Article **ECORFAN Journal-Bolivia**
June 2023, Vol.10 No.18 24-32

Nephroprotection of *p*-coumaric acid against sublethal dose of carbon tetrachloride in Wistar rats: histological evidence

Nefroprotección del ácido *p*-cumárico ante la dosis subletal de tetracloruro de carbono en rata Wistar: evidencias histológicas

MACÍAS-PÉREZ, José Roberto*†, ALDABA-MURUATO, Liseth Rubí*, HERNÁNDEZ-MARTÍNEZ, Jazmín Guadalupe and SÁNCHEZ-BRIONES, María Eugenia

Facultad de Estudios Profesionales Zona Huasteca, Universidad Autónoma de San Luis Potosí. Romualdo del Campo No. 501, Rafael Curiel, C.P. 79060, Ciudad Valles, San Luis Potosí, México

ID 1st Author: *José Roberto, Macías-Pérez* / **ORC ID:** 0000-0001-7925-2494, **Researcher ID Thomson:** X-2998-2018, **CVU CONAHCYT:** 172982.

ID 1st Co-author: *Liseth Rubí, Aldaba-Muruato* / **ORC ID:** 0000-0002-9641-662X, **Researcher ID Thomson:** X-3211-2018, **CVU CONAHCYT ID:** 176507.

ID 2nd Co-author: *Jazmín Guadalupe, Hernández-Martínez* / **ORC ID:** 0009-0004-6239-6300, Becario CONAHCYT ID: 1138163.

ID 3rd Co-author: *Sánchez-Briones María Eugenia* / **ORC ID:** 0000-0001-9968-0322, **Researcher ID Thomson:** ABE-2865-2020, **CVU CONAHCYT ID:** 265765

DOI: 10.35429/EJB.2023.18.10.24.32 Received: January 30, 2023; Accepted: June 30, 2023

Abstract

In Mexico, chronic kidney disease is a public health problem, when is diagnosed in advanced stages, the only treatment options are dialysis, hemodialysis or organ transplantation, however, the health system does not have the economic capacity or the infrastructure to fully cover these treatments. Therefore, the objective of this research work was to evaluate the activity of the *p*-coumaric acid (*p*CA) as a possible nephroprotective agent against toxic carbon tetrachloride (CCl_4)-induced kidney damage in male Wistar rats. Renal parenchyma was evaluated using two stains, hematoxylin and eosin (H&E) and periodic acid with Schiff's reagent (PAS). The administration of CCl_4 (4 g/kg, p.o., one dose) induced tubular necrosis and glomerular rupture within 24 h, with loss of microvilli and basement membranes, with widening of the lumen of the distal and proximal tubules. On the other hand, *p*CA (100 mg/kg, p.o., administered 24 h and 1 h before CCl_4 and 1 h after this toxic agent) showed nephroprotective action by reducing the presence of these morphological changes. Our results suggest for the first time that *p*CA, when administered preventively, slows the deterioration of renal structure induced by acute exposure to a sublethal dose of CCl_4.

Nephropathy, Acute kidney injury, CCl_4, *p*-coumaric acid, Nephroprotective

Resumen

En México la enfermedad renal crónica es un problema de salud pública, que tiene como opción de tratamiento la diálisis, la hemodiálisis o el trasplante de órgano, sin embargo, el sistema de salud no tiene la capacidad económica ni la infraestructura para cubrirlos en su totalidad. Por lo tanto, el objetivo del presente trabajo fue evaluar la actividad del ácido *p*-cumárico (*p*CA) como un posible agente nefroprotector contra el daño inducido con el tóxico tetracloruro de carbono (CCl_4) en las ratas Wistar macho. El parénquima renal fue evaluado mediante dos tinciones, la de hematoxilina y eosina y la del ácido peryódico de Schiff. La administración de CCl_4 (4 g/kg, p.o., una dosis) indujo en 24 h necrosis tubular y ruptura glomerular, con pérdida de microvellosidades y de membranas basales, con ensanchamiento de la luz de los túbulos distales y proximales. Por otra parte, el *p*CA (100 mg/kg, p.o., administrado 24 h y 1 h antes que el CCl_4 y 1 h después de este agente tóxico) mostró acción nefroprotectora al disminuir la presencia de estos cambios morfológicos. Nuestros resultados sugieren por primera vez que el *p*CA puede prevenir el deterioro de la estructura renal ante la exposición aguda de CCl_4.

Nefropatía, daño renal agudo, CCl_4, *ácido p*-cumárico, nefroprotector

Citation: MACÍAS-PÉREZ, José Roberto, ALDABA-MURUATO, Liseth Rubí, HERNÁNDEZ-MARTÍNEZ, Jazmín Guadalupe and SÁNCHEZ-BRIONES, María Eugenia. Nephroprotection of p-coumaric acid against sublethal dose of carbon tetrachloride in Wistar rats: histological evidence. ECORFAN-Bolivia Journal. 2023. 10-18:24-32.

* Correspondence to Author (E-mail: roberto.macias@uaslp.mx, liseth.aldaba@uaslp.mx)
† Researcher contributing as first author.

Introduction

Currently, one of the diseases that most afflict human beings are those of renal origin, with chronic kidney disease (CKD) being considered a serious public health problem both in Mexico and in the world (Evans et al., 2022; Reyna-Sevilla et al., 2022). CKD is directly related to diabetes and hypertension, however, it can be caused by other factors, from the consumption of toxic substances, autoimmune diseases, infections, obstructive problems, and congenital antecedents (Talati, 2019; Perazella, 2018; Stevens, 2018; Tecklenborg, 2018; Wyatt, 2017).

Oxidative stress is one of the main factors affecting the kidney, this occurs when the production of oxidative molecules or reactive oxygen species (ROS) exceeds the endogenous antioxidant capacity of the organism, these ROS are produced in the plasma membrane, cytoplasm, endoplasmic reticulum and mitochondria (Ho & Shirakawa, 2022). The kidney, being an organ with abundant mitochondria, becomes the main site of ROS production, which under normal conditions is regulated by the regenerative cycle of mitochondrial ROS formation and release known as ROS-induced ROS release (RIRR), which upon dysfunction of mitochondrial homeostasis ROS accumulate and are released activating cell signalling pathways leading to bioenergetic and stress alterations that cause inflammation, endothelial and vascular damage, with subsequent development of acute or chronic kidney damage (Ho & Shirakawa, 2022; Zorov, et al 2014).

P-coumaric acid (pCA) or 4-hydroxycinnamic acid is a phenolic acid that is ubiquitously distributed in plants and fungi and is a precursor of a wide range of other molecules, such as flavonoids and lignin (Combes et al., 2021: Pei et al. 2016). In addition, it has numerous applications in the pharmaceutical, cosmetics and food industries (Boo, 2019; Pei et al. 2016). Moreover, various researches have shown that pCA has important biological activities such as antioxidant, anti-inflammatory, anti-apoptotic, anti-necrotic, anti-cholestatic, amebiostatic and antimicrobial (Ayazoglu et al 2022; Daroi et al 2022; Aldaba-Muruato et al., 2021; Ojha & Patil 2019).

These aforementioned properties make it suitable to be evaluated against sublethal oral dose (per os; p.o.) of 4 g/kg of carbon tetrachloride (CCl_4) (Yoshioka et al., 2016) which at high concentrations causes oxidative damage to kidney tissue (Suzuki et al., 2015; Ozturk et al., 2003).

Methodology

Experimental animals

In this research work, male Wistar rats (Rattus norvegicus) weighing approximately 230-250 g were used and subjected to a standard diet (Nutricubos®), with free access to drinking water, and maintained at a temperature of 24°C with 50-60% relative humidity and 12-hour light-dark cycles.

Ethics

The present research work belongs to the project entitled "Evaluation of compounds with hepatoprotective activity" carried out with male Wistar rats, which was accepted by the Research Ethics Committee of the Facultad de Estudios Profesionales Zona Huasteca, UASLP. All animals received humane care based on the biosafety terms and guidelines established by this committee, as well as on the specifications dictated by the official Mexican standard (NOM-062-ZOO-1999) regarding the technical specifications for the production, care and use of laboratory animals.

Chemical compounds and reagents

The reagents used for the in vivo experimental protocol were CCl_4 (mallinckrodt), pCA (sigma), carboxymethylcellulose 0.5% (sigma), mineral oil (mystic moments). On the other hand, for haematoxylin eosin (H&E) staining, xylene (CTP Scientific), ethanol (CTP Scientific), haematoxylin (CTP Scientific), eosin (Jalmek) were used and for PAS staining, Schiff's reagent, periodic acid (CTP Scientific), Mayer's haematoxylin (CTP Scientific), xylene (CTP Scientific) and ethanol (CTP Scientific) were used.

ISSN-On line: 2410-4191

Induction of renal damage with CCl_4

The twenty experimental animals were equally divided into four groups (Figure 1). Rats in the Control group were administered mineral oil (0.5 mL/100 g, p.o.), which was used as a vehicle for CCl_4, those in the CCl_4 group were induced renal damage with a single sublethal dose of CCl_4 (4 g/kg, p. o.), and rats in the CCl_4 + pCA group were administered pCA (100 mg/kg, p.o.) on three occasions, one day before CCl_4 administration, as well as one hour before and one hour after the same intoxication. The pCA group was administered pCA in the same way as in the CCl_4 group, and instead of CCl_4 the mineral oil was administered orally (0.5 mL/100 g, p.o.), and the pCA group was administered orally (0.5 mL/100 g, p.o.), and the pCA group was administered in the same way as in the CCl_4 group).

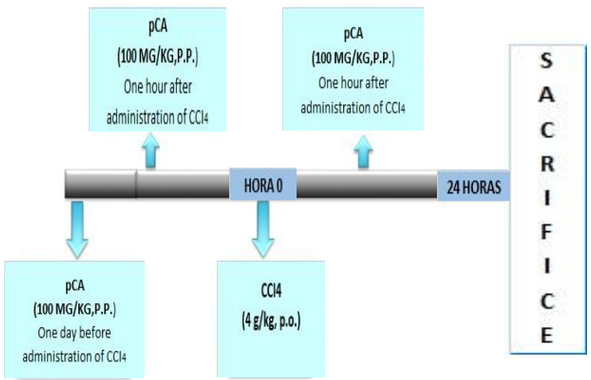

Figure 1 Experimental procedure. Twenty male Wistar rats were divided equally into four experimental groups: CCl_4 group was administered a single dose of CCl_4 (4g/kg, p.o.); animals in the CCl_4 + pCA group were administered 3 doses of pCA (each 100 mg/kg, p.o., the first two doses 24 h and 1 h before CCl_4 toxicant administration and the last dose 1 h after CCl_4). The Control group was administered only with CCl_4 and pCA vehicles (mineral oil and carboxymethylcellulose 0.5%) and the pCA group was administered in the same way as in the CCl_4 + pCA group, but instead of CCl_4, p.o. mineral oil was administered

Sacrifice

The animals were sacrificed 24 hours after CCl_4 intoxication or administration of the mineral oil. For this, the rats were first sedated with a mixture of ketamine (0.9 mL/100 g, i.p.) and xylazine (0.5 mL/100 g, i.p.), and then sacrificed by cardiac puncture.

Collection of biological samples

The left kidney was dissected out and embedded in 4% p-formaldehyde for a period of 72 h.

Paraffin-embedding of kidney tissue

After fixation, the tissues were processed with the Leica TP1020 Histochinete equipment, in order to facilitate dehydration, clarification, pre-impregnation and paraffin infiltration of the biological samples. The tissues were then immersed in paraffin to form solid blocks with the aid of MYR EC350-1 semi-automatic paraffin embedding equipment.

Histological sections

Paraffin-embedded tissue sections with a thickness of 4 µm were obtained using the Ecoshel model 202A microtome. The sections were transferred to a CA Scientific flotation bath model XH-1001 at a temperature of 40°C, and the slice was recovered with a previously silanised slide.

Haematoxylin-Eosin (H&E) staining

Dewaxing was started with xylol, 2 washes for 10 min and 1 min respectively, followed by dehydration in absolute alcohol 2 washes for 1 min, then in 96 % alcohol for 1 min, then in 80 % alcohol for 1 min and then in distilled water for 1 min. The slides were then stained with the first stain, Harris haematoxylin, in which the slides were immersed for 10 min, then washed in tap water for 5 min, immersed in acid alcohol for 15 s, placed in distilled water for 1 min, immersed in ammonia water for 1 s, then washed in distilled water for 1 min, then immersed in ammonia water for 1 min, then washed in distilled water for 1 min, then immersed in ammonia water for 1 min, washed with distilled water twice, then immersed in the second dye, eosin, for 2 min, followed by dehydration, immersed in 80% alcohol, then 96% alcohol, twice in absolute alcohol and finally with xylol, all for 1 min each. Finally, the tissue was mounted with a drop of entellan, placed on a coverslip and left to dry.

ISSN-On line: 2410-4191

Periodic acid staining with Schiff's reagent (PAS)

PAS staining began with dewaxing with xylol, 2 washes for 10 min and 1 min respectively, followed by dehydration in absolute alcohol for 2 washes for 1 min, then in 96% alcohol for 1 min, then in 80% alcohol for 1 min and then in distilled water for 1 min. The slides were placed in running water for 5 min, then in periodic acid for 5 min, at the end of this time they were placed in distilled water for 20 seconds more, and then the slides were placed in Schiff's reagent for 15 min, and then in running water for 5 min, at the end of this time the slides were placed in Schiff's reagent for 15 min, and then in running water for 5 min, at the end the slides were placed in Arris haematoxylin for 10 min, and then placed in running water for 5 min, at the end they went through the dehydration train, immersing in 80 % alcohol, then 96 % alcohol, twice in absolute alcohol and finally with xylol 2 times, all these for 1 minute each.

Photographic images

Images were taken with a KOPPACE 16 MP camera (KP-1660) adapted to an Axiostar plus (HBO 50/AC, ZEISS) brightfield microscope, which were processed and analysed in S-Eye (1.6.0.11) and ImageJ (Version: 1.52) software, respectively.

Results

The pCA is able to prevent CCl_4-induced renal damage: histopathology with H&E.

Renal architecture was assessed by H&E staining and representative images are shown at 5x (Figure 2), 10x (Figure 3) and 40x (Figure 4) magnification. Figures 2 and 3 show the main morphological changes observed at the level of the renal cortex. The Control and pCA groups showed a mostly preserved morphology with normal appearing glomeruli and distal and contoured tubules and tubules, although some glomeruli with slight morphological changes were visible. The CCl_4 group showed marked damage to the renal architecture, with evident tubular necrosis, with mostly collapsed or fragmented glomeruli.

The CCl_4 + pCA group preserved the integrity of the renal parenchyma, with the presence of mostly normal glomeruli, with occasional altered glomeruli, and the renal tubules showing an architecture with a typical appearance.

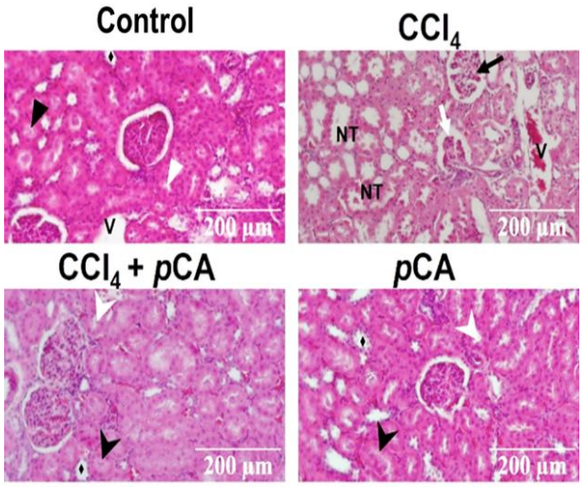

Figure 2 Representative photomicrographs at 5x of renal cortex sections stained with H&E. Experimental groups: Control (healthy group), CCl_4 (damage control), CCl_4 + pCA (test group) and pCA (pCA control). Black arrows: glomeruli with morphological alterations; White arrow: collapsed glomerulus; Glomerular rupture: (*); Tubular necrosis: NT; Artery: A; Vein: V.

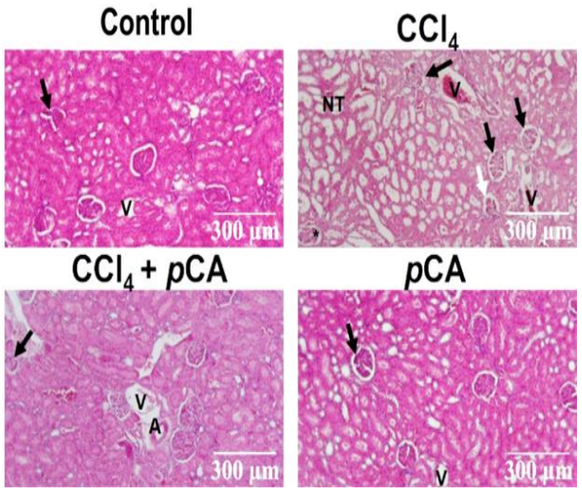

Figure 3. Representative 10x photomicrographs of renal cortex sections stained with H&E. Experimental groups: Control (healthy group), CCl_4 (damage control), CCl_4 + pCA (test group) and pCA (pCA control). Black arrowhead: proximal convoluted tubules; white arrowhead: distal convoluted tubules; black arrow: damaged glomeruli with presence of fragmentation and a wide glomerular space; white arrow: glomerular rupture and collapse; tubular necrosis: TN; loops of Henle; tubular necrosis: NT; and white arrow: glomerular rupture and collapse: (⧫).

ISSN-On line: 2410-4191

Photomicrographs at 40x magnification showed that in the healthy groups (Control and pCA) the kidneys have a normal cellular structure, with intact glomeruli (Figure 4A and B) and regular tubular contour (Figures 4A, B and C). On the other hand, glomerular atrophy (Figures 4D and E) as well as tubular destruction was observed in the CCl_4-intoxicated groups (Figures 4D, E and F), compared to the integrity shown by the healthy groups. The CCl_4 + pCA group largely prevented CCl_4-induced renal damage, the glomeruli show apparently normal morphology (Figure 4G), although it is possible to observe some glomeruli with abnormal architecture (Figure 4H), and overall the tubular morphology appears normal (Figures 4G, H and I). The pCA group showed similarities to the Control group (Figures 4J, K and L).

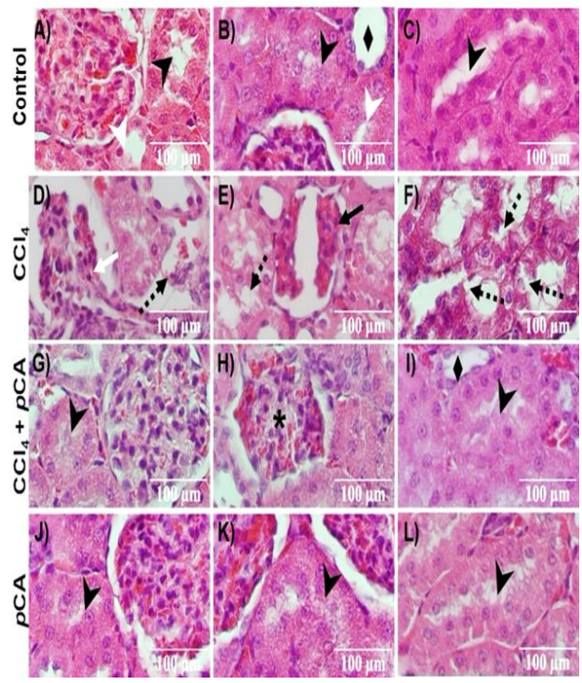

Figure 4 Representative photomicrographs at 40x of renal cortex sections stained with H&E. Experimental groups: Control (healthy group), CCl_4 (damage control), CCl_4 + pCA (test group) and pCA (pCA control). Head of black arrows: proximal convoluted tubules; Head of white arrows: distal convoluted tubules; White arrow: damaged glomeruli with presence of fragmentation and a wide glomerular space; Black arrow: glomerular collapse and rupture; Dotted black arrows: rupture of distal and proximal tubules; Loops of Henle: (⧫); Damaged glomerulus: (*)

pCA protects the integrity of the convoluted tubules: histopathology with PAS

PAS staining is used to investigate the morphological structure of the renal parenchyma, but it also allows us to correlate with the content and integrity of carbohydrates present both in the basement membrane and in the microvilli of all the epithelia and connective tissue. This gives us an idea of the condition of the convoluted tubules and whether there is damage or not.

Microscopic observations of renal tissue stained with PAS at magnifications of 5x, 10x, 40x

Observations by light microscopy at 5x (Figure 5), 10x (Figure 6) and PAS staining allowed us to evaluate the renal tubular architecture and the integrity of the basement membranes. Thus, it was possible to visualise that the healthy groups (Control and pCA) presented a normal histology, with preserved basement membrane structures, as well as the microvilli of the proximal tubules. CCl_4 intoxication induced tubular necrosis, showing loss of basement membrane and microvilli. The CCl_4 + pCA group showed a preserved architecture, preventing the loss of glomerular mass, proximal and distal tubules and microvilli.

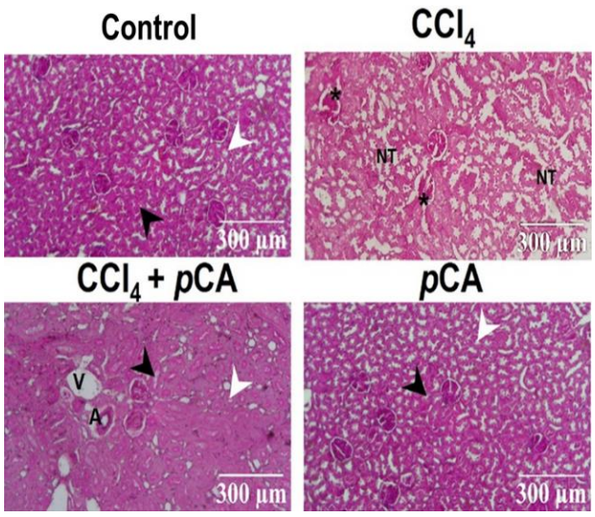

Figure 5 Representative 5x photomicrographs of PAS-stained renal cortex sections. Experimental groups: control (healthy group), CCl_4 (damage control), CCl_4 + pCA (test group) and pCA (pCA control). Head of black arrows: proximal convoluted tubules; Head of white arrows: distal convoluted tubules; Tubular necrosis: NT; glomerular rupture (*); Artery: A; Vein: V

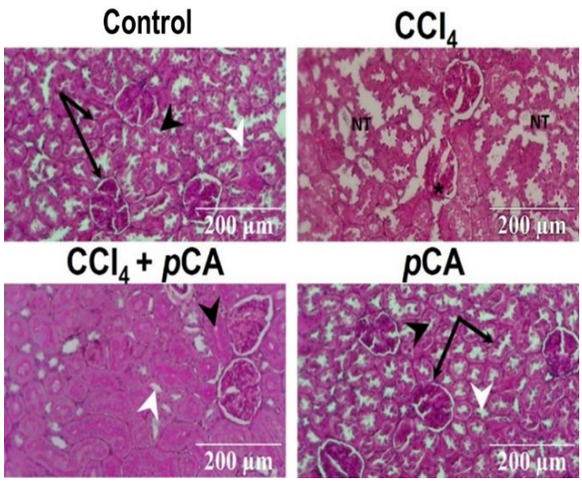

Figure 6 Representative 10x photomicrographs of PAS-stained renal cortex sections at 10x. Experimental groups: Control (healthy group), CCl_4 (damage control), CCl_4 + pCA (test group) and pCA (pCA control). Head of black arrows: proximal convoluted tubules; Head of white arrows: distal convoluted tubules; Black arrows: intact basement membranes; Tubular necrosis: NT; atrophied glomeruli: (*)

The photomicrographs at 40x magnification (Figure 7), show that the CCl_4 group presented tubular destruction with loss of microvilli and basement membrane, widening of the lumen of the distal and proximal tubules was observed in comparison with the integrity shown by the healthy groups (Mineral Ac. and pCA). The CCl_4 + pCA group prevented these morphological changes due to CCl_4-induced renal damage.

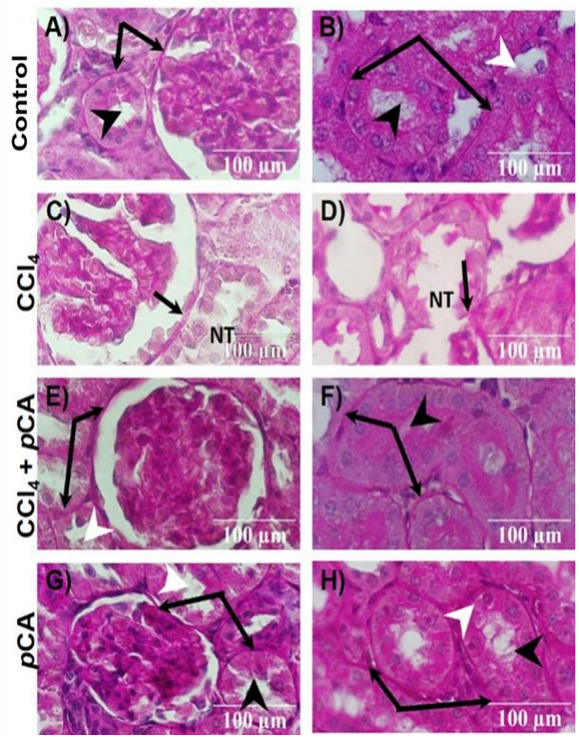

Figure 7 Representative photomicrographs at 40x of PAS-stained renal cortex sections. Experimental groups: Control (healthy group), CCl_4 (damage control), CCl_4 + pCA (test group) and pCA (pCA control). Head of black arrows: proximal convoluted tubules; Head of white arrows: distal convoluted tubules; Black arrows: basement membrane; Tubular necrosis: NT

Discussion

Prevention or early detection of kidney diseases are considered the best strategies to avoid CKD, because when CKD is already established, the patient's life expectancy decreases, as persistent urinary abnormalities with impaired nephron function occur (Romagnani et al., 2017). Therefore, in the present work, the ability of pCA as a preventive agent against acute damage induced with a sublethal dose of CCl_4 in Wistar rats was evaluated, considering that CCl_4 is a potent nephrotoxic agent (Suzuki et al., 2015; Ozturk et al., 2003).

ISSN-On line: 2410-4191

In H&E and PAS stained kidney sections, it was observed that the healthy groups (Control and pCA) which were administered mineral oil+CMC 0. 5% or mineral oil+pCA, respectively, presented a normal appearing renal parenchyma, with tissue morphology similar to a healthy kidney, with intact basement membranes, with intact glomeruli and convoluted tubules, with visibly normal cytoplasm and nuclei, however, in these healthy groups some lesions were also evident in some glomeruli and in distal and proximal convoluted tubules. These observations are related to some works that have described that olive oil which is used as a vehicle for CCl_4 induces severe renal lesions, with the presence of atrophy and destruction in the glomerulus with the presence of pyknotic nuclei and cellular infiltration (Alsalam, 2016). Therefore, our results support the fact that mineral oil has harmful effects at the renal level. Furthermore, it should be emphasised that the pCA group did not show additional morphological changes relative to the Control group.

On the other hand, CCl_4 is a chlorinated hydrocarbon composed of a mixture of chlorine with chloroform, named tetrachloromethane by the International Union of Pure and Applied Chemistry Nomenclature (IUPAC), and is highly harmful when ingested, inhaled, or by direct contact with the skin (Al Amin & Menezes, 2020). This toxic agent causes damage to multiple organs, with the liver and kidney being mainly affected; in the liver it induces necrosis, steatosis and cirrhosis and at the renal level it causes glomerular necrosis and histological alterations in distal tubules (Suzuki et al., 2015; Aldaba-Muruato et al. 2012; Ozturk et al., 2003).

A previous work published by our research group showed for the first time that pCA has anti-necrotic and anti-cholestatic activity against acute damage induced by CCl_4 or common bile duct ligation in rats, as well as amebiostatic activity against the parasite *Entamoeba histolytica* (Aldaba-Muruato et al., 2021).

The results of the present work demonstrate that pCA possesses anti-nephrotic activity at a sublethal dose of CCl_4. On the one hand, it was confirmed that CCl_4 is able to induce drastic changes in renal architecture, such as glomerular atrophy and partial or total destruction of the convoluted tubules, known as tubular necrosis (Figures 2, 3 and 4), observations consistent with other authors (Suzuki et al., 2015; Ozturk et al., 2003). On the other hand, our H&E and PAS-stained renal histopathological studies indicate that pCA possesses the ability to protect against CCl_4-induced nephrotoxic damage, with a visible reduction in cell damage, with relative integrity of the proximal convoluted tubule, as well as its visible cytoplasm and nuclei with no apparent alterations (Figures 2, 3 and 4). The PAS technique was useful to demonstrate the integrity or morphological alterations of the basement membrane of the convoluted tubules and glomeruli (Ochoa et al., 1957; Sugai et al., 1992). Similarly, microscopic observations of PAS-stained kidney sections showed that in the CCl_4 group, there is loss of basement membrane continuity of the different structures of the nephron, as well as of the microvilli of proximal convoluted tubules, while these structures are more preserved in the CCl_4 + pCA group. These results are consistent with previous observations describing that pCA protects against tubular necrosis by preventing the production of oxidative stress that is generated by cisplatin (Ekinci et al 2017). Likewise, Gentamicin-induced tubular necrosis and tubulointerstitial inflammation of the proximal tubules was reduced by pCA (Hakyemez et al 2022). In addition, another work demonstrated that the antioxidant effect of pCA reduces oxidative stress induced in diabetic rats and prevents the development of diabetes-associated nephropathy (Mani, et al., 2022).

Conclusion

The present work demonstrates that pCA is a potent nephroprotectant against renal damage induced by sublethal doses of CCl_4.

Funding

The authors are grateful to CONAHCYT for funding No. 320331 "Basic and/or Frontier Science Modality: Paradigms and Controversies of Science 2022".

ISSN-On line: 2410-4191

References

Al Amin, A. S. M., & Menezes, R. G. (2023). Carbon Tetrachloride Toxicity. In *StatPearls*. StatPearls Publishing. Available from: https://www.ncbi.nlm.nih.gov/books/NBK562180/

Aldaba-Muruato, L. R., Moreno, M. G., Shibayama, M., Tsutsumi, V., & Muriel, P. (2012). Protective effects of allopurinol against acute liver damage and cirrhosis induced by carbon tetrachloride: modulation of NF-κB, cytokine production and oxidative stress. *Biochimica et biophysica acta*, *1820*(2), 65–75. https://doi.org/10.1016/j.bbagen.2011.09.018

Aldaba-Muruato, L.R., Ventura-Juárez, J., Perez-Hernandez, A.M., Hernández-Morales, A., Muñoz-Ortega, M.H., Martínez-Hernández, S.L. ... Macías-Pérez, J.R. (2021). Therapeutic perspectives of p-coumaric acid: Anti-necrotic, anti-cholestatic and anti-amoebic activities. World Academy of Sciences Journal, 3, 47. https://doi.org/10.3892/wasj.2021.118

Alsalam Ali Abd, Elshaer Fathy M., Mansour Hamdi Abdou. 2016. Assessment of the Potential role of Hesperidin as an Antioxidant on the Carbon Tetrachloride -Induced Kidney Damage in Rats. The Egyptian Journal of Hospital Medicine. 64: 277-286. Recuperado de https://journals.ekb.eg/article_15141_4281e11f3f4058ba9bb22abf634bab6c.pdf

Ayazoglu Demir, E., Mentese, A., Kucuk, H., Turkmen Alemdar, N., & Demir, S. (2022). p-Coumaric acid alleviates cisplatin-induced ovarian toxicity in rats. The journal of obstetrics and gynaecology research, 48(2), 411–419. https://doi.org/10.1111/jog.15119

Boo Y. C. (2019). p-Coumaric Acid as An Active Ingredient in Cosmetics: A Review Focusing on its Antimelanogenic Effects. Antioxidants (Basel, Switzerland), 8(8), 275. https://doi.org/10.3390/antiox8080275

Combes, J., Imatoukene, N., Couvreur, J., Godon, B., Brunissen, F., Fojcik, C., Allais, F., & Lopez, M. (2021). Intensification of p-coumaric acid heterologous production using extractive biphasic fermentation. Bioresource technology, 337, 125436. https://doi.org/10.1016/j.biortech.2021.125436

Daroi, P. A., Dhage, S. N., & Juvekar, A. R. (2022). p-Coumaric acid mitigates lipopolysaccharide induced brain damage via alleviating oxidative stress, inflammation and apoptosis. The Journal of pharmacy and pharmacology, 74(4), 556–564. https://doi.org/10.1093/jpp/rgab077

Ekinci Akdemir, F. N., Albayrak, M., Çalik, M., Bayir, Y., & Gülçin, İ. (2017). The Protective Effects of p-Coumaric Acid on Acute Liver and Kidney Damages Induced by Cisplatin. Biomedicines, 5(2), 18. https://doi.org/10.3390/biomedicines5020018

Evans, M., Lewis, R. D., Morgan, A. R., Whyte, M. B., Hanif, W., Bain, S. C., Davies, S., Dashora, U., Yousef, Z., Patel, D. C., & Strain, W. D. (2022). A Narrative Review of Chronic Kidney Disease in Clinical Practice: Current Challenges and Future Perspectives. Advances in therapy, 39(1), 33–43. https://doi.org/10.1007/s12325-021-01927-z

Hakyemez, I. N., Cevizci, M. N., Aksoz, E., Yilmaz, K., Uysal, S., & Altun, E. (2022). Protective effects of p-coumaric acid against gentamicin-induced nephrotoxicity in rats. Drug and chemical toxicology, 45(6), 2825–2832. https://doi.org/10.1080/01480545.2021.1993703

Ho, H. J., & Shirakawa, H. (2022). Oxidative Stress and Mitochondrial Dysfunction in Chronic Kidney Disease. Cells, 12(1), 88. https://doi.org/10.3390/cells12010088

Mani, A., Kushwaha, K., Khurana, N., & Gupta, J. (2022). p-Coumaric acid attenuates high-fat diet-induced oxidative stress and nephropathy in diabetic rats. Journal of animal physiology and animal nutrition, 106(4), 872–880. https://doi.org/10.1111/jpn.13645

Ochoa PC, Smith OD, Swerdlow M. "The Dermal-Eepidermal Junction; A Preliminary Study with Periodic Acid-Schiff Stain". AMA Arch Dermatol 1957; 75(1): 70-77. doi:10.1001/archderm.1957.01550130072007

ISSN-On line: 2410-4191

Ojha, D., & Patil, K. N. (2019). p-Coumaric acid inhibits the Listeria monocytogenes RecA protein functions and SOS response: An antimicrobial target. Biochemical and biophysical research communications, 517(4), 655–661. https://doi.org/10.1016/j.bbrc.2019.07.093

Ozturk, F., Ucar, M., Ozturk, I. C., Vardi, N., & Batcioglu, K. (2003). Carbon tetrachloride-induced nephrotoxicity and protective effect of betaine in Sprague-Dawley rats. *Urology*, *62*(2), 353–356. https://doi.org/10.1016/s0090-4295(03)00255-3

Pei, K., Ou, J., Huang, J., & Ou, S. (2016). p-Coumaric acid and its conjugates: dietary sources, pharmacokinetic properties and biological activities. Journal of the science of food and agriculture, 96(9), 2952–2962. https://doi.org/10.1002/jsfa.7578

Perazella M. A. (2018). Pharmacology behind Common Drug Nephrotoxicities. Clinical journal of the American Society of Nephrology: CJASN, 13(12), 1897–1908. https://doi.org/10.2215/CJN.00150118

Reyna-Sevilla A, Borrayo-Sánchez G, Duque-Molina C, Ascencio-Montiel IJ, Torres-Toledano M. Análisis geográfico de nefropatía diabética e insuficiencia renal en el primer nivel de atención IMSS 2019. Rev Med Ins Mex Seguro Soc. 2022; 60(2): 156-163. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10395952/?report=reader

Romagnani, P., Remuzzi, G., Glassock, R., Levin, A., Jager, K. J., Tonelli, M., Massy, Z., Wanner, C., & Anders, H. J. (2017). Chronic kidney disease. Nature reviews. Disease primers, 3, 17088. https://doi.org/10.1038/nrdp.2017.88

Stevens S. (2018). Obstructive Kidney Disease. The Nursing clinics of North America, 53(4), 569–578. https://doi.org/10.1016/j.cnur.2018.07.007

Sugai SA, Gerbase AB, Cernea SS, Sotto MN, Oliveira ZN, Vilela MA, Rivitti EA, Miyauchi LM, Sampaio SA. "Cutaneous Lupus Erythematosus: Direct immunofluorescence and Epidermal Basal Membrane Study". Int J Dermatol 1992; 31(4): 260-264. https://doi.org/10.1111/j.1365-4362.1992.tb03567.x

Suzuki, K., Nakagawa, K., Yamamoto, T., Miyazawa, T., Kimura, F., Kamei, M., & Miyazawa, T. (2015). Carbon tetrachloride-induced hepatic and renal damages in rat: inhibitory effects of cacao polyphenol. Bioscience, biotechnology, and biochemistry, 79(10), 1669–1675. https://doi.org/10.1080/09168451.2015.1039481

Talati, A. N., Webster, C. M., & Vora, N. L. (2019). Prenatal genetic considerations of congenital anomalies of the kidney and urinary tract (CAKUT). Prenatal diagnosis, 39(9), 679–692. https://doi.org/10.1002/pd.5536

Tecklenborg, J., Clayton, D., Siebert, S., & Coley, S. M. (2018). The role of the immune system in kidney disease. Clinical and experimental immunology, 192(2), 142–150. https://doi.org/10.1111/cei.13119

Yoshioka, H., Usuda, H., Nonogaki, T., & Onosaka, S. (2016). Carbon tetrachloride-induced lethality in mouse is prevented by multiple pretreatment with zinc sulfate. The Journal of toxicological sciences, 41(1), 55–63. https://doi.org/10.2131/jts.41.55

Wyatt C. M. (2017). Kidney Disease and HIV Infection. Topics in antiviral medicine, 25(1), 13–16. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5677039/?report=reader

Zorov, D. B., Juhaszova, M., & Sollott, S. J. (2014). Mitochondrial reactive oxygen species (ROS) and ROS-induced ROS release. Physiological reviews, 94(3), 909–950. https://doi.org/10.1152/physrev.00026.2013

ISSN-On line: 2410-4191