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SOME BIOLOGICAL RISKS IN RATS AS A RESULT OF COOKING IN ALUMINUM UTENSILS

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ABSTRACT

The effects of cooking and / or storage for 7 days of fresh green peas using aluminum kitchen utensils at three different pH values with or without adding sodium chloride in comparison with stainless steel utensils were examined. Biological demonstration in rats revealed the effects of consuming aluminum contaminated diet on hematological measurements RBC's, WBC's, platelets counts and erythrocyte indices. Further more the biochemical changes in blood hemoglobin, hematocrit, and the levels of serum iron, calcium and aluminum, as well as the oxidative stress status and tibia characteristics were also investigated. The results showed that using aluminum utensils at acidic medium significantly increased aluminum concentrations in cooked and / or stored peas samples by about 11.5% and 18.7% , respectively, while adding NaCl dose,.3g/20g peas resulted in progressive increment reaching 14.45% and 26.9% respectively. The levels of aluminum were also elevated markedly in the stored samples with or without adding NaCl in both neutral and alkaline medium, while it's increment ranged between 4 to 5% in cooked samples in case of adding NaCl or not. Aluminum accumulation decreased hematological measurements due to its toxic effects. The decrease of hemoglobin and hematocrit reached 30.0% and 8.36%, respectively, accompanied by decreasing the levels of iron and calcium in serum by about 6.35% and 18.3%, respectively. In contrast, there was 21% elevation in serum aluminum concentration which significantly lowered the antioxidant mechanisms as shown in plasma level of malondialdehyde (5.76 ± 0.24 nmol/ml) as compared to (1.64 ± 0.10 nmol/ml) associated with decreased level of erythrocytes super oxide dismutase by about 19.4%.Tibia characteristics showed a significant increase in weight and density as aluminum accumulation with calcium demineralization at the end of the experiment (12 week). It could be concluded that aluminum leaching from aluminum utensils, especially during storage of acidic foods, in hematological measurements and its physiological function roles also, will cause undesirable changes in oxidative stress and bone dysfunction.
Keywords: Aluminum- Utensils- Rats- Cooking-Oxidative stress-blood indicies

INTRODUCTION

There are many pots materials that are available for use in home cooking either metals such as stainless steel, aluminum, tefal coated layer and copper which coated in with inner core or non-stick teflon, porcelain and pyrex *(Marion 1985).* Many investigators studied the effects of aluminum migration from utensils and tools into foods, water and beverages as well as factors affecting the leaching amount such as chemical constituents of foods, the pH of cooking medium, duration and temperature of cooking and storage periods as complex reactions that result in dissolution of complexes metals, *(Gaballa 2000, Scancar et al 2004, Diab 2005, Mohamed 2006).* Aluminum is the most common material metal used in food preparation in houses, restaurants kitchen tools and utensils as low coast, hard work, and a good

conductor of heat, *(Diab 2005).* Aluminum supply comes from natural sources including water, food additives, leavening agents as baking powder used in baked products. Also, aluminum is found in commercial products like infant formulas and in some pharmaceutical products as well as in the widly uses of aluminum foil in food packaging *(Rondeou et al 2000, Metwally et al 2002).* Since the accumulation of aluminum is statistically significant in cooked and stored foods. Many studies investigated the systemic effects of aluminum toxicity due to potential dietary source as cell membranes disruption by altering the gating of highly selective ions channels such as inhibition of calcium binding to phosphatidyl serine which results in membrane rigidity, fusion and increases the permeability as well as replaces magnesium that confers structure of triphosphate which disrupts of the G-protein activity of the second messenger system. Moreover, it binds to negatively charged phospholipids molecules which could alter the physiochemical properties of the membranes and enhancing lipid peroxidation, in addition of abnormal iron distribution *(Anand and Kanwar 2000, Kaya et al 2003, and El-Demerdash 2004).* Several studies reported that the bulk of aluminum concentration increased in case of brain dysfunction with increases its risk such as increases the presence of depression, dementia and Alzheimer disease. Their findings in human and animals as the etiologic factors of neurodegenerative diseases cause loss of memory and brain functions *(Kucuk et al 2001, Abdl-Hamid and Khairy 2003 & El-Demerdash 2004).* Other studies investigated possible relations between aluminum accumulation and some health problems affecting liver, spleen, kidney injuries and on hematopoetic tissues results of increasing the risk of pathological changes which affects their function roles with increasing the ability of oxidative stress, *(Cunant et al 2000, Maria et al 2000, Cox and Dunn 2001, Fernandez - Martin et al 2001, Farina et al 2002, Vittori et al 2002),* such findings agreed with the good explanation of other studies such those by *Othman et al(2004) and Mohamed(2006).*

The aim of the present study was to study the effects of using aluminum kitchen utensils in case of cooked and stored fresh green peas for one week at different pH conditions with or without adding sodium chloride salt in comparison with using the stainless steel utensils. In addition the biological study was conducted to evaluate the overload and toxicity of aluminum contaminated diet on blood biochemical analysis and bone characteristics.

MATERIALS AND METHODS

Materials:

The edible portion of peas was obtained by splitting the pods were collected from supermarket of Ryiadh City at season of 2006 (1427 H). Aluminum concentration of samples were determined according to the method *Khan et al (1989) and Jorhem (2000).*

Kitchen utensils used were made from high quality of aluminum and stainless steel covers utensils with dimensions of 8cm diameter and 6 cm

height, were obtained from the FOOD LABORATORY OF GRILS CENTER OF KING SAUD UNIVERSITY.

Animals

Twenty male albino (Wistar strain) with an initial body weight of 160 g ± 5 g were supplied from animal house of king Khaled hospital.

Diet

The diet used was the normal balanced diet was prepared according to American Institute Of Nutrition (AIN-93) adjusted by *Reeves et al (1993).* A toxic dose of aluminum carbonate was used to prepare a contaminated diet which provided daily about 20 mg aluminum for kg body weight the dose was adjusted according to *Pagat & Barnes, (1964)*. The composition of the diet was presented in Table (1).

Table (1): composition of balanced diet g/100g

Ingredients	g/100g
Corn starch	60.95
Sucrose	10.00
Corn oil	5.00
Casein	14.00
Fiber	5.00
Salt mixture (AIN-93)	3.50
Vitamin mixture (AIN-93)	1.00
L Cystine	0.30
Choline chloride	0.25

Methods:

Cooking method was done using the two tested metals utensils (aluminum and stainless steel). Constant volumes of solutions(100 ml) at pH's 4.5, 7 and 9 were added to 20g fresh peas, and then boiled for 20 minwith or without 0.3g NaCl/20g fresh peas. The cooked samples were divided into two portions, the first one was analyzed as cooked samples, and the second portion was stored at 4 º C ± 1 º C for 7 days.

The aluminum concentrations (μg/g) were determined in the dry ash of the cooked and stored samples as described by *Khan et al (1989)* followed by determination of the aluminum level using Atomic Absorption Spectrometry technique as described by *Jorhem (2000).*

Biological experiments:

Throughout the study, a total number of twenty healthy male albino rats Wistar strain were subjected to experimentation. All rats were offered the balanced diet for 4 days for adaptation. Rats were classified into two groups, the first fed on the normal balanced diet while the other fed on the aluminum contaminated diet. Rats were randomly housed individually with constant environments in controlled stainless steel cages, temperature 25±5º C, humidity 50%±10% and light/dark cycle 12/12hrs. The experimental period was 12 weeks, at the end of experiment, the rats were scarified under effect of diethyl ether anesthesia after 12 hrs fasting, then blood samples were taken from hepatic portal vein and immediately used for hematological

procedures for counting blood cells red blood cells (RBCs), white blood cells (WBCs), platelets, and counting of RBC_s absolute constants as described by *Dacie and Lewis (1984).* The values of the following constants were calculated; mean corpuscular volume (MCV) and volume index (VI) in relation to cells size, while mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC) and saturation index (SI) in relation to hemoglobin concentration. Hemoglobin concentration was measured as described by *Wintrobe (1965)* and % hematocrit was analyzed as described by *Dacie & Lewis (1984).*

Biological measurements:

Serum and plasma were used for the biochemical measurements using kits of serum iron (*Edward 2003* and serum concentration of aluminum *(Jorhem 2000).* Calcium level was detemined as shown by *Walker (1987)*. Enzyme activity of RBCs super oxide dismutase (SOD) was done as described by *Winterbourn et al (1975),* and plasma malondialdehyde (MDA) was measured as described by the method of *Draper & Hadly (1990).* Bone characteristics; weight, volume and density were measured as described by *Andersen & Reimert (1986).* In addition, bone calcium and aluminum were determined as shown by *Khan et al (1989) and Jorhem (2000).*

Statistical analysis:

All data were subjected to significance analysis by using analysis of variance, one way classification and least significant difference as factorial experimental design according to *Snedecor & Cochran (1967).*

RESULTS AND DISCUSSION

Cooking evaluation:

Figure (1) represents the aluminum contents of tested pea's samples after being cooked and stored at different pH values with or without adding sodium chloride in case of using aluminum and stainless steel utensils. It was clear that the acidic medium (pH 4.5) and storage for 7 days as well as the presence of sodium chloride were found to increase significantly the leachability of aluminum from their utensils as shown in the progress increment in the aluminum content of the cooked and stored peas samples. The percentages of increments in cooked samples in acidic medium with or without adding sodium chloride were 14.45% and 11.5% respectively. Moreover, the percentages of increments in stored samples at pH 4.5 in case of adding sodium chloride or not were 26.9% and 18.7% respectively. In general, the storage condition at different pH values (4.5, 7.0, and 9.0) showed a marked elevation in aluminum contents of the tested samples, which was not affected in case of using stainless steel either with or without adding sodium chloride. Particular attention in this study focused on the percentages of aluminum leaching from aluminum utensils used in case of different cooking conditions, and the contaminated risks that result from exposure to its administration biologically.

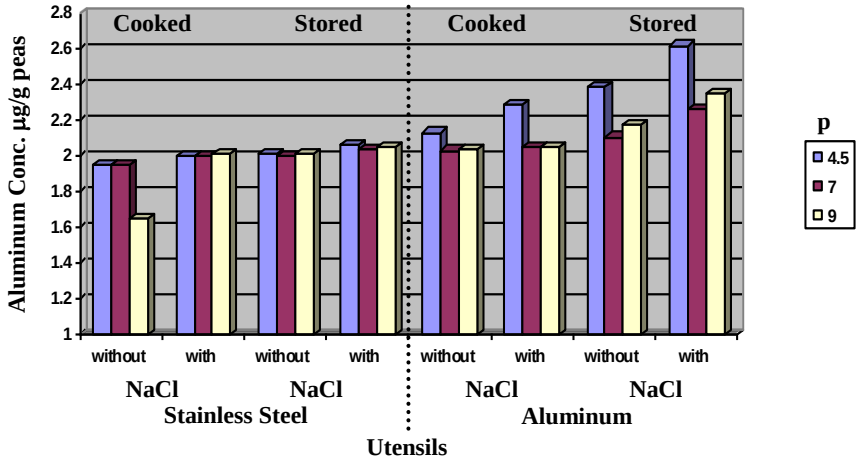

Fig. (1): Aluminum concentration of cooked and stored samples at different pH values with and without sodium chloride in case of using stainless steel and aluminum utensils

Aluminum concentrations which statistically increased in cooked samples or storage pea's samples when using aluminum utensils especially concerning aluminum contents of different foods. Many investigators had been discussed the effects of cooking the acidic foods in aluminum pots and its aluminum contents. There was a statistically significant relation between aluminum leaching and certain factors that affected the accumulation amount of aluminum in foods when cooked, processed and stored in aluminum pans or enameled and non stick pots. Such factors include the presence of organic acids as citric acid and oxalic acid which are naturally present in different foods or being added throughout the cooking process such as acetic acid or others. These increased the solubilization of aluminum from pans and foil especially with elongation the duration of storage and the used temperature *(Diab 2005 and Mohamed 2006)*.

Others explained the mechanism of leaching aluminum from aluminum cooking utensils as a result of the effects of pH and adding sodium chloride or the fluoride which is present naturally in some foods and beverages, aluminum leaching can be expressed by the following mechanism. Aluminum is oxidized by the action of oxygen through cooking processes and the heat producing Al_2O_3 which ionizes forming Al^{+3}. This legend with the organic acids forming more stable complex compounds. The corrosion of aluminum in aqueous media may be enhanced by halide ions. Others reported that aluminum leaching from aluminum utensils was due to the temperature and the duration time used. Their results demonstrated that the increments of aluminum leachability were the greatest as the most important aluminum exposure source for individuals *(Neelam et al 2000, Abdel Hamid and Khairy 2003, Scancar et al 2004& Diab 2005).*

Biochemical evaluation:

The results presented in Table (2) show the numerical counts of circulating blood cellular fractions RBC_s, WBC_s and platelets of rats fed on contaminated diet by aluminum salt dose in comparison with the control group fed on normal balanced diet. It was clear that cells count affected statistically significant with the presence of aluminum contaminations, the percentage of decrements reached 17.16% and 13.2% for erythrocytes and leukocytes, respectively as compared to their numerical controls, while the blood platelets which appear as small bodies with principle function at their role in blood coagulation was affected significantly everless the hepatic cells were affected the decrement being 6.65% in comparison with the value of rata fed normal diet, the decrement as response to adrenaline secretion due to the toxicity of aluminum overload(Jeffery et al 1996). The feeding on contaminated diet resulted in toxic alteration in the hematological cell characteristics and increases the hazard of overload aluminum which lost their nuclei and thus lead to inactivating biological mechanisms resulting in inhibition of hematopoetic function role and / or increasing the oxidative damage in erythrocytes and leukocytes as shown in their constant values.

Tables (2): The numerical counts of blood cellular fractions

Counts of / Group of rats fed on	RBC's 10^6 cumm	WBC's 10^3 cumm	platelets 10^3 cumm.
Normal diet (control)	5.01 ± 0.06^a	7.53 ± 0.12^a	348.17 ± 2.99^a
Contaminated diet	4.15 ± 0.40^b	6.53 ± 0.15^b	325.00 ± 2.61^b
L.S.D < 0.05	0.141	0.139	3.506

Values are means ± SD of three replicates/ rat, 10 rats in each group
There is significant difference of P > 0.05 between means have different letter at the same column.
RBC'S= Red blood cells WBC'S=White blood cells

Table (3) tabulated the RBC_s constants relating to either size or to hemoglobin content of rats fed on contaminated diet by aluminum salt dose in comparison with the control group fed on normal balanced diet. From mean values of MCV, it was observed that there was a significant decrement being (26.89%) in case of the presence of aluminum contamination. It was clear that values of VI as the relative constant were also affected; it recorded 0.840 ± 0.04 v.s. 1.00 ± 0.014 of the control. The values of MCH and MCHC as absolute constants in case of a aluminum contaminations were significantly decreased and the values were being 23.20 ± 0.93 Pg and 32.67 ± 0.72% v.s. 28.60 ± 0.34 Pg and 33.92 ± 0.31%, respectively as compared to their corresponding controls. The values of SI as relative constant were 0.964 ± 0.02 in case of rat group fed on contaminated diet against 1.00 ± 0.01 for the group fed on the normal diet (control). From the clinical standpoint, the determination of MCV over determination of VI as an expression of the mean size of red blood cells which were important for more comprehensive understanding of the effects of overload aluminum toxicity involved

physiologically status. Moreover, values of the means ± SD of MCV and MCHC in conjunction give an information concerning the abnormally changes such as anemia, while the indices added a lot to know about the state of the case such as giving inestimable information concerning the anemia that result from the toxic aluminum administration dose. These results had good relationship with those of the present study data of hemoglobin, hematocritc and iron deficiency and other factors that appeared as main role in anemic case results from over load of heavy metals as minerals toxicity in general including aluminum that affects the erythropoietin *(Fernandez-Martin et al 2001, Metwally et al 2002, Farina et al 2002, Vittori et al 2002).*

Table (3): RBC's constants relating to size and to hemoglobin content.

RBC's indices / Group of rats fed on	MCV Cu	VI	MCH Pg	MCHC %	SI
Normal diet (control)	84.33 ± 1.21[a]	1.00 ± 0.014[a]	28.60 ± 0.34[a]	33.92 ± 0.31[a]	1.00 ± 0.01[a]
Contaminated diet	71.01 ± 1.40[b]	0.840 ± 0.04[b]	23.20 ± 0.93[b]	32.67 ± 0.72[b]	0.964 ± 0.02[b]
L.S.D. < 0.05	0.358	0.013	0.813	0.665	0.019

Values are means ± SD of three replicates / rat, 10 rats each group
There is significant difference at P > 0.05 between means have different latter of the same column.
MCV=mean corpuscular volume VI=volume index
MCH=mean corpuscular hemoglobin
MCHC=mean corpuscle haemoglobulin concentration

From the results presented in Table (4) it could be concluded that overload aluminum leached from aluminum utensils specially in acidic stored foods as shown in Fig (1) had a high toxic effects which reduced the hematopoetic tissue and induced microcytic anemia as shown in values red of cell constant presented in Table (4) the associated with reduction in the hemoglobin content and the percentage of hematocrit. The decrements were being 30%, 8.36%, respectively as compared to the control. The results reflected the risk effects of overload aluminum which its level was about 0.21 ± 0.12 μg/l and accompanied by decreasing the levels of iron and calcium in the serum by 6.35%, 9.98%, respectively, as compared to the control. Aluminum overload induced lipid peroxidation of RBC_s through the inhibition of RBC_s enzyme activities and affected the oxidative stress status of rats exposed to aluminum oral dose. Many investigators studied the risks of gastrointestinal long term aluminum exposure which result in increase osmotic fragility and affected deformability of erythrocytes, *(Jain et al 1995, and Vittori et al 2002).* However, such effects lead to microcytic anemia, the etiology of it was considered to decrease the level of hemoglobin by affecting it's biosynthesis in friend erythroleukemia cells and in bone marrow cells *(Abero et al 1990). Meanwhile, Markowitz et al (1990)* investigated the hematological parameters especially the MCV which influenced by the iron level, iron deficiency was known as a results of aluminum retention and

toxicity due to disturbance in heme biosynthesis in case of heavy metal toxications through its antagonism of iron and its interference with several enzymatic steps in the heme pathway that leads to decrease production of hemoglobin combined with red cell counts shown clinically as anemia, which is mild or moderate as shown from Table (4) the percentage level of Hct (39.64 ± 0.60 % v.s 43.26 ± 0.15%).

Table 4: Biochemical measurements in blood (B), serum (S), plasma (P) and erythrocytes (RBCs)

Measurements / Group of rats fed on	B.HB g/dl	B.Hct %	S.Iron µg/dl	S. Calcium µg/dl	S. Aluminum µg/dl	P. MDA nmol / ml	RBC SOD u/ml
Normal diet	14.55 ± 0.10[a]	43.26 ± 0.15[a]	81.97 ± 0.37[a]	6.01 ± 0.80[a]	0.174 ± 0.01[a]	1.64 ± 0.16[a]	90.36 ± 3.31[a]
Contaminated diet	10.16 ± 0.29[b]	39.64 ± 0.60 [b]	76.76 ± 0.76[b]	5.41 ± 0.36 [b]	0.21 ± 0.12 [b]	5.76 ± 0.24[b]	72.83 ± 3.11[b]
L.S.D P < 0.05	0.15	0.43	0.63	0.39	0.026	0.28	4.15

Values are means ± SD of three replicates / rat , 10 rats each group
There is significant difference at P < 0.05 between means have different latter of the same column.
HB=hemoglobin Hct= hematocrit MDA= malondialdehyde
SOD= superoxide dismutase

The amount of hemoglobin affected strongly by the poor status as a condition of overload toxic elements, which results a hemoglobin deficiency in association with erythrocytes immaturation factor which affected hemoglobin functions. With respects to hematocrit, the volume of packed erythrocyte which is affected significantly by anemia in general; however the hematocrit alone does not disclose the nature of the anemia but failing its percentage level revealed the existing state.

The hematocrit value is still necessary to give an all over view on the determination of erythrocyte constants that is affected significantly by the level of hemoglobin in association with iron deficiency, *(Jeffery et al 1996, Farina et al 2002)* or in general is effected by heavy metals as shown by, *Mohamed (2006).* Lipid peroxidation is one of the main manifestations of oxidative damage and has been found to play an important role in the mechanism risks of toxicity and many chronic diseases through the alteration of physiological and biological characteristics of the biological system. It was clear from the data given in Table (4) that oral dose of aluminum which was present in rats diet inhibited the enzyme activity against lipid peroxidation process as shown in the enzyme activity level of erythrocyte superoxide dismutase (SOD) which was decreased to reach 72.83 ± 3.11 u/ml against it's normal value of the control group (90.36 ± 3.31 u/ml). Decreasing erythrocyte SOD enzyme activity level go hand in hand with the significant increment of Malondialdhyde (MDA) to more than three folds in case of the oxidative damage elevator of the aluminum overload, *(El-Demerdash 2004, Yousef 2004, Mohamed 2006).*

The results presented in Table (5) show the effects of consuming the aluminum carbonate orally on right tibia characteristics as the weight, volume and density as well as the bone contents of aluminum and calcium concentrations. It is clear that values of both weight and volume were not significantly affected while the density value showed a statistical significance increment by about 7%, this increment was combined with a significant accumulation of aluminum in bone more than 5 fold, while there was no significant effect in the calcium content of bone (right tibia) (7.94 ± 0.23 μg/g of the rats fed on contaminated diet against 8.13 ± 0.36 μg/g for the control). Aluminum toxicity resulted in a significant increment in bone density as aluminum ions overload were retained within cartilage by forces of electrostatics bonding which accompanied by trabecular networking that increased bone density in the surrounding areas in case of highest aluminum concentration, *(Chen et al 1997 and Mohamed 2006).*

Table 5: Bone characteristics of the right tibias

Measurements / Group of rats fed on	weight g	volume cm^3	Density g/cm^3	Aluminum μg/g	Calcium μg/g
normal diet	0.26 ± 0.05[a]	0.475 ± 0.08[a]	0.549 ± 0.06[a]	0.11 ± 0.02[a]	8.13 ± 0.36[a]
Contaminated diet	0.279 ± 0.14[b]	0.474 ± 0.11[b]	0.288 ± 0.12[b]	0.616 ± 0.17[b]	7.94 ± 0.23[b]
L.S.D P < 0.05	N.S	N.S	0.029	0.0481	N.S

Values are means ± SD of three replicates / rat, 10 rats each group
There is significant difference at P < 0.05 between means have different latter of the same column.

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تقييم عملية الطهى باستخدام أواني المطبخ الألومنيوم وعلاقته ببعض المخاطر البيولوجية متمثلة في الجرذان

أمل الحسين

قسم علوم الأغذية والتغذية -كلية علوم الأغذية والزراعة - جامعة الملك سعود – الرياض

درس تأثير الطهى والتخزين لمدة ٧ أيام لعينات البسلة الخضراء الطازجة في ثلاثة مستويات مختلفة من درجة تركيز أيون الأيدروجين pH باستخدام أواني المطبخ الألومنيوم عند إضافة أو عدم إضافة ملح الطعام مقارنة باستخدام أواني الأستنلس ستيل. تم إجراء التقييم البيولوجي لتأثير تناول الطعام الملوث بالألومنيوم على قياسات خلايا الدم وثوابتها بالإضافة إلى تقدير بعض التغيرات البيوكيمائية بالدم مثل مستوى الهيموجلوبين ونسبة الهيماتوكريت ومستويات السيرم من الحديد والكالسيوم والألومنيوم، بالإضافة إلى تقييم حالة الضغط التأكسدي والمواصفات القياسية لعظمة الفخذ. أوضحت النتائج أن استخدام أواني الألومنيوم في الطهى في الوسط الحامضي أدى إلى زيادة معنوية في محتوى عينات البسلة المطهية والمخزنة في الألومنيوم إلى حوالي ١١,٥% ، ١٨,٧% على الترتيب ، بينما أدى إضافة ملح الطعام إلى زيادة مفرطة حيث بلغت نسب الزيادة ١٤,٤٥% ، ٢٦,٩% بنفس الترتيب. ارتفعت مستويات الألومنيوم لدرجة محسوسة في العينات المطهية المخزنة سواء في وجود أو عدم وجود ملح الطعام في كل من الوسط المتعادل والقلوي ، بينما تراوحت الزيادة ما بين ٤ – ٥% في العينات المطهية فقط عند إضافة أوعدم إضافة ملح الطعام . وقد ادى تراكم الألومنيوم، إلى نقص بعض قياسات خلايا الدم وثوابتها وذلك نتيجة التأثير السام للتلوث بالألومنيوم لذلك حدث انخفاض في كل من الهموجلوبين والهماتوكريت بمقدار ٣٠% ، ٨,٣٦ % على الترتيب مصحوباً بنقص مستويات السيرم من الحديد والكالسيوم بلغ حوالي ٦,٣٥% ، ١٨,١% ، في المقابل ارتفع مستوى الألومنيوم في السيرم بمقدار ٢١% مما أدى إلى انخفاض معنوى في الميكانيكية المضادة للأكسدة فأنعكس ذلك على ارتفاع مستوى البلازما من Malondialdehyde إلى ٥,٧٦ ± ٠,٢٤ نانومول/لتر مقابل ١,٦٤ ± ٠,١ نانومول/لتر للمجموعة الضابطة بالتزامل مع انخفاض النشاط الإنزيمي Superoxide dismutase بكرات الدم الحمراء بلغ ١٩,٤% . تدهورت مواصفات وقياسات عظمة الفخذ معنوياً نتيجة تراكم الألومنيوم الذي انعكس على زيادة كثافتها رغم فقد مكوناتها من الكالسيوم عند نهاية مدة التجربة (١٢ أسبوع). لذلك يمكن القول أن هجرةعنصر الألومنيوم من الأواني أثناء عمليات الطهى والذي يزداد تأثيره الضار مع الأطعمة الحامضة يؤدي إلى زيادة تراكمه بالجسم مسببا خفض قياسات الدم وتقلص دورها الوظيفي بالإضافة إلى تلك التغيرات السيئة على حالة الضغط التأكسدي المصاحب لتدهور مكونات العظام.

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