by Atomic Absorption spectrophotometer (AAS) after wet digestion. The results showed a decrease in the levels of Pb, Cr, Ni, Mn, Co and Cu in boiled corn, and Pb, Ni, Al, Mn, Co, Cu and Mg in the extracted oil and Ni, Mn, and Co in corn bread, while, increase the elements Cd, Hg, Al and Mg in boiled corn and Cd, Hg and Cr the extracted oil and Cd, Pb, Hg, Cr, Al, Cu and Mg in corn bread. The results showed that the levels of Cd, Pb, Cr, Ni, Co and Cu exceeded the permissible limits according to the Codex Alimentarius Commission, which indicates contamination of corn grown in Iraq, which is reflected in the health of humans or animals that feed on it.

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