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Effect of Aluminum Leaching Process of Cooking Wares on Food

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The intake of aluminum from cooking utensil is of growing concern to the health of the community. In the present work, leaching of aluminum from aluminum utensils in different food solutions was investigated. Two aluminum utensil of different origin were chosen from the available local market. Minced meat was used with two types of water, drinking and tap. Two techniques for analysis were used, weight loss (W_L) measurement and inductively coupled plasma- mass spectrometry (ICP-MS). The results showed little variation between the whole meat and meat extract solution. The latter was chosen for all experimental work. Different solutions were examined starting from water, different concentrations of meat extract, 40% meat extract solution with tomato juice, citric acid, and table salt. The results of the two measurements were almost consistent. The amount of leaching of aluminum was found to be high in the cooking solutions using all the above additives. According to the world health organization (WHO), the obtained values can be considered to be unacceptable related to their limitations which indicate a high risk to the consuming community.

Keywords: Aluminum, cooking utensil, food processing, leaching, toxicity

1. INTRODUCTION

The effect of aluminum cookware on the food has been extensively investigated. More than half of the cookware ever sold is made of aluminum. Aluminum is so popular due to its low price and quick heating. It has been reported that the use of aluminum utensils for cooking provide an important route for aluminum metal to enter food and consequently to consuming human bodies [1].

There has been many evidence reported that Aluminum has a toxic environmental impact of considerable importance [2, 3]. The daily intake of aluminum is studied, and the contribution of food groups to daily aluminum intake is estimated. The major sources of dietary aluminum include artificially added aluminum (grain products, processed cheese and salt) and naturally occurring high aluminum dosages (tea, herbs and spices). The outer source of aluminum intake is the non – prescription drugs which include but are not limited to anti-acids, buffered aspirins, anti-diarrheal products [3]. The aluminum that may migrate from aluminum utensils is probably not a major or consistent source of this element. Daily intakes of aluminum, as reported prior to 1980, are 18-36 mg per day. Humans consume about 30 mg of aluminum /day on an average basis (WHO 1986). More recent data, which are probably more accurate, indicate intakes of 9 mg per day for teenage and adult females and 12-14 mg per day for teenage and adult males [4]. The world health organization (WHO) reported in 1989 that the Provisional Tolerance Weekly Intake (PTW I) is 7 mg of aluminum /kg body weight. The acceptable dosage is therefore not more than 60 mg/ day for a person weighing 60 kg. Karbouj has reported that aluminum present in food utensils can expose humans to the ingestion of big quantities of aluminum [5], especially in the case of acidic dishes as tomato sauce. The high concentrations of aluminum have been detected in the brain tissue of patients with Alzheimer's disease, Parkinson disease and dialysis encephalopathy [6, 7]. Aluminum is regarded as a neurotoxin agent due to its accumulation in brain, bones and liver. Also, it is harmful to patients with bone disease or renal dialysis. Aluminum toxicity especially to the elderly and to people with kidney failure is also reported by Soni et al. [8]. In our human body, aluminum ion can inhibit different metabolism processes by competition reactions with other ions such as iron, magnesium, calcium, phosphorus, fluoride, and others. It is also reported [9] that aluminum is associated with anemia, osteomulacia, and a neurologic syndrome.

Although aluminum shows this toxicity, it is remarkably preferred for its ability to resist corrosion due to passivation. The corrosion of aluminum alloys in acidic environment has been reported by Abd El Rehim [10-13].

In this study, we report on the corrosion process of aluminum utensils. Two types of different origin (India and Egypt) are used and the contribution of aluminum corrosion under different conditions (pH, food composition and concentration) is studied. The importance of people's awareness regarding aluminum use and the related daily aluminum intake is addressed.

2. EXPERIMENTAL PROCEDURE

2.1. Materials

Two kinds of aluminum cooking utensils are chosen from the local market. They are of different origins, namely from Egypt and India. These are cut into rectangular specimens of dimensions 1 x 1.2 cm, 1.5 mm thickness with small hole of 1 mm diameter at one end to hang the specimens in different environments.

2.2. Food and additives

Minced beef meat, tomato juice, citric acid, and salt used in different concentration. The work performed at boiling temperature using drinking or tap water.

2.3. Test performed

2.3.1. Weight loss (W_L)

The aluminum samples are cleaned by distilled water and acetone dried and weighed using a four digits sensitive balance. The meat solution in drinking water or tap water is boiled for 1 h, followed by filtration to get the meat extract. The volume is adjusted to give the desired weight to volume (wt/v) concentration of extract. After boiling the samples for two hours, the aluminum samples are cleaned by distilled water followed by acetone and weighed. The pH of the solution is measured before and after the experiment. To assure consistency, all the experiments are performed in duplicates.

2.3.2 ICP-MS Tests

The amount of aluminum and other metal dissolved in the solutions after the weight loss experiment are analyzed using inductively coupled plasma- mass spectrometry (ICP-MS).

3. RESULTS AND DISCUSSION

3.1. Weight Loss (W_L) Results

The corrosion rates presented in tables (1-3) are calculated by using equation (1)

$$\text{Corrosion rate} = WL/AT \quad (1)$$

where: WL is the weight loss [mg], A is the surface area of the test specimen [cm^2] and T is the immersion time [hours].

3.1.1. Leaching in Water

The weight loss result reported in Table (1) indicates that, using tap water cause more leaching of aluminum for both materials.

Table 1. Effect of the type of boiling water on leaching of aluminum

Cookware origin	Type of water (boiling for 2 hrs)	Initial pH	Final pH	Corrosion rate $mg/cm^2.hr*10^{-2}$
Indian	Tap	7.30	9.40	31.45
	Drinking	6.80	9.50	10.50
Egypt	Tap	6.70	8.70	42.10
	Drinking	7.00	9.10	2.22

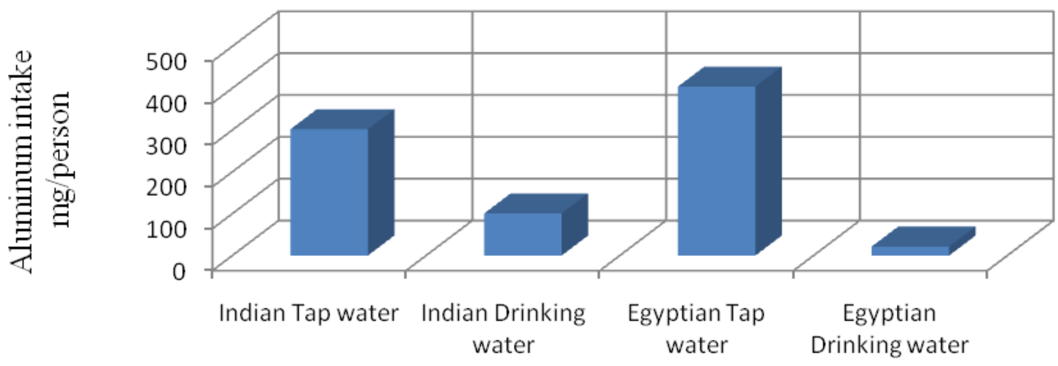

Figure 1. Effect of the type of water on leaching of aluminum at boiling temperature

All the pH of solution changes to more alkaline nature at the end of the test. The estimated aluminum intake mg/person shown in Figure (1) indicates a big difference between using drinking water or tap water, the latter more aggressive. This calculation based on the assumption that an Al utensil of 20cm diameter and 18cm height is used for a family of 3 person. The area exposed to the food will be around 1440 cm^2.

3.1.2. Leaching in Meat and Meat Extract

The experiment of the W_L method of the whole meat at 40% concentration is compared with the meat extract at 40% concentration. It is shown that there is no considerable difference. On this basis the meat extract is used instead of the whole meat.

Table 2. Effect of meat extract solutions on leaching of aluminum at boiling state

Solution	Type of water	Origin of cooking ware	Initial pH	Final pH	Corrosion rate $mg/cm^2.hr*10^{-2}$
20% meat extract	Drinking water	Indian	6.22	6.28	2.15
		Egyptian	6.20	6.30	2.27
30% meat extract		Indian	6.20	6.30	2.10
		Egyptian	6.20	6.30	2.40
40% meat extract		Indian	6.50	6.48	6.29
		Egyptian	6.50	6.48	4.43

The effect of different concentration of meat extract on the leaching values and the aluminum intake of the two materials in drinking water is shown in Table (2) and Figure (2). The corrosion rate is almost constant in the 20% and 30% meat extract solution. In 40% meat extract solution both materials show higher corrosion rate. The amount of intake per person in mg for the 40% meat extract solution is higher than the lower concentration. For this reason the 40% meat extract solution is chosen for further investigation. There are no significant differences in the pH value and this is in agreement with another study [14]. The dissolution of aluminum may change the local pH on aluminum surface but it does not affect the pH of the solution.

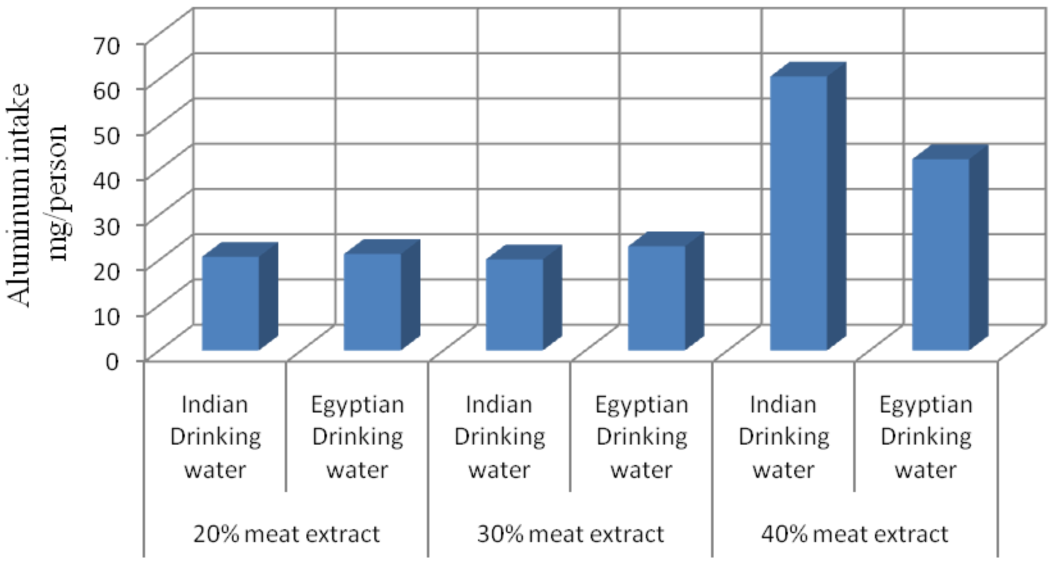

Figure 2. Effect of concentration of meat extract on the leaching of aluminum

Comparing the leaching of aluminum of an Egyptian sample in meat extract in drinking water with the leaching of the same sample in drinking water without meat, the leaching is almost, double, while with the Indian sample the leaching is reduced from 100 mg/person to 61 mg/person. In the first case the finding is completely opposed by Karbouj et al. where they showed that boiling water in Al utensils may reduce Al leaching in cooking by 60% [15]. In the case of the Indian samples the findings are in agreement with work reported by Severus who states that Al leaching is reduced by the presence of amino acids which are available in the meat extract [16].

3.1.3. Leaching in Food Solutions

Corrosion rate in two food solutions are listed in Table (3). It is clear that the second solution is more aggressive than the first for both, material and two types of water. The pH again shows no significant changes. Using the same previous assumption the intake as mg/person calculated and plotted in Figure (3). In solution (1) the Indian and Egyptian sample in drinking water show very high leaching 121 and 101 mg/person, respectively.

In solution (2) all samples show very high values especially the Indian sample in drinking water which show 181 mg/person, which is very bad situation. This means that in one meal a person can take more than 150 mg aluminum which is intolerable, assuming that the other 31 mg will be tolerated with the aluminum from food, water and medicine.

Table 3. Effect of different food solutions (at boiling temperatures) on the leaching of aluminum

Solution No.	Solution composition	Type of water	Origin	Initial pH	Final pH	Corrosion rate mg/cm^2.hr*10^{-2}
1	250 ml 40% meat extract + 250 ml tomato juice + 10 gm citric acid+ 5 gm table salt	Tap	Egyptian	3.2	3.0	4.43
		Drinking	Egyptian	3.2	3.0	10.50
		Tap	Indian	3.4	3.0	6.64
		Drinking	Indian	3.0	2.8	12.58
2	250 ml 40% meat extract + 250 ml tomato juice + 20 gm citric acid (0.2 M) + 5 gm table salt	Tap	Egyptian	3.2	2.9	13.30
		Drinking	Egyptian	2.8	3.0	12.58
		Tap	Indian	3.2	3.0	15.5
		Drinking	Indian	2.8	2.6	18.87

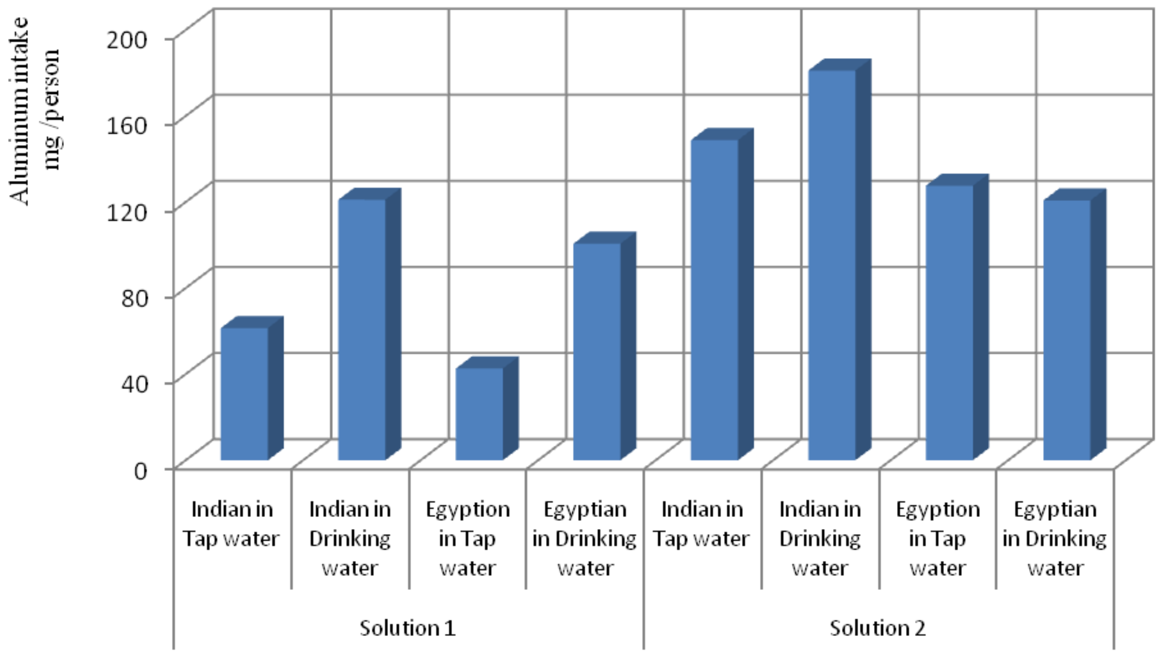

Figure 3. Effect of different food solutions on leaching of aluminum: solution 1 (250 40% meat extract + 250 ml tomato juice + 10gm citric acid + 5 gm table salt, solution 2 (250 ml 40% meat extract + 250 ml tomato juice + 20 mg citric acid + 5 gm salt

3.2. ICP-MS Results

The detail metal analysis of liquid samples after cooking, using inductively coupled plasma-mass spectrometry (ICP- MS) is shown in Tables 4 and 5.

Table 4 is for meat extract solution using drinking water and Table 5 for the four samples of food solutions after cooking process for two hours using two metal samples. These results are consistence with the weight loss results.

Table 4. ICP-MS analysis of metal content in the food solution after the test

Element	Egyptian cooking ware		Indian cooking ware		
	20% meat extract	40 % meat extract	20% meat extract	30% meat extract	40 % meat extract
Li	1.8	3.9	5.8	18.3	4.7
Al	81.2	123.6	73.2	209.4	90.3
Sc	4.4	5.8	16.7	2.9	19.6
Ti	82.8	146	203.1	237.9	361.3
V	1.4	2.4	1.7	5.4	2
Cr	45.3	74.4	33.3	73.6	51.6
Mn	14.6	21.6	13	17.5	18.5
Fe	68	0.0	78.3	257.1	242.2
Co	0.2	5.9	0.2	0.4	0.6
Ni	0.0	0.2	0.0	2	0.0
Cu	20.5	15.2	12.3	28.6	18.8
Zn	123.2	172.8	109.5	349.7	270.6
Se	7	9.1	10.3	6.4	7.6
Rb	223.7	450.3	349.6	676.6	618.6
Sr	37.7	48.5	27.7	48.8	33.7
Mo	0.7	0.2	1.7	2.2	2.2
Ba	26.4	30	26.4	8.4	29.7
W	1.1	4.8	9	0.0	14.8
Hg	0.2	0.3	0.4	0.4	0.6
Pb	1.5	32.4	1.7	5.8	6.8
Total	741.7	1147.4	973.7	1951.2	1794.2

4. CONCLUSION

The leaching process of aluminum during the food manufacturing process using two origins of cooking utensils is studied using different techniques.

The experimental work analysis detects a significant level of aluminum in the most of the cooked food for these two origins of cooking utensils. The leaching process is increased by the addition of salt and citric acid.

These results showed that low pH enhanced the leaching of aluminum but without a big change between the initial and final pH values of the test solutions. The change may be affecting the local pH on aluminum surface. It can also be concluded that the tap water in aluminum utensils leaching more than the drinking water.

Table 5. ICP-MS analysis of metal content in the sample after cooking

Element	Indian sample in Solution 1*	Indian sample in Solution 2 #	Indian sample in Solution 1*	Indian sample in Solution 2 #
			(Tap water)	
Li	38.7	39.5	35.3	47.8
Al	3782.6	4491.3	5776.1	6312.4
Sc	1.7	2.3	9.3	15.8
Ti	144.2	150	258.7	263.5
V	74.2	71.7	83.5	95.9
Cr	350.4	380	439.4	490.9
Mn	663	597.6	881.6	939.1
Fe	2041.0	2069.6	4385	6176.4
Co	7.1	6.4	11.2	12.1
Ni	80.9	60.7	151.6	143.5
Cu	442.6	415.5	698.8	718.9
Zn	1476.5	1152.1	1243.6	1855.9
Se	30.4	23.6	25.7	19.6
Rb	1691.3	1493.4	2237.8	2376.1
Sr	1441	1298.4	1450.6	1507.3
Mo	33.2	31.1	39.3	38.6
Ba	218	163.6	209.5	276.2
W	1.1	0.6	4.3	3.6
Hg	1	0.3	0.4	0.0
Pb	87.1	32.9	74.5	56.6
Total	12606.3	12480.6	18016.2	21350.2

* Solution 1: 250 ml 40% meat extract + 250 ml tomato juice + 10 gm citric acid+ 5 gm table salt
# Solution 2: 250 ml 40% meat extract + 250 ml tomato juice + 20 gm citric acid (0.2 M) + 5 gm table salt

5. ACKNOWLEDGEMENT

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