Therapeutic Potential of Pomegranate and *Annona muricata Linn.* Fruit Juices in Aluminum Chloride-Induced Neurologic Dysfunction: Focus on Oxidative Stress

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Abstract

Pomegranate (*Punica granatum*) and *Annona Muricata* linn fruit juices are rich in bioactive compounds with potent antioxidant and neuroprotective properties. Therefore, this Study was conducted to investigate the antioxidant activity of pomegranate and *Annona Muricata* fruit pulp juice on aluminum chloride induced rat neurologic disease model. Fifty adult male rats were randomly divided into five equal groups (n = 10 each). The first group (negative control) was fed on a basal diet. The other groups were injected with aluminum chloride ($AlCl_3$) to induce oxidative stress (OS), the second group (positive control) received basal diet. The other groups (3 : 5) were fed on a basal diet and given orally pomegranate juice (PJ), *Annona Muricata* juice (AMJ) and mixture of PJ and AMJ (1:1 v/v) at (1 ml/100 g body weight), respectively. The results demonstrated that administration of PJ and AMJ significantly ($P<0.05$) improved body weight status as compared to the positive control group. Liver functions and oxidative stress biomarkers including malondialdehyde (MDA), superoxide dismutase (SOD), glutathione peroxidase (GPX), and total antioxidant capacity (TAC) were significantly ($P<0.05$) ameliorated in the treated groups. These findings support the potential therapeutic application of both Pomegranate and *Annona Muricata* fruit juices through their antioxidant effects.

Keywords: Pomegranate, *Annona Muricata*, Aluminum chloride, Antioxidant, Oxidative stress, Liver function, Body weight, Rats.

INTRODUCTION

Continuous exposure to heavy metals has multiple negative impacts on human health. One of the widely used heavy metals is Aluminum, which is used in foils, utensils (**Kinawy, 2019)**, food additives, beverages, toothpaste, paper making (**Praveenkumar *et al*., 2019)**. Aluminum reduced the activities of the antioxidant enzymes and upraise lipid peroxidation in rabbit brain and rat plasma **(Newairy et al., 2009).**

Fresh fruits and vegetables are considered very important in improving human health due to their high content of useful phytochemicals and other micronutrients **(Opara and Al-Ani, 2010).** The importance of these compounds is attributed to their antioxidant activity which can scavenge the free radicals that cause oxidative stress which can lead to cellular damage and many degenerative disorders **(Boyer and Leo, 2004).**

Pomegranate *(Punica granatum* L.*)* belongs to the family Punicaceae and has gained multi-functionality and great nutritional benefit in the human diet. It is now grown globally in many geographical regions, satisfying the nutritional and medicinal needs of populations of various countries **(Holland *et al.,* 2009).** Commercial orchards of diverse pomegranate cultivars are grown in countries such as Iran, India, Egypt, China, Israel, Tunisia, Syria, Lebanon, Turkey, Greece, Cyprus, Italy, France, Spain, Chile, Portugal, USA, Oman and most recently in South Africa **(Al-Said *et al.,* 2009 and Fawole *et al.,* 2011).**

Pomegranate fruit has been recognized as some fruit rich in bioactive molecules. It has been extensively used in traditional medicine, due to containing the highest amount of polyphenols such as anthocyanins, tannins, flavonoids, phenolic acids, and lignans (**Huang *et al*., 2021)**. The nutraceuticals are contained both in the edible part of the fruit (pulp and seeds) and in the peel, leaves, flowers, and hull, the processing by-products of the plant (**Wang *et al*., 2017 and Wang *et***

***al.,* 2016)**. The edible part of the fruit contains considerable amounts of acids, sugars, polyphenol and important minerals **(Jalikop, 2007 and Opara *et al.,* 2009).**

Due to an increasing consumer interest and awareness on the health benefits of the fruit juice, numerous studies have reported the content and composition of major health and medicinal components in various pomegranate fruit cultivars **(Shwartz *et al.,* 2009, Elfalleh *et al.,* 2011).** The beneficial health qualities of pomegranate are attributed to the exceptionally high antioxidant capacity that strongly correlates with high content and unique composition of phenolic compounds **(Fischer *et al.,* 2011, He *et al.,* 2011).**

Annona muricata Linn. (Annonaceae) fruit is commonly known as "Soursop" or "Graviola" It is a terrestrial deciduous tree and produces an edible fruit. This species of Annona has been grouped with the "cherimoya" plants of the Annonaceae family. Although this Annonacea is native to America, it has now become established in many tropical countries (**Adewole *et al*., 2008 and Jacobo *et al*., 2016**).

Along with the synergistic effects of polyphenols, flavonoids, alkaloids and lipophilic antioxidant compounds. Also, it is well known that the species of the Annonaceae family besides producing polyphenols, flavonoids and alkaloids, produces large quantities of acetogenins, a secondary metabolite derived from long-chain fatty acids (**León *et al*., 2015)** that have been found to have anticancer, anti-inflammatory, antibacterial and antiviral properties (**Pieme *et al*., 2014)**. The phenolic compounds in A. muricata, such as quercetin and gallic acid, are reported to be the compounds most responsible for the antioxidant capacity of the plant **(Biba *et al*., 2014).**

Recently, natural flavonoid compounds of plant origin have become increasingly popular due to their excellent pharmacological properties (**Ishfaq *et al*., 2019)**. Polyphenols, as natural products found in large quantities in vegetables and fruits, can modulate antioxidant factors, scavenge free oxygen and nitrogen radicals, as well as control the formation of cellular redox transcription factors and maintain

proper metabolic functions (**Chedea *et al*., 2019)**. Polyphenols may also influence intercellular signaling, gene regulation, inflammatory enzyme activity, and receptor sensitivity (**Fathy *et al*., 2021)**. Their beneficial effects largely depend on their bioavailability in the target tissue, as well as cellular distribution and metabolism after absorption **Fraga and Oteiza, (2011)**.

Aim of the Study: This Study was conducted to investigate the antioxidant effects of pomegranate and *annona muricata linn* fruit juices on aluminum chloride induced rat neurologic disease model.

Materials and Methods

Materials:

Plants: Fully ripe fresh Pomegranate and *Annona Muricata linn* were obtained from the local market and were identified at the Agriculture Research Centre. Fifty-three adult male rats (Strain), weighing 190±10g, were obtained from the Laboratory Animal Colony, Helwan, Egypt. Casein, cellulose, choline chloride, D-L methionine, vitamins and minerals, constituents were purchased from El-Gomhoriya Pharmaceutical Company, Cairo, Egypt. Starch, soybean oil and sucrose were obtained from the local market. Chemicals and Kits for biochemical analysis were purchased from the Gamma Trade Company for Pharmaceutical and Chemical, Dokki, Egypt.

Methods:

1. **The taxonomic classification of:**

A. pomegranate: Kingdom: Plantae; **Division**: Magnoliophyta; **Class**: Magnoliopsida; **Order**: Myrtales; **Family:** Punicaceae; **Genus**: Punica; Species: P. granatum or P. protopunica

B. *Annona Muricata* linn**: Kingdom**: Plantae; **Division**: Magnoliophyta; **Class**: Magnoliopsida; **Order:** Magnoliales; **Family**: Annonaceae; **Genus**: Annona L.; **Species**: *Annona Muricata L.*

2. **Chemical composition:** The Chemical composition and the active ingredients of the tested fruits were determined according to the official methods **(AOAC, 2019).** Total phenolic and total flavonoid content were expressed as mg of gallic acid equivalent (GAE) per g of sample determined according to the procedure of **(Zilic *et al*., 2012)**. The total flavonoid content of pomegranate and *Annona muricata* (soursop) juices was determined by the method of **Kim *et al.,* (2003).** The DPPH radical scavenging activity of these juices was assessed as described by **Blois, (1958).**
3. **Preparation of Basal Diet:** The basal diet (AIN-93M) consisted of protein (14%), corn oil (**4**%), minerals mixture (3.5%), vitamins mixture (1%), fiber (5%), sucrose (10%), choline chloride (0.25%) and the remainder was corn starch up to 100%. These constituents were thoroughly mixed and formulated according to **Reeves *et al.,* (1993).**
4. **Preparation of Fruits juice**: One kilogram of pomegranate seeds and/or Annona pulp fruit were blended, filtered through a double layer of gauze to obtain fruit juices and kept in a refrigerator till use.
5. **Induction of Oxidative Stress:** Aluminum chloride was dissolved in water and administered to rats via the intraperitoneal (i.p.) route at a dose of 4.2 mg/kg body weight, with the animals lightly anesthetized using ether. Aluminum chloride was given daily for 28 days, following the protocol of **Bitra *et al.,* (2014).** To confirm the induction of oxidative stress, random blood samples were collected from three rats, and serum levels of MDA, SOD, GPX, and TAC were measured.
   - **The Biological study:** All rats were housed at a room temperature of 25 ± 2 °C, relative humidity of 50–55% and 12 hr. light/12 hr. dark cycles in the animal house of the Faculty of Home Economics, Cairo, Egypt for one week for acclimatization. All animals were randomly divided into five equal groups (n=10 rats of each) as follows: **Group 1**: Normal rats were fed on the basal diet and were kept as (negative control group). The other

groups were injected with aluminum chloride ($Alcl_3$) to induce oxidative stress. **Group 2:** Rats with induced oxidative stress were fed on the basal diet and were kept as (positive control group). **Group 3:** Rats with induced oxidative stress were fed on the basal diet and given orally 1 ml/ 100-g body weight of Pomegranate juice. **Group 4**: Rats with induced oxidative stress were fed on the basal diet and given orally 1 ml/ 100-g body weight of *Annona Muricata* juice. **Group 5**: Rats with induced oxidative stress were fed on the basal diet and given orally a mixture of PJ and AMJ (1:1 v/v) at (1 ml/100 g body weight).

- Feed intake (**FI)** was calculated every day. Body weight gain percent **(BWG%)** and feed efficiency ratio **(FER)** at the end of the experimental period (12 weeks) were determined according to **Chapman *et al*., (1959)** using the following equations:
  - **BWG % =** ((final body weight – initial body weight)/Initial body weight) × 100.
  - **FER** = Weight gain (g)/ Feed intake (g).

At the end of the experimental period, rats were fasted for 12 hours then sacrificed. Blood samples were collected from the portal vein into dry clean centrifuge tubes. Serum was separated by centrifuge at 3000 r.p.m for 15 min and serum aliquots were stored at –20ºC until use for biochemical analysis.

6. **Biochemical analysis:** All of the biochemical assays were carried out at the National Research Center, Cairo, Egypt. Serum was analyzed to determine the following parameters:

Serum Total antioxidant capacity (TAC) was determined according to **(Liu Z. and Liu H. (2014),** MDA was determined according to **(Draper and Hadley, 1990),** SOD was determined according to **(Sun *et al.,* 1988).** Glutathione peroxidase (GPX) activity was measured as described by **Flohé and Günzler, 1984).** Serum Aspartate amino transferase (AST) and alanine amino transferase (ALT) were determined according to **(Bergmeyer *et al*.,**

1978), serum alkaline phosphates (ALP) was determined according to (**Belfield and Goldberg, 1971)**.

7. **Statistical analysis:**

The obtained results were expressed as Mean ± SE. Data were evaluated statistically with computerized SPSS package program (SPSS 22.00 software for Windows) using one-way analysis of variance (ANOVA). A significant difference among means was estimated at $P<0.05$ (**Sendcor and Cochran, 1979).**

Results and Discussions

Table (1) presents the chemical composition and nutritional profile of pomegranate juice and *Annona muricata* (soursop) juice. The moisture content was high in both juices, reaching (85.55 g/100 mL) in pomegranate and (81 g/100 mL) in *Annona muricata*, reflecting their high water content. Protein and fat contents were relatively low in both juices, with *Annona muricata* showing higher values (1.02 g/100 mL) protein and (0.31 g/100 mL) fat compared to pomegranate (0.14 g/100 mL) protein and (0.04 g/100 mL) fat. Ash content was also slightly higher in *Annona muricata* (0.50 g/100 mL) than in pomegranate (0.33 g/100 mL).

Dietary fiber was measured at (2.79 g/100 mL) in pomegranate juice and (3.28 g/100 mL) in *Annona muricata* juice, while carbohydrate content was higher in *Annona muricata* (16.8 g/100 mL) compared to pomegranate (11.15 g/100 mL).

Both juices contained significant amounts of bioactive compounds. Total phenolic content was highest in pomegranate (780 mg GAE/100 mL) while *Annona muricata* contained (186 mg GAE/100 mL). Total flavonoid content was (12.1 mg CE/100 mL) in pomegranate, whereas *Annona muricata* had (87.17 mg

quercetin/100g). The DPPH radical scavenging activity, which reflects antioxidant potential, was (47.38%) for pomegranate and (32.60%) for *Annona muricata*. Vitamin C content was higher in *Annona muricata* (29.6 mg/100 mL) than in pomegranate (6.09 mg/100 mL), further supporting its nutritional value and antioxidant activity.

These results highlight the nutritional and antioxidant potential of both pomegranate and *Annona muricata* juices, supporting their inclusion as health-promoting beverages in the diet.

Table (1): Chemical composition of Pomegranate and *Annona Muricata* fruit juices

Component	Pomegranate	*Annona Muricata*
Moisture	85.55 (g/100ml)	81 (g/100ml)
Protein	0.14 (g/100ml)	1.02 (g/100ml)
Fat	0.04 (g/100ml)	0.31 (g/100ml)
Ash	0.33 (g/100ml)	0.50 (g/100ml)
Dietary fiber	2.79 (g/100ml)	3.28 (g/100ml)
Carbohydrate	11.15 (g/100ml)	16.8 (g/100ml)
Total phenolic content	780 (mg GAE/100 mL)	186 (mg GAE/100 mL)
Total flavonoid content	12.1 (mg CE/100 mL)	87.17 (mg quercetin/100g)

DPPH radical scavenging activity	47.38 %	32.60 %
Vitamin C	6.09 (mg/100 mL)	2٩.6 (mg/100 mL)

Results recorded in **Table (2)** present the effects of Pomegranate juice, *Annona Muricata* juice, and their mixture on body weight status on rats with induced neurologic disease with aluminum chloride. There were no significant differences in the initial body weight among all experimental groups, with values ranging from (200.67 ± 1.04 g to 202.90 ± 1.05 g). All groups indicate statistical homogeneity at the beginning of the experiment. This confirms the reliability of the comparative outcomes observed post-treatment.

Feed intake was slightly higher in the treated groups compared to the control groups, with the mixture group consuming the most (20.50 g/day/rat), followed by the *Annona Muricata* group (20.20 g) and the pomegranate group (20.00 g). The results suggest a mild improvement in appetite or feed consumption in the treated groups.

Significant ($P<0.5$) increases in the final body weight were observed in the treated groups compared to both control groups (positive and negative). The mixture group exhibited the highest final weight (261.26 ± 1.12 g), followed by the *Annona Muricata* group (255.00 ± 1.14 g), and the pomegranate group (253.63 ± 1.40 g). In contrast, the control groups had lower values (approximately 241–242 g). The mixture group demonstrated the highest percentage increase in BWG% (28.92 ± 0.65%), followed by the *Annona Muricata* (26.08 ± 0.42%) and pomegranate (25.00 ± 0.45%) groups. These increases were significantly higher than those observed in the control groups (approximately 20%), indicating a positive impact of the treatments on growth performance.

Regarding FER values were significantly elevated at ($P< 0.05$) in all treated groups compared to controls, with the mixture group

achieving the highest efficiency (0.064 ± 0.01), followed by *Annona Muricata* (0.058 ± 0.05) and pomegranate (0.056 ± 0.01). The control groups exhibited the lowest FER values (0.047–0.048), indicating poor nutrient utilization in the presence of aluminum chloride without treatment. Higher FER in the treated groups suggests enhanced metabolic efficiency and nutrient conversion.

The obtained results indicate that both pomegranate juice and *Annona Muricata* juice exert a beneficial effect on growth parameters in aluminum chloride-induced rats. Their mixture produced the most pronounced improvements, suggesting a potential synergistic effect.

The mixture of both juices exhibits the highest BWG (28.92%) and FER (0.064), indicating a synergistic effect between their bioactive compounds. These findings are supported by previous studies. **Abdel Moneim, (2012)** administered pomegranate peel at 300 mg/kg/day to aluminum-exposed rats and observed improved body weight and reduced oxidative stress, consistent with the protective effects seen in the present study. Furthermore, pomegranate peel given at 50 mg/kg and reported improved physiological performance in rats (**Harakeh *et al.,* 2020)**.

Similarly, **Shukry *et al.,* (2020)** administered *Annona muricata* extract at 200 mg/kg/day to rats, resulting in enhanced BWG and FER. The treated rats showed a noticeable increase in FI and improved physiological performance compared to the control group, demonstrating the beneficial effects of *A. muricata* on growth and nutritional utilization, aligning with the obtained results in the present study. Consistently, **El-Dashlouty *et al.,* (2020)** found that (*Annona muricata*) fruit parts at 5% and 7.5%, resulting in enhanced BWG, FI, and FER. Collectively, these results corroborate the outcomes of the present study.

Table (3) presents the results that clearly highlight the effect of Pomegranate juice and *Annona Muricata* fruit juice, on liver function markers in rats subjected to aluminum chloride-induced oxidative

stress. The assessed parameters include AST, ALT, and ALP. Elevated levels of these enzymes typically reflect liver cell damage or dysfunction. The positive control group, which received aluminum chloride alone, exhibited a marked elevation in AST, ALT, and ALP levels compared to the negative control group, indicating significant ($P<0.05$) hepatic damage. However, all treated groups showed a clear reduction in these enzyme levels, reflecting improved liver function. These reductions in liver enzyme levels were statistically significant ($P<0.05$), compared to the positive control group suggesting the effectiveness of these natural juices. The combination demonstrated the strongest protective effect among all treatment groups, supporting its potential as a natural antioxidant and hepatoprotective agent against chemically induced liver damage.

Table (2): The effect of Pomegranate, *Annona Muricata* fruit juices and their mixtures on body weight, FI and FER in Aluminum Chloride Induced Rat Model

Parameters / Groups		IBW (g)	FI (g/d/rat)	FBW (g)	BWG (%)	FER
-Ve Control group		200.67± 1.04[a]	19.20	241.83± 0.96[c]	20.51± 0.15[c]	0.048± 0.01[c]
+Ve Control group		201.83± 1.66[a]	19.10	242.10± 1.38[c]	19.96± 0.33[c]	0.047± 0.04[c]
Treated groups	**Pomegranate Juice**	202.90± 1.05[a]	20.00	253.63± 1.40[b]	25.00± 0.45[b]	0.056± 0.01[b]
	***Annona Muricata* Juice**	202.26± 1.59[a]	20.20	255.00± 1.14[b]	26.08± 0.42[b]	0.058± 0.05[b]

	Mixture	202.66± 1.02[a]	20.50	261.26± 1.12[a]	28.92± 0.65[a]	0.064± 0.01[a]

Data are expressed as mean ± SE
Means with different letters in each column are significantly differs at $p<0.05$

Treatment with pomegranate juice, *Annona Muricata* juice, individually reduced these enzyme activities, while the combined treatment exhibits the greatest hepatoprotective effect, indicating synergistic interactions between their bioactive compounds. These findings are supported by previous animal studies with clearly defined doses. **El-Demerdash *et al*., (2024)** administered pomegranate peel extract at 100 mg/kg/day to rats exposed to aluminum chloride, resulting in significant reductions in oxidative stress markers and liver damage. Likewise, **Elmas *et al.,* (2022)** indicated a significant reduction in oxidative stress markers and improvement in liver histopathology, demonstrating the protective effects of A. muricata leaf extract at 300 mg/kg/day on liver function. These findings support the antioxidative and hepatoprotective effects observed in the present study.

As additional supportive evidence, **Fahmy *et al.,* (2020)** conducted a clinical trial in non-alcoholic fatty liver disease patients, who consumed pomegranate peel extract at 1000 mg/day (two capsules, each containing 500 mg) for 10 weeks, which improved liver enzyme profiles. Although this clinical study used a fatty liver model rather than aluminum-induced toxicity, it further supports the hepatoprotective potential of pomegranate-derived compounds across species.

Furthermore, pomegranate peel extract at 500 mg/kg/day to rats exposed to fenpropathrin, which mitigated liver damage and improved liver enzymes **(Jebur *et al.,* 2023)**. Similarly, *Annona muricata* leaf extract at 300 and 600 mg/kg/day to male Wistar rats resulted in significant reductions in serum levels of AST, ALT, and

ALP, indicating hepatoprotective effects **(Hassan, 2025)**. These findings are consistent with the results obtained in the present study."

Table (3): The effect of Pomegranate, *Annona Muricata* fruit juices and their mixtures on liver functions in Aluminum Chloride Induced Rat Model

Parameters / Groups		AST	ALT	ALP
		(µ/L)		
-Ve Control group		37.60±1.97^{e}	55.07±1.80^{e}	74.33±2.09^{e}
+Ve Control group		76.20±2.11^{a}	110.76±2.21^{a}	122.93±1.42^{a}
Treated groups	**Pomegranate Juice**	65.53±2.17^{b}	96.60±2.51^{b}	112.53±2.60^{b}
	***Annona Muricata* Juic**	58.56±1.05^{c}	88.33±0.86^{c}	100.83±1.63^{c}
	Mixture	46.73±2.07^{d}	76.43±2.02^{d}	94.43±2.08^{d}

Data are expressed as mean ± SE

Means with different letters in each column are significantly differs at $p<0.05$

The impact of Pomegranate juice, *Annona Muricata* fruit juice, and their combination on antioxidant biomarkers in rats subjected to aluminum chloride-induced oxidative stress was recorded at table (4). The findings highlight the marked disruption in oxidative balance caused by aluminum toxicity and the significant ameliorative effects exerted by the administered fruit juices ($p < 0.05$).

Malondialdehyde, a well-recognized indicator of lipid peroxidation, was markedly elevated in the +Ve control group (10.42 ± 0.49), signifying extensive oxidative damage. This increase contrasts sharply with the –Ve control group, which recorded a much

lower level (3.36 ± 0.15). Administration of pomegranate or A. *Muricata* juices individually led to significant (P<0.05) reductions in MDA levels (7.76 ± 0.08 and 6.06 ± 0.16, respectively). However, the most pronounced effect was observed in the mixture group (5.07 ± 0.11), reflecting a stronger attenuation of lipid peroxidation. Although none of the treatments fully restored MDA levels to normal, the reductions were statistically significant, confirming their protective efficacy.

Regarding to, SOD activity was significantly (P<0.05) decreased by aluminum exposure, as evidenced by the decline in the +Ve control group (3.00 ± 0.22) compared to the –Ve control (7.02 ± 0.39). Giving rats the juice mixture resulted in a complete normalization of SOD activity (7.21 ± 0.18), exceeding the baseline value of the –Ve control. Improvements were also observed in the pomegranate and A. *Muricata* groups (4.77 ± 0.34 and 5.27 ± 0.16, respectively).

The aluminum-induced suppression of GPX, a critical antioxidant enzyme, was evident in the +Ve control group (1.32 ± 0.07) relative to the –Ve control (5.00 ± 0.24). All treatments significantly elevated GPX levels, with the mixture producing the strongest effect (3.33 ± 0.14), followed by A. *Muricata* juice (2.43 ± 0.10) and pomegranate juice (1.93 ± 0.06). These increases suggest a partial restoration of enzymatic antioxidant capacity.

Total antioxidant capacity mirrored the trends seen in enzymatic biomarkers. The +Ve control group exhibited a substantial reduction (0.96 ± 0.04), indicating weakened overall antioxidant defense. The combination treatment yielded the highest recovery (1.88 ± 0.02), approaching normal levels (2.11 ± 0.09). Meanwhile, A. *Muricata* and pomegranate juices resulted in moderate increases (1.67 ± 0.04 and 1.44 ± 0.02, respectively).

Both pomegranate and *Annona Muricata* fruit juices demonstrated protective antioxidant effects against aluminum-induced oxidative stress. Notably, the combination of the two juices

consistently produced superior outcomes across all biomarkers, indicating a synergistic enhancement of the body's antioxidant defense mechanisms. Administration of pomegranate juice, *Annona Muricata* juice, and particularly their combination significantly mitigated these effects, restoring antioxidant defenses and reducing lipid peroxidation.

These findings are supported by previous studies with clearly defined doses. **Rak-Pasikowska *et al.,* (2024)** found that pomegranate peel extract at 100 and 200 mg/kg/day to rats with metabolic syndrome, resulting in a significant decrease in MDA levels and enhancement of GPX activity, consistent with our findings. Similarly, pomegranate peel extract at 100 mg/kg/day to rats, which also led to decreased MDA, increased GPX activity, and improved total antioxidant capacity and reduced oxidative stress markers (**Hamieda *et al.,* 2024)**. In addition, **Moghadamtousi *et al.,* (2015)** reported that *Annona Muricata* leaf extract at 200 mg/kg/day, which increased SOD and GPx levels, confirming the antioxidant potential observed in the present study.

Annona muricata leaf extract at 50, 100, and 200 mg/kg/day to rats, caused a significant reduction in MDA levels and improvements in SOD and GPx activities (**Nsor *et al.,* 2024).** These results are supported also by **Menon *et al.* (2023),** who observe significant reductions in oxidative stress markers, including MDA, and improvements in liver function, highlighting the antioxidant potential of *Annona muricata* fruit pulp powder (1 and 2 g/kg body weight). Collectively, these results are also in agreement with **Jimoh *et al.* (2018),** who reported that administration of *Annona muricata* juice at 0.55–2.22 mL/kg body weight to heat-stressed rabbits significantly decreased MDA levels and improved SOD and GPx activities, further supporting the antioxidative potential of the juice. Overall, all the evidence supports the findings obtained in this study. Additional studies have confirmed that polyphenol- and acetogenin-rich fruit juices synergistically enhance antioxidant defenses and reduce lipid peroxidation in metal-induced toxicity model **(Maisto *et al.,* 2024).**

Table (4): The effect of Pomegranate, *Annona Muricata* fruit juices and their mixtures on antioxidant biomarkers in Aluminum Chloride Induced Rat Model

Parameters / Groups		MDA (nmol/mL)	SOD (µ /L)	GPX (µ/ml)	TAC (mM/L)
-Ve Control group		3.36±0.15^{e}	7.02±0.39^{a}	5.00±0.24^{a}	2.11±0.09^{a}
+Ve Control group		10.42±0.49^{a}	3.00±0.22^{e}	1.32±0.07^{e}	0.96±0.04^{e}
Treated groups	Pomegranate Juice	7.76±0.08^{b}	4.77±0.34^{b}	1.93±0.06^{c}	1.44±0.02^{b}
	Annona Muricata Juic	6.06±0.16^{c}	5.27±0.16^{b}	2.43±0.10^{b}	1.67±0.04^{b}
	Mixture	5.07±0.11^{d}	7.21±0.18^{a}	3.33±0.14^{b}	1.88±0.02^{b}

Data are expressed as mean ± SE

Means with different letters in each column are significantly differs at $p<0.05$

Finally, these obtained results support the potential therapeutic application of both Pomegranate and *Annona Muricata* fruit juices against aluminum toxicity that caused oxidative stress through their antioxidant effects. For neurologic patients experiencing oxidative stress, a comprehensive and integrated management approach is strongly recommended, beginning with the daily incorporation of pure, unsweetened pomegranate juice and *Annona muricata* juice to leverage their potent, evidence-based antioxidant properties, though

the latter should be used under medical supervision due to its bioactive compounds.

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الإمكانات العلاجية لعصير الرمان و القشطة في الخلل العصبي الناجم عن كلوريد الألومنيوم : التركيز على الإجهاد التأكسدي

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الملخص العربي

عصير فاكهة الرمان والقشطة غنيان بالمركبات النشطة حيوياً ذات الخصائص المضادة للأكسدة والمحفزة للحماية العصبية. وبناءً عليه، هدفت هذه الدراسة إلى تقييم النشاط المضاد للأكسدة لعصير لب الرمان وعصير فاكهة القشطة في الخلل العصبي الناجم عن كلوريد الألومنيوم. تم تقسيم خمسين فأرًا ذكرًا بالغًا بشكل عشوائي إلى خمس مجموعات متساوية (١٠ فئران لكل مجموعة). تلقت المجموعة الأولى (الضابطة السالبة) النظام الغذائي الأساسي فقط، بينما تم حقن المجموعات الأخرى بكلوريد الألومنيوم لاحداث الإجهاد التأكسدي، حيث تلقت المجموعة الثانية (الضابطة الموجبة) النظام الغذائي الأساسي فقط. أما المجموعات من الثالثة إلى الخامسة، فقد تم تغذيتها على النظام الغذائي الأساسي مع اعطائها عصير الرمان، عصير فاكهة القشطة، ومزيج منهما بنسبة ١:١ (v/v) بجرعة ١ مل لكل ١٠٠ جرام من وزن الجسم، على التوالي. أظهرت النتائج أن تناول عصير الرمان وعصير فاكهة القشطة حسّن بشكل معنوي ($P<0.05$) حالة الوزن مقارنة بالمجموعة الضابطة الموجبة. كما لوحظ تحسن معنوي ($P<0.05$) في مؤشرات وظائف الكبد ومؤشرات الإجهاد التأكسدي، بما في ذلك المالوندهايد، إنزيم سوبرأوكسيد ديسميوتاز، جلوتاثيون بيروكسيداز، والقدرة الكلية لمضادات الأكسدة، في المجموعات المعالجة. تدعم هذه النتائج إمكانية الاستفادة العلاجية المحتملة لكل من عصيري الرمان والقشطة من خلال تأثيراتهما المضادة للأكسدة.

الكلمات المفتاحية: الرمان، فاكهة القشطة ، كلوريد الألومنيوم، مضادات الأكسدة، الإجهاد التأكسدي، وظائف الكبد، وزن الجسم، الفئران.