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Detection of aluminum residue in fresh and stored canned beer

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The United States produces about 200 million barrels of beer each year from which a large percentage is packaged into aluminum cans. It is important to identify the possible effects a particular foodstuff may induce on its package especially when it is being purchased and consumed nationwide on a regular basis. Very few studies have been done on aluminum can corrosion by beer. The purpose of this study was to compare aluminum levels in fresh, and stored, canned beer representative of U.S. quality draft. A 2 × 2 × 4 design was employed for two brands of beer, A and B, held at two different temperatures of 23°C (room temperature) and 5°C (refrigerated) over a period of 5 months. Room temperature beer was found to contain more aluminum (108 $\mu g\,l^{-1}$) than refrigerated beer and brand A at room temperature had significantly more aluminum content (546 $\mu g\,l^{-1}$) than brand B (414 $\mu g\,l^{-1}$) at the end of the duration of storage period. Aluminum content changes from day 0 to day 150 were significant. From these results, it is shown that aluminum cans are corroded over time by canned beer. However this corrosion may be reduced through refrigeration.

INTRODUCTION

Beer production in the United States increases annually. In 1991 alone, 204 million barrels of beer were produced and put into kegs, bottles, or aluminum cans (U.S. Bureau of the Census, 1993). The aluminum can is made of approximately 99.7% aluminum and is lined with a spray coating which may be composed of a variety of substances. Approximately 78% of beer production is packaged in cans. Companies which manufacture aluminum cans have their own product specification, and they determine the amount of coating to be used for the lining so that can corrosion does not occur. Several factors influence the type of can lining. For example, the more acidic the beverage, the thicker and heavier the inside spray coating. The amounts of coating used vary from one company to another since the can manufacturers along with the beer producers decide the amount to be used for each specific beverage (Susa, pers. comm., 15 April, 1993).

Presence of aluminum is generally not tested for in beer facilities. Some quality control departments claim there is no aluminum in the beer they produce, and therefore, no interaction between the beer and the can.

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It is important to identify any interaction between a foodstuff and its package, particularly when it is being purchased and consumed nationwide on a regular basis. During recent years, an increasing number of toxic effects to the human body have been established but many basic questions still remain unanswered (Ganrot, 1986). One possible contributor to these toxic effects is aluminum.

On average, a person's daily aluminum intake is approximately 20 mg day^{-1} via the gastrointestinal tract and 3–15 $\mu g\,day^{-1}$ per day via inhalation (Birchall and Chappell, 1988). Foods with high values of aluminum are those food stuffs with a content of greater than 1 mg aluminum kg^{-1} food. They are usually foods prepared with aluminum-containing additives and those prepared or stored over a length of time in aluminum vessels. Those foods that tend to be strongly acidic (pH 3) or slightly basic (pH 7–9) tend to leach the most aluminum from containers (Ondreicka *et al.*, 1971; Samsahl and Wester, 1977). Beer has a pH of 4.15 which is somewhat acidic as a result of CO_2 concentration. Therefore, it is expected to leach some amount of aluminum from the can despite the coating of the can.

A literature search gave mixed results of the controversial issue linking aluminum intake with Alzheimer's disease (McLachlan *et al.*, 1992; Commenges *et al.*, 1994; Foster *et al.*, 1995; Masters, 1995). The World Health Organisation (WHO, 1989, 1994) has recently stated that it is still impossible to drive a health-based guideline for aluminum in drinking water, in response to its relationship to Alzheimer's disease, but California has suggested a limit of $100\,\mu g\,l^{-1}$ in drinking water (Anonymous, 1988). Also, a weak link between aluminum and the pH of drinking water was found to be related to cognitive impairment in Alzheimer's patients (Commenges *et al.*, 1994). The purpose of this research was not to make implications about toxicity, but to determine aluminum content level in canned beer from two brands as being affected by temperature variation during storage at 5 and 23°C on intervals over a 5 month period. As one potential contributor to aluminum residue intake is humans, it is important to look at the implications.

MATERIALS AND METHODS

Samples

A total of 48 cans of beer were randomly chosen from the two leading beer manufacturers (24 cans each). Each can was picked from the production line every 15 min. All cans were randomly grouped into two groups, A or B, depending on the source of manufacturing. Three 12 oz cans of beer were mixed for each analysis performed.

Sample size is limited because there are more than 8 beer brands available, but not all are produced locally in Southern California. It was extremely difficult to get approval to visit the plant and pick up samples because of trade secrecy, especially at the brewing step.

Procedures

Samples were divided evenly and stored at 5°C and at room temperature (23°C). Four analysis were conducted, at day 0, 1 month, 3 months, and 5 months. All refrigerated beer at 5°C was set out of the refrigerator to reach room temperature before analysis. A thermo Jarrell Ash Atom Scan model #25 (Boston, MA, 1989) spectrometer was used for aluminum analysis involving atomic emission spectrometry (AES) using inductively coupled plasma (ICP) or ICP–AES linked with computer programming (IBM-PS2/50). This method was used for testing samples according to the procedure outlined in the EPA manual (method #200.7) (1991).

Twenty-five ml of beer were mixed with 5 ml of nitric acid (HNO_3) and 10 ml of hydrochloric acid (HCl) and were placed on a hot plate at 90–95°C for 30 min to eliminate carbonation and for digestion of any organic matter that may be present in the sample. Additional HCl was added to the sample and then the sample was covered to prevent evaporation. The mixture was refluxed for 15 min to ensure complete digestion. The contents were cooled and subsequently adjusted to 25 ml volume by adding distilled water. The solution was then ready for analysis. The calibration was set on the spectrometer following the computer program by analyzing a bland and a standard containing 1 mg aluminum l^{-1} solution. Results are expressed in $\mu g\,l^{-1}$.

As a point of comparison, a separate random survey was also done on five different brands of canned beer (manufactured out of state) purchased from a local supermarket and analyzed. No previous knowledge of date of manufacturing was known. All beer was stored at room temperature (23°C). All analyses were conducted in duplicate.

DATA ANALYSIS

Data were analyzed using Analysis of Variance (ANOVA) using SPSS/PC+(1994) at a significance level of $p < 0.05$. The ANOVA investigated significance between the two different brands of beer A and B, differences between storage methods (temperatures), and differences in any interaction between the beer types and storage methods.

Significance in changes over time was also analyzed using ANOVA. The ANOVA established differences at each point in time (day 0, 1, 3, and 5 months) for each treatment condition. The four treatment conditions consisted of brand A at room temperature, brand A at refrigeration, brand B at room temperature, and brand B at refrigeration. Scores were compared for each beer brand to establish significant differences over time at the two different temperatures. Duncan's post hoc test was done to determine which groups were significantly different.

RESULTS AND DISCUSSION

For both brand A and B, when refrigerated, there were minor but insignificant fluctuations in aluminum content over the five month storage period, but when beer was stored at room temperature, there was a significant increase in aluminum content (Table 1) beginning at the third month of storage through the fifth month. This indicates that cold temperature slows down the migration of aluminum ions from can to beer. It was also suggested that the longer beer is stored without refrigeration, the more aluminum is leached out from the inner wall of the can. Brand B was found to have significantly higher gains in aluminum at all analysis periods during refrigerated conditions. This was probably due to the differences in the thickness of the can coating. The same trend was found for brand B at room temperature except at 5 months, where brand A increased more than B in aluminum level. This increase in aluminum content could have been due to the durability of the inside spray used by company A. It was strong

Table 1. Aluminum content between beer brands

Time	Brand A mean ± SD $\mu g l^{-1}$	Brand B mean ± SD μg^{-1}	t
at 5° C			
Day 1	50.0 ± 0.0	118.5 ± 6.4	15.22***
Month 1	50.0 ± 0.0	108.5 ± 7.6	10.64***
Month 3	50.0 ± 0.0	102.0 ± 1.4	52.00***
Month 5	50.0 ± 0.0	117.0 ± 9.9	9.57
at 23°C			
Day 0	50.0 ± 0.0	108.0 ± 8.5	9.67
Month 1	50.0 ± 0.0	127.0 ± 5.7	19.25***
Month 3	202.0 ± 5.7	258.0 ± 5.7	9.90***
Month 5	546.5 ± 9.2	414.0 ± 33.9	5.33**

** $p < 0.05$.
*** $p < 0.005$.

enough to protect the beer content when cold but was not as durable at room temperature, and by the fifth month it was ineffective. The average pH levels for both brands were taken from corresponding quality control department records. The average pH of CO_2 was 4.5. It is apparent that aluminum found in beer is accumulated at a faster pace after 3 months of storage especially under room temperature conditions when compared to refrigerated temperature (Table 2). A study in Japan by Fukushima *et al.* (1990) found similar results, but with lesser amounts of detected aluminum. In this study, the interaction between beer brands and storage condition (temperature) showed a significant increase of aluminum in trend especially at the 3 months interval (Tables 3–6). The survey from randomly selected brands of consumed draft beer showed that a 3-fold difference is not a wide variation in aluminum contents ranging from 58.7 to 166 $\mu g l^{-1}$ with an overall mean of 102.1 $\mu g l^{-1}$. This denotes presence of aluminum in a wide range of brands other than the two brands which were studied (Table 7). This warrants further investigation into the thickness and evenness of lacquer coating and the pH of beer.

According to some researchers, aluminum is an environmental toxicant that has been linked with a number of disorders in man, i.e. Alzheimer's disease (Graves *et al.*, 1990; Exley and Birchall, 1992). In 1989, the Joint FAO/WHO committee on food additives established a 'provisional' tolerable weekly intake of aluminum. This tolerance level is between zero and seven micrograms of aluminum per kilogram of body mass.

Foodstuffs with large values of aluminum are classified as greater than 1 milligram (1000 $\mu g kg^{-1}$) of aluminum per kilogram of food (Birchall and Chappell, 1988). This does not mean that only foods with large amounts of aluminum should be considered dangerous. There are many interrelating human factors (organ and blood/brain barrier differences among people), environment, pH level of small intestine, dietary constituents present when consuming aluminum, etc. Since the appropriate conditions where aluminum may be considered a

Table 2. Scores for brand A from Day 0 to Month 5 at 23°C and for Brand B from Day 0 to Month 5 at 23°C

Time	Mean ± SD $\mu g l^{-1}$	df	t
A			
Day 0	50.0 ± 0.0	2	38
Month 1	2020 ± 5.7		
Month 3	50.0 ± 0.0	2	76.38
Month 5	546.5 ± 9.2		
B			
Day 0	108.0 ± 8.5	2	15.00**
Month 3	258.0 ± 5.7		
Day 0	108.0 ± 8.5	2	10.20**
Month 5	414.0 ± 33.9		

** $p < 0.05$.

Table 3. Comparison of aluminum levels based on type of beer and storage temperature

Day 0	F
Differences between beer Brand A vs B	284.48
Differences in storage method	1.96
Interaction of beer B and A × storage method	1.96
1 Month	
Differences between beer Brand A vs B	396.98***
Differences in storage method	7.4
Interaction of beer A and B × storage method	7.4
3 Month	
Differences between beer Brand A vs B	353.45
Differences in storage method	2874.67
Interaction of beer A and B × storage method	0.48
5 Month	
Differences between beer Brand A vs B	6.34***
Differences in storage method	943.64***
Interaction of beer A and B × storage method	59.65***

*** $p < 0.0001$.
Note, df 1,4.

Table 4. ANOVA comparison of changes in aluminum levels based on beer type and storage temperature

Change over time	F
Changes from Day 0–1 Month	
Differences between beer brands A vs B	0.41
Differences in storage method	4.2
Interaction of beer A and B × storage method	4.2
Changes from Day 0–3 Month	
Differences between beer brands A vs B	2.67
Differences in storage method	790.97***
Interaction of beer A and B × storage method	1.64
Changes from Day 0–5 Month	
Differences between beer brands A vs B	38.87**
Differences in storage method	681.51***
Interaction of beer A and B × storage method	37.65**

** $p < 0.005$.
*** $p < 0.0001$.

Table 5. ANOVA comparison of treatment conditions for beer type and storage method

	Refrigerated means			Room temperature means	
Period	Brand A	Brand B	Brand A	Brand B	F
Day 0	50	118.5	50	108	96.13***
Day 3050	50	108.5	50	127	137.26***
Day 9050	50	102	202	258	1076.20***
Day 150	50	117	546.5	414	336.57***

Duncan's post hoc test (time period)

Day 0	E, F > C, D
Day 30	E > F > C, D
Day 90	E > C > F > D
Day 150	C > E > F > D

C— Brand A at room temperature; E—Brand B at room temperature.
D— Brand A refrigerated; F— Brand B refrigerated.
Note df 3,4.
*** $p < 0.0001$.

Table 6. ANOVA comparison of treatment conditions for beer type and storage method

	Refrigerated means			Room temperature means	
Period	Brand A	Brand B	Brand A	Brand B	F
Day 0 to 1 Month	0	150	152	−16.5	1076.20***
Day 0 to 5 Month	0	306	495.5	−1.5	336.57***

Duncan's post hoc test (time period)

Time period	
Day 0 – Month 3	E, F > C, D
Day 0 – Month 5	C > E > D, F

C— Brand A at room temperature; E—Brand B at room temperature.
D— Brand A refrigerated; F— Brand B refrigerated.
Note, df 3,4.
*** $p < 0.0001$.

risk factor for disease have not yet been specified, preventative measures are recommended.

Beer in aluminum cans does contribute to aluminum ingestion. Any beer purchased should be purchased fresh and refrigerated to minimise aluminum levels consumed through beer. This can be done by learning to read the code dates printed on each beer can. Manufacturers are urged to use an 'expiration date' or 'use by a certain date' code which might be printed on each can so that it is clear to the consumer that there is a shelf-life for the beer. Beer production companies should be aware of the findings and work with the can manufacturers to develop more resilient inside coatings so that absolutely no contamination occurs from the can to the beverage. Possible long-term health benefits and also an increase in product quality would result.

Table 7. Random survey of aluminum levels in 5 brands of canned beer

Beer brand	Aluminum content mean $\mu g\,l^{-1}$	±SD
Brand F	166±	8.5
Brand G	144±	22.6
Brand X	82.9±	8.5
Brand Y	59.1±	2.8
Brand Z	58.7±	12.2
Mean for all brands	102.1	

This study showed that aluminum migrated to the beer components. It was found that the longer the length of storage, the more aluminum was detected. In addition, the higher the temperature, the more rapid the rate of deterioration from the can, regardless of can coating, and the higher the accumulation of aluminum in beer. However, while this study did find detectable levels of aluminum in beer, aluminum did not exist to an alarming extent. That is, there is no currently known toxicological implication given this study's detected aluminum levels.

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