Review Article Pol J Public Health, Vol. 134 (2024): 73-76

BARTOSZ PRZYBYSZ[1], JOANNA SMALIRA[2], ANGELINA LĘGAS[3], WERONIKA ROGALA[2], KATARZYNA POCHODOWICZ[2], KAROLINA ROGOWSKA[2], JULIA ZAWISTOWSKA[4], JAKUB KAWALEC[5], WERONIKA RUTKOWSKA-KAWALEC[6], AGATA MORMUL[2]

The impact of preparing food in aluminum cookware on human health – a literature review

Abstract

Introduction. Aluminum is an element commonly found in the environment. It is used in various industrial sectors, for example as a manufacturing material for food-grade utensils.

Aim. The aim of this scientific paper is to answer to the question of whether people expose their health to the harmful effects of aluminum by utilising these types of items for preparing and storing food.

Description of the state of knowledge. Aluminum has a proven noxious impact on the human body. Due to its neurotoxic properties, it may induce clinical symptoms. Excessive exposure to this element is also associated with the occurrence of bladder and lung cancer, while the connection with breast tumours remains debatable. Additionally, aluminum can be harmful to our health, as a component of some medical preparations.

Conclusions. It is crucial to emphasise the necessity of complying with the amounts of aluminum consumption recommended by international institutions. Short-term use of aluminum pots does not pose a threat to our well-being. Also, long-term usage in most cases does not lead to exceeding the aluminum consumption standards, although children may be at risk. However, it is good practice to avoid cooking acidic products in aluminum utensils. Furthermore, it is worth washing the dishes according to the manufacturers' recommendations and replacing them with new ones every few years. In addition, some scientists suggest choosing pots made of different materials, e.g. titanium. Moreover, a noticeable decrease in the levels of vitamin B1 and C in food prepared in aluminum dishes may be one of the reasons for their lower nutritional value, however this issue should be examined further.

Keywords: aluminum; cooking and eating utensils; food safety; neurotoxicity.

DOI: 10.12923/2083-4829/2024-0016

INTRODUCTION

The metal marked as Al in the periodic table of elements is one of the main components of the Earth's crust. In terms of abundance, it ranks third, following only oxygen (O) and silicon (Si) [1]. Aluminum occurs naturally in drinking water and consumed foods, such as spinach, oats, potatoes and tea. It is widely exploited by people in various industrial sectors. Al is used as raw material in the production of items for preparing and storing food, such as pots, kettles, trays and foils. Moreover, it can be an ingredient of many cosmetics e.g. antiperspirants or sunscreens. Furthermore, aluminum is used in the manufacture of vaccines and desensitisation preparations as their immunomodulatory element. In medicine it is also utilised for medicaments neutralising the acidic environment or as a component of dialysis fluids [2]. Despite such a widespread distribution of this element in inanimate nature, scientists have not yet demonstrated that Al is essential to forming any structure in the cells of living organisms or to carrying out any chemical reaction that occur within them [3]. Nevertheless, aluminum can significantly affect the functioning of the human body.

AIM

The aim of this article is to answer the question whether preparing and storing food in aluminum utensils threatens peoples' health.

DESCRIPTION OF THE STATE OF KNOWLEDGE

Biological mechanisms of aluminum action

Aluminum enters the body in three different ways: through digestive tract, integumentary system or respiratory tract. The vast majority of this element reaches human body through the consumed food [4]. However, only about 0.1% of the supplied aluminum is absorbed in the intestines [5]. The quantity of this metal assimilated through the skin is even lower [6].

[1] 2nd Department of Internal Medicine, Bielanski Hospital in Warsaw, Poland
[2] Department of Internal Medicine, Praski Hospital in Warsaw, Poland
[3] Department of Internal Medicine, Hypertension and Vascular Diseases, University Clinical Centre of the Medical University of Warsaw, Poland
[4] Department of General, Minimally Invasive and Oncological Surgery, Voivodeship Hospital in Bialystok, Poland
[5] Departament of Radiology, Specialist Hospital for Pulmonary Diseases in Zakopane, Poland
[6] Pediatric Departament, Tytus Chałubiński Regional Hospital in Zakopane, Poland

Furthermore, it is estimated that the absorption of inhaled Al by employees of steelworks and factories using this element in production is about 1% [7]. When it comes to elimination of Al from the human organism, the urinary system plays a vital role because of the filtration process in the renal glomeruli [8].

When aluminum reaches the body, it can modify the function of cells in many ways. If it is in the third oxidation state, it can adhere to elements of DNA strand, influencing gene expression. Also, it has an impact on functioning of some enzymes such as kinases or phosphatases, which in turn disrupts their activity. Aluminum, combining with phosphorylated parts of proteins, disturbs their degradation and causes their accumulation. Additionally, discussed metal can cross the blood-brain barrier and deposit itself in the nervous tissue. Huat et al. found that most of this element is captured by glial cells. This results in local inflammation, which is the source of cytokines such as IL-6. Moreover, aluminum contributes to the formation of reactive oxygen species. Their destructive effect is intensified by the inhibitory impact of Al on many ROS-neutralising enzymes. Also, scientists have demonstrated that aluminum can modulate neurotransmission by influencing the synthesis and transport of neurotransmitters such as acetylcholine, serotonin, dopamine, glutamate and aspartate. The same study also found that this metal disrupts the metabolism of calcium and iron in the nervous tissue [9]. As a result, aluminum is considered neurotoxic [10].

Diseases caused by aluminum

The neurodegenerative effect of Al means that this element certainly hinders the function of the central nervous system. This may manifest clinically in the form of memory and speech disorders, tremors and even muscle paralysis [11]. However, there is a considerable debate regarding the connection between excess of aluminum in the body and the occurrence of Alzheimer's disease (AD). Although significant amounts of Al are observed in the brain tissue of Alzheimer's patients, it is unclear whether this is the cause of the disease or a secondary change. For this reason, some believe that aluminum encephalopathy should not be treated identically as AD and needs to be considered as a separate nosological entity [12], while according to C. Exley, excessive exposure to Al is treated as one of the factors of Alzheimer's disease [13].

Additionally, the cause and effect relationship between breast cancer and usage of antiperspirants containing aluminum is also difficult to clearly confirm. Over the last decades scientists have observed an increase in the incidence of this neoplasm in the upper outer quadrant of breast [14]. Due to the proximity of this area to the place where the cosmetics are applied, it was suspected that this may be related. However, it was found that it cannot be admittedly considered as the cause of the development of the cancer process, although significant accumulation of aluminum was observed in the tumour cells [15].

Another chronic disease resulting from overloading human organism with aluminum is aluminosis. It is one of the restrictive lung disorders due to occupational exposure to Al [16]. Furthermore, growth in frequency of respiratory tract and bladder cancer has been demonstrated among employees of tanneries and steelworks in the aluminum industry [17]. Therefore, according to the International Agency for Research on Cancer (IARC), Al is admitted as a carcinogen contributing to the development of bladder and lung cancer [18].

Paradoxically, the detrimental impact of aluminum on human health can also be noticed in the medical sector. Excessive accumulation of this element may occur as a result of the usage of substances for parenteral nutrition and fluids utilised during haemodialysis or peritoneal dialysis. Also, chronic intake of products containing Al to neutralise acidic environment of the stomach may overload the body with aluminum. Patients with renal failure are particularly exposed to this, because of problems with removing this metal from the organism. Therefore, calcium and phosphate metabolism may be dysregulated, which can lead to parathyroid dysfunction and bone fractures caused by osteomalacia [19].

International regulations

The harmful effects of aluminum on the human body prompted researchers to define standards for the safe consumption of this element. Consequently, the European Food Safety Authority guidelines appeared, according to which the Tolerable Weekly Intake (TWI) was set at 1 mg aluminum per 1 kg of body weight [20]. Moreover, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) lowered the previously established Provisional Tolerable Weekly Intake (PTWI) for Al from 7 mg/kg of body weight, to 2 mg/kg due to the research suggesting an adverse impact of consuming higher quantities [21]. In turn, the Council of Europe in its resolution on metals and alloys used in food contact materials and articles defined Specific Release Limits (SRL). It is the amount of metal released into the nourishment that is stored in containers made of it. For aluminum SRL is set at 5 mg per 1 kg of food [22].

Does preparing meals in aluminum dishes change its composition, affecting human health?

Daily habits are vitally important in the perspective of a lengthy and fulfilling life. Human well-being mainly depends on the lifestyle one leads [23]. One's attention to details that seem trivial at first glance, may result in health and prosperity in the future. The conception of this scientific work is to answer the question whether preparing food in aluminum cookware indeed modifies its properties, which results in medical conditions. While reviewing available literature, we found some compelling articles explaining this issue.

Daily cup of coffee is an essential ritual to many populations in the world. One of the convenient methods of preparing the beverage is to use an aluminum pot. Windish et al. compared the amount of Al in coffee drinks made in an aluminum kettle, a steel pot, a filtering machine and using capsules. It turned out that the most of this element was in the coffee prepared with aluminum cookware. Moreover, a fact worth noting that surprised research workers is that there was less Al in the coffee drink prepared in aluminum utensil than in clear water boiled in the same kettle. It can be explained by the absorbent properties of ground coffee beans. However, if one consumed daily 500 ml of coffee made in the kettle with the highest concentration of Al, scientists calculated that one would deliver only 0.36% of tolerable weekly intake. It does not pose a significant risk to one's well-being. Although the bulk of healthy people do not have to be cautious, scientists emphasise that elderly could be at risk, due to an intensification of absorption of substances from the gastrointestinal tract with passing of time [24].

Aluminum content in beverages depends not only on the vessel in which it is prepared, but also on the type of drink. Publication which proved this issue is an article by Stahl et al. It has been demonstrated that regular consumption of 500 ml of apple juice or tea from aluminum bottles a day can result in reaching nearly 100% TWI of Al for an adult and exceed the weekly intake for a child weighing 15 kg. This sort of risk did not exist in coffee usage, in case of which TWI was comparably low (4%) with association to the previously discussed study. Slightly higher values could have been observed due to the fact that in this research aluminum jugs for preparing coffee were intentionally washed in the dishwasher, despite the manufacturer's recommendation to the contrary. The conclusion of this study was that the inner layer of the utensil is also significant. Bottles without lining released more aluminum into the drink than those with a special internal covering. Additionally, an interesting deduction was that while brewing coffee in an aluminum pot, the most Al is released during the first use of the cookware and after cleaning in a dishwasher [25].

Another study by lastly mentioned authors reveals transcending of TWI for adult people. They confirmed that the acidic reaction of nourishment prepared in aluminum utensils causes an increased transfer of Al from dish to food. The sample which yielded 187% TWI for an adult was a fish in marinade with lemon juice cooked in an aluminum camping cookware. TWI was calculated for a person weighing 70 kg and consuming 250 g of this meal daily, over the course of a week. Also, in this study it has been found that children are even more at risk. For a 15-kilogram child TWI equalled 871%. Moreover, specific release limits were exceeded in dishes with usage of citric acid. However, SRL was within limits, when food was prepared with water and oil [26].

Noteworthy publication is an article by Alabi and Adeoluwa. They used aluminum pots to boil water and after measuring the level of aluminum and other heavy metals in these liquids, it occurred that their concentration was beyond permissible standards. It was observed that the longer utensil was exploited, the greater the amount of elements penetrated into the water. Then they examined the ability of these solutions to induce mutation and damage of DNA in bacterial cells. In effect, mutagenicity and genotoxicity of substances contained in water cooked in aluminum pots was confirmed and their intensity was the highest in vessels used for longer time (6 years). It was concluded that as a result of long employment of cookware, the internal coating deteriorates, which causes increasing leaching of metals into cooked products and poses a risk to human health [27].

In turn, Hiller et al. wanted to check the level of Al load in the body while following a diet containing meals that were in contact with aluminum utensils. The main measurement was the concentration of Al excreted in urine corrected for creatinine concentration, but one of exclusion criteria was renal dysfunction. A group of people was examined for 30 days. This time was divided into three 10-day periods. In the first and third one participants consumed food free of Al addition, whereas in the second one an aluminum load was administered in the form of a diet consisting of meals prepared or stored in cookware made of this metal. As a result of this study, a completely reversible increase of the Al quantity in urine was found after applying this type of diet. An average concentration growth was 0.19 µg/l of urine, which was approximately 8% of the initial amount. Converting these numbers into TWI value, this would constitute circa 4.5% of additional aluminum intake, which can be considered as a quantity that does not pose a threat to human well-being. It is also worth emphasising that during the application of Al addition, no reported symptoms were observed in the participants [28].

Apart from the amount of aluminum released from cookware, it is the loss of nutrients from heat-treated nourishment that deserves attention. Onyeka et al. checked if the material the pot is made of influences the degree of nutritional value reduction in various foods. Products like rice, tomato, yam, beef and legumes cooked in utensils manufactured from different metals have been examined. The greatest loss of both macro- and microelements compared to raw food was observed in food prepared in aluminum cookware, especially older ones. On the other hand, the most valuable properties remained in products cooked in titanium pots. This difference may be explained by the fact that aluminum has a greater thermal diffusivity than titanium, which makes it easier for nutrients sensitive to high temperatures to be degenerated and washed out. Vitamins B1 (38.97%) and C (38.77%) were the most at risk of reduction as a result of heating in aluminum pots [29].

CONCLUSION

Taking into account the conclusions drawn from the above studies, it is necessary to notice that the assessment of harmful aspects of preparing food in aluminum cookware, should be performed in the context of their long-term usage. It is certainly worth emphasising the need to comply with the quantity of Al intake recommended by the international institutions. Due to the fact that the standards are given in a weekly period of time, short-term usage of pots made of this metal does not pose a threat to human health. Also, their long-term utilisation does not lead to exceeding suggested norms of aluminum consumption. However, children may be at risk because it is much easier for them to reach their Al tolerable weekly intake per kilogram of body weight. Additionally, elderly tend to have a greater absorption of this element from gastrointestinal tract and patients with kidney diseases due to their reduced ability to remove aluminum from their body, can also be in peril. Moreover, the type of the prepared food also influences the Al content, therefore cooking acidic products in aluminum dishes should be avoided, as low pH increases the penetration of this metal to food. Furthermore, frequent and improper use of the cookware may cause their damage, especially destruction of the internal layer that protects the release of the mentioned element to the meals. Therefore, it is a positive practice to wash the dishes according to manufacturer's recommendations and replace them with new ones every few years. In addition, some scientists encourage people to choose pots made of materials other than Al, for example titanium [29]. Besides, worsened quality of food prepared in aluminum utensils, seen as a noticeable decrease in some nutritional values, should be examined further to find if it could be one of the reasons for deficiency of macro- and microelements. Certainly, regardless of what type of cookware is used, it is extremely important to follow a well-balanced diet which will cover the daily demand for all nutrients.

REFERENCES

1. Ecotoxicology of Aluminium. Polish J Environ Stud. 2002;11(3):199-203.
2. Tietz T, Lenzner A, Kolbaum AE, et al. Aggregated aluminium exposure: risk assessment for the general population. Arch Toxicol. 2019;93(12):3503-21.
3. Bryliński Ł, Kostelecka K, Woliński F, et al. Aluminium in the Human Brain: Routes of penetration, toxicity, and resulting complications. Int J Mol Sci. 2023;24(8):7228.
4. Ma J, Jiang G, Zheng W, Zhang M. A longitudinal assessment of aluminum contents in foodstuffs and aluminum intake of residents in Tianjin metropolis. Food Sci Nutr. 2019;7(3):997-1003.
5. Corkins MR. Committee on nutrition. Aluminum effects in infants and children. Pediatrics. 2019;144(6):e20193148.
6. de Ligt R, van Duijn E, Grossouw D, et al. Assessment of dermal absorption of aluminum from a representative antiperspirant formulation using a 26 Al microtracer approach. Clin Transl Sci. 2018;11(6):573-81.
7. Riihimäki V, Valkonen S, Engström B, et al. Behavior of aluminum in aluminum welders and manufacturers of aluminum sulfate – impact on biological monitoring. Scand J Work Environ Health. 2008;34(6):451-62.
8. Colomina MT, Peris-Sampedro F. Aluminum and Alzheimer's Disease. Adv Neurobiol. 2017;18:183-97.
9. Huat TJ, Camats-Perna J, Newcombe EA, et al. Metal toxicity links to Alzheimer's disease and neuroinflammation. J Mol Biol. 2019;431(9):1843-68.
10. Asghar H, Siddiqui A, Batool L, Batool Z, Ahmed T. Post-exposure self-recovery reverses oxidative stress, ameliorates pathology and neurotransmitters imbalance and rescues spatial memory after time-dependent aluminum exposure in rat brain. Biometals. 2024;37(4):819-38.
11. Kandimalla R, Vallamkondu J, Corgiat EB, et al. Understanding aspects of Aluminum exposure in Alzheimer's Disease development. Brain Pathol. 2016;26(2):139-54.
12. Klotz K, Weistenhöfer W, Neff F, Hartwig A, van Thriel C, Drexler H. The health effects of Aluminum exposure. Dtsch Arztebl Int. 2017;114(39):653-659.
13. Exley C. Aluminum should now be considered a primary etiological factor in Alzheimer's Disease. J Alzheimers Dis Rep. 2017;1(1):23-25.
14. Darbre PD. Recorded quadrant incidence of female breast cancer in Great Britain suggests a disproportionate increase in the upper outer quadrant of the breast. Anticancer Res. 2005;25(3c):2543-2550.
15. Alasfar RH, Isaifan RJ. Aluminum environmental pollution: the silent killer. Environ Sci Pollut Res Int. 2021;28(33):44587-44597.
16. Kuman OE, Altundaş HE, Acar KD, et al. A current example of historical cases: Occupational pulmonary aluminosis. Turk Thorac J. 2021;22(1):83-85.
17. McClure ES, Vasudevan P, DeBono N, et al. Cancer and noncancer mortality among aluminum smelting workers in Badin, North Carolina. Am J Ind Med. 2020;63(9):755-65.
18. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Chemical agents and related occupations. IARC Monogr Eval Carcinog Risks Hum. 2012;100(Pt F):9-562.
19. Klein GL. Aluminum toxicity to bone: A multisystem effect? Osteoporos Sarcopenia. 2019;5(1):2-5.
20. European Food Safety Authority (EFSA). Safety of aluminium from dietary intake – Scientific opinion of the Panel on Food Additives, Flavourings, Processing Aids and Food Contact Materials (AFC). EFSA J. 2008;6(7):754.
21. Seventy-fourth report of the Joint FAO/WHO Expert Committee on Food Additives. Evaluation of certain food additives and contaminants. [http://apps.who.int/iris/bitstream/10665/44788/1/WHO_TRS_ 966_eng.pdf]. (access: 10.04.2024).
22. Council of Europe (2013) Resolution CM/Res (2013) 9. Metals and alloys used in food contact materials and articles. A practical guide for manufacturers and regulators prepared by the Committee of Experts on Packaging Materials for Food and Pharmaceutical Products (P-SC-EMB). Strasbourg; 2013.
23. Bodai BI, Nakata TE, Wong WT, et al. Lifestyle medicine: A brief review of its dramatic impact on health and survival. Perm J. 2018;22:17-025.
24. Windisch J, Keppler BK, Jirsa F. Aluminum in coffee. ACS Omega. 2020;5(25):15335-43.
25. Stahl T, Falk S, Rohrbeck A, et al. Migration of aluminum from food contact materials to food-a health risk for consumers? Part II of III: migration of aluminum from drinking bottles and moka pots made of aluminum to beverages. Environ Sci Eur. 2017;29(1):18.
26. Stahl T, Falk S, Rohrbeck A, et al. Migration of aluminum from food contact materials to food-a health risk for consumers? Part III of III: migration of aluminum to food from camping dishes and utensils made of aluminum. Environ Sci Eur. 2017;29(1):17.
27. Alabi OA, Adeoluwa YM. Mutagenicity and genotoxicity of water boiled in aluminum pots of different duration of use using SOS chromotest and Ames fluctuation test. Toxicol Res (Camb). 2021;10(4):771-6.
28. Hiller J, Göen T, Seibold-Wulf N, Meyer S, Drexler H. Effect of an aluminum foil-processed diet on internal human aluminum burden. Environ Int. 2023;177:108000.
29. Onyeka UE, Ibeawuchi ON. Loss of food nutrients orchestrated by cooking pots: a common trend in developing world. J Food Sci Technol. 2021;58(8):2906-13.

Corresponding author
Bartosz Pszybysz
2nd Department of Internal Medicine, Bielanski Hospital in Warsaw
e-mail: bartoszprzybysz98@gmail.com