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Research Article

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Aluminum Content of Selected Foods and Beverages Available in Irish Market

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Abstract

Aluminium (Al) is a non-essential element for life which has no recognized biological functions in humans. Al is ubiquitous in our environment and ingestion, through food and drink, is currently unavoidable due to its natural presence in soils, crops, water and packaging. With rising concerns regarding Al intake and the associated toxicity from packaging materials, the primary aim of this study was to assess the safety of Al packaged foods by measuring and contrasting Al content in common foods, available for sale in Ireland, in both Al and non-Al packaging. In addition, recommended servings for adults and children along with percentage contribution to the Tolerable Weekly Intake (TWI) of Al were calculated, as defined by the European Food Safety Authority. It was observed that ready to drink beverages has Al levels ranging from 0.07 mg/L to 2.77 mg/L, whilst the Al content of solid foods was between 1.81-21 mg/kg. Baby foods proved to have particularly high Al levels and even sometimes higher levels than those intended for adults. Results also showed no significant difference between many forms of packaging with regard to Al content, indicating that leaching is limited. However, Al packaged orange juice, cola and cider proved to have significantly higher Al content than their non-Al packaged versions. This may be attributed to their high acid concentration, corrosion as well as contact time between the can and drink and to the presence of aggressive substances i.e. salts and acids and the quality of material used for the can production.

Keywords

Aluminium content, Aluminium toxicity, Foods, Beverages, ICP-AES, Aluminium packaging

Introduction

Aluminium (Al) is a metallic element present naturally within the environment. It is the most abundant metal and the third most abundant element on the Earth, comprising approximately 8.3% of the Earth's crust, mainly existing in the form of oxides, silicates and hydroxides. Most natural waters such as lakes, rivers, ground water and the sea also contain Al at trace levels of approximately 0.15, 0.4, 0.1, 0.001– 0.007 mg l-1. As a result, it exists as a trace element in drinking water and many foodstuffs [1].

Al is a very versatile metal, with several properties which allow it to serve as a component in many articles of daily use, thus humans are frequently exposed to this metal. The use of Al can be traced back 5,000 years, to when the Egyptians used Al potassium sulphate, otherwise known as Alum, as a dye fixer and the Greeks utilized anhydrous Al sulphate as an astringent to treat wounds [2].

Since then, Al has been utilized to varying degrees and has numerous applications in modern industry. In the cosmetic and medical sector, it is used in the production of personal hygiene and medical care products such as toothpastes, antiperspirants, acne treatments, dermal care and antidiarrheal medicines. In vaccines Al serves as an adjuvant to improve antigenic properties and elicit immune response. It is present in antacids/antiulcerative medications as phosphate binders due to its superior ability to bind strongly with phosphates. These are just some of the examples of human exposure routes for this metal [1, 3].

The primary route of human exposure to Al is thought to be through diet, via food and drinking water. Drinking water has variable levels of Al and is estimated to account for approximately 5% of total dietary intake. This element occurs naturally in water, but it is also added, in the form of Al sulphate, during water treatment, this helps to purify drinking water, derived from the ground surface, by coagulating pollutants. Al content in water can be significantly higher if there is poor control of pH during water treatment or if the water is particularly dirty. More recently, it has come to light that a reduction in the pH of water, as a result of increased amounts of acid rain fall, can lead to the release of Al salts from insoluble minerals and converted into more soluble forms, which have consequently entered sources of drinking water, resulting in greater bioavailability of Al, thus increasing the body burden of Al through oral ingestion [4-6].

Al is naturally present in some foods and is commonly used as a food additive e.g. as an anticaking agent, firming agent, carrier, dying agent, buffer, neutralizing agent, dough strengthener, stabilizer, thickener, curing agent. The Al content in foods varies greatly and is dependent on numerous factors including the type of food product, growth region, food processing practices and storage conditions. Plant based foods can have varying levels depending on the plants ability to accumulate Al, (e.g. tea plants can have Al deposits in their leaves) [1, 7, 8]. Pure Al has found further applications in the food industry in packaging systems most notably Al foil, Al trays, rigid packaging like beverage cans and pre-threaded closures for packaging of fresh, processed and ready to cook meat, poultry and fish, thus allowing the industry to meet the customers desire for convenience, quality and hygiene [9, 10]. The use of such metals like Al and their alloys in packaging has however more recently brought about concerns of potential 'leaching' into food which could pose a risk to human health if the total content of the metals in the food exceeds the health-based guideline values. Baby food and canned food/beverages are of concern here regarding leaching of metal ions like Al from their packaging sources [11].

For many years Al was considered as 'safe' and not to pose any major threat to human health due to its low oral bioavailability, however, a study conducted by Virk et al. described the possible connection between Alzheimer's disease and Al, whereby Al was found to cause tissue alterations in the brain [12]. A further study by Alfrey et al. [13] heightened the concerns surrounding Al intake when they demonstrated a clear link between increased Al intake and the progression of neurologic diseases in dialysis patients. Since then, many experimental and epidemiological findings suggest that even low levels of Al intake can lead to behavioural and morphological changes associated with age-related neurodegeneration and progress other chronic diseases [6].

With this emerging knowledge of Al bioavailability and potential toxicity, it brought about the need for stringent regulations for ingestion limits. EFSA set a tolerable weekly intake level of 1 mg/kg/bodyweight/week [14]. In 2011, The World Health Organisation (WHO) also laid down a tolerable weekly intake limit (PTWI) of 2 mg/kg/bodyweight/week based on a no-observed-adverse-effect level (NOAEL) of 30 mg/kg body weight. The PTWI applies to all food sources of Al, including food additives. The EFSA advice of 1 mg/kg/bodyweight/week also still stands. Additionally, the maximum permissible limit for Al in infant formula is set at 0.4 mg/kg as stated by FAO/WHO [15] due to the greater risk posed to small children since ingestion limits are based on body weight. In relation to drinking water, The Environmental Protection Agency (EPA) is responsible for monitoring Al levels in drinking water in Ireland and the parametric value is currently set at 200 μg/L in Ireland.

With the rising concerns around Al intake and the associated toxicity along with its potential for leaching from packaging materials, the primary aim of this study was to assess the safety of Al packaged foods, by measuring and contrasting Al content in common foods available for sale in Ireland. Testing both Al and non-Al packaged foods and to determine the contribution of these foods to the Tolerable Weekly Intake outlined by EFSA.

Materials and Methods

Reagents, chemicals and sample selection

Anhydrous Al chloride, nitric acid (68% purity) and hydrogen peroxide solution (30%) were obtained from Sigma-Aldrich, Wicklow, Ireland. Common food products and beverages in both Al packaging and non-Al packaging available to the Irish consumer were purchased from a local supermarket at the time of testing. A list of samples used in this study is presented in table 1.

A survey was conducted (results not shown) to assess whether the food and beverage products selected were popular choices amongst the Irish population and the typical quantities they are consumed in. Many of the products chosen for this study were marketed for young children.

Sample preparation and open digestion

All glassware was rinsed out with 68% nitric acid prior to use to avoid any contamination. Liquid samples were shaken and sampled directly from their container using a pipette. The contents of the solid samples were removed from their packaging and the entire contents homogenized by grinding or mashing depending on the consistency of the food 1 g of each solid sample was weighed to 2 decimal places and transferred into clean test tubes. 5 ml of nitric acid was added to the samples which were then left overnight to digest.

Table 1: List of samples selected for the study.

Food category	Individual food types	Number of samples
Fruits and Vegetables	Tomato, Tomato Puree, Mandarin, Beans, Peas.	18
Cereals	Corn flour, Buckwheat seeds, Wheat Flour, Rice.	18
Dairy, Dairy Alternatives and Baby Milk	Cows Goats Soya, Almond, Ready to use Baby Milk.	16
Desserts, Baby desserts and Confectionary	Apple pie, Rhubarb Pie, Soya Custard, Baby desserts, Chocolate, Chocolate Biscuits, Rusks.	24
Tea and Coffee (dry)	Instant Coffee, Fresh Coffee, Black Tea, Hibiscus Tea.	12
Alcoholic Beverages	Irish Stout, Cider, Lager.	12
Non-alcoholic Beverages and Water	Water, cola, Lemon and lime, Carbonated Apple, Orange Juice.	22

Samples within the test tubes were subsequently decanted into Erlenmeyer flasks and the test tubes were rinsed out with 3 ml of HNO_3 into the flasks to limit sample loss. Digests in the Erlenmeyer flask were then heated to approximately 95 ˚C on hot plates and by placing them within a heated water bath. Samples were heated until the solutions were transparent. The digestion time varied amongst the food and beverage samples and was dependent up on the sample type and temperature. The clarified samples were removed from the heat and 2 ml of distilled water was added to each flask followed by 3 ml of H_2O_2. The flasks were returned to the heat for an additional 30mins and reduced to a volume between 2 ml-5 ml. Any sa mples which still appeared turbid or where fat was clearly still present were filtered utilizing a vacuum, Buchner funnel and Whatman No.1 filter paper (Pore Size: 11µm). Samples were diluted with ddH_2O to a consistent volume of 50 mls in volumetric flasks.

ICP analysis of aluminum content

ICP-AES analytical procedure was carried with the Varian Liberty ICP system [16]. Standard solutions of 25 ppm, 20 ppm 15 ppm, 10 ppm, 5 ppm, 0.50 ppm, 0.25 ppm, 0.15ppm, 0.05ppm and 0.02ppm were prepared and used to calibrate the ICP system for analysis of samples. The system was calibrated with the above standards after every 15 samples. Double distilled water was used as a blank. Results of the ICP analysis were recorded in mg/L.

Statistical analysis

Experimental data was statistically analyzed using STATGRAPHICS Centurion XV software (Stat Point Technologies Inc. Warrenton, VA, USA). Significant differences between samples was evaluated using analysis of variance (ANOVA) and the multiple comparison test (Fischer's least significant difference test). Analysis was performed in duplicate and repeated twice unless stated and results were expressed as mean values ± the standard deviation. Differences were said to be significant if the P value was < 0.05.

Results

The overall Al content of the food and beverage samples measured in this study ranged from 0 mg/L (drinking water) to 1444 mg/kg (Tea). These findings correlate to results obtained in a 2011 European study [17], published in Environmental Science Europe, where Al levels recorded ranged from 0.4mg to 737mg/kg or mg/L.

Tea and coffee

Black tea, rosehip tea and coffee packaged within different materials of Al laminate, Al composite, paper and glass were analyzed for Al content. The highest Al level was noted for the supermarkets own branded black tea which was packaged within Al composite packaging. It was found to contain an average of 1444.15mg/kg of Al (Figure 1). This was followed by a popular brand of black tea which was contained in cardboard packaging where an Al content of 899.6 mg/kg was recorded. In contrast, only trace amounts were measured for both glass and Al laminate packaged coffees. Similarly, a Japanese study [18] analyzed brewed black tea infusions and recovered high Al contents with the initial tea leaf containing 576 mg/kg of Al. Other research found 30% of the Al stored in black tea leaves was transferred into infusions (4.2 mg Al/l from leaves containing 899 mg /kg) and ground coffee was very low as per this present study [19]. Al levels observed in the Hibiscus tea samples in this study were also comparable to previous research with 272 ± 19 mg/kg of Al detected [20].

These findings come of no surprise since tea in general is known to have significantly high levels of Al due to the tea plants known ability to accumulate Al and deposit it in their leaves [1]. Tea is also often grown in Laterite soil; due to their hardiness they can tolerate the harsh and high mineral conditions. Laterite soil is particularly high in Al and poor in silica which may also explain the high Al content of tea [21]. Based on this estimation, the Irish consumer could be exposed to Al levels of between 4.2 mg–6.7 mg/L through tea alone. For the 25.6% who consume 15+ mugs of tea per week, this total would amount to 15.75 mg of Al per week (Figure 1).

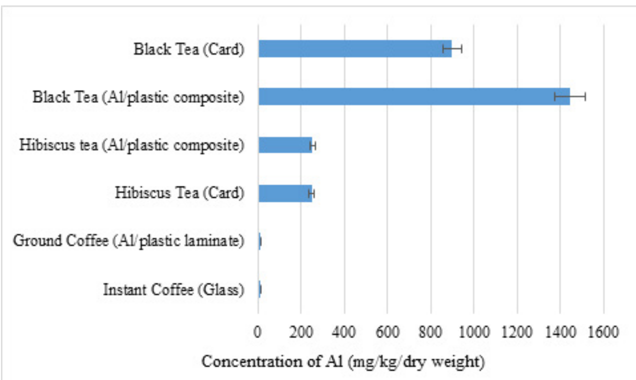

Figure 1: Aluminium concentration in tea and coffee.

Fruits and vegetables

Fruit and vegetables contained in tin, Al and plastic packaging were selected and analyzed for Al levels. Overall, the highest Al levels were observed for tomato paste in Al tubing (13.9 mg/kg) followed by frozen peas in plastic packaging (9.7 mg/kg), baked beans in plastic packaging with an Al composite seal (8.5 mg/kg) and tinned peas (5.6 mg/kg) (Figure 2). The high Al content of tomato puree could be accounted for the fact that the acidity of tomatoes means they generally take up more Al from the material they are packaged in, which in this case was an Al tube, in comparison to nonacidic foodstuff [22]. Interestingly, for the baked beans packaged in plastic, with a heat seal Al lid, a three-fold increase in Al levels was noted compared to the tinned product (2.6 mg/kg). The beans stored in plastic had a pH of 4.9 which is a pH level where leaching should be reduced, unfortunately there are no studies available on contamination from this form of packaging to make a comparison. The high Al levels detected in peas could be explained by the fact peas have been shown to be naturally high in Al with levels of 10-80 ppm and 14-27 mg/kg being recorded previously, this is believed to be due to the acidity of the soils in which peas are grown (pH 4-5) [23, 24]. Acidic soils are demonstrated to increase the concentration of soluble forms of Al in the soil, uptake by plants then increase its potential bioavailability [25]. When portion size is accounted for, no statistical difference is perceived between the Al levels in tinned and plastic packaged peas. Contrastingly, low levels of Al were recorded for mandarin despite being in tinned and plastic packaging with 1.81 mg/kg and 1.58 mg/kg of Al measured respectively, and no significant difference noted in Al levels between the plastic and tinned packaging for this product (Figure 2).

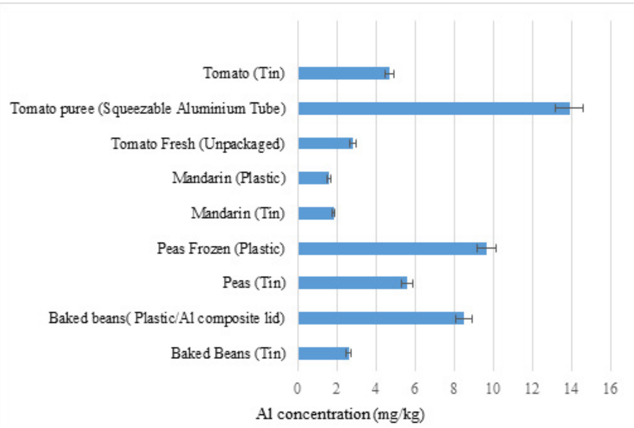

Figure 2: Aluminum concentration in fruits and vegetables.

Cereal products

The Al concentration of cereal products observed (basmati rice, buckwheat, flour and oats) ranged from 4.35-21.24 mg/kg with the highest levels detected in children's milled oats (20.38 mg/kg) and milled baby oats (21.24 mg/kg) (Figure 3). Results obtained for oat cereal are significantly higher than those obtained by other researches. For example, Ayivor et al. [26] recorded Al levels of 4.77-6.14 mg/kg for baby oats, whilst slightly higher values of 7.13-16 mg/kg were obtained for infant cereals by de Souza et al. [27]. Nonetheless, the low levels of Al detected in corn flour in this present study (4.35 mg/kg) correlate with that of de Souza et al. [24] with similar low Al levels noted for this cereal type (1.3 – 5.75 mg/kg).

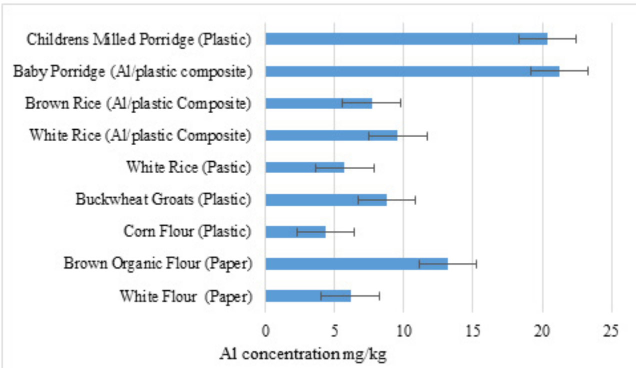

Figure 3: Aluminium content in cereals.

Al content in oats is thought to be surface-borne and is associated with trichome's (unicellular hairs) on the surface of the grain. The process of pearling has been shown to be capable of removing such trichome's and thus 100% of Al [28]. Many researchers have concluded that the Al concentration levels within cereal types vary due to the origin of the cereal and as a result of the food processing and packaging systems [24, 29]. Cultivation methods and irrigation may also be a contributing factor as they can influence cereals absorption capacity. With baby porridge being introduced to the diet at 4-6 months of age, as part of the weaning process, and children's oats introduced as a follow-on food, the levels of Al detected in oats is of concern for the modern customer [30]. The recommended serving for children's oats is 30 g. Eaten daily for 1 week that equates to an intake of 4.28 mg of Al (before the addition of milk), representing 48% of the Tolerable weekly intake 48% for a 1-year-old weighing 9 kg. The results of this present study are therefore of concern for young children, although individual servings are within the tolerable limit, more effort need to be made by manufacturers to significantly reduce Al contents of such cereals particularly porridge and oats which are consumed by young children.

Dairy and baby milk

Overall, analysis of dairy, baby dairy products and non-dairy substitutes showed no statistical difference between product type and packaging. Interestingly milk substitutes displayed the highest Al concentration with values of between 2.35-2.76 mg/L observed (Figure 4). The Al levels in baby milk products were unexpectedly high (Follow-on Milk; 1.8 mg/L, Hungry Milk; 1.6 mg/L and Growing up milk; 1.6 mg/L) especially when compared to some recent research conducted in the UK ,where Al content was 3-4 times less than measured in the present study [10]. In 2001, a Canadian study found that ready-made infant formula contained on average 437 mcg/L with the highest recorded level at 3.44 ppm [31].

Al levels in whole cows' milk averaged at 1.4 mg/L which is similar to the findings in an Egyptian study analyzing

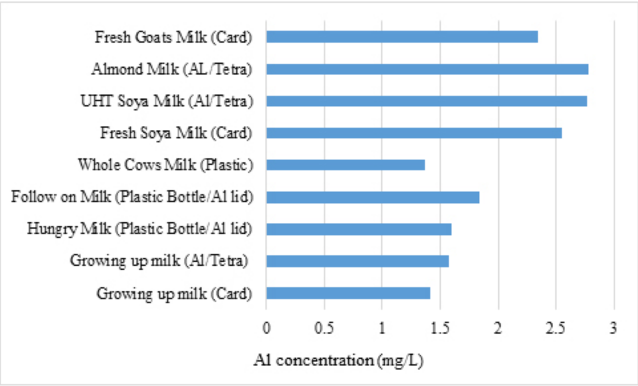

Figure 4: Aluminium content in cereals.

50 milk samples where the mean Al level was found to be 1.57 mg/L and only 4% of samples fell below the permissible limit of 500 mcg/L [32]. In an older study by Fernandez-Lorenzo [33], cows' milk was found to have 1.2-1.7 ppm which also correlates well with this study's findings. The high Al levels in both cows and goats' milk were unexpected, as they were not stored in Al packaging. As a comparison, Al levels in human breast milk, tested in another study, ranged from 0.004 mg/L to 2.67 mg/L with a mean value was 0.38 mg/L [34]. Therefore, taking all this into consideration it is likely that processing and storage may be the primary contributing factors to varying Al concentrations in milk rather than packaging type, which is also the assumption made by Meshref, Moselhy, and Hassan [35], whereby they found that the processing and storage of milk and milk products with Al utensils rather than stainless steel versions caused an increase in their Al content. It was further observed that the pH lowering process of 'curdling' of milk using Al utensils also increased Al levels.

Alcoholic beverages

Observation of different alcoholic beverage type and packaging types showed that Al concentration varies significantly. Al concentration ranged from 0.066 – 0.941 mg/L for all alcoholic beverages investigated, with the maximum concentration of Al recorded for canned Cider which was significantly higher in Al than the bottled variety (Figure 5). Cider does contain malic acid which is known to chelate Al and so could be the underlying reason for its particularly high Al content in comparison to other alcoholic drinks [36]. In comparison, Irish stout contained the lowest levels of Al with

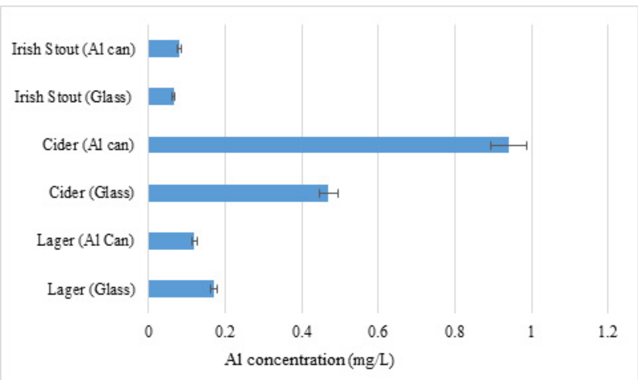

Figure 5: Aluminium content in alcoholic beverages.

less than 0.078 mg/L (78 μg/L) observed. As seen in table 2, in general canned beers were seen to have slightly higher levels of Al than their bottled counterparts which suggests the possibility that leaching may be a contributing factor here when taking into consideration the packaging type. Other researchers have also drawn conclusions that other factors which may affect Al content in beers are the chemical content of raw materials utilized during manufacturing, adjuncts and water used during production, the purity and type of Al used for production of canned packaging, pH and temperature of the beer, type of equipment used during processing (i.e. whether it is Al or not) and the storage time (i.e. contact time between the can and the beer) which are all potential factors which may account for the varying concentrations of Al detected for the beers in this present study [37].

Nonetheless, with the exception of Cider, the alcoholic beverages were still found to fall below the permissible levels for drinking water of 200 μg/L (0.2 mg/L) as outlined by the Irish Environmental Protection agency (EPA), Ireland [38].

Non-alcoholic beverages

All water tested appeared to be Al free and bottled fizzy drinks were seen to be below the permissible level of 200 μg/l (0.2 mg/L) recommended for drinking water (Figure 6). In comparison, all Al packaged drinks investigated (organic long life orange juice (Al tetra), cola (Al can), fizzy apple (Al can) and lemon and lime (Al can)) were above the permissible levels for drinking water with levels of 1.8 mg/L, 0.89 mg/L, 0.44 mg/L and 0.3 mg/L measured respectively which were all comparable to the values obtained by Seruga, et al [39], for the same beverage types. Thus, this demonstrates that packaging type may be a key component, in terms of Al content, when it comes to soft drinks. Interestingly, organic orange juice, which was tetra packed and sold in children's size portion stood out from the group as being significantly higher in Al with an Al concentration of 1.8 mg/L. It has been demonstrated in other studies that the pH value and total acid concentration are accountable for soft drinks Al content, proving to increase with increasing acid concentration and decreasing pH. With a pH of 3.7, this would explain why the Al content was highest for this orange juice.

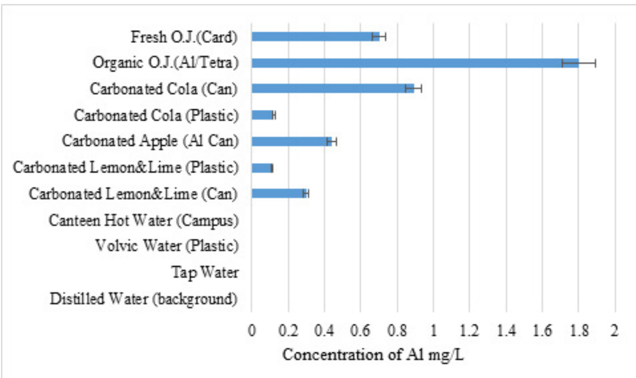

Figure 6: Aluminium content in non-alcoholic beverages.

The Al canned beverages investigated in this study are all acidic in nature due to presence of acids such as ascorbic acid and citric acid. In cola, the presence of orthophosphoric

Table 2: Alcoholic beverages and their contribution to TDI, TWI and contributions in relation to consumption.

Alcoholic Beverage	Serving size (ml)	Al	Al	% TWI	% TWI	% TWI	% TWI	%TWI
		Per product (mg /L)	Per serving (mg/L)	1 Serving	6 Servings	9 Servings	12 Servings	1 Serving daily/7 days
Irish stout (bottle)	330	0.066	0.022	0.03%	0.18%	0.27%	0.36%	0.22%
Irish Stout (can)	500	0.077	0.038	0.05%	0.30%	0.45%	0.60%	0.38%
Lager (bottle)	500	0.177	0.088	0.13%	0.78%	1.17%	1.56%	0.88%
Lager (can)	500	0.116	0.058	0.08%	0.48%	0.72%	0.96%	0.58%
Cider (bottle)	568	0.471	0.267	0.39%	2.34%	3.51%	4.68%	2.67%
Cider (can)	500	0.941	0.471	0.67%	4.02%	6.03%	8.04%	4.71%

acid and carbonic acid could cause corrosion and consequently leaching of Al from their packaging and therefore account for the higher Al contents observed for these sample. Other factors thought to increase Al content of canned soft drinks are contact time between the can and drink, presence of aggressive substances i.e. salt and acids and the quality of material used for can productions [35].

Confectionary and desserts

The Al content of the confectionary analyzed in this study ranged from 2.4 mg/L – 10.33 mg/kg (Figure 7), which are comparable to values observed in a previous study conducted by Stahl, Taschan, and Brunn [14]. Out of all sweets and desserts investigated, the product of most concern with regard to Al content were the children's rusks since they are a popular snack from four months of age and are significantly higher in Al content than most other baby food and desserts. An Al content of 10.33 mg/kg was measured for this snack which proved to be 4.2 mg/kg more than measured in wheat flour, which may indicate a possible contribution from processing and packaging. The Al content of the baked products on the Irish market (including those baked in Al trays), which were free from Al additives, proved to be above the 4mg average reported by a European study by Stahl, Taschan and Brunn [14] but considerably lower than those analyzed in a recent survey in Southern China [40] where the average was 82 mg per kg. No statistically significant difference was noted between apple pastry baked with or without an Al tray in this study. There was no evidence of leakage of acidic fruit juices at the base of the apple or rhubarb pie that could theoretically

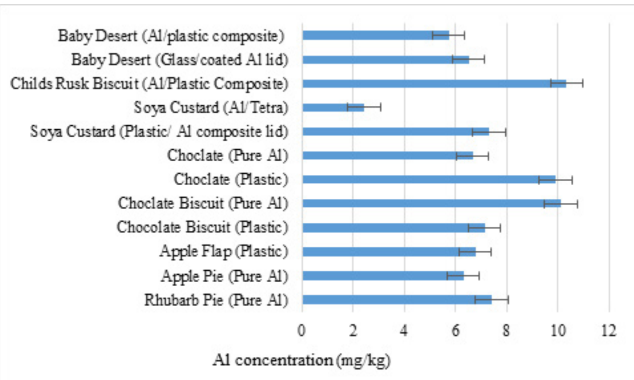

Figure 7: Aluminium concentration in desserts and confectionary.

cause leaching, this excludes packaging type and leaching as contributing factors to the Al content of these products.

The clear statistically significant difference observed between soya desserts packed in tetra pack and plastic tubs is of concern. These particular products had the same brand and ingredients, but the plastic contained version, with an Al composite easy peal, heat-sealed lid, contained 7.31 mg/kg as opposed to 2.42 mg/kg for the tetra product. In comparison, the chocolate products analyzed in this study (chocolate biscuits and chocolate bars) had considerably high Al concentrations (6.68 – 10.11 mg/kg). It should be taken into account that the chocolate products contained varying proportions of cocoa and considering the Al levels found in cocoa, the high Al values observed for these products can be partially attributed to the cocoa portion. Contamination by Al utensils and equipment used during production cannot be excluded as a contributing factor also.

Estimation of weekly aluminium intake

"Given the persistence of Al in the body, the Panel found it appropriate to establish a tolerable weekly intake (TWI) rather than a tolerable daily intake, and established a TWI of 1 mg/kg bw/week"[14]. It is exceedingly difficult to assess the overall weekly intake of Al through the diet with many previous studies indicating varying levels of Al in the same foods and it is also difficult to assess the eating patterns across a population.

The tolerable weekly intake was estimated to be 1 mg/kg/body weight by European Food Safety Authority (EFSA) which translates as a tolerable daily intake (TWI) of 4.3 mg for a 30 kg child and 10 mg per week for a 70 kg adult. The % contribution per food sample serving is calculated in order to display how that may represent a % of TWI. As can be seen in the tables 3 and 4, the TWI for children is reachable by consuming combination of the foods. It would appear that baby foods are very high in Al in proportion to their weight and exceeding the TWI for this group is very likely, especially for brand loyal customers. It is also possible for adults to reach their TWI especially with consumption with processed fruit, vegetables and canned fish and interestingly 43.5% of those surveyed in this study said they consumed canned fish on a regular basis with 75% opting regularly for beans and 59.3% for tinned tomatoes thus demonstrating that although

Table 3: The percentage (%) Al contribution per food serving as per manufactures instructions to the tolerable daily intake (TDI) for children and adults (%TDI is equivalent to %TWI for 1 serving/day/7days).

Product	Serving defined by manufacturer (g)	Aluminium (mg /l)	Aluminium (mg)/ serving	% TDI (30kg Child)	%TDI (70kg Adult)
Soya Custard (Tetra)	125	2.4	0.3	7%	3%
Soya Custard (Plastic/Al composite)	125	7.3	0.91	21.70%	9.10%
Rhubarb Pie (Pure Al)	92	7.41	0.68	15.80%	6.80%
Apple Flap (Plastic)	83	6.78	0.58	13.49%	5.80%
Apple Pie (Pure Al)	86.2	6.3	0.54	12.50%	5.40%
Organic Baby Dessert (Foil)	100	5.741	0.57	13.25%	5.7%
Baby Dessert (Glass and metal lid)	100	6.512	0.65	15.12%	6.5%
Baby rusks	17	10.33	0.18	4.19%	1.80%
Chocolate Biscuit (Al foil wrap)	14	10.11	0.14	3.25%	1.40%
Chocolate Biscuit (Plastic wrap)	17	7.13	0.12	2.79%	1.20%
Chocolate (Plastic wrap)	25	9.9	0.25	5.80%	2.50%
Chocolate (Al foil wrap)	20	6.68	0.13	3.02%	1.30%
Mandarins (Tinned)	149	1.81	0.27	6.28%	2.70%
Mandarins (Plastic)	125	1.58	0.20	4.65%	2%
Fresh Tomatoes (Unpackaged)	80	2.8	0.22	5.12%	2.20%
Tomatoes (Tinned)	200	4.7	0.94	21.86%	9.40%
Tomato Puree double concentrate (Al tube)	15	13.9	0.21	4.88%	2.10%
Baked Beans (Tinned)	220	2.6	0.572	13.30%	5.70%
Baked Beans (Plastic/Al composite lid)	220	8.5	1.87	43.50%	11.90%
Peas (Tinned)	225	5.6	1.26	29.30%	12.00%
Peas Frozen (Plastic)	130	9.7	1.26	29.30%	12.20%
Brown Basmati Rice (Al composite)	75	7.68	0.576	13.50%	5.76%
White Basmati	75	9.58	0.718	16.74%	7.18%
White Basmati	75	5.74	0.430	10%	4.30%
Buckwheat (Plastic)	75	8.78	0.658	15.58%	6.58%
Organic Brown flour (Paper)	28	13.16	0.368	8.60%	3.68%
White flour (Paper)	28	6.14	0.172	4%	1.75%
Cornflour (Plastic)	28	4.35	0.122	2.84%	1.22%
Children's Milled oat	30	20.38	0.611	14.21%	6.11%
Milled baby oats	20	21.24	0.425	9.88%	4.25%
Cup soup (Paper and Foil)	14	12.38	0.173	4.02%	1.73%
Crisps (Foil)	25	11.1	0.227	6.44%	2.30%
Crisps (Plastic)	18	7.08	0.127	3.02%	1.30%
Salmon (Tinned)	213	8.72	1.86	43.25%	18.60%
Whole Almonds	40	4.96	0.198	4.60%	1.98%
Almond Milk (Al Tetra)	250	2.77	0.692	16.10%	6.92%
Long life soya (Al Tetra)	250	2.76	0.960	22.32%	9.60%
Fresh soya (Card)	250	2.55	0.637	14.81%	6.37%
Fresh cow's milk (Plastic)	250	1.37	0.345	7.98%	3.45%
Fresh goats' milk (Non- Al Card)	250	2.35	0.587	13.66%	5.87%
Lemon & Lime (Plastic)	500	0.11	0.055	1.28%	0.55%
Lemon & Lime (Al Can)	330	0.3	0.099	2.30%	0.99%
Fizzy Apple (Al Can)	330	0.44	0.145	3.37%	1.45%
Cola (Plastic)	500	0.12	0.06	1.39%	0.60%
Cola (Al Can)	330	0.89	0.294	6.84%	2.94%
Organic Orange Juice UHT (Al Tetra)	200	1.80	0.36	8.37%	3.60%
Fresh Orange Juice (Card)	200	0.70	0.14	3.2%	1.40%

Table 4: Examples of foods consumed by babies and children, serving's size as per manufacturer's instructions and % TWI per serving calculated in relation to the child's weight and age.

Product	Serving amount as per instruction (g)	Al per product	Al per serving	%TWI 1 serving daily for 7 days	%TWI 1 serving daily for 7 days	%TWI 1 serving daily for 7 days	%TWI 1 serving daily for 7 days
		(mg /l)	(mg)/ serving	7.5 kg Child	9 kg Child	10 kg Child	30 kg Child
Organic Baby Dessert (Al composite)	100	5.74	0.57	53.2%	44.33%	39.9%	13.3%
Baby Dessert (Glass metal lid)	100	6.51	0.65	60.67%	50.56%	45.5%	15.17%
Baby rusks (Al composite)	17	10.33	0.18	16.8%	14.00%	12.6%	4.2%
Milled children's oats	30	20.38	0.61	57.03%	47.52%	42.77%	14.26%
Milled baby oats	20	21.24	0.43	39.67%	33.06%	29.75%	9.92%
Follow on milk (Al lid)	200	1.84	0.37	34.35%	28.62%	25.76%	8.59%
Hungry milk	200	1.6	0.32	29.87%	24.89%	22.4%	7.47%

many food and beverage products on the market have low Al contents, even still consumers can easily exceed their TWI by eating a combination of such foods.

Conclusion

Though Al packaged foods generally scored higher Al content than pure plastic or tetra pack alternatives. Results showed no significant difference between many forms of packaging with regard to Al content, indicating that leaching is limited. There are exceptions however – Al packaged orange juice, cola and cider in particular, observed to be significantly higher in Al than their non-Al packaged versions, but this may be attributed to their high acid concentration which has been proven in previous studies to contribute to increased Al content due to corrosion as well as contact time between the can and drink, presence of aggressive substances i.e. salt & acids, and the quality of material used for the can production. Efforts have been made to reduce food contact with Al with plastic lined Al beer containers and the acidic tinned mandarin displaying surprisingly low levels. Baby foods proved to have particularly high Al levels and even sometimes higher levels than those intended for adults. Therefore, greater efforts should be made by manufacturers to reduce Al levels in foods intended for babies and young children considering the emerging studies with regard to its toxicity. Breast feeding and weaning with non-processed foods should be encouraged along with Al avoidance for pregnant and breastfeeding mothers. Specific TWIs are yet to be set for mothers or babies. A more intensive study into the Al levels in all foods as well as contact time with packaging (storage time) and quantification of leaching over this time would be helpful to gain more insight into the influence of packaging systems on Al content of foods.

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Conflicts of Interest

The authors declare no conflict of interest.

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