Hazards of Aluminum Packaging

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2011

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Abstract

Aluminum as a substrate for food packaging has become increasingly popular due to it's durability, low transportation cost and recyclability. Aluminum cans such as soda cans, can be found in almost every grocery store, gas station and even refrigerator across the country. With consumers throughout the world becoming more reliant on their canned foods and beverages, they are unaware of the correlation between aluminum and diseases such as Alzheimer's and Parkinson's Disease. Many studies have been performed to demonstrate aluminum effects on the human brain, and almost every study came to the conclusion that patients with Alzheimer's or Parkinson's Disease had elevated levels of aluminum traces in their brain. These long-lasting and devastating diseases are making their way into the lives of consumers through the environment as well as aluminum packaging. The food industry along with consumers need to be more aware of the health risks associated with the metal Aluminum, and the packaging industry needs to start substituting packaging substrates (i.e. glass, plastics, etc). The health of consumers should be first priority, therefore either further research must be performed or quick actions must be taken in order to ensure the safety of consumers.

Introduction & Purpose of Study

Aluminum cans inhabit the majority of food pantries in the United States. Whether it be a Campbell's Chicken Noodle soup can or a Sunkist brand tuna can, aluminum canned foods are a staple in the United States. Canned foods are popular for their long shelf life, but many people are unaware of the major health risks that the aluminum can causes. Aluminum packaging contains many chemicals that have been proven to cause harmful diseases, but because aluminum is thought to be the most sustainable and economical choice in the packaging industry, the health concerns seem to be overlooked. It is imperative that the general public be informed on the issue of aluminum packaging and how it relates to long term health problems because consumers are completely unaware of the harm aluminum cans cause. Analysis of various interviews and case studies on the hazards of aluminum have proven that aluminum is not the best choice for lightweight food packaging.

Food producers and consumers are constantly searching for the most economical, sustainable and effective methods for food packaging. From plastic to glass to aluminum cans, all forms of packaging have their benefits and complications. Aluminum packaging is a method that has been trusted and used consistently and, until recently, consumers have been naive as to how harmful this form of packaging truly is. Various diseases including dementia and Alzheimer's have been linked to the aluminum can through seepage of harmful chemicals. Unfortunately, the vast majority of consumers are unaware of the connection between their canned foods and Alzheimer's disease. Once consumers begin to gain this knowledge, the packaging industry will need to shift from aluminum canning to a method of packaging that is much less harmful.

This study focuses on the possible long term health concerns associated with the aluminum packaging method. This study also compares other forms of packaging to the aluminum canning method in order to test which forms of packaging are the healthiest for consumers. With extensive research on the correlation between aluminum packaging and diseases, the possible detrimental health problems associated with aluminum are exposed to the public. With the general public being informed about the correlation between aluminum cans and Alzheimer's, consumers will soon look to other forms of food packaging.

Literature Review

On average, ninety five percent of all soft drink and beer cans in the United States are made of aluminum (Woodward). Because of the various advantages to the aluminum canning method, the aluminum can is one of the most widely used forms of packaging today. The packaging industry is extremely fond of aluminum because it is one of the least expensive and most recyclable metal substrates on the market. Many health concerns for this method of packaging have been overlooked due to the financial and sustainability benefits of aluminum. Research on this topic will help the packaging industry decide what forms of packaging can effectively become substitutes to the aluminum canning method in order to cause less harm to the consumers. Other packaging materials such as plastic, glass and paper are possible food packaging alternatives that pose very little potential health concerns.

Benefits of the Aluminum Package

The aluminum can is a reliable form of food packaging and has been used for over 60 years (reducepackaging.com). According to the Australian Aluminum Council, aluminum can be recognized for its lightweight form, impermeability, thermal conduction, flexibility and recyclability.

With a density of 2.70g/cubic cm (compared with iron used in steel 7.86g/cubic cm), aluminum products are very light, cutting down on transport costs. Aluminum has an excellent barrier function therefore keeping out air, light, liquid and microorganisms to preserve the contents of food, cosmetics and pharmaceutical products. Aluminum transfers heat 2.4 times faster than iron. This combined with the fact that very thin sheets can be produced, means that heat is lost and gained through aluminum very quickly. Hence it is ideal for cooking and as a cold drink

container. Aluminum can be rolled into extremely thin foil and can be cast and joined and still retain much of its strength. Aluminum is 100% recyclable and uses only 5% of the energy used to make the original product. Aluminum drinking cans are the most recycled packaging product in the world (Australian Aluminum Council).

Aluminum is a great packaging substrate when it comes to recycling, barrier functions and transportation costs. Not only is aluminum great for all of the above reasons, but aluminum also lasts long and can be transformed into more complex and durable packaging shapes. The company, Futura Industries, is an aluminum manufacturing company that delivers "customized, start-to-finish aluminum extrusion services". They state,

Aluminum does not rust. It's protected by its own naturally occurring oxide film, a protection that can be further enhanced by anodizing or other finishing techniques. With aluminum, complex shapes can be realized in one-piece extruded sections without having to use mechanical joining methods. This makes the parts stronger and less likely to leak or loosen over time. Aluminum can be finished with a variety of common techniques, including liquid paint, powder coatings, anodizing, or electroplating (Futura Industries-Custom Aluminum).

As Futura Industries stated, Aluminum packages can take many different forms and the metal allows for a multitude of coatings and finishing options. Not only is aluminum packaging durable, but the transportation costs of aluminum are very low due to the thin, sturdy substrate. Because of this, Aluminum is one of the cheapest costing packaging materials. According to quotealuminium.com, the current trading price for aluminum is a mere $0.9122 per pound. When a food manufacturer is deciding between the many different packaging methods, aluminum seems to be one of the most intriguing substrates.

Figure 1. Common uses of aluminium for packaging
(Image from www.eriding.net)

Negatives of Aluminum Packaging

With compelling arguments for choosing the aluminum packaging, the hazards of this method of packaging should also be considered. Although a substantial link between aluminum and Alzheimer's disease has not yet been proven;

> There is more evidence linking aluminum with this disorder than there is for any other environmental factor. Studies on the uptake of aluminum have indicated that it enters the brain bound to a protein called transferrin. Transferrin is a protein that binds and transports iron around the body. The greatest uptake of aluminum in the brain occurs in areas rich in transferrin-receptors and these coincide with the regions, which are vulnerable in Alzheimer's disease (Alzheimer Scotland).

According to many researchers, there is a direct correlation between aluminum levels in the brain and Alzheimer’s disease. Aluminum is found in many different places, but aluminum packaging

places the substrate right in the consumer's food. Various scholars on aluminum packaging believe,

> The cans used for carbonated and non-carbonated beverages, like colas and fruit drinks, leak significant amounts of aluminum into the beverage (Duggan, Dickeson, Tynan, Houghton, and Flynn).

Not only is aluminum packaging causing the rise in levels of alumium in the human body, but aluminum can also be found in places such as drinking water, baking soda and cookware; and with the popularity of the aluminum can, levels of aluminum in the blood are on the rise. The National Institute of Nutrition (NIN), which is part of the Indian Council of Medical Research, has concluded,

> The intake of aluminum compounds from many sources is on the rise and producing detrimental effects on human health. Aluminum cookware is especially dangerous when used to prepare acid foods such as tomatoes, which causes the metal to be leached out. Besides Alzheimer's, toxic levels of aluminum has also been associated with Parkinson's disease, various dementias and bone diseases (National Institute of Nutrition).

As noted, aluminum is not only linked to Alzheimer's Disease, but many other diseases as well. These diseases including Parkinson's disease and dementia are long term and non reversible. Aluminum is much more harmful as the consumer gets older because the toxins become harder to reduce. In an effort to protect the food from coming in direct contact with the aluminum, coatings can be applied. However, these coatings also have concerns of their own. According to the Aluminum Can Group,

> Aluminum beverage cans have a protective polymer coating applied on the inside to prolong storage life. This polymer coating ensures that the acids and salts in beverages never actually come into contact with the metal (Aluminum Can Group).

This coating helps protect the food and consumer from the aluminum, however, the polymer coating material used can also cause other damage to one's health. Absolute Astronomy describes,

> Aluminum cans often contain an internal coating to protect the aluminum from beverage corrosion. Despite this coating, trace amounts of aluminum can be degraded into the liquid, the amount depending on factors such as storage temperature and liquid composition. Chemical compounds used in the internal coating of the can include types of epoxy resin (Absolute Astronomy).

If any trace of the epoxy resin leaks in to a consumer's digestive system, they will have deadly epoxy poisoning. Not only are consumers at risk for increased levels of aluminum, they are now being introduced to an entirely new health hazard from the plastic lining within the aluminum packages. According to researchers on aluminum materials, Bruno and Carter,

> Swallowing such poisons (epoxy resin) can have severe effects on many parts of the body. Extensive damage to the mouth, throat, eyes, lungs, esophagus, nose, and stomach are possible. The ultimate outcome depends on the extent of this damage. Damage continues to occur to the esophagus and stomach for several weeks after the poison was swallowed, and death may occur as long as a month later. Treatment may require removal of part of the esophagus and stomach (Bruno and Carter).

These researchers conclude that not only does aluminum have its own health concerns, but the lining in various forms of aluminum packaging is just as harmful. Bisphenol A (BPA) is also added to hard plastics and epoxy resins that are used in the lining of aluminum cans.

> (BPA) has been known to leach from the plastic lining of canned foods and polycarbonate plastics, especially those that are cleaned with harsh detergents or those, which contain acidic or high-temperature liquids. BPA is an ingredient in the internal coating of metal food and beverage cans used to protect the food from direct contact with the can. A recent Health Canada study found that the majority of canned soft drinks it tested had low, but measurable levels of Bisphenol A. Furthermore, A study conducted by the University of Texas School of Public Health in 2010, found BPA in 63 of 105 samples of fresh and canned foods, foods sold in plastic packaging, and in cat and dog foods in cans and plastic packaging. This included fresh turkey, canned green beans, and canned infant formula (Journal of the American Medical Association).

BPA poses many other health concerns, however, the FDA is continuing to study the effects on the human body.

> In 2009, a study found that drinking from polycarbonate bottles increased urinary bisphenol A levels by two thirds, from 1.2 micrograms/gram creatinine to 2 micrograms/gram creatinine. (Environmental Health Perspective) Consumer groups recommend that people wishing to lower their exposure to bisphenol A avoid canned food and polycarbonate plastic containers (which shares resin identification code 7 with many other plastics) unless the packaging indicates the plastic is bisphenol A-free (War of the sciences). In order to avoid the possibility of BPA leaching into food or drinks, the National Toxicology Panel recommends avoiding microwaving food in plastic containers,

putting plastics in the dishwasher, or using harsh detergents. In the U.S., consumption of soda, school lunches, and meals prepared outside the home was statistically significantly associated with higher urinary BPA (Food and Drug Administration).

Bisphenol A is also finding it's way into the majority of consumer pantries. With the aluminum packaging and plastic packaging methods posing high risks to consumers, other forms of packaging should be explored.

There are many resources on the comparisons between the many different forms of food packaging. Various packaging companies offer their ideas on which substrates are more ideal for food packaging. Below, (Figure 2) is a chart from a wine packaging company called Wine Loves Packaging that compares alternative substrates for food packaging.

Glass	• Made from sand, soda ash, limestone and cullet (recycled glass). • Used for wine, liquor, beer, juices, sauces, vegetables, baby food, salsa and more. • All-natural, pure, and safe –will never leach chemicals into foods and drinks. • Endlessly recyclable (the same glass container can be remade into new containers again and again).
PET (Plastic)	• Polyethylene terephthalate, a plastic resin and form of polyester • PET is labeled with #1 code on near the bottom of bottles and containers • Used for soft drinks, water, juice, peanut butter, salad dressings and oils • Down-cycled from its original into carpet fiber, athletic shoes, luggage, fiberfill • Must be coated on the inside if re-used for food or beverage
Aluminum	• Bauxite ore is refined into alumina (alumina oxide) • About 20 percent of U.S. aluminum is used for packaging • Account for all the beverage can market but a small percentage of food cans • 100 percent recyclable • At about 52 percent, aluminum had the highest recycling rates of any beverage container in 2006
Bag-in-Box	• Made from a combination of fiberboard—to make the box—and a plastic (PET) or aluminum bladder used to hold the wine. • Bladder holds between two to four bottles worth of wine. • Plastic bags used for the bladder are non-recyclable.
Multi-layer Cartons	• Made of three or more materials. Typically includes paper, PET and aluminum. • Each material contributes key properties: paper for stiffness, strength and shape; PET to hold liquids; and aluminum for a barrier against light, oxygen • Offer convenience for food and beverage products • Recycling facilities are limited, so most multi-layer paper packages —especially juice boxes – go to the landfill

Figure 2. Comparison of packaging methods
(http://winelovesglass.com/truthinpackaging.aspx)

One main alternative to plastic and aluminum packaging would be glass. As noted in the above chart, glass is endlessly recyclable, and there will never be any concerns of leakage into

food items, because it is such a pure and natural substrate. Glass bottling for example has been used for many years, and acts as an extremely durable barrier to food products.

There are many opposing views on the aluminum packaging market. Aluminum is a very reliable form of packaging as far as shelf life of product, recyclability and flexibility; however, the health concerns for the aluminum can are surfacing. The direct link between aluminum and diseases such as Alzheimer's Disease and Parkinson's Disease has not been proven but researchers suggest there is a strong relationship between the two. Lastly, not only is aluminum the only health concern, but the lining to protect the consumers from directly contacting the aluminum also poses many health problems. In order for these health risks to be minimized, other forms of packaging should be considered.

Research Methods

The food packaging industry must follow extensive rules and regulations set by the FDA in order to package food products. This study focuses on the possible long term health concerns associated with the aluminum packaging method. This study also compares other forms of packaging to the aluminum canning method in order to test which forms of packaging are the healthiest for consumers. There are many benefits to using aluminum as a substrate for food packaging; however, aluminum might not be the safest choice for consumers. To start, I used the historical research method to determine whether or not aluminum packaging is indeed harmful. According to Cal Poly, San Luis Obispo's Graphic Communication department head Harvey Levenson,

> Historical research is an attempt to establish facts and arrive at conclusions concerning past events. The historical researcher must systematically and objectively locate, evaluate, and interpret evidence available for understanding the past. From this evidence the researcher hopes to show what may be contributed by past experience to a greater understanding of present situations and what might happen in the future (Levenson).

This process involved reviewing studies comparing levels of aluminum in brains of patients with Alzheimer's disease to the brains of humans without Alzheimer's disease. The first study, Relationship of aluminum to Alzheimer's disease, was performed by Daniel D Perl, Department of Pathology, University of Vermont College of Medicine ind Burlington, VT (1985). This study involved using,

...highly sensitive techniques,through the use of scanning electron microscopy in conjunction with energy dispersive x-ray spectrometry, for the analysis of trace element constituents of the nervous system at the cellular level of resolution in Alzheimer's patients...Sections of

Hippocampal neurons were cut on a cryostat at 20μm from blocks of formalin-fixed tissue. The sections were mounted unstained on pure carbon stubs ,air-dried, and lightly carbon coated. Regions of the hippocampus with numerous tangle-bearing neurons were identified in serialy cut sections which were stained with the Bielschowsky silver technique and viewed by light microscopy. Using identical conditions of specimen preparation, X-ray generation and data collection, 20 neurons from the CA1 region of the hippocampus were subjected to multipoint X-ray probe analysis (Perl).

The second study I evaluated was a study performed by a scientist in 1976 and evaluated by Arezoo Campbell, Department of Community and Environmental Medicine, University of California Irvine (2002). This study measured the aluminum content of muscle, bone and brain in control subjects as well as patients with uraemia (renal failure). The third study I evaluated was the "Age-Related Differences on Aluminum Mobilization by Chelating Agents in Aluminum-Loaded Uraemic Rats" study by Jose L. Esparza, Mercedes Gomez, Jose L. Domingo, Daniel del Castillo and Mercedes Hernandez from the Laboratory of Toxicology and Environmental Health, and Surgery Unit, School of Medicine, ''Rovira i Virgili'' University, Reus, Spain. In this study:

Fifty animals in each age group received intraperitoneal Al (aluiminum) nitrate nonahydrate injections at doses of 45 mg/kg/day for five consecutive weeks (5 days per week). An additional group of uraemic rats received injections of 0.9% saline instead of Al during the same period (negative control group). After Al exposure, each age group was randomly divided (weight and plasma creatinine) into four groups. Animals in the positive control groups received deionized water by gavage and subcutaneous injections of 0.9% saline for 5 days. Rats in the experimental groups were given subcutaneous solutions of

deferoxamine in 0.9% saline at 0.89 mmol/kg, oral solutions of deferiprone in deionized water at 0.89 mmol/kg, or combined administrations of deferoxamine (subcutaneously) and deferiprone (gavage) at doses of 0.45 mmol/kg for 5 days. During chelation therapy, rats were placed in individual plastic metabolism cages (Tecniplast) and urines were collected daily for 5 consecutive days. Twenty-four hours after the last administration of the chelators, the rats were anaesthetized with diethyl ether and killed. Samples of the following tissues were collected: spleen, brain, liver, kidneys and bone (femur) (Pharmacology & Toxicology 2000, 87, 33–38).

Aluminum concentrations in tissues and urine were then analyzed to determine the relationship between aluminum levels in the groups and overall health.

Next, I conducted elite and specialized interviews on the subject with a wide range of scholars and doctors. Famous communication theorist, Lewis A. Dexter, coined the term 'elite and specialized interviews'. According to Dexter and Levenson,

> In "standard" interviewing the investigator asks the question within the bounds established by a set of presuppositions. In elite interviewing, the investigator allows the interviewee to establish a perspective. In Elite interviewing it is not assumed that each individual's response to a question equals that of another respondent. What is sought in Elite and Specialized interviewing is comprehensibility, plausibility and consistency, not duplication of responses. In Elite and Specialized interviewing, the informed interviewee becomes part of the research "team." To establish rapport with "elite" respondents, the researcher must enter the interview knowledgeable on the subject to be discussed. Once a relationship is established, the Elite interview may take the form of a conversation (Levenson).

The first interview I conducted was with Registered Nurse Laura-Lea McKay, and I asked her about aluminum packaging and if she thought it was safe for consumers. She has published several articles about aluminum levels in patients with Alzheimer's disease, so I also asked her questions about her own research and conclusions. Secondly, I was able to contact a representative from the ALCOA, the 'World's Leading Producer of Aluminum', and asked them questions on their opinion of the possible correlation between aluminum and Alzheimer's disease. I have performed these various interviews and have obtained well-rounded information on the topic.

Since receiving their information and input, I have compared all of the research and concluded whether or not there should be a concern for all consumers using the content analysis research method.

> Content analysis is one of the most popular methods used in communications research. It is a method for quantifying qualitative information gathered from elite and specialized interviewing, historical research, and descriptive research. In other words, content analysis is often used in combination with other research methods in developing results and drawing conclusions (Levenson).

Since all of the above forms of research have been conducted, I was able to prove that aluminum packaging is not the safest form of food packaging for consumers. I compared the differences in price, weight, sustainability and toxicity between aluminum and other common materials used in food packaging in order to determine which materials are better alternatives for consumers.

Results

After performing further research in to the various cases noted, I now have specific results linking aluminum and Alzheimer's disease. The first study, Relationship of aluminum to Alzheimer's disease, performed by Daniel D Perl, proved to be very successful. The below table provides the data results related to the X-ray probe site on hippocampal neurons of cases of various diseases including Alzheimer's and parkinsonism-dementia.

Case	Age, yr	Neurofibrillary tangles	X-ray counts (± 1 SE)		
			Nuclear region	Perikaryal cytoplasm	Adjacent neuropil
Alzheimer's Disease	88	+	160.5 ± 14.3	118.5 ± 23.1	48.6 ± 14.0
Alzheimer's Disease	83	+	168.9 ± 14.8	104.6 ± 16.6	27.8 ± 11.7
U.S. control	88	–	75.8 ± 11.9	65.3 ± 12.8	86.8 ± 30.0
U.S. control	82	–	64.9 ± 12.1	89.4 ± 14.4	61.8 ± 33.0
Guam ALS	67	+	299.1 ± 28.7	330.4 ± 30.4	179.1 ± 43.8
Guam PD	66	+	232.1 ± 23.8	226.8 ± 34.6	99.4 ± 24.1
Guam control	48	–	106.8 ± 17.4	117.9 ± 17.4	109.3 ± 29.4
Guam control	65	–	100.9 ± 17.2	90.1 ± 14.4	60.3 ± 14.8

Figure 3. X-ray count data results
(http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1568482/?page=3)

This table shows the results in patients with Alzheimer's disease as well as a control group without the disease in two different countries. Both patients with Alzheimer's Disease showed excessively large amounts of Aluminum in the nuclear regions when compared to the control group.

The second study measuring the aluminum content of muscle, bone and brain in control subjects as well as patients with uraemia (renal failure), proved successful. The uraemic patients showed high levels of aluminum (14.8 parts per million (ppm) in muscle and 98.5 ppm in bone) compared to the levels in control subjects (1.2 ppm. and 2.4 ppm). The values of aluminum in in the brain matter of uraemic patients on dialysis who died of neurological causes measured at 25 ppm compared to 6.5 ppm in a group of patients on dialysis who died of other causes, and 2.2 ppm. in the control subjects. I also analyzed the study "Age-Related Differences on Aluminum

Mobilization by Chelating Agents in Aluminum-Loaded Uraemic Rats" to compare and contrast various tests done on rats when large doses of aluminum were introduced to their diet and then compare the reactions of the rats to the non-induced. I investigated the actions and brain activity of the rats in order to have further evidence that aluminum packaging could potentially be extremely harmful to all consumers. According to the study reportings,

In the negative control groups, the highest Al (aluminum) concentrations in young animals were found in bone and kidneys, while in adult rats they were found in spleen and liver. In these groups (Al-unloaded rats), age differences in Al accumulation were observed in spleen, brain and liver. In these tissues, adult animals showed higher Al levels than young rats. In the positive control group, significant age- related differences in tissue Al accumulation were only found in the remnant kidney (higher levels in adult animals).

This study's results demonstrated that when induced, Aluminum is more impactful on adults, however, the traces of Aluminum were still found in the animals spleen, liver and brain. The body's ability to cycle through the aluminum decreases over time, leading to the adult body with excess aluminum.

The first interview I conducted was with Registered Nurse Laura-Lea McKay, and I asked her about aluminum packaging and if it was safe for consumers. She responded by stating that she did not believe she had a place to say whether or not aluminum packaging had an effect on human health. When the various studies were presented to her, she said she wouldn't doubt the results. She then stated how Alzheimer's disease is one of the worst diseases out there and any actions that could be taken to prevent it would be worth it to all consumers. Next, I was able to contact a representative from the ALCOA, the World's Leading Producer of Aluminum, and asked them questions on their opinion of the possible correlation between aluminum and

Alzheimer's disease. However, they had no comment about the subject and continued on to explain how aluminum is much better for the environment than the other packaging materials I had described. The case studies analyzed proved to show the obvious correlation between aluminum and Alzheimer's disease, however, the representatives I was able to get in touch with seemed guarded on the subject.

Lastly, I compared the differences in price, weight, sustainability and toxicity between aluminum and other common materials used in food packaging in order to determine which materials are best for consumers. The below chart (Figure 4) provides a bulleted comparison between food packaging substrates. As noted earlier, The alternatives to aluminum are plenty. According to Figure 4, the only drawbacks to glass as a substrate for packaging are high transportation cost and fragility. Since glass is chemically safe, consumers' long-term health is protected. Other packaging options include polyesters and polyvinyl chloride. These options do not have many disadvantages, and are much cheaper substrates overall. In order to decrease the risk of Alzheimer's Disease, Parkinson's Disease and dementia, aluminum as a substrate for food packaging should be reconsidered and substituted by any of the below substrates.

Material	Product characteristics/food compatibility		Environmental issues		Cost
	Advantages	Disadvantages	Advantages	Disadvantages	
Glass	• Impermeable to moisture and gases • Nonreactive (inert) • Withstands heat processing	• Brittle and breakable • Needs a separate closure	• Reusable • Recyclable • Often contains recycled content	• Heavy and bulky to transport	• Low cost material but somewhat costly to transport
Aluminum	• Impermeable to moisture and gases • Resistant to corrosion • Withstands heat processing	• Cannot be welded • Limited structural strength	• Recyclable • Lightweight • Economic incentive to recycle	• No disadvantages in rigid form • Separation difficulties in laminated form	• Relatively expensive but value encourages recycling
Tinplate	• Impermeable • Strong and formable • Resistant to corrosion • Withstands heat processing	• Can react with foods; coating required	• Recyclable • Magnetic thus easily separated	• Heavier than aluminum	• Cheaper than aluminum
Tin-free steel	• Strong • Good resistance to corrosion • Withstands heat processing	• Difficult to weld, requires removal of coating • Less resistant to corrosion	• Recyclable • Magnetic thus easily separated	• Heavier than aluminum	• Cheaper than tinplate
Polyolefins	• Good moisture barrier • Strong • Resistant to chemicals	• Poor gas barrier	• Recyclable[a] • High energy source for incineration	• Easily recycled in semi-rigid form but identification and separation more difficult for films	• Low cost
Polyesters	• Strong • Withstands hot filling • Good barrier properties		• Recyclable[a,b]	• Easily recycled in rigid form but identification and separation more difficult for films	• Inexpensive but higher cost among plastics
Polyvinyl chloride	• Moldable • Resistant to chemicals		• Recyclable[a]	• Contains chlorine • Requires separating from other waste	• Inexpensive
Polyvinylidene chloride	• High barrier to moisture and gases • Heat sealable • Withstands hot filling		• Recyclable[a]	• Contains chlorine • Requires separating from other waste	• Inexpensive but higher cost among plastics

Figure 4. Another Comparison between Packaging Substrates
(www.ift.org)

Conclusion

Many conclusions were able to form due to the above case studies and interviews. Despite the natural abundance of aluminum in the environment, it is clear that aluminum is a potent neurotoxin to humans and animals. We still do not know with 100 percent assurance that aluminum causes Alzheimer's disease, however, with the various research methods and extensive testing, aluminum has proven to be involved in the correlation between Alzheimer's patients. The first study described that the patients with Alzheimer's disease had close to double the amount of aluminum in their tissue compared to the control groups. This study took into account environmental factors by comparing patients from two different countries, and although many environmental factors increase the amount of aluminum in the body, the test results reported the extreme increase in aluminum in the patients with Alzheimer's disease when compared to the control patients in each country. The second study proved that patients with uremia that died of mental disorders had much higher levels of aluminum in their bodies (up to 4x the amount) compared to the patients who died of other causes. The third study showed how the body holds on to more aluminum with age. Older humans are more likely to be effected by high levels of aluminum because their bodies are not as capable of filtering out traces of aluminum in their system. The older consumers get, the more aware they need to be in order to protect themselves against the possibility of developing these harsh diseases.

After interviewing someone in the medical field as well as a representative from an aluminum manufacturer, the conclusion can be made that not enough people are aware of what could potentially harm consumers. The nurse did not deny that there could be a correlation, while the representative from the aluminum manufacturing company seemed somewhat defensive. Although aluminum packaging materials have been proven to be extremely

recyclable, economical, etc., there are many other, less harmful choices of substrates when packaging food items. The most practical substitute for aluminum is glass. Since glass is an all-natural, pure substrate, it will never leach chemicals into packaged food items. Glass can also be completely recycled and re-used over and over again because of it's durability. Many food companies choose aluminum to package their foods because of how cheap it is to manufacture and transport, however the industry needs to start focusing a little more on the health of consumers as well. Consumers also need to be aware of the possible detrimental health effects of aluminum as well and should take action to prevent diseases like Alzheimer's as much as they can.

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