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ALUMINUM CONTAMINATION OF FOOD DURING PREPARATION IN ALUMINIUM COOKWARE

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The health ramifications of rising aluminium concentration in the humans' body have been a major source of worry. The primary source of aluminium metal for humans is thought to be aluminium utensils. Dani Dordevic and co-workers [3] measured the aluminum content by AAS and ICP/MS methods. In their study they observed the highest aluminum increase in the samples of marinated Salmo salar (41.86 ± 0.56 mg/kg), Scomber scombrus (49.34 ± 0.44 mg/kg), and duck breast (117.26 ± 1.37 g/kg). Their research was also supported by the survey that consisted of 784 respondents with different sociodemographic characteristics. The study clearly showed the occurrence of aluminum contamination of food when it is prepared by baking in aluminum foil. The leaching of aluminium from aluminium utensils in various food solutions was investigated in our study. From the local market, three aluminium kitchenware of various origins were picked. To make diverse meal solutions, different veggies (spinach, cabbage, and brinjals) were used. Weight loss assessment and SEM were employed as analysis methodologies. The findings clearly show that metal leaching from aluminium utensils during the cooking operation of each vegetable contributed significantly to the daily human intake of aluminium. After the cooking process, the level of leaching in the meal solution was determined to be high. The values obtained, per the World Health Organization (WHO), are all above their limits, which could result in a variety of health problems.

Keywords: Leaching; aluminium; spinach; WHO.

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1. INTRODUCTION

Aluminum is the 3rd most abundant element on the planet. It's a good heat carrier, but it's also a soft metal that absorbs more molecules than stronger metals employed in cookware. It is susceptible to scratches and distorts readily at extreme temps since it is a soft metal. Aluminum has a number of health disadvantages, including the fact that it is a sensitive material that reacts with both alkaline and acidic foods. The reaction imparts an off-metallic flavour to the meal and alters its colour, giving it an unappealing grey hue. More significantly, food cooked in aluminium can generate aluminium salts when it reacts with the metal. Although its presence in food & medication, aluminium is harmful to humans and may cause a variety of ailments. Excess aluminium levels in the blood may contribute to the development of Alzheimer's disease, according to certain research [1]. Apart from the other levels of dietary aluminium, aluminium cookware is thought to be a possible store of this element for humans. Anodizing the cookware has been used to combat aluminium leaching. Chemicals treatments are being used to thicken the oxide film, creating it tougher, more resilient, and less prone to corrode and leach; providing the face is not harmed. Although anodized aluminium is harder to damage than non-anodized aluminium, superficial damage can nonetheless occur. One thing to keep in mind when shopping for cookware is that it’s not all anodized aluminium cookware on the marketplace uses this substance on the internal surfaces that come into touch with food. Rather, manufactures utilize anodized aluminum's heat-transferring capabilities on the outside of the kitchenware and a separate non-sticking coating on the inside. Aluminum, from an environmental standpoint, cannot be eliminated; it can only change its form [2]. Worries about the possible link between environmental aluminium intake and Alzheimer's disease have inspired research into all kinds of human aluminium intake, even food. Aside from food components, aluminium cookware is thought to be a potential source of aluminium for people. Many tests were carried out to investigate the leaching effects of various meals, beverages, and water in relation to pH variations. Unfortunately, several of the results in terms of leached aluminium levels were contradictory. This could be the result of a variety of variables, including non-systematic and non-uniform methodological approaches and settings. The human consumption values of aluminium will be determined exactly in this study by standardising aluminium sample sizes, utilising real cooking circumstances, emphasising the role of aluminium science in different cooking solution media, and employing strict analysis authority in the estimation of aluminium [3,4,5,6,7,8,9,10,11,12]. In this study, the leaching of aluminium from three types of aluminium cookware (Indian, Chinese, and Japanese) in various food solutions containing spinach, is investigated.

2. METHODOLOGY

Three different types of aluminium cookware are picked from the local farmers market, each with a different origin. India, China, and Japan are the foundations of the cookware. The cookware is cut into small rectangle forms with measurements of 1x1.2 cm and a 1 mm diameter hole on one end to allow them to be hung in the vegetable food solution. Spinach, are among the veggies utilized.

These veggies, drinkable water, salts, and tomato juice are used to make the following culinary solutions:

300 g spinach + 150 ml drinking water + 3 g salt + 150 ml tomato juice	150 g spinach + 300 ml drinking water + 3 g salt	300 g spinach + 300 ml drinking water + 3 g salt

2.1 Weight Loss (WL) Method

The losing weight method (WL) is employed in this research to investigate the leaching of aluminium into various vegetable food solutions at boiling temperature. The aluminium specimens are washed with pure water as well as acetone, dried, and assessed on a precise four-digit balance. After twenty minutes of boiling, the aluminium specimens are rinsed with distilled water and acetone before being reweighed. Following the initial research, the pH values of the liquids are also determined. All of the studies are repeated in order to maintain accuracy.

2.2 ESEM

Environmental scanning electron microscopy (ESEM) utilizing an energy dispersive x-ray source is used to examine the samples prior and afterwards the experiment. When compared to the original state, this test indicates whether the metals have been leached.

3. RESULTS AND DISCUSSION

According to a WHO report from 1989, the preliminary tolerance weekly intake for aluminium is 7 mg per kilogram of body weight. This suggests that a daily consumption of 50 mg of aluminium is tolerable for an individual of average weight of 50 kg. Nevertheless, such advice is frequently depending on the outcomes of short-term toxicology studies [13].

As a result, this number is liable to change as new evidence from chronic toxicity studies becomes available. It's also worth looking at the relevance of such suggestions, particularly in populations where other minerals like iron and calcium are commonly deficient. Recent evidence suggests that minerals including iron, calcium, and zinc have a significant impact on aluminium absorption. The aluminium leaching rate increases as the pH value lowers, as evaluated by cooking spinach specimens in various acidic cooking solutions. The aluminium leaching rate was determined to be 5.1 mg of aluminium per 100 g of broccoli boiled in lime juice at pH 2.6, and 2.7 mg of aluminium per 100 g of tomato sauce with sugar and 4.9mg of aluminium per 100 g of tomato sauce without sugar for those cooked in tomato sauce. Additionally, the very same samples maintained in the refrigerator for 48 hours yielded similar results: 2.8 mg of aluminium per 100 g of tomato sauce containing sugar and 5.0 mg of aluminium per 100 g of tomatoes sauce without sugar [14]. Throughout a 20-minute contact, aluminium leaching was observed from across all cookware in all food solutions, according to our findings. The corrosion rate is determined by dividing the losing weight by the sampling site and the 20-minute exposure duration in each experiment. The calculated aluminium intake per person is based on the assumption that a three-person family uses aluminium utensils with a diameter of 20 cm and a height of 18 cm. A total of 1440 cm2 will be exposed to the meal.

Green vegetable preparation, according to Neelam, add significantly to daily total aluminium intakes [15]. This assertion is supported by this work.

When analyzing the 3 samples, the Indian sample has the most aluminium leaching, that is explored further using ESEM. Fig. 1 illustrates the Indian sample under various magnifications, emphasising grains and grain boundaries, indicating that the outer layer of aluminium oxide is now almost dissolved in the food solution. It depicts a metal's uniform thinning without any localised attack. Table 2 shows the effect of adjusting the level of the food solution and adding tomato sauce on the extraction stage. Leaching is reduced by adding 150 mL tomato juice.

Table 1. Three cookware samples from different origins were used to cook a meal mixture for twenty minutes at boiling point of water

Sample origin	Solution composition	Initial pH value	Corrosion rate ($mg/cm^2.hr.10^{-2}$)	Final pH value	Weight loss (mg)	Aluminum intake (mg/person)
China	150 g of spinach + 300 ml of drinking water + 3g of salt	6	25.2	6	0.2	40.4
Japan		6	12.6	6	0.1	20.2
India		6	37.8	5.8	0.3	60.6

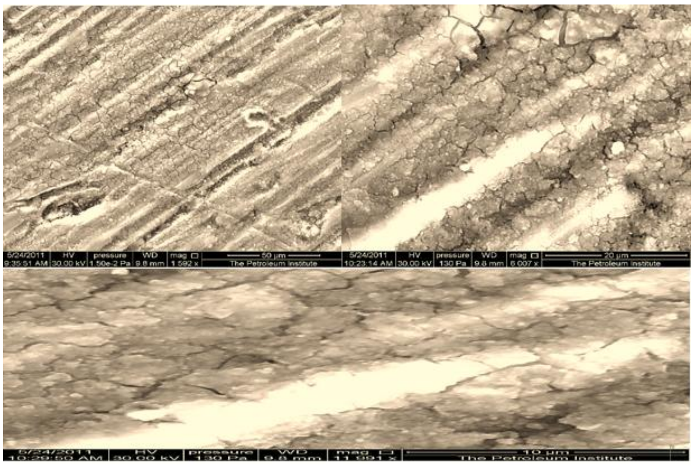

Fig. 1. ESEM photos of the Indian aluminium sample following 20 minutes of immersion in a spinach liquid at boiling temperatures

Table 2. Shows the aluminium corrosion rate of an Indian cookware sample after 20 minutes of boiling in various spinach meal solutions

Solution number	Solution composition	Weight loss (mg)	Aluminum intake (mg/person)	Spinach solution concentration	Corrosion rate ($mg/cm^2.hr.10^{-2}$)
1	150 g of spinach+ 300 ml of drinking water + 3 g of salt	0.3	60.6	33.1 %	37.8
2	300g of spinach+ 300 ml of drinking water + 3 g of salt	0.2	40.4	49.8 %	25.2
3	300 g of spinach +150 ml of drinking water + 3 g of salt +150 ml of tomato juice	0.1	20.2	49.8 %	12.6

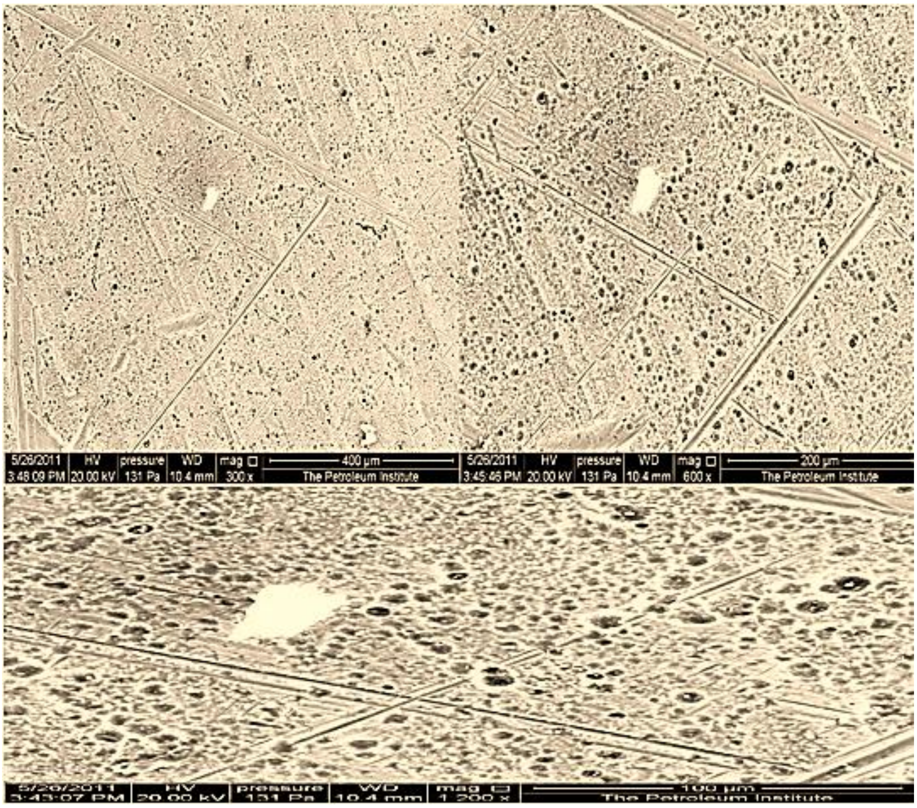

Fig. 2. ESEM images of an Indian aluminium sample after 20 minutes of immersion in a concentrated spinach solution at boiling temperature

Pitting corrosion on the surface of the Indian aluminium sample following immersion in solution (Table 2) is shown in Figs. 2 A-C.

This could explain why at high spinach concentrations, the leaching rate is reduced. Pitting occurs when the surface of the metal is almost completely covered by the vegetable, leaving a small area exposed to the solution. It's a type of localised metal surface corrosion in which tiny portions corrode preferentially, forming cavities or pits, while the rest of the surface remains unaffected. This type of corrosion is common in aluminium. It happens when the entire surface loses a modest amount of weight. The explanation for the reduction of corrosion in the presence of tomato juice is the same. The reduction in leaching rate caused by adding tomato juice to the spinach is consistent with earlier research [16].

4. CONCLUSION

The findings of this study clearly show that using aluminium utensils to prepare spinach, contributes significantly to total daily aluminium consumption. The leaching of aluminium into the food solution is reduced when the amount of spinach in the food solution is increased from 33 percent to 50 percent. This is because the nature of the reaction between aluminium and solution has changed. At low concentrations, uniform corrosion occurs, whereas at high concentrations, pitting occurs. Furthermore, extending the cooking time increases aluminium leaching in food solutions tested in this study. Thus in conclusion, we can say that the target of that study was met, and we have expanded new up-to-date data on aluminum levels in a extensive range of foods that was not been accessible in this research area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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