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Detection of aluminium residue in sauces packaged in aluminium pouches

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Abstract

The interactions between food and aluminium packaging can be a potential source of aluminium release which can contribute to aluminium ingestion in the human body. Hence, it is important to identify the possible effects of such an interaction. The purpose of this study was to compare the aluminium content and the pH levels of three different types of sauces, packaged in aluminium packaging at two different temperatures and at two different periods in time. A three way analysis of variance test was utilized and the samples were stored at 22 °C (ambient room temperature) and at 50 °C. Stored samples showed minor changes in the aluminium contents when compared with fresh samples. Negligible changes in pH levels over the entire length of the study were observed for all three samples. The results of this study suggest that there is little cause for concern about possible aluminium accumulation in sauces packaged in aluminium packaging.

Keywords: Aluminium contamination; Packaging; Pouches; Storage; Sauces

1. Introduction

Packaging is the tool that protects and contains goods so that the environmental impact on the food in the package is minimized. Effective packaging is vital to the health and welfare of the consumer. The materials and methods used to package food have changed more in the past 10 or 15 years than over the preceding 150 years. However, there is scanty research information on the effects of packaging in aluminium on food items. The data on aluminium concentration in food items are scarce, although aluminium containers are widely used to cook, freeze, or wrap foods (Gramiccioni, Ingrao, Milana, Santaroni, & Tomassi, 1996). The quality, safety, and nutritional content of packaged foods has not been thoroughly researched for certain newly packaged products. The desire for higher quality and safer food with a longer shelf life has led to increased interest in the interaction between foods and food packaging (Hotchkiss, 1988). The migration of food packaging elements to the contacted food has received some attention over recent years (Page & Lacroix, 1992). Food packaging interactions can be defined as an interplay between food, packaging, and the environment, which produces an effect on the food and/or package (Hotchkiss, 1997). Rajwanshi et al. (1997) reported that aluminium was earlier considered to be a non-risk element and its toxicological evaluation ratio was only recently presented in the report of the Joint WHO/FAO Expert Committee on Food Additives (1989). Now that a provisional tolerable weekly intake (PTWI) of 7 mg/kg body weight has been established for aluminium it is even more important to pursue and collect data through studies on this topic.

Aluminium is a ubiquitous element, comprising approximately 8% of the earth's crust. It is commonly inhaled as well as ingested (Nabrzyski & Gajewska, 1998). Aluminium is noted for its light weight, good thermal conductivity, high reflectivity, resistance to oxidation, and superior barrier qualities. As such, it finds a number of applications in packaging, ranging from beverage cans to aseptic containers. About 27% of all aluminium consumed in the United States is used for the purpose of packaging. In addition, most of the growth in aluminium consumption between 1979 and 1989 was in packaging (Stilwell, Canty, Kopf, & Montrone, 1991).

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In packaging, aluminium is used either in a plain or converted form. There are three major applications of plain aluminium: household foil, foil containers, and wrappings (either paper laminated or plastic coated for sealing). Besides these applications of plain aluminium, the vast majority of aluminium in packaging is used in converted form, which means that the packed goods do not come into contact with the aluminium itself, but rather with an intermediate layer of lacquer, plastic, paper, or cardboard covering the aluminium. These coatings serve as protective layers, similar to can coatings or as heat sealants to produce tightly sealed lids (Massey & Taylor, 1989). Packaging accounts for 75% of the applications of aluminium foil, with the remainder in decorative wrap, insulation, and other construction uses. Aluminium packaging in the food industry is very popular because it is impermeable, greaseproof, nonabsorptive, inert, and highly formable with excellent deadfold characteristics. Aluminium laminates and composites have been extremely important in tamper-resistant lids and form/fill/seal pouches (Stilwell et al., 1991). In the case of aluminium containers, it has been demonstrated that aluminium surfaces can deteriorate whenever they come into contact with salty, acidic, or even neutral aqueous media (Gramiccioni et al., 1996; Vela, Toma, Reiboldt, & Pierri, 1998). Aluminium resists mildly acidic products better than mildly alkaline products. Concentrated mineral acids are not packaged in aluminium because of the possible corrosive effects (Stilwell et al., 1991).

Recent research suggests a correlation between the ingestion of aluminium in man, and Alzheimer's disease. In spite of the high corrosion resistance of aluminium against most foods, the use of aluminium food containers, cans, cookware, and utensils for preparation and storage of food can lead to some migration of aluminium into foods. It is, therefore, important to determine the aluminium concentration in packaged foods since dietary intake represents the main source of exposure to aluminium for healthy populations (Gramiccioni et al., 1996).

The purpose of this study was to detect the levels of aluminium content in three different types of acidic sauces packaged in aluminium packaging at two different temperatures and at different time periods.

2. Materials and methods

2.1. Samples

Forty-eight packages, i.e. 16 packages of each of three different types of sauces, were randomly selected from the production lines of a leading manufacturer in Southern California. These packaged sauces were immediately transported to the testing site. All designated samples were analyzed on day 0 at two different temperatures of 22 °C (ambient room temperature) and 50 °C, at two time intervals. The sauces used for the analyses were:

Sauce A—Chicken Dijon; Sauce B—Chicken Fajita and Sauce C—Veal Marsala.

2.2. Procedure

Out of the 16 packages, eight of the packages of each sample A, B, and C were used for the initial analyses on day 0 and the remaining eight were stored unopened for later analyses of aluminium and pH on day 45 of storage. Half of the remaining samples were kept at 22 °C and the other half at 50 °C by incubation. At the time of analysis all of the four packets were cut open with a clean pair of scissors and mixed in a beaker to obtain a homogeneous sample. A representative portion of the composite homogeneous sample was used for the analysis in duplicate. pH was measured according to the procedure outlined by the Association of Official Analytical Chemists (1990). Aluminium content was determined in duplicate using atomic emission spectroscopy according to the procedure outlined by the American Standard Testing Materials (1994). The concentration of aluminium in the sauces was expressed in mg/kg.

2.3. Data analyses

Multifactorial analyses of variance (ANOVA) with full interaction model was used to analyse results from various levels with respect to time and temperature factors. A significance level of $P<0.05$ was used to determine whether or not there were any significant differences in the aluminium content or the pH of the sauces with respect to time and temperature. The Statistical Package for the Social Sciences (1999) was used for the analyses.

3. Results and discussion

In all three different types of sauce samples, when stored at room temperature, there were minor but insignificant changes in the aluminium content over the 6-week storage period. These insignificant changes in the aluminium levels could in part be due to the thin plastic lining on the interior surface of the packaging which might have acted as a protective barrier against any possible corrosion. To test the aluminium content, a three way analysis of variance test was utilized using temperature, sauce, and day as independent variables. The overall model was highly significant, $F(11,23)=66.87$, $P<0.0001$ and accounted for 98.4% of the variance in the aluminium scores (Table 1), which

Table 1
Summary of three-way analysis of variance for temperature, sauce and time conditions affecting aluminium content (measured in mg/kg)

Source	df	SS	MS	*F*
Temperature (T)	1	1.76	1.76	0.61
Sauce (S)	2	2075.65	1037.82	359.68*
Day (D)	1	21.09	21.09	7.31
T×S	2	5.15	2.57	0.89
T×D	1	1.76	1.76	0.61
S×D	2	11.81	5.91	2.05
T×S×D	2	5.15	2.57	0.89
Within	12	34.62	2.89	
Full model	11	2122.36	192.94	66.87*
Total	23	2156.99	93.78	

$R^2=0.984$; MS, mean square or variance estimate; SS, sum of squares.
* $P<0.0001$.

revealed that the *type* of sauce accounted for almost all the variance (96.2%) with the next highest independent variable, *day*, which accounted for only 1.0% of the variance in aluminium content. The findings of this study are in agreement with those of Sugden and Sweet (1989) on the leaching of aluminium ions from lacquered drink containers (cans) using deionized water and buffers (pH 1–13) and stored at 20±2 °C for 60 days, which showed that drinks packaged in aluminium cans do not leach out significant amounts of aluminium and hence do not present a significant risk to healthy people.

Samples stored at 50 °C showed slightly higher aluminium contents than those stored at room temperature but were still statistically insignificant. The results suggest that higher temperatures might leach out more aluminium from the packaging than those stored at lower temperatures. Higher temperatures seem to surpass any protective barriers offered by the plastic lining sooner than room temperatures. The study was in agreement with results presented by Vela et al. (1998) on beer. The findings showed that the duration of storage could have an effect on the corrosion process of aluminium. Hence, the longer the storage period and higher the storage temperature, the more the leaching of aluminium from the packaging. Table 2 gives the differences in outcome measures for the sauce samples between day 0 and day 45.

Sample A (Chicken Dijon sauce) showed a higher degree of aluminium leaching than both sample B (Chicken Fajita sauce) and sample C (Veal Marsala sauce). This could have been due to the slightly lower pH of sample A than the other two samples. A study conducted by Seruga and Hasenay (1996) showed a similar trend of increased aluminium leaching with an increase in the acidity of soft drinks packaged in aluminium cans. Tables 3 and 4 depict the mean (raw) scores in mg/kg for the aluminium and pH analyses of the sauces, respectively.

Sauce A showed a slight rise in aluminium content with a rise in pH during storage. The aluminium and pH levels, in stored sauces, were higher at 50 °C than at room temperature. Sauce B showed a negligible change in the aluminium content with a slight lowering of the pH after storage. Similarly, sauce C showed a negligible change in the aluminium content after storage, with the pH remaining constant throughout the study. However, these changes in the aluminium content and the pH levels of all three types of sauces were statistically insignificant. These insignificant changes could be due to a shorter storage period, lower storage temperature, or some other factor outside the scope of this study.

Table 2
Differences in outcome measures for selected sauces between day 0 and day 45

Sauce	Day 0	Day 45	Difference
	M±S.D.	M±S.D.	
Aluminium content			
Dijon 22 °C	0.029±0.0	0.031±1.4	n.s.
Dijon 50 °C	0.029±0.0	0.0345±4.9	n.s
Fajita 22 °C	0.012±0.0	0.012±0.0	n.s.
Fajita 50 °C	0.012±0.0	0.0128±2.5	n.s
Marsala 22 °C	0.095±0.7	0.0115±0.7	n.s
Marsala 50 °C	0.095±0.7	0.0105±0.7	n.s
pH level			
Dijon 22 °C	3.1±0.0	3.1±0.0	u.s.
Dijon 50 °C	3.1±0.0	3.1±0.0	n.s.
Fajita 22 °C	3.7±0.0	3.7±0.0	n.s.
Fajita 50 °C	3.7±0.0	3.6±0.0	n.s.
Marsala 22 °C	3.1±0.0	3.1±0.0	n.s.
Marsala 50 °C	3.1±0.0	3.1±0.0	n.s.

None of the comparisons was significantly different at the $P<0.05$ level.

Table 3
Mean (raw) scores for aluminium analyses of sauce samples[a]

Time	Sauce A		Sauce B		Sauce C	
	22 °C	50 °C	22 °C	50 °C	22 °C	50 °C
Day 0	0.029	0.0 29	0.012	0.012	0.095	0.095
Day 45	0.031	0.034	0.012	0.013	0.0115	0.0105

Results are in duplicates as (mg/kg).
[a] Sauce A: Chicken Dijon. Sauce B: Chicken Fajita. Sauce C: Veal Marsala.

Table 4
Mean (raw) values for pH analyses of sauce samples[a]

Time	Sauce A		Sauce B		Sauce C	
	22 °C	50 °C	22 °C	50 °C	22 °C	50 °C
Day 0	3.09	3.09	3.67	3.67	3.10	3.10
Day 45	3.09	3.12	3.66	3.58	3.10	3.10

[a] Sauce A: Chicken Dijon. Sauce B: Chicken Fajita. Sauce C: Veal Marsala.

The assessment of aluminium exposure is complex. Scientists need to define the dietary, physiological, and pathological factors that affect the absorption and retention of dietary aluminium. Ultimately, these variables are more important than the absolute amounts of aluminium in foods and in the environment (Gregor, 1992). Although the role played by aluminium in the human body is stifi controversial, ingestion of aluminium from potential sources, such as pharmaceuticals and food additives, should be kept to minimal levels.

Since most of the research in the field of aluminium corrosion from packaging has concentrated mostly on aluminium cans, more studies on aluminium pouches and foil are warranted. Increased efforts should be directed toward defining the full range of potentially harmful effects of aluminium accumulation in humans. To this end, multidisciplinary collaborative research efforts are encouraged to widen the scope for future research work. Emphasis should be placed on increasing our understanding of the chemistry of aluminium in biological systems, and on determining the cellular and molecular mechanisms of aluminium toxicity. Therefore, further research is warranted, using different conditions with the above factors.

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