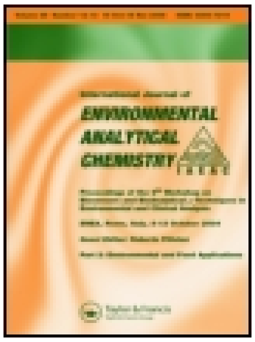

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Investigation of heavy metal release from variety cookware into food during cooking process

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ABSTRACT

The issue of material migration from cookware to food is one of the main concerns of consumers, and which cookware is suitable for cooking is a challenge. The answer to this question can effectively maintain the safety of consumed food. Therefore, this study investigated heavy metals' migration from the usual cookware used in cooking food in two new and old forms. Migration Cr, As, Ni, Pb, Al, Cu, Cd, Se, and Co from copper, glass, aluminium, stone, cast iron, plastic, Teflon, and stainless steel cookware was quantified by the ICP device. The results showed that the release of heavy metals increases in old containers due to frequent use and damage or abrasion. On the other hand, cooking time had a significant relationship with the release of metals in food, especially in old cookware. This study showed the release of some heavy metals into food from old cookware. Therefore, the use of high-risk damaged cookware should be restricted.

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Heavy metal; cookware; metal release; food safety; cooking process

1. Introduction

The process of cooking and the kind of containers used to cook food plays an essential role in the health and safety of foods. Increasing the tendency for health and higher quality food has increased attention to the migration of elements from containers to food [1,2]. So, the safety of these utensils is as important as the final link in the food preparation chain. The choice of cooking utensils depends on the tradition, culture, and level of human civilisation [3,4]. In addition, economical, easy cleaning, corrosion resistance, and rust resistance are other reasons for choosing the cookware. Different

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cooking utensils are made of cast iron, aluminium, copper, ceramic, glass, and stainless steel [5,6]. Stainless steel is another kitchen container made of metals such as cadmium and nickel in the structure of these containers [7]. Metals and alloys are widely used in the manufacture of cooking utensils due to their high conductivity and thermal stability. The most commonly used metals are Al, Fe, Sn, Cu, Ni, and Cr. On the other hand, metals such as As, Pb, and Cd are impurities in containers. Heavy metals are a group of chemical pollutants that harm human health. These pollutants are stable and non-degradable and enter the body through various pathways, including inhalation, digestion, and skin absorption [8,9]. Recently, suggested that arsenic can cause skin, kidney, lung, bladder, pigment changes, neurological disorders, muscle weakness, loss of appetite, and nausea [8]. Lead is another heavy metal that is considered the most dangerous since it affects human health. It disrupts the central nervous system and causes anaemia [10]. Nickel is needed in minimal amounts in food for the body, and more than its recommended amount can cause lung, nose, laryngeal, and prostate cancers [11]. Aluminium is a chelating agent for essential elements such as calcium, zinc, and copper, disrupting the beneficial role of these elements. This metal causes Alzheimer's disease [3,12]. Cadmium is another dangerous metal that is widely used in industry. Humans are exposed to it. This metal causes lung cancer and is carcinogenic [10,13]. According to a classification proposed by the International Agency for Research on Cancer (IARC), these elements cause organ toxicity and are also carcinogenic [14,15]. Such metals can migrate to food from metal kitchen utensils used for packing, cooking, or storing food. Previous studies have mainly highlighted the release of alloy compounds in food containers. Koo et al. (2020) investigated the effect of stimulants, repeated use, washing, and oiling on releasing toxic metals from metallic kitchen utensils. The results show that this release of toxic metals highly depends on pH. Generally, the release of toxic metals tended to decrease with repeated use, and the release of Cr and Ni from stainless steel samples was significantly higher in the first test compared to the third test [16]. Mazinanian et al. (2015) investigated the influence of citric acid and exposure conditions on the metal release from an austenitic manganese stainless steel (AISI 201). Surface wear, increasing temperature, increasing the surface to volume ratio of the solution, and increasing the concentration of citric acid caused more metal to be released [17]. In Europe, specific release limits (SRL) for 21 metals and metalloids were adopted by the Council of Europe (CoE) in 2013; these limits stipulate that the release levels of Cr, Ni, As, Cd and Pb should be less than 0.25, 0.14, 0.002, 0.005, and 0.01 mg/kg, respectively. This study aims to determine the release concentrations of nine toxic metals from kitchen utensils of different types, such as cast iron, aluminium, copper, teflon, glass, stainless steel, stone, and plastic, using inductively coupled plasma-mass spectroscopy (ICP-MS), and to investigate the effects of time of baking on metal release.

2. Materials and methods

2.1. Materials

Different cookware made of Cast iron, aluminium, copper, Teflon, glass, stainless steel, stone, and plastic were purchased (Figure 1). Cookware was selected in approximately the

Figure 1. Types of cookware used in this study.

same capacity and volume. Old cookware samples used and worked in similar dimensions were prepared from all consumers' homes.

Three kettle samples were prepared to investigate the aluminium release amount from the aluminium kettle and the role of sediments resulting from water hardness in metals release amount from the kettle to water (A new kettle, a kettle with a thin layer of sediment, and a kettle with a thick layer of sediment as illustrated in Figure 2).

Figure 2. Types of kettle used in this study.

2.2. Sample preparation

All cookware (28 samples) were cleaned with deionised water before use. An equal volume of water (3000 ml) up to about one centimetre from the edge was poured into each cookware and boiled at 100 oC on the flame for 1, 2, 3, and 4 hours) average cooking time of vegetables, summer vegetables, meat). The lids of the cookware were placed during boiling to prevent excessive evaporation. Sampling was performed at one-hour intervals at a rate of 10 ml from each cookware.

2.3. Measurement of heavy metals

10 ml of standard 1000 mg/L solutions of each element were transferred to a 100 mL volumetric flask. Then it was diluted with 100% nitric acid to a volume of 100 mL and mixed well. The resulting solution had a concentration of 100 mg/L or 100 ppm of the desired element. To measure each element in drinking water samples, the optimal wavelength was selected according to Table 1. Blank samples and standards were injected, and the standard curve was drawn. After calibrating the device for measurement, drinking water samples were analysed by the ICP device (Inductively Coupled Plasma, Model: SpectroAcrose –76004555, Made in Germany).

2.4. Statistical analysis

All obtained data are expressed as mean ± standard deviation. For compare of metals in iron, aluminium, copper, Teflon, glass, stainless steel, stone, and plastic (new and old) with together was used ANOVA. Data was not normal distribution, Kruskal – Wallis test was used.

3. Result and discussion

The releasing of metals from all kinds of old and new cookware into the water at boiling temperature (100 oC) for different times (1,2,3 and 4 h) are presented in Tables 1–8. The results showed that a longer boiling time causes more metals to be released into the solution. On the other hand, old cookware release more metals than new and unused cookware. A comparison of the results of this study with previous studies also shows this fact.

3.1. Aluminium cookware

In Table 1, in the new type of samples, the toxic metal aluminium and chromium begin to release after two hours of boiling. In comparison, the leakage of lead and arsenic metals is in the third and fourth hours of boiling. In contrast, the release of arsenic, chromium, nickel, lead, cadmium, and aluminium from old aluminium cookware has been present since the first hour of boiling and has shown an increasing trend over time. Of course, this upward trend in toxic aluminium is greater than all other metals. Mbabazi et al. reported that the highest rate of metal leaching from local aluminium cookware was for the toxic metal aluminium [18]. Semwal et al. reported that in alkaline and acidic environments, the rate of aluminium leakage was higher, but in neutral pH conditions, there was no significant

Table 1. Concentration of metals (mg kg^{-1}) during boiling at 100 oC in aluminium cookware (mean ± SE).

Type of cookware	New Cookware					Old Cookware			
Time (h)	*C	1	2	3	4	1	2	3	4
As	ND	ND	ND	0.001 ± 0.0005	0.001 ± .0004	0.78 ± 0.001	1.21 ± 0.013	1.78 ± 0.014	1.83 ± 0.013
Cr	ND	ND	0.001 ± 0.0004	0.0025 ± 0.0001	0.0038 ± 0.0002	0.011 ± 0.005	0.045 ± 0.001	0.068 ± 0.0016	0.099 ± 0.0019
Ni	ND	ND	ND	ND	ND	0.0075 ± 0.00	0.0187 ± 0.004	0.0251 ± 0.005	0.036 ± 0.0045
Pb	ND	ND	ND	0.001 ± 0.0003	0.002 ± 0.0005	0.011 ± 0.007	0.087 ± 0.005	0.096 ± 0.04	1.012 ± 0.008
Al	ND	ND	0.001 ± 0.0002	0.002 ± 0.00025	0.0035 ± 0.0002	10.5 ± 0.05	11.20 ± 0.012	11.28 ± 0.016	11.88 ± 0.019
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	0.003 ± 0.0001	0.00045 ± 0.0001	0. 57 ± 0.0012	0.69 ± 0.01	0.98 ± 0.025	1.054 ± 0.21
Sn	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND

*C: Control sample (distilled water free of toxic metal).
ND, Not detected or below LOQ.
In new and old Cookware the value of ($p < 0.05$).

Table 2. Concentration of metals (mg kg^{-1}) during boiling at 100 oC in copper cookware (mean ± SE).

Type of cookware	New Cookware					Old Cookware			
Time (h)	*C	1	2	3	4	1	2	3	4
As	ND	ND	ND	ND	ND	0.01 ± 0.003	0.018 ± 0.001	0.0187 ± 0.005	0.024 ± 0.0013
Cr	ND	ND	ND	ND	ND	0.12 ± 0.01	0.11 ± 0.052	0.13 ± 0.021	0.14 ± 0.01
Ni	ND	ND	ND	ND	ND	3.25 ± 0.01	6.41 ± 0.054	7.82 ± 0.087	9.12 ± 0.012
Pb	ND	ND	ND	0.008 ± 0.0001	0.0084 ± 0.0001	3.25 ± 0.43	4.78 ± 0.16	5.28 ± 0.77	5.87 ± 0.61
Al	ND	ND	ND	0.004 ± 0.0008	0.042 ± 0.0005	4.25 ± 0.85	6.87 ± 0.28	7.63 ± 0.34	8.23 ± 0.66
Cu	ND	ND	0.002 ± 0.0	0.007 ± 0.0006	0.008 ± 0.002	0.08 ± 0.004	1.054 ± 0.28	1.098 ± 0.39	2.12 ± 0.14
Cd	ND	ND	ND	ND	ND	0.005 ± 0.0001	0.007 ± 0.0002	0.009 ± 0.001	0.015 ± 0.002
Sn	ND	0.007 ± 0.001	0.02 ± 0.004	0.04 ± 0.003	0.32 ± 0.04	1.61 ± 0.25	1.97 ± 0.38	2.51 ± 0.77	2.69 ± 0.69
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND

*C: Control sample (distilled water free of toxic metal).
ND, Not detected or below LOQ.
In new and old Cookware the value of ($p < 0.05$).

Table 3. Concentration of metals (mg kg^{-1}) during boiling at 100 oC in glass cookware (mean ± SE).

Type of cookware	New Cookware					Old Cookware			
Time (h)	*C	1	2	3	4	1	2	3	4
As	ND	ND	ND	ND	0.001 ± 0.0004	0.006 ± 0.0004	0.003 ± 0.0002	0.009 ± 0.0001	0.011 ± 0.002
Cr	ND	ND	ND	0.007 ± 0.0003	0.0008 ± 0.0001	0.022 ± 0.0014	0.046 ± 0.005	0.098 ± 0.0014	0.099 ± 0.0018
Ni	ND	ND	ND	0.004 ± 0.0002	0.006 ± 0.001	0.02 ± 0.0002	0.08 ± 0.001	0.11 ± 0.0012	0.16 ± 0.0014
Pb	ND	ND	ND	0.007 ± 0.0004	0.0085 ± 0.0003	0.012 ± 0.002	0.025 ± 0.0015	0.028 ± 0.0041	0.031 ± 0.0018
Al	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sn	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND

*C: Control sample (distilled water free of toxic metal).
ND, Not detected or below LOQ.
In new and old Cookware the value of ($p < 0.05$).

Table 4. Concentration of metals (mg kg^{-1}) during boiling at 100 oC in stainless steel cookware.

Type of cookware	New Cookware					Old Cookware			
Time (h)	*C	1	2	3	4	1	2	3	4
As	ND	ND	ND	ND	ND	0.0068 ± 0.0004	0.0079 ± 0.00	0.0096 ± 0.00041	1.008 ± 0.0018
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ni	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND	0.013 ± 0.002	0.016 ± 0.0025	0.028 ± 0.0014	0.036 ± 0.0051
Al	ND	ND	ND	ND	ND	0.018 ± 0.007	0.043 ± 0.0092	0.069 ± 0.0046	0.087 ± 0.0059
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sn	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND

*C: Control sample (distilled water free of toxic metal).
ND, Not detected or below LOQ.
In new and old Cookware the value of ($p < 0.05$).

leakage within the first hour [19]. In the current study, there was no leakage in new cookware until the first hour. The results of the study by L. Zhou et al. showed that under high temperature (100°C) for 2 hrs, the amount of lead and cadmium from undetectable levels to 0.790 ± 0.261 and 0.27 ± 0.011 μg/L respectively [1]. In the present study, the amount of cadmium released after boiling for three hours from an undetectable level reached 0.0003 ± 0.0001, and the results of these two studies were almost similar. In contrast, we observed significant leakage of old dishes at different times. This difference in the release of metals into food in new and old containers indicates the effect of repeated use of containers on the release rate. Aluminium cookware are one of the most common cookware used in cooking due to their lightweight, ease of use, convenient washing, and low price [20]. Various metals and recycled alloys with impurities may be used in manufacturing these containers [21]. There are minor differences in the amount of metals released and the type of metals. The reason can be due to differences in the types of containers and their materials, the percentage of purity of alloys and compounds used in their manufacture, and the simulated conditions of the experiments [22]. The results of this study indicate that since the toxic metal aluminium is an unnecessary element for health, its release rate is higher than aluminium cookware, especially those damaged. Also, the German Federal Institute for Risk Assessment (BfR) emphasises that aluminium containers should never be used for salty and acidic foods. Therefore, it is suggested to be careful in using this cookware, especially in foods with acidic pH [16]. Most aluminium containers are made solely of aluminium metal, a soft, porous metal easily soluble at a constant high temperature. In addition, Aluminium containers release more metals as they age. Also, abrasive washing methods cause holes in the surface of aluminium cookware and cause the release of more metal [21].

3.2. Copper cookware

Copper cookware are another type of traditional cooking cookware that have long been used for cooking food in Iran. Tin metal is used as the inner coating of this cookware. The results of the present study and the review of previous studies showed that most of the metals released from copper cookware are included chromium, cadmium, arsenic, nickel, aluminium, and tin [23]. As shown in Table 2, the three toxic metals, lead, aluminium, and

Table 5. Concentration of metals (mg kg^{-1}) during boiling at 100 oC in cast iron cookware (mean ± SE).

Type of cookware	New Cookware					Old Cookware			
Time (h)	*C	1	2	3	4	1	2	3	4
As	ND	ND	ND	0.001 ± 0.0004	0.003 ± 0.0002	0.74 ± 0.012	1.28 ± 0.14	1.94 ± 0.24	2.36 ± 0.98
Cr	ND	ND	ND	ND	0.008 ± 0.0001	1.13 ± 0.25	1.89 ± 0.58	2.63 ± 0.89	2.76 ± 0.14
Ni	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pb	ND	ND	ND	0.0016 ± 0	0.02 ± 0.004	1.56 ± 0.21	1.94 ± 0.14	2.12 ± 0.18	2.46 ± 0.65
Al	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	0.079 ± 0.015	0.86 ± 0.001	0.92 ± 0.31	0.45 ± 0.002	0.25 ± 0.001
Sn	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND

*C: Control sample (distilled water free of toxic metal).
ND, Not detected or below LOQ.
In new and old Cookware the value of ($p < 0.05$).

Table 6. Concentration of metals (mg kg^{-1}) during boiling at 100 oC in Tefal cookware (mean ± SE).

Type of cookware	New Cookware					Old Cookware			
Time (h)	*C	1	2	3	4	1	2	3	4
As	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ni	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pb	ND	ND	0.008 ± 0.0001	0.012 ± 0.001	0.017 ± 0.004	0.78 ± 0.025	0.97 ± 0.054	1.025 ± 0.15	1.18 ± 0.87
Al	ND	ND	0.004 ± 0.0001	0.008 ± 0.0002	0.01 ± 0.001	0.56 ± 0.04	0.68 ± 0.65	0.54 ± 0.087	0.98 ± 0.023
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	0.065 ± 0.005	0.087 ± 0.001	0.091 ± 0.006	1.24 ± 0.25	1.89 ± 0.32	2.54 ± 0.21	2.99 ± 0.17
Sn	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND

*C: Control sample (distilled water free of toxic metal).
ND, Not detected or below LOQ.
In new and old Cookware the value of ($p < 0.05$).

Table 7. Concentration of metals (mg kg^{-1}) during boiling at 100 oC in plastic cookware (mean ± SE).

Type of cookware		New Cookware				Old Cookware			
Time (h)	*C	1	2	3	4	1	2	3	4
As	ND	ND	ND	0.007 ± 0.0001	0.009 ± 0.0004	0.16 ± 0.02	0.25 ± 0.012	0.46 ± 0.04	0.53 ± 0.014
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ni	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pb	ND	ND	ND	0.015 ± 0.001	0.018 ± 0.0021	0.36 ± 0.01	0.57 ± 0.021	0.42 ± 0.031	0.69 ± 0.022
Al	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sn	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND

*C: Control sample (distilled water free of toxic metal).
ND, Not detected or below LOQ.
In new and old Cookware the value of ($p < 0.05$).

Table 8. Concentration of metals (mg kg^{-1}) during boiling at 100 oC in Stoneware (mean ± SE).

Type of cookware	New Cookware					Old Cookware			
Time (h)	*C	1	2	3	4	1	2	3	4
As	ND	ND	ND	0.001 ± 0.0007	0.006 ± 0.0004	1.89 ± 0.01	1.64 ± 0.16	1.023 ± 0.7	0.89 ± 0.016
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ni	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pb	ND	ND	0.005 ± 0.0003	0.002 ± 0.0001	0.007 ± 0.0001	0.93 ± 0.02	0.78 ± 0.04	0.69 ± 0.06	0.45 ± 0.023
Al	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	0.001 ± 0.0002	0.003 ± 0.0007	0.98 ± 0.061	0.89 ± 0.045	0.67 ± 0.06	0.51 ± 0.032
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sn	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND

*C: Control sample (distilled water free of toxic metal).
ND, Not detected or below LOQ.
In new and old Cookware the value of $p < 0.05$.

copper begin to release from the third hour of boiling, and the fourth hour of boiling has shown an increasing rate. However, the tin metal has been released since the first hour of boiling. Perhaps one reason for this is that tin metal, as the outermost layer of the container, is in contact with food, and this release rate can occur sooner. In comparison, the release rate of metals in old cookware showed a significant difference with new cookware ($p < 0.05$). Since some uncoated copper utensils are used, this should be considered as the release rate of metals from uncoated copper utensils in saline and acidic solutions will be much higher [24]. Evidently, containers that have been used frequently have more metals released into the food than new containers.

3.3. Glass cookware

Glassware is another type of cookware that has recently entered the modern lifestyle. This cookware is in great demand due to its beauty. So, this cookware is widely used in cooking and food storage [25]. As shown in Table 3, most metals released from glass containers include arsenic, chromium, nickel, and lead. One of the reasons for releasing toxic metals nickel and chrome from these containers is to increase the appearance of glass containers; manufacturers use nickel and chrome compounds to increase the colour and shade of pigments [26]. Therefore, the release of these compounds in food depends on the type of food, duration of heating, and temperature. The release of metals from the surface of glass containers depends on various factors. Improper combination of manufacturing formulations, improper manufacturing techniques, faulty decorative and pigment processes, and exceptionally insufficiently high firing temperatures can all cause this release [27]. On the other hand, any cracks and breaks in the body of these containers can increase the release rate in old containers.

3.4. Stainless steel cookware

As shown in Table 4, the results of the present study showed that most of the metals released from stainless steel containers were chromium, nickel, arsenic, and lead. Several studies have reported nickel release from stainless steel containers in foods during cooking [16]. Mazinanian et al'.s study showed that chromium and nickel released in different foods' steel containers have the highest amount [17]. In Table 4, the amounts of metal released from the new steel cookware were undetectable throughout the boiling period. Therefore, it can be concluded that any crack can facilitate the release of metal from the inner areas of the alloy because alloys are more vulnerable in this form. According to the previous study, the abrasion of surface oxides and damage to the passivation layer of stainless steel is the cause of the heavy metal release from stainless steel cookware. Generally, different percentages of chromium and nickel metals are used to manufacture stainless steel kitchen utensils; these two metals are the most common constituents of this cookware. In the production of stainless steel containers, 6 wt% by weight of nickel and at least 16 wt% of chromium are used [28].

3.5. Cast iron cookware

As shown in Table 5, the metals released from cast iron containers included arsenic, chromium, lead, and cadmium. Comparing the results of this study with the study of Ye Ji Koo et al. in 2020 was similar [16]. The difference is that in the present study, the release rate of nickel was undetectable. This difference may be due to the metals used in the construction of the containers. In the study of Zhou et al., the results showed that in iron containers, the amounts of lead and cadmium ions increase with increasing temperature. The reason for this increase can be the increase in kinetic energy of lead and cadmium ions, which has caused the acceleration of releasing these ions from containers. On the other hand, increasing the temperature accelerates the ion exchange reactions and causes the faster release of metal ions [1]. The findings of previous significant research show that the acidic and alkaline conditions of food have a much broader impact on the release of metals from containers [16]. Very few studies have been done on metal release from cast iron alloys, but the results indicate that cast iron alloys are vulnerable to the leaching of toxic metals, especially in acidic conditions [1]. In the present study, lead showed the highest release from cast iron cookware of aged appearance. Nevertheless, this was not the case for cadmium.

3.6. Tefal cookware

Tefal cookware are another type of cookware for cooking, which are also called non-stick cookware. These containers are aluminium or steel containers covered with a particular substance called polytetrafluoroethylene (PTFE). This substance prevents food from sticking to the container, so they are called non-stick cookware [29]. As shown in Table 6, Cadmium, lead, and aluminium metals had the highest amount released from these containers. Considering that the inner coating layer of these cookware is sensitive to impact, any improper washing operation can cause the layer to be destroyed, and as a result, the release and transfer of metals are easier. Therefore, it is quite evident that in older containers, due to frequent use, we have a higher rate of release of metals than new and less used containers [29].

3.7. Plastic cookware

The present study investigated the release rate of heavy metals from electric plastic tea makers (new and old models). As shown in Table 7, arsenic and lead metals were the primary metals released from these containers. In old containers, the amount of arsenic metal reached from 0.16 mg kg^{-1} to 0.53 mg kg^{-1} after 4 hours of boiling, which shows a significant increase. Also, a significant difference was observed between new and old containers ($p < 0.05$). Metals in plastic can be considered the residue of catalytic reactions [30]. Functional additives are other sources of metals in plastics, which are used in the form of insoluble inorganic compounds, semi-soluble organic compounds, or organic metallic liquids or salts. These compounds are inert fillers, stabilisers, and colour generators [31]. Therefore, to maintain public health, it is suggested to boil the water for less time if these containers are used for boiling water and making tea.

Table 9. Concentration of metals (mg kg^{-1}) during boiling at 100 oC in Kettles (mean ± SE).

	Type of kettles		
Heavy mtals	New Kettle	Old Kettle with tin sediments	Old Kettle with sediments
As	0.001 ± 0.0004	ND	ND
Cr	0.003 ± 0.0002	ND	ND
Ni	ND	ND	ND
Pb	0.001 ± 0.00025	ND	ND
Al	0.003 ± 0.0002	0.001 ± 0.0003	ND
Cd	0.002 ± 0.0001	0.0005 ± 0	ND

In new and old Kettles the value of $p < 0.05$.

3.8. Stoneware

Stoneware is one of the types of local cookware used for cooking. According to Table 8, the major metals released from these containers include arsenic, lead, and cadmium. Undoubtedly, the dispersion of metals in the soil and the environment and the ability to dissolve toxic metals in releasing them from these containers are not without influence. Depending on the type of soil and clay and the raw materials in making these containers, the percentage of pollution and the release of metals may occur [32]. Comparing new and old cookware shows a significant difference between the samples. However, during the heating time, a decreasing trend in the amount of arsenic and lead was observed in old containers.

3.9. Type of kettles

The release rate of toxic metals, especially aluminium, from the new kettle and the other two forms of kettles were shown in the Table 9. The release amount occurred in a smaller amount in old forms of kettles. One of the main reasons for this issue can be the direct effect of the amount of sediment in old kettles. Drinking water contains a certain amount of temporary hardness or carbonate, which turns into permanent hardness or non-carbonate as a result of boiling, and because it is unstable in its new state, it quickly deposits at the bottom of the container and on the walls of the container [33,34]. For this reason, over time, different layers of deposits are created in the kettle (Figure 2). However, a thin layer of sediments can play a positive role in preventing the release of toxic metals, especially from aluminium containers. Although due to the accumulation and creation of thick layers of sediments, heat transfer is reduced; therefore, based on the results of this study, it is recommended not to descale the containers thoroughly, and the presence of a thin layer of sediment is recommended.

4. Conclusion

In summary, most studies on releasing heavy metals into food have focused more on before food is produced or on food packaging, and the study of heavy metal migration during cooking has rarely been done. In the present study, we investigated the release of heavy metals from used cooking utensils in new and old conditions. This study showed that the best type of container for safe and secure cooking is primarily steel. Glass and cast iron containers, if new and undamaged, did not show any release of metals until two hours after boiling. Therefore, it is necessary to pay attention to the cooking time and the type of food in terms of acidity or alkalinity when using other cookware. The findings of this study highlight the importance of the quality of the dishes used in cooking. Therefore, it should be noted that containers that have lost their original quality due to long-term use and cannot be used should be discarded. Also, according to the type of each cookware, suitable detergents and pads should be used for washing so that the least damage is caused to the inner layer of the cookware. Notably, aluminium and copper containers (without a protective layer) should not be used for cooking acidic foods. It is suggested that factories producing cooking utensils provide the instructions and regulations related to the use of each type of material used and describe how to wash the cookware correctly on their products so that the customer would have the accessibility and the availability of the necessary knowledge for the use of the utensils.

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