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Aluminium contents in baked meats wrapped in aluminium foil

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Abstract

In this investigation, the effect of cooking treatments (60 min at 150 °C, 40 min at 200 °C, and 20 min at 250 °C) on aluminium contents of meats (beef, water buffalo, mutton, chicken and turkey) baked in aluminium foil were evaluated. Cooking increased the aluminium concentration of both the white and red meats. The increase was 89–378% in red meats and 76–215% in poultry. The least increase (76–115%) was observed in the samples baked for 60 min at 150 °C, while the highest increase (153–378%) was in samples baked for 20 min at 250 °C. It was determined that the fat content of meat in addition to the cooking process affected the migration of aluminium ($r^2 = 0.83$; $P < 0.01$). It was also found that raw chicken and turkey breast meat contained higher amounts of aluminium than the raw chicken and turkey leg meat, respectively. Regarding the suggested provisional tolerable daily intake of 1 mg Al/kg body weight per day of the FAO/WHO Expert Committee on Food Additives, there are no evident risks to the health of the consumer from using aluminium foil to cook meats. However, eating meals prepared in aluminium foil may carry a risk to the health by adding to other aluminium sources.

Keywords: Aluminium; Cooking; Meat; Aluminium foil

1. Introduction

Aluminium has a variety of industrial applications because of its attractive properties such as low specific gravity, high thermal and electric conductivity and attractive appearance. Aluminium is also preferred due to its corrosion resistance and easy processing properties (Joshi, Toma, Medora, & O'Connor, 2003; Rajwanshi, Singh, Gupta, & Dass, 1997; Ranau, Oehlenschlager, & Steinhart, 2001). Aluminium is widely used for manufacturing household utensils and packaging materials. Aluminium foil is widely used for packaging, storing, and cooking of various foods. Especially, it is common practice to wrap meat and fish and grill or cook them in the oven in order to prevent water uptake (McWilliams, 1989) and avoid direct heat (Ranau et al., 2001). The widespread use of aluminium foils makes them a significant potential source of dietary aluminium.

Aluminium toxicity is well known in patients with longstanding chronic renal failure (Meiri, Banin, Roll, & Rousseau, 1993). In recent years, aluminium has also been associated with various bone (osteomalacia) and neurological failures (Alzhemier's disease) (Gauthier et al., 2000; Grant, Campbell, Itzhaki, & Savory, 2002; Gupta et al., 2005; Miu, Olteanu, & Miclea, 2004; Polizzi et al., 2002; Rondeau, Commenges, Jacqmin-Gadda, & Dartigues, 2000). Although a direct relationship between aluminium in food and these diseases has not been established, public interest in effects of aluminium on human health has increased in recent years and several studies have been conducted on aluminium leaching into foods cooked in aluminium utensils or wrapped with aluminium. In these studies, the extent of aluminium leaching was strongly related to several factors such as the type of aluminium utensils, pH of the food and/or cooking medium, form and composition of food, duration of contact/cooking and presence of fluoride, etc. Scancar, Stibilj, and Milacic (2004) found that cooking sauerkraut and sour turnip in

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aluminium cookware appreciably increased the concentration of aluminium (313 and 260 mg/kg DM, respectively). The concentration of aluminium in unheated sauerkraut and sour turnip was 2.2 and 1.5 mg/kg DM, respectively. Yaman, Gunes, and Bakirdere (2003) determined the aluminium concentrations of cooked Turkish meals in new and old aluminium and the various other cooking utensils (clay, foil, steel, teflon, boron glass and tinned Cu) and found that the aluminium concentrations of Turkish meals cooked in old aluminium utensil were higher than these cooked in other utensils. Ranau et al. (2001) determined the aluminium contents of grilled and baked fish (cod, saithe, ocean perch and mackerel) fillets with and without ingredients wrapped in aluminium foil and found that the aluminium concentrations of both baked and grilled fillets wrapped in aluminium foil clearly increased during heating for all fish types. They observed that, generally, the aluminium contents of grilled fillets were higher than those of baked fillets. Rajwanshi et al. (1999) determined the effect of pH and fluoride concentration on the leaching of aluminium from aluminium food containers and found that the extent of metal leaching increased with lower pH and rose with fluoride. Leaching of aluminium was found to be maximal in case of all the acids (acetic, citric, oxalic and tartaric acid), containing 10 ppm fluoride (pH 2), while it was found to be minimal in all the acid solutions at pH 4 in the absence of fluoride. Fimreite, Hansen, and Pettersen (1997) reported that the aluminium concentrations in black currant juice and stewed rhubarb prepared in aluminium cookware increased with the cooking time.

In recent years, it is a common practise to wrap the meat and fish prior to oven cooking. Due to the possible relation between aluminium uptake and the specific diseases mentioned above, it is important to determine the aluminium concentration of foods wrapped with aluminium. This study was conducted to detect the levels of aluminium content in different meats (beef, water buffalo, mutton, chicken and turkey) packed with aluminium foil and cooked in an oven at three different temperature/time periods (150 °C for 60 min, 200 °C for 40 min, and 250 °C for 20 min).

2. Materials and methods

Fresh red meat (beef: round; water buffalo: round; mutton: legs) and poultry (chicken: breast, legs; turkey: breast, legs) were all purchased from a local market. Muscle from each species was trimmed to remove bones, skin and most of the surface fat, cut into small pieces of $\approx 3\ cm^3$ and was divided into four portions. Each portion consisted of approximately 200 g. One portion was analysed as a fresh sample [beef: round (75.39% moisture, 20.21% protein, 2.28% fat and 1.05% ash); water buffalo: round (74.35% moisture, 19.23% protein, 4.33% fat and 1.02% ash); mutton: legs (69.74% moisture, 16.79% protein, 11.38% fat and 0.97% ash); chicken: breast (74.43% moisture, 20.72% protein, 2.82% fat and 1.00% ash), legs (76.30% moisture, 18.43% protein, 3.49% fat and 1.00% ash); turkey: breast (72.69% moisture, 23.22% protein, 2.23% fat and 1.13% ash), legs (75.78% moisture, 20.18% protein, 2.54% fat and 0.94% ash)], the second portion was wrapped in aluminium foil (30×30 cm, thickness 12 μm, density 2.71 g/cm^3) and baked in an electrical oven at 150 °C (Arcelik Midi Firin MF 6, 1200 W, 220 V, 50 Hz) for 60 min, the third portion was wrapped in aluminium foil and baked at 200 °C for 40 min and the fourth portion was wrapped in aluminium foil and baked at 250 °C for 20 min. The raw and cooked samples were ground in a glass mortar to ensure homogeneity and representative samples taken for analysis. Samples were packed in glass jars and analysed for aluminium and moisture content. In addition raw samples were analysed also for protein, fat and ash contents. The homogenized samples of each species were individually analysed in triplicate and the result of each replication was given as the mean value. All reagents were of analytical grade, and deionized water was used throughout. Glassware was washed in concentrated HCl and rinsed with deionized water.

Moisture, protein ($N \times 6.25$), fat and ash contents were determined according to AOAC (1990).

Aluminium levels of all samples were determined, using an ATI UNICAM 929 Model atomic absorption spectrophotometer (AAS) according to Yaman et al. (2003) with a slight modification. An accurately weighed 3 g wet sample was dried for 4 h at 125 °C and then heated at 500 °C for 6–8 h. This process was repeated, if necessary, until a white ash was obtained. The ash was digested in 5 ml of 2 M HNO_3 by boiling for about 2 min and then cooling to room temperature. The cooled solution was filtered through Whatman filter paper (No. 41) and made up to 25 ml with 2 M HNO_3. The clear solutions were then analysed for aluminium by AAS at a wavelength of 309.3 nm.

The data obtained from three replications were analysed by one-way ANOVA using the SPSS statistical package program, and differences among the individual means were compared using the Duncan's Multiple Range test (SPSS, 1998). A significance level of 0.05 was chosen. Furthermore, a stepwise linear regression analysis was performed to evaluate any relationship between the fat contents and increases of aluminium.

3. Results and discussion

Aluminium and moisture contents for raw and baked red meats wrapped in aluminium foil are given in Table 1. Aluminium values are given in mg/kg dry weight. Additionally, the proportional increases of aluminium are given in Table 1. The effects of cooking treatment on aluminium contents of red meats were significant ($P < 0.05$) but water content did not change significantly ($P > 0.05$). The aluminium content in raw beef increased from 16.39 to 30.99 mg/kg at 150 °C for 60 min, 38.27 mg/kg at 200 °C for 40 min, and 48.85 mg/kg at 250 °C for 20 min. Therefore, the least increase of 89% was in the samples cooked

Table 1
Aluminium and moisture contents in raw and baked red meats wrapped in aluminium foil[A]

	Treatments[B]	Aluminium, mg/kg DM	Moisture, %	Increase of aluminium, % (dry weight basis)
Beef round	1	16.39 ± 1.35a	75.39 ± 0.60	–
	2	30.99 ± 2.66b	75.15 ± 0.68	89
	3	38.27 ± 2.73b	74.11 ± 1.06	133
	4	48.85 ± 2.56c	74.78 ± 1.14	198
Water buffalo round	1	14.50 ± 0.95a	74.35 ± 0.62	–
	2	29.10 ± 3.51b	74.27 ± 0.93	101
	3	35.88 ± 2.70b	73.45 ± 1.12	147
	4	47.25 ± 4.03c	72.74 ± 1.24	226
Mutton leg	1	11.19 ± 0.86a	69.74 ± 0.81	–
	2	24.03 ± 0.71b	67.92 ± 1.20	115
	3	33.99 ± 1.32c	68.94 ± 0.81	204
	4	53.48 ± 1.97d	67.90 ± 0.90	378

[A] Means for a species in a column with different letters are significantly different ($P < 0.05$). Values are means ± SE of three replicates.
[B] (1) Raw, (2) baked 60 min at 150 °C, (3) baked 40 min at 200 °C, and (4) baked 20 min at 250 °C.

at low temperature for a long time (150 °C for 60 min) and the highest increase of 198% was in the samples cooked at a high temperature for a short time (250 °C for 20 min). Similar results were obtained in water buffalo meat and mutton. These results suggest that cooking temperature is more important in aluminium leaching than cooking time. This may be explained that the higher cooking temperature stimulated the leaching of aluminium from foil to meats, because at elevated temperatures, the oxide layer becomes thicker and changes from an amorphous to a crystalline structure (Rajwanshi et al., 1997). Similar to our results, Ranau et al. (2001) found that the aluminium concentration of wrapped and grilled fillets was higher than samples cooked in an oven at 200 °C. Other researchers stated that cooking in aluminium utensils increased the aluminium concentration of foods (Fimreite et al., 1997; Gramiccioni, Ingrao, Milana, Santaroni, & Tomassi, 1996; Greger, Goetz, & Sullivan, 1985; Scancar et al., 2004; Watanabe & Dawes, 1988; Yaman et al., 2003). While Gramiccioni et al. (1996) determined that aluminium concentration of 'meat cannelloni' prepared in aluminium cookware increased by 25%, Scancar et al. (2004) found an even greater increase in sauerkraut and sour turnip and stated that aluminium utensils are not suitable for acidic foods. The increase in aluminium concentrations of water buffalo meats (4.33% fat) (101% at 150 °C for 60 min, 147% at 200 °C for 40 min, and 226% at 250 °C for 20 min) after cooking gave similar results to beef (2.28% fat). In contrast, the increase in aluminium content of mutton (11.38% fat) (115% at 150 °C for 60 min, 204% at 200 °C for 40 min, and 378% at 250 °C for 20 min) was significantly higher than both beef and water buffalo meat. Parallel to our results, Ranau et al. (2001) found that the aluminium contents of the baked fillets of lean fish (cod and saithe) were lower than those of fatty fish (ocean perch and mackerel). In the present study, it was found that the positive correlation between fat content and increase of aluminium was significant ($r^2 = 0.83$; $P < 0.01$). This result suggests that not only is aluminium leaching a function of cooking process, but also fat content of product.

Cooking treatments significantly affected the aluminium contents of poultry meats ($P < 0.05$) but had no significant effect on water content ($P > 0.05$) (Table 2). As in the case of red meats, the lowest aluminium content was observed in the raw meats and the highest in those cooked at 250 °C for 20 min. The percentage increases in the aluminium content of chicken breast, chicken leg, turkey breast and turkey leg, cooked for 60 min at 150 °C and 40 min at 200 °C, were not significant ($P > 0.05$). For baked chicken breast, chicken leg, turkey breast and turkey leg cooked in aluminium foil increases were 76%, 76%, 84%, and 89% at 150 °C for 60 min; 83%, 96%, 115%, and 109% at 200 °C for 40 min, and 153%, 192%, 215%, and 196% at 250 °C for 20 min, respectively. This variation may be due to the chemical composition of meats. It was reported that various foods cooked in aluminium utensils resulted in different aluminium migration (Fimreite et al., 1997; Gramiccioni et al., 1996; Greger et al., 1985; Scancar et al., 2004; Watanabe & Dawes, 1988; Yaman et al., 2003). In addition, raw chicken and turkey breast meats had higher aluminium contents than the raw chicken and turkey leg meat, respectively. This finding shows that poultry breast meats store more aluminium than leg meats.

Table 2
Aluminium and moisture contents in raw and baked poultry meats wrapped in aluminium foil[A]

	Treatments[B]	Aluminium, mg/kg DM	Moisture, %	Increase of aluminium, % (dry weight basis)
Chicken breast	1	23.58 ± 1.33a	74.45 ± 0.58	–
	2	41.39 ± 2.40b	73.17 ± 1.03	76
	3	43.19 ± 1.28b	72.52 ± 1.29	83
	4	59.76 ± 2.54c	73.14 ± 1.23	153
Chicken leg	1	16.45 ± 0.52a	76.30 ± 0.53	–
	2	28.91 ± 0.50b	75.73 ± 1.37	76
	3	32.17 ± 1.18b	75.56 ± 0.60	96
	4	48.11 ± 3.13c	75.14 ± 0.98	192
Turkey breast	1	19.12 ± 0.70a	72.69 ± 0.86	–
	2	35.12 ± 2.48b	71.75 ± 1.21	84
	3	41.09 ± 1.98b	71.00 ± 1.13	115
	4	60.21 ± 3.68c	70.70 ± 1.18	215
Turkey leg	1	18.29 ± 1.02a	75.78 ± 0.62	–
	2	34.56 ± 0.64b	75.74 ± 0.83	89
	3	38.20 ± 2.07b	75.63 ± 0.58	109
	4	54.11 ± 3.19c	75.47 ± 1.04	196

[A] Means for a species within the group in a column with different letters are significantly different ($P < 0.05$). Values are means ± SE of three replicates.
[B] (1) Raw, (2) baked 60 min at 150 °C, (3) baked 40 min at 200 °C, and (4) baked 20 min at 250 °C.

4. Conclusion

Our research findings showed that cooking in aluminium foil increased the aluminium content of red or white meats. Aluminium contents ranged from 11.19 to 16.39 mg/kg in raw red meats, 24.03 to 53.48 mg/kg in cooked red meats, 16.45 to 23.58 mg/kg in raw poultry meats, and 28.91 to 60.21 mg/kg in cooked poultry meats. In all samples, the lowest increase (76–115%) was observed in the samples cooked at 150 °C for 60 min, the highest (153–378%) in the samples cooked at 250 °C for 20 min. It should be noted that not only aluminium leaching is a function of cooking process, but also fat content of the product ($r^2 = 0.83$; $P < 0.01$). Also, raw chicken and turkey breast meats had higher aluminium contents than the raw chicken and turkey leg meat, respectively. Regarding the suggested provisional tolerable daily intake of 1 mg Al/kg body weight per day of the FAO/WHO Expert Committee on Food Additives (FAO/WHO, 1994), it can be stated that there is no evident risk to the health of consumer. However, it is possible that excessive consumption of foods packed with aluminium foil may carry a health risk.

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