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Investigation of Heavy Metals Release from Grilled Skewers and Disposable Aluminum Containers into Food

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ABSTRACT

The intake of toxic metals from cooking utensils through food is of growing concern to the health community. This intake poses serious risk to human health. In the present study, the migration of some metals including cadmium, lead, tin, iron, aluminum and chromium from steel and aluminum grill skewers as well as aluminum disposable containers to various foods including tomatoes, Koobideh, chicken kebab and rice investigated. According to the results, in the case of tomatoes, during the grilling process, both migration and leaching of metals along with water took place, so that the migration was related to metals that were not naturally present in raw tomatoes (for example, tin concentration was increased upto 18 ppm). In general, the migration of aluminum and iron were observed to be higher than the remaining minor elements in the aluminum and steel skewers, respectively, which is due to the higher concentration gradient of these metal ions in two types of skewers. The lowest level of migration occurs in grilled chicken. In this regard, no migration level of lead, cadmium and tin metals was observed in chickens from both types of skewers. It seems that the higher pH of chicken meat is related to this result. In the case of the aluminum foil cookware, the migration of only two metals, Al and Fe, to rice was significantly done, so that the amount of these metals increased by 2 and 2.8 times, respectively. THQ and HI values were less than 1 in all examined foods (except for tin in grilled tomatoes), which shows that the migration of heavy metals to food from the examined cookwares is not a concern. Nevertheless, the present study emphasizes the necessity of establishing policies related to the materials and types of food cookware used in kitchens to protect consumers by minimizing the health risks associated with the migration of elements.

1. Introduction

The exponential increase in the use of heavy metals in various industrial processes for the manufacturing of common household goods has raised great concerns regarding the possible exposure of humans to potentially toxic metals. Due to contamination from unanticipated sources like food storage containers and eating utensils, human exposure to heavy metals is steadily rising through the use of contaminated food and water (1). Various types of household utensils (such as containers and skewers) made of steel, zinc, copper and aluminum are widely used for cooking or storing food. The use of disposable utensils that appear to be aluminum is also increasing in modern societies. The use of such utensils has increased significantly with the onset of the COVID-19 outbreak in restaurants and food preparation and serving centers of various institutions and offices (2). In addition, heavy metals may migrate into foods as impurities from any of these food preparation methods. Studies have shown that the nature of the cooking utensils, food properties (such as pH), cooking conditions (such as time and temperature), and storage can affect the levels of heavy metals in foods, and by increasing the release of metals into foods, acute or chronic poisoning in humans occurs. Toxic effects of heavy metals include vomiting, diarrhea, headache, irritability, high blood pressure, adverse effects on the heart, lungs, kidneys, and liver, and mental, neurological, and cancer problems. Accordingly, most national and international organizations in the field of food quality have reduced the maximum permissible levels of metals (3).

Aluminum is increasingly used for a number of important applications, including cookware, food packaging, and consumer products (such as foil). Although the kidney appears to be able to excrete aluminum in healthy individuals, the extent to which aluminum is excreted by this route is not known, and it is well established that individuals with chronic renal failure are unable to excrete it, as fatal cerebral encephalopathy has been reported in dialysis patients (4). On the other hand, aluminum containers made from scrap metals have been identified as a potential source of lead, copper, and cadmium poisoning, especially in developing countries. The release of metals such as Al, Pb, Cd, As, Cu, and Ni into food from aluminum alloy containers during cooking is highly dependent on pH, temperature, and the presence of complexing agents from the alloys used during manufacture (5). Many of these heavy metals have adverse effects at high concentrations. The release of heavy metals from commercial containers and packaging has been investigated in several studies. However, despite the common use of disposable aluminum containers and skewers, these food containers have not been studied for their metal release into real food.

Therefore, in this study, the effects of thermal cooking and storage processes on the migration of metals from these containers to real food (in the case of disposable containers) or grilled foods (in the case of skewers) will be investigated.

2. Materials and methods

2.1. Design and Implementation Method

The equipment and containers evaluated in this study, including aluminum skewers, steel skewers, and aluminum foil, were obtained from a selected restaurant in Kermanshah province of Iran. These containers had the same shape and capacity. The containers were washed with distilled water before use to remove primary and surface contamination.

In order to qualitatively determine the elemental composition of the containers (68-element analysis), first, a 1.2-gram piece of aluminum skewer, 3.4-gram piece of steel skewer, and 1.2-gram piece of aluminum foil were cut with a hacksaw and weighed using a digital laboratory scale.

These samples were subjected to 68-element analysis, and the 5 most important elements were selected by the research team in terms of toxicity, and their migration to food was then evaluated.

2.2 Selection of elements for treatment studies

The criteria for selecting elements for treatment studies were: (1) firstly, the selected elements were identified as heavy and toxic metals and (2secondly, the elements were identified as essential nutrients by their higher relative availability content (RAC) (3).

The RAC of each element was calculated as follows:

$$\text{RAC}\ (\frac{Person\ \times Day}{g}) = \frac{Detected\ concentration\ (ppm)}{Recommended\ daily\ value\ (\frac{\mu g}{Person\ \times Day})}$$

Where the recommended daily allowance of a nutrient is applied according to the FDA. A higher RAC of an ingredient indicates a higher risk of overconsumption, which can be toxic.

2.3 Preparation of food samples

Samples of kebab, chicken and tomato were prepared according to the instructions of a restaurant. For kebab, onions were grated and pressed and mixed with ground meat, infused saffron, salt and black pepper and kneaded. Then, the kebab batter was stretched onto aluminum and steel skewers and cooked on a gas grill with fire bricks for 15 minutes. Sampling was done from raw and cooked kebab batter. For chicken kebab, 1 kg of fresh chicken breast was mixed with red pepper, lemon juice, chopped onion, saffron and corn oil and after skewering, it was cooked on a gas grill for 15 to 20 minutes. Raw and cooked chicken kebabs were also sampled. Tomatoes were also stretched onto skewers and grilled on the grill for 10 minutes. Rice was prepared by the rinse-cooking method. All samples were individually packaged and prepared for analysis.

Figure 1. Food samples prepared with steel and aluminum skewers

2.4 Sample preparation before injection into the device

For acid digestion, 2 g of the pre-prepared samples were weighed and placed in acid solutions according to the American Society for Testing and Materials (ASTM) method. The acid solution contained 30 ml of nitric acid (70%), 10 ml of perchloric acid (70%), and 5 ml of sulfuric acid. Then, the mixture containing the acid solution and the sample was shaken for 30 min at laboratory temperature to mix thoroughly and then heated to boiling point, which was continued until the sample evaporated and a clear extract of 3 ml was obtained. Then, the extract was filtered using Whatman filter paper (41 µm) in 25 ml flasks. The final volume was brought to 25 ml using deionized water and stored in polyethylene bottles for further analysis (6).

2.5 Heavy Metal Measurement

Metal measurements were performed using an inductively coupled plasma (ICP) instrument, model 730-ES, manufactured by Varian, USA, manufactured in 2010, wavelength range 167-785 nm, RF source, 40 MHz, and axial plasma source. The detection limit of the instrument for most elements is in the range of 1 to 100 micrograms per liter (ppb). The ICP-OES instrument was calibrated with pure standard solutions.

The standard solutions used for instrument calibration are: Mix AVHG-SM80C-100 and Mix B VHG-SM90C-100. The Mix A standard solution contains the standards of the elements Ag, Al, As, Ba, Bi, Ca, Cd, Ce, Dy, Eu, Ga, Gd, Ho, La, Lu, Mg, Na, Nd, P, Pb, Pr, Rb, Sc, Se, Sm, Sr, Tb, Tn, Th, T1, Tm, U, Y, Yb 10 grams in 40 ml of aqueous solution and the Mix B solution contains the standards of the elements Au, B, Be, Co, Cr, Cu, Fe, Ge, Hf, Ir, K, Li, Mn, Mo, Nb, Ni, Os, Pd, Pt, Re, Ru, Si, Sn, Ta, Te, Ti, V, W, Zn, Zr 10 grams in 40 ml of aqueous solution.

2.6 Risk assessment

Risk is expressed as a target hazard ratio (THQ) index, which is the ratio between the exposure to a heavy metal through consumption of the food in question and the reference dose (the permissible dose of heavy metal intake from all routes that does not pose a significant risk to the consumer over a lifetime):

$$THQ_{(\text{certain heavy metal})} = \frac{EDI}{RfD_{(\text{certain heavy metal})}}$$

The estimated daily intake (EDI) of a heavy metal is calculated from the following equation:

$$\text{EDI (mg/kg day)} = \frac{\text{FIR} \times \text{MC}}{\text{BW}}$$

Where FIR is the rate of food digestion (kg of food consumed per person per day), MC is the metal concentration in the food in question (mg/kg dry matter), and BW is the average body weight of consumers (the average weight of adult consumers is 70 kg) (7). The FIR value was calculated based on the consumption of the foods studied in the employees' diet as follows: grilled tomatoes: 17 g/day, mashed potatoes: 11.5 g/day, grilled chicken: 43 g/day, and rice consumed in aluminum foil: 47 g/day. The reference dose (RfD) values based on scientific sources for lead, tin, iron, aluminum, and chromium were 0.0035, 0.0003, 0.7, 1, and 0.003 mg/kg BW/day, respectively (8-10).

2.7 Data analysis method

Comparison between a group before and after cooking was performed using t-Test statistical tests. To determine the significance of the difference between several sample groups, one-way analysis of variance was used and, if significant, comparison of means was performed using Duncan's multiple range test at the 5% level. Data analysis and comparison of means were performed using SPSS 19 software.

3. Results and Discussion

3.1 68-element analysis of the studied containers

The results of the elemental composition analysis of steel and aluminum skewers showed (Table 1) that in steel skewers, the two metals iron (83%) and chromium (11%) formed the major part of the composition, so that they comprised 94% of the total elements of the skewer. Other important elements included manganese, nickel, copper and vanadium, and the lowest amount of metallic element was calcium with 0.00086%. In contrast, in aluminum skewers, aluminum (98.5%) and iron (0.86%) were the main constituent metals, which together comprised 99.36% of the skewer structure. Other important metals included copper (0.1900%), magnesium (0.1634%), zinc (0.1600%) and smaller amounts of chromium, gallium and titanium, respectively. The presence of two metals, lead (0.028%) and cadmium (0.0003%) in aluminum skewers is also significant in terms of food safety. Strontium had the lowest amount (0.00015%) in these skewers.

In the elemental composition of the aluminum foil (Table 1), the highest amounts belonged to aluminum (97.3%) and iron (0.42%), which constituted 97.72% of the structure. Other important metals included manganese (0.04%), gallium (0.01%), titanium (0.016%), and vanadium (0.015%), and zirconium had the lowest amount at 0.0001%.

According to the data in Table 1, heavy metals such as aluminum, chromium, nickel, and tin were detected in the steel skewer, aluminum, cadmium, lead, chromium, nickel, and tin in the aluminum skewer, and aluminum, chromium, and nickel in the aluminum foil. These results indicate that if these containers are used repeatedly, there is a possibility of heavy metals migrating into food and causing chronic poisoning. None of the containers examined contained the heavy metals arsenic, selenium, and mercury. Previous studies have also examined the elemental composition of aluminum, stainless steel, and copper cookware and shown that these containers are composed of impurities. In these studies, non-anodized aluminum containers contained elements such as aluminum, iron, lead, chromium, and nickel. Similar results were obtained for stainless steel and copper containers, which showed the composition of different metals in different concentrations (11).

Table 1. 68-element analysis (in percentage) of aluminum skewer and disposable aluminum containers

	Wavelength	Element	Wavelength	Element	Wavelength	Element	Wavelength	Element
	242.794	Au	188.980	As	396.152	Al	328.068	Ag
Steel skewer	ND		ND		0.0025		ND	
Aluminum skewer	ND		ND		97.3		ND	
Disposable container	ND		ND		98.5		ND	
	222.821	Bi	313.107	Be	455.403	Ba	249.772	B
Steel skewer	ND		ND		ND		ND	
Aluminum skewer	ND		ND		ND		0.0016	
Disposable container	ND		ND		ND		0.0011	
	228.615	Co	418.659	Ce	228.802	Cd	318.127	Ca
Steel skewer	0.01		ND		ND		0.00086	
Aluminum skewer	0.00012		ND		ND		0.00064	
Disposable container	0.00025		ND		0.0003		0.003	
	369.265	Er	364.540	Dy	324.754	Cu	267.716	Cr
Steel skewer	ND		ND		0.050		11	
Aluminum skewer	ND		ND		0.006		0.001	

Disposable container	ND		ND		0.190		0.010	
	342.246	Gd	294.363	Ga	259.940	Fe	420.504	Eu
Steel skewer	ND		ND		83		ND	
Aluminum skewer	ND		0.01		0.42		ND	
Disposable container	ND		0.01		0.86		ND	
	389.094	Ho	435.834	Hg	264.730	Hf	219.871	Ge
Steel skewer	ND		ND		ND		ND	
Aluminum skewer	ND		ND		ND		ND	
Disposable container	ND		ND		ND		ND	
	408.671	La	766.491	K	236.804	Ir	410.176	In
Steel skewer	ND		ND		ND		ND	
Aluminum skewer	ND		0.00076		ND		ND	
Disposable container	ND		0.00050		ND		ND	
	260.568	Mn	280.270	Mg	547.668	Lu	670.783	Li
Steel skewer	0.36		0.0002		ND		ND	
Aluminum skewer	0.04		0.0005		ND		ND	
Disposable container	0.05		0.1634		ND		ND	
	406.108	Nd	295.088	Nb	568.821	Na	202.032	Mo
Steel skewer	ND		0.001		0.003		0.008	
Aluminum skewer	ND		ND		0.007		ND	
Disposable container	ND		ND		0.007		ND	
	220.353	Pb	213.618	P	228.228	Os	231.604	Ni
Steel skewer	ND		0.013		ND		0.0520	
Aluminum skewer	ND		ND		ND		0.0023	
Disposable container	0.028		ND		ND		0.0066	
	420.179	Rb	306.471	Pt	410.072	Pr	324.270	Pd
Steel skewer	ND		ND		ND		ND	
Aluminum skewer	ND		ND		ND		ND	
Disposable container	ND		ND		ND		ND	
	181.972	S	349.894	Ru	343.488	Rh	227.525	Re
Steel skewer	0.003		ND		ND		ND	
Aluminum skewer	ND		ND		ND		ND	
Disposable container	ND		ND		ND		ND	
	359.259	Sm	196.026	Se	335.372	Sc	206.834	Sb
Steel skewer	ND		ND		ND		ND	
Aluminum skewer	ND		ND		ND		ND	

Disposable container	ND		ND		ND		ND	
	350.914	Tb	263.558	Ta	460.733	Sr	235.485	Sn
Steel skewer	ND		ND		ND		0.003	
Aluminum skewer	ND		ND		ND		ND	
Disposable container	ND		ND		0.000015		0.003	
	276.789	Tl	334.188	Ti	283.730	Th	182.153	Te
Steel skewer	ND		ND		ND		ND	
Aluminum skewer	ND		0.016		ND		ND	
Disposable container	ND		0.010		ND		ND	
	222.590	W	292.401	V	367.007	U	376.133	Tm
Steel skewer	ND		0.041		ND		ND	
Aluminum skewer	ND		0.015		ND		ND	
Disposable container	ND		0.003		ND		ND	
	349.619	Zr	334.502	Zn	328.937	Yb	360.074	Y
Steel skewer	ND		0.003		ND		ND	
Aluminum skewer	0.0001		0.007		ND		ND	
Disposable container	0.0003		0.160		ND		ND	

Among the metals identified in the 68-elemental analysis of the examined food containers (17 elements for steel skewers, 21 elements for aluminum skewers, and 17 elements for aluminum containers), the definitely toxic heavy metals at any level were selected for further investigation; these elements were aluminum, cadmium, lead, and tin. In the case of essential metals, the RAC was calculated and the results are shown in Table 2. As is clear from the data in this table, the RAC values of the three elements chromium, iron, and manganese are significantly higher than the other essential elements. However, due to the toxicological and food safety importance of chromium, the two elements iron and chromium were selected along with the four toxic elements aluminum, cadmium, lead, and tin to investigate the migration rate into food. It should be noted that both non-essential metals and essential metals can be toxic depending on their levels. The difference between these two groups is that for essential metals, as well as other essential elements that can cause toxicity in high amounts, the human body has a critical range, which is the range between the lowest intake to prevent deficiency syndromes and the highest acceptable intake to prevent toxicity (12).

Table 2. RAC values for essential metals identified in the examined cookware

Row	Essential element	Steel skewer	Aluminum skewer	Disposable container
		RAC		
1	Ca	0.0000086	0.00003	0.0000064
2	CU	0.25	0.95	0.03
3	Cr	0.92	0.00083	0.0000833
4	Fe	46.1	0.48	0.233
5	Mn	1.8	0.25	0.20

6	Mg	0.000005	0.0041	0.0000125
7	Na	0.0000125	0.0000291	0.0000292
8	P	0.00013	-	-
9	Zn	0.002	0.107	0.005
10	K	-	0.00000143	0.00000217

3.2 Comparison of the amounts of metals studied in raw foods

The amounts of heavy metals including lead, cadmium and tin were investigated in tomatoes, chicken meat, kebab and cooked rice. The results (Tables 3, 4, 5 and 6) showed that none of these foods contained these heavy metals. Aluminum was not present in chicken meat and its amounts in tomatoes, kebab batter and cooked rice were 6.6, 1.8 and 1.3 ppm respectively. Kebab batter had the highest amount of iron (40 ppm) among the samples and tomatoes showed the highest amount of chromium (3.3 ppm). According to the national standards of Iran and Codex, these values are within the permissible limits (13).

Compared to previous studies, the samples examined in this study had lower levels of heavy metals and were in better condition. For example, previous studies in Iran and Egypt showed higher contamination of tomatoes with heavy metals such as lead and cadmium (14). While, the samples in this study had lower levels. Also, studies conducted on chicken meat in other countries have reported higher levels of heavy metals, which, compared to the results of this study, indicate a better condition in the samples under study (15-21).

No study has investigated the levels of heavy metals in kebabs, and in the case of rice, studies have usually examined heavy metals in their raw form, which limits the possibility of direct comparison with this study.

3.3 Migration of heavy metals into grilled tomatoes

The data in Table 3 show that the highest migration of metals from skewers to tomatoes occurred for aluminum metal. The amount of aluminum in grilled tomatoes increased by almost 6 times compared to raw tomatoes, such that tomatoes grilled with aluminum skewers contained an average of 0.65 ppm of aluminum. This finding is consistent with the results of the 68-element analysis of the skewers, which confirmed the presence of lead in aluminum skewers and its absence in steel skewers. In contrast, cadmium and lead were not observed in any of the tomatoes grilled with steel skewers, and migration of lead from aluminum skewers to tomatoes was also negligible. In addition to aluminum, migration of tin from steel skewers to grilled tomatoes was also observed, and its amount was an average of 17 ppm. While, this metal was not found in raw tomatoes nor in tomatoes grilled with aluminum skewers. The presence of tin was recorded in both types of skewers at the same level (0.003%). However, the difference in the migration of this metal could be due to the more cohesive physical structure of the aluminum skewer. Banavi et al. (2020) also reported in a similar result that the microstructure of copper containers has a significant effect on the release of metals into food (3). The results also showed that iron metal migration into tomatoes was not observed in any of the samples. The decrease in chromium metal content in tomatoes grilled with both types of skewers can be attributed to the loss of metal along with tomato juice during grilling.

Table 3. Concentration of selected heavy metals in the raw and grilled tomatoes using two methods: steel (SS) and aluminum (AS) skewers

Selected metal	Metal content in tomato (ppm)		
	Raw	Grilled by SS	Grilled by AS
Al	6.60 ± 1.65[a]	5.40 ± 0.78[a]	54.50 ± 3.73[b]
Cd	ND	ND	ND
Pb	ND	ND	0.65 ± 0.13
Sn	ND	17.00 ± 5.04	ND
Fe	21.00 ± 9.58[a]	29.00 ± 4.02[a]	ND
Cr	3.10 ± 0.96[a]	1.30 ± 0.87[ab]	1.10 ± 0.65[b]

ND: Not detected

Different lowercase letters indicate significant differences in a row of the table ($p < 0.05$).

Kamerud et al. (2013) reported in a study that stainless steel cookware can transfer significant amounts of chromium to food. They showed that after six hours of cooking, the chromium concentration in tomato sauce increased by 28-fold, indicating the effect of cooking time and frequency of use of stainless steel cookware (22).

In general, aluminum migration from aluminum skewers to tomatoes was more pronounced compared to other elements. Aluminum skewers had a greater driving force for metal ion migration to tomatoes due to their high aluminum content (98.5% by weight). While steel skewers had a higher tin migration, which is likely due to the difference in physical structure and concentration gradient of metal ions in the two types of skewers.

3.4 Migration of heavy metals into grilled chicken

Aluminum was not present in raw chicken meat (Table 4). However, significant amounts of this metal migrated from both types of skewers, with the migration level from the aluminum skewer being approximately twice that of the steel skewer. This seems reasonable, given the higher amount of aluminum in the 68-element analysis of the aluminum skewer.

Table 4. Concentration of selected heavy metals in the raw and grilled chicken using two methods: steel (SS) and aluminum (AS) skewers

Selected metal	Metal content in chicken (ppm)		
	Raw	Grilled by SS	Grilled by AS
Al	ND	2.80 ± 0.44[a]	4.80 ± 1.20[b]
Cd	ND	ND	ND
Pb	ND	ND	ND
Sn	ND	ND	ND
Fe	7.60 ± 2.35[a]	18.00 ± 5.70[b]	5.40 ± 1.64[a]
Cr	0.30 ± 0.00[a]	0.70 ± 0.15[c]	0.50 ± 0.07[b]

ND: Not detected

Different lowercase letters indicate significant differences in a row of the table ($p < 0.05$).

The heavy metals of cadmium, lead and tin were not present in the chicken meat and no level of their migration was observed from both types of skewers to the chicken kebab. This result is noteworthy, considering the presence of cadmium and lead in the microstructure of the aluminum skewer and the presence of tin in both types of skewers. A significant amount of iron metal migration was observed from the steel skewer to the chicken kebab, as its amount increased by approximately 2.5 times compared to raw chicken. However, no significant level of migration of this metal was observed from the aluminum skewer to the chicken kebab. Such a difference in the level of iron migration from the two types of skewers is explained by its amount in the microstructure of the skewer (83 and 0.86 percent, respectively) and also the lack of water release from the meat during grilling (unlike tomatoes).

In a study by Ali et al. (2023), the concentrations of essential metals (including iron) and highly toxic heavy metals (lead and cadmium) in chicken kebabs sampled in restaurants in Pakistan ranged from 67-180, 0.1-0.9, and 1.3-70 mg/kg, respectively (23), which were all higher than the results obtained for chicken kebabs prepared with both types of skewers in the present study. The amount of chromium in chicken kebabs prepared with both types of skewers showed an increase compared to chicken meat (approximately 2.5 and 1.5 times for steel and aluminum skewers, respectively), indicating migration of chromium from the microstructure of the skewer into the food. This difference in the migration rate from the two types of skewers may be related to the significant difference in the amount of chromium in the microstructure of the two types of skewers (11 and 0.01% for steel and aluminum skewers, respectively) and the resulting greater concentration gradient of metal ions in the steel skewer, which acts as the driving force for migration. In general, the migration of aluminum from the aluminum skewer and iron from the steel skewer to the chicken kebab was more pronounced compared to the other elements, which is due to the creation of a greater concentration gradient of these metal ions in the two types of skewers.

3.5 Migration of heavy metals into kebabs

According to the results in Table 5, significant migration of aluminum (Al) from aluminum skewers to the kebab was observed, such that the concentration of this metal increased by 4.5 times. In contrast, no significant migration of aluminum from steel skewers to the food was observed. This difference is due to the different microstructural composition of the two types of skewers. Cadmium and tin metals were not present in the kebab batter and migration of these metals was not measured from any of the skewers. In addition, a significant migration of lead was recorded into the kebabs prepared with aluminum skewers, with a concentration of 2.57 mg/kg. This value is due to the presence of lead in the microstructural composition of the aluminum skewer. Also, the migration trend of iron and chromium metals into the kebabs was similar to the results of chicken kebabs, but the migration of chromium in kebabs prepared with steel skewers was higher than its migration in chicken kebabs. Among the three food types studied, the lowest levels of metal migration were observed in the chicken kebab. No migration of lead, cadmium, or tin occurred in the chicken kebab from aluminum and steel skewers. This could be related to the higher pH of the chicken meat. Previous studies have also shown that increasing pH is usually associated with reduced metal migration from the container (1).

Table 5. Concentration of selected heavy metals in the Koobideh kebab paste and grilled Koobideh using two methods: steel (SS) and aluminum (AS) skewers

Selected metal	Metal content in koobideh kebab (ppm)		
	Koobideh Paste	Grilled by SS	Grilled by AS
Al	1.80 ± 0.96^{a}	2.70 ± 1.10^{a}	8.70 ± 3.65^{b}
Cd	ND	ND	ND
Pb	ND	ND	2.57 ± 1.30
Sn	ND	ND	ND
Fe	32.00 ± 4.15^{a}	48.00 ± 5.70^{b}	27.00 ± 1.86^{a}
Cr	0.40 ± 0.06^{a}	2.00 ± 0.45^{cb}	1.70 ± 0.55^{b}

ND: Not detected

Different lowercase letters indicate significant differences in a row of the table ($p < 0.05$).

3.6 Migration of heavy metals into cooked rice

According to the results of Table 6, no level of migration of cadmium, lead and tin metals from the aluminum foil to the food was observed. Chromium also did not show a significant level of migration into the food. On the contrary, migration of two metals Al and Fe from the foil to the rice occurred, such that the amount of these metals increased by 2 and 2.8 times, respectively. Such a difference in the amount of migration of metals from the foil corresponds to their concentration in the microstructural composition of this container.

Table 6. Concentration of selected heavy metals in the cooked rice stored in plastic packaging (SPP) and aluminum disposable container (SADC)

Selected metal	Metal content in the rice (ppm)	
	SPP	SADC
Al	1.30 ± 0.37^{a}	2.60 ± 0.50^{b}
Cd	ND	ND
Pb	ND	ND
Sn	ND	ND
Fe	5.00 ± 1.46^{a}	14.00 ± 4.40^{b}
Cr	0.50 ± 0.26^{a}	0.70 ± 0.44^{a}

ND: Not detected

Different lowercase letters indicate significant differences in a row of the table ($p < 0.05$).

3.7 Risk assessment of food exposed to migration

The present study, by analyzing the THQ and HI indices, showed that the values of these indices were below 1 in all the foods examined, indicating that daily exposure to heavy metals in these foods is unlikely to have any adverse health effects (Table 7). In the case of toxic metals such as lead, the THQ and HI values did not reach dangerous levels. These findings indicate that the migration of heavy metals from cooking utensils to food is not a cause for concern. However, the significant migration of tin from steel skewers to grilled tomatoes resulted in a significant increase in THQ and HI, which may require further investigation. From a local impact perspective, this study highlights the importance of awareness of metal migration from cookware in local communities. The widespread use of aluminum skewers and foil wrappers may pose health risks associated with increased concentrations of heavy metals in food. Therefore, it is necessary to increase awareness in local communities. At the national level, the results of this study could lead to the development or revision of public health policies related to materials used in cookware. National standards organizations may establish new regulations to reduce health risks from the migration of metal elements into food. From an international perspective, this study could influence global standards related to international trade regulations and cookware materials. The findings of this study could help ensure the quality and safety of culinary products worldwide, as well as increase consumer awareness through local, national, and international educational campaigns. These measures can play an important role in reducing the potential risks associated with improper use of aluminum and steel containers.

4. Conclusion

In this study, the amount of heavy metals in several foods including tomatoes, chicken and Koobideh kebab and cooked rice was investigated. The results showed that none of the samples were contaminated with heavy metals such as lead, cadmium and tin, and the amounts of aluminum, iron and chromium were within the permissible range. Tomatoes contained a significant amount of iron and chromium. While, raw batter of Koobideh had the highest amount of iron. Also, preparing Koobideh with aluminum skewers increased the migration of aluminum and lead into it. While, steel skewers did not transfer any significant metal contamination to the food. These results emphasize the importance of choosing the right type of skewer and paying attention to the quality of food. Therefore, considering the findings of this study, it is suggested that similar studies be conducted with a larger number of samples and a wider distribution in different regions of the country in order to achieve a better understanding of the status of heavy metals in food. Also, investigating the effect of the number of times that skewers are used on the migration of metals and different grilling methods can help optimize the cooking process. In addition, evaluating the microstructure of different skewers during heating can identify the mechanisms of metal migration and be effective in determining food safety standards. These measures can help improve food quality and protect public health.

Table 7. Target hazard quotients index (THQ) of heavy metals for adults through consumption of grilled tomatoes, chicken and meat and cooked rice stored in aluminum disposable container

Metals	Tomato			Chicken kebab			Koobideh kebab			Rice	
	Raw	SS	AS	Raw	SS	AS	Raw	SS	AS	SPP	SADC
Pb	-	-	0.046	-	-	-	-	-	0.120	-	-
Sn	-	13.73	-	-	-	-	-	-	-	-	-
Fe	0.007	0.010	-	0.003	0.016	0.005	0.007	0.011	0.006	0.005	0.013
Al	0.002	0.001	0.013	-	0.002	0.003	0	0	0.001	0.001	0.002
Cr	0.250	0.100	0.090	0.060	0.143	0.100	0.020	0.110	0.093	0.113	0.157
HI	**0.259**	**13.84**	**0.103**	**0.063**	**0.161**	**0.108**	**0.027**	**0.121**	**0.220**	**0.119**	**0.172**

Note: The raw values are calculated only to provide an overview of the increase in THQ index, obviously raw chicken and batter are not consumed. HI = Sum of THQs of different metals in a particular food
SS: : Grilled by steel skewers, AS: Grilled by aluminum skewers, SPP: Cooked rice stored in plastic packaging, SADC: Cooked rice stored in aluminum disposable container.

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بررسی رهایش فلزات سنگین از سیخ‌های کبابی و ظروف یک‌بارمصرف آلومینیومی به مواد غذایی

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چکیده

دریافت فلزات سمی از طریق ظروف پخت و پز غذا باعث نگرانی روزافزون متخصصان سلامت و بهداشت شده است. چنین مصرفی خطر جدی برای سلامت انسان دارد. در مطالعه حاضر، مهاجرت فلزات کادمیوم، سرب، قلع، آهن، آلومینیوم و کروم از سیخ‌های کبابی استیل و آلومینیومی و همچنین ظرف یکبار مصرف آلومینیومی به مواد غذایی شامل گوجه، کباب کوبیده، کباب جوجه و برنج بررسی شد. بر اساس نتایج، در مورد گوجه فرنگی طی فرآیند کباب کردن هم مهاجرت و هم خروج فلزات به همراه آب صورت گرفت طوریکه مهاجرت به فلزاتی مرتبط بود که به طور طبیعی در گوجه خام وجود نداشتند (به عنوان مثال قلع که غلظت آن به ۱۸ ppm رسید). به طور کلی، مهاجرت آلومینیوم از سیخ آلومینیومی و آهن از سیخ استیل به مواد غذایی در مقایسه با سایر عناصر بارزتر بود که به دلیل ایجاد شیب غلظتی بیشتر این یون‌های فلزی در دو نوع سیخ می‌باشد. کمترین سطح مهاجرت به کباب جوجه اتفاق افتاد. در همین راستا، هیچ مسطح مهاجرتی از فلزات سرب، کادمیوم و قلع به جوجه از هر دو نوع سیخ مشاهده نشد. به نظر می‌رسد pH بالاتر گوشت مرغ با این نتیجه در ارتباط باشد. در مورد ظرف پوش‌برگ آلومینومی مهاجرت تنها دو فلز Al و Fe از پوشبرگ به برنج به طور معنی‌داری انجام گرفت طوریکه مقدار این فلزات به ترتیب ۲ و ۲/۸ برابر افزایش یافت. در همه مواد غذایی بررسی شده مقدار THQ و HI کمتر از ۱ بودند (به جز قلع در گوجه کبابی) که نشان می‌دهد مهاجرت فلزات سنگین به مواد غذایی از ظروف مورد بررسی نگران کننده نیست. با این وجود، مطالعه حاضر بر ضرورت ایجاد سیاست‌های مربوط به مواد و نوع ظروف طبخ مواد غذایی مورد استفاده در آشپزخانه‌ها برای محافظت از مصرف‌کنندگان از طریق به حداقل رساندن خطرات بهداشتی مرتبط با مهاجرت عناصر تأکید می‌کند.