Emirates Journal of Food and Agriculture. 2022. 34(11): 915-922
doi: 10.9755/ejfa.2022.v34.i11.2969
http://www.ejfa.me/

RESEARCH ARTICLE

Hydro-alcoholic extract of *Ochradenus baccatus* exhibits anti-oxidative and anti-inflammatory properties and inhibits enzyme of uric acid metabolism: Implications for bioactive molecules

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ABSTRACT

Background: Traditional medicines have been an accessible, affordable, and culturally acceptable model of healthcare that is trusted across the globe in terms of disease management, symptoms relief and patient satisfaction. The natural products derived from plant sources are the fundamental ingredients of traditional and folk medicine and serve as lead compounds or pharmacophore for most effective drugs in modern pharmacology for treatment of infectious and chronic diseases. *Ochradenus baccatus*, which belongs to family *Resedaceae*, is a perennial shrub, widely distributed in the arid regions of Arabian Peninsula and finds mention in the traditional medicine for reproductive health, inflammation and infection. **Results:** As a proof-of-concept, this study has investigated the various bioactive properties of the plant *vis-à-vis* anti-oxidative, anti-inflammatory and inhibition of xanthine oxidase using standard *in vitro* experimental models. The bioactive molecules found in the extract included flavonoids, phenolics, tannins, saponins and alkaloids in varying quantities, which are known to be associated with a multitude of pharmacological properties. Our results show that the extract caused a progressive inhibition of DPPH radical and neutralizes superoxide anions in a dose-dependent manner. The extract demonstrated its redox-active potential by means of its ability to reduce Cu (II) to Cu (I) that is detected using bathocuproine, a Cu (I)-specific sequestering agent. Progressive doses of the extracts inhibited the denaturation of protein (a factor associated with inflammation), with maximum inhibition of 70.6% observed at concentration of 600 µg/ml, after which the effect plateaued for further doses. Moreover, the extract displayed a progressive inhibitory property against the enzymatic activity of xanthine oxidase with a maximum inhibition of 66% observed at a dose of 300 µg/ml. **Conclusion:** Inhibition of xanthine oxidase reduces the hyperuricemia in patients with gout and nephrolithiasis as it alleviates the tendency of salt accumulation in the joints and kidney. The interest in the natural products pharmacology is escalating and exploring novel bioactive properties in plants of interest is a significant stride from the traditional knowledge to evidence-based practice.

Keywords: Plant secondary metabolites; Pharmacology; Traditional Medicine; Uric acid metabolism; xanthine oxidase

INTRODUCTION

The rising healthcare expenditures and an enhanced consciousness towards preventive strategies have considerably increased the popularity of alternative approaches to disease prevention in recent years worldwide (Jonas et al., 2013). Traditional medicine have been an accessible, affordable, and culturally acceptable model of healthcare that is trusted across the globe in terms of disease management, symptom relief and patient satisfaction (WHO 2013). The natural products derived from plant sources are the fundamental ingredients of traditional and folk medicine and serve as lead compounds for certain most effective drugs in modern pharmacology for treatment of infectious and chronic diseases (Atanasov et al., 2015; Harvey et al., 2014; Ullah et al., 2022). Evidence suggest that the plant-derived chemically diverse bioactive molecules serve as the major constituents of traditional medicine in various countries including China, India, Korea, Thailand, and England, for treating conditions such as inflammatory disorders (Ramawat et al.,2009). *Ochradenus baccatus,* which belongs to family *Resedaceae,* is a perennial shrub and it is widely distributed in the arid regions of Arabian Peninsula (Bhatt and Pérez-García, 2016). The plant is rich in the contents of antioxidant and anti-inflammatory molecules (Alqasoumi

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Received: 13 November 2021; **Accepted:** 15 October 2022

et al., 2012). In traditional medicine, the documented application of the plant formulations include beneficial effects in reproductive health, inflammation and infection (Alqasoumi et al., 2012; Soliman et al., 2012; Abdel-Sattar et al., 2008). Reactive oxygen species such as hydroxyl radicals, superoxide anions and nitric oxide radicals have the ability to interact with cellular structures and cause oxidative damage to DNA, proteins and lipids in cells (Li et al., 2015). Although the cellular antioxidant system, which includes enzymes and antioxidant biomolecules, can scavenge these radicals and maintain the balance in the redox state, an excessive oxidative stress leads to degenerative and chronic diseases (Tan et al., 2018). It is believed that intake of exogenous antioxidants mitigates the disturbed redox status by reducing the oxidative stress through distinct cellular pathways (Fang et al., 2002; Lobo et al., 2010; Del-Toro-Sánchez et al., 2021). Inflammation, which is a protective response, can induce tissue damage and cause chronic diseases if it occurs in an unregulated and prolonged manner (Collins 1999). Studies have shown the simultaneous presence of low-grade chronic inflammation and oxidative stress in chronic diseases like cancer, neurodegenerative disease, diabetes, liver disease and arthritis (Biswas 2016; Zamudio-Cuevas et al., 2016). Anti-proliferative effects of *Ochradenus baccatus* has also been reported against human hepatocellular carcinoma cells (Thoppil et al., 2013). A comparative study evaluating the cytotoxic properties of certain medicinal plants against cancer cells has reported *Ochradenus baccatus* extracts exhibiting 24.8% decrease in cell viability on HepG2 cells, which was one of the highest among the tested plants (Khan et al., 2022). A recent work on *Ochradenus baccatus* has shown significant antimicrobial potential of the plant and also its ability to reduce serum triglycerides in an animal model (Al-Omar et al., 2021). The study also demonstrated the absence of any significant toxic effects of the plant on the livers and kidneys. The focus of the current study was to examine the bioactive properties of *Ochradenus baccatus* as a proof-of-concept in order to relate to its pharmacological benefits in traditional medicine. The objectives of the current study includes semi-quantitative phytochemical profiling of the extract and evaluation of its inhibitory properties against reactive oxygen species, protein denaturation (as in inflammation) and enzyme of uric acid metabolism with implication in gouty arthritis.

MATERIALS AND METHODS

Materials

The IUCN classified the plant *Ochradenus baccatus* as "least concern" or "non-threatened" (https://www.iucnredlist.org/species/45014/10971341). As such the regulations required for the "threatened or endangered" species listed in IUCN do not apply on this plant. However, for the purpose of encouraging plant conservation our research involved analysis of material collected non-lethally as recommended by IUCN. The aerial part of the plant *Ochradenus baccatus* was collected from the natural habitat in the Deesa valley (Tabuk, Saudi Arabia). The collection was done under the supervision of an institutional team assisted by a botanist. The plant was authenticated by a taxonomist and specimen voucher was submitted (Department of Botany, Faculty of Science). Ultrapure water and methanol were purchased from Thermo Fisher Scientific (Fremont, CA, USA). Whatman paper (Sigma-Aldrich Co., St. Louis, MO, USA). DPPH (2,2-Diphenyl-1-pycrylhydrazyl) was purchased from Fluka (St. Louis, MO, USA). Xanthine oxidase (E.C. 1.1.3.22), xanthine, allopurinol, gallic acid, ascorbic acid, and phosphate buffered saline (PBS) were purchased from Sigma-Aldrich Co. (St. Louis, MO, USA). All other chemicals and reagents were of analytical grade.

Extraction and phytochemical analysis

The procedure for preparing the extract followed the standard protocol as described previously (Suarez et al., 2010; Ullah 2017). Initially, the aerial parts of Ochradenus *baccatus* was cleansed with cold water and then dried in an oven at 45°C. Once dried, the material was crushed and ground using a blender to obtain a fine dry powder. One liter of methanol (80%) was used to soak 250 g of dry powder in a conical flask which was left for 24 h in a water bath (40°C) with constant shaking. The extracted material was passed through two-layered cheesecloth and the process was repeated with a double-layered Whatman paper. The extract was then concentrated under vacuum in a rotatory evaporator (Buchi® R-210, Flawil, Switzerland) at 35 °C. Following the concentration under reduced pressure, the extract was left under vacuum at -30°C for three days to obtain a solid/thick paste. The residual material was weighed to be 17 g with a total yield of 8.5% (w/w). The contents of major phytochemicals such as flavonoids, phenolics, saponins, alkaloids and tannins were determined in the extract using standard references such as pyrogallol (phenolics), tannic acid (tannins), quercetin (flavonoids) and gravimetric estimations (alkaloids and saponins) (Blainski et al., 2013; Makkar et al., 2000; Harborne 1976; Miliauskas et al., 2004).

Anti-oxidative potential and redox activity

DPPH radical scavenging assay: DPPH free radical is stable with a purple color, which can be read spectrophotometrically at 510 nm. The assay uses the ability of the antioxidants to reduce DPPH to a colorless compound, 2, 2-diphenyl-1-picryl hydrazine (Vani et al. 1997). The reaction mixture had a vehicle control (methanol) and ascorbic acid (standard compound) or the extract (25–500 μg/mL), along with DPPH (0.132 mM). The reaction mixture was placed for

incubation at 25°C for 20 min, after which the absorbance was read at 510 nm (UV-spectrophotometer. The results were presented as % inhibition of the radicals (when compared with control without any test agent).

Superoxide scavenging assay: The NADH-PMS system was used to generate superoxide radicals, which could be estimated by the reduction of NBT (Guleria et al., 2011). The reaction mixture containing 0.1 ml PMS (0.1mM), 0.1 ml NBT (1mM) and varying concentration of extract was adjusted to 1 ml with 50 mM KH_2PO_4 buffer (pH 7.4). Afterwards, 0.1 ml NADH (2mM) was added to the mixture to initiate the reaction, along with incubation for 10 min. at 25°C. After incubation, the absorption was recorded at 570 nm and results were shown as % inhibition (compared to the control without any test agent). Vehicle control (methanol) did not show any interference.

Copper reduction assay: The reducing capacity of the extract was assessed by its ability to reduce Cu(II) to Cu(I), which was detected by bathocuproine, a Cu(I)-specific sequestering agent (Ahmad et al., 1992). The reaction mixture contained 300 mM bathocuproine with Tris-HCl buffer (10 mM; pH 7.5) and indicated concentrations of the following: A-Bathocuproine and 100mM Cu (I); B-bathocuproine and 100 mM Cu(II); C-bathocuproine and 50 µg extract; D-bathocuproine, 50 µg extract and 100 mM Cu(II).

Anti-inflammatory assay

Inhibition of albumin denaturation was used to determine the anti-inflammatory properties of the extract (Shamsi et al., 2018). Different concentrations of the extract as shown in the figure legend were mixed with 1% BSA aqueous solution. 1 ml phosphate buffered saline (pH 6.3) was added to each tube. After incubation at 37°C for 20 min, the samples were heated at 57°C for another 20 min. The samples were then kept at room temperature to cool down and then the turbidity was measured at a wavelength of 660 nm using a UV-VIS spectrophotometer. BSA (1%) was taken as control whereas aspirin (100 µg/ml) was used as a standard. Inhibition of protein denaturation by the standard and the test extracts was calculated using the following formula:

$$\text{Inhibition (\%)} = (\text{Abs}_{\text{control}} - \text{Abs}_{\text{sample}})/\text{Abs}_{\text{control}} \times 100$$

Xanthine oxidase inhibition assay

The xanthine oxidase inhibitory activity of the extract was assayed *in vitro* as described previously (Owen and Johns 1999; Ullah 2017) using the test extract and allopurinol as a positive control. The 3 ml reaction mixture contained 1 ml of different concentrations of the test extract dissolved in methanol, phosphate buffer 2.9 mL (pH 7.5) and 100 µl of the xanthine oxidase enzyme (0.1 units/mL in phosphate buffer, pH 7.5). The reaction mixture was then pre-incubated at 25°C for 15 min. Following this, 2 mL of xanthine (150 mM in the phosphate buffer, pH 7.5) was added as a substrate to initiate the enzymatic reaction. The mixture was placed at 25°C for 30 min, after which 1 mL of hydrochloric acid (1N) was added to stop the reaction. The product was analyzed by absorbance, which was measured at 290 nm using an UV-spectrophotometer. The inhibition of xanthine oxidase was expressed as the percentage inhibition using the formula:

$$\text{Inhibition (\%)} = (1- [B/A]) \times 100$$

A-activity of the enzyme in the absence of the plant extract
B-activity of the enzyme in the presence of the plant extract

Statistical analysis

Statistical analysis was performed using ANOVA, followed by an F-test using SPSS version 11.5 (SPSS, Inc., Chicago, IL). Values of p that were ≤0.05 were considered significant. Experiments were carried in three different sets, with each set in triplicate. The data are expressed as the mean ± standard error of the mean (SEM).

RESULTS AND DISCUSSION

Pharmacologically significant secondary metabolites constitute the bioactive extract of *Ochradenus baccatus*

Phytochemical characterization of the extracts is an important step in studies that examine the biological activity of natural products. *Ochradenus baccatus* extract was subjected to quantitative phytochemical analysis and as reported in Fig. 1, it displayed the presence of various major plant metabolites in varying concentrations. The bioactive molecules which include flavonoids, phenolics, tannins, saponins and alkaloids are known to be associated with a multitude of pharmacological properties (Ramawat et al., 2009). These secondary metabolites constitute a

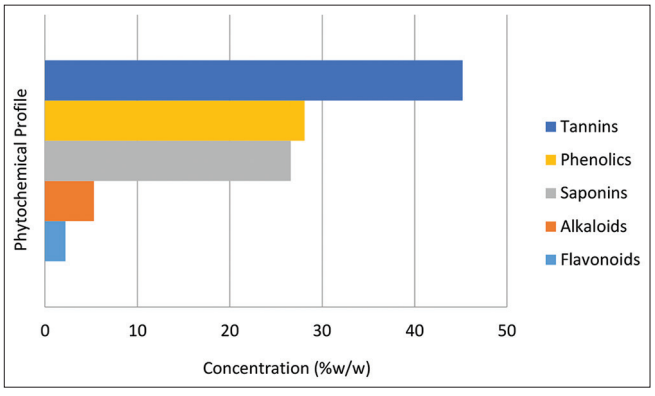

Fig 1. Phytochemical profile of the *Ochradenus baccatus* extract show spectrum of bioactive secondary metabolites.

significant number of prescription based drugs used in current therapeutics. The results show that tannins are present in highest concentrations as compared to the other constituents in the extract, followed by phenolics, saponins, alkaloids and flavonoids in the order respectively. Tannins have been shown to possess anti-inflammatory properties causing reduction in the inflammatory conditions in animal models by decreasing the myeloperoxidase enzyme activity (Soyocak et al., 2019). These have also been reported to have cytotoxic effects against various cancer cells such as lung, liver, pancreatic and colorectal cancer cells by interfering with oncogenic pathways including mTOR, JAK-STAT and TGF-β1 (Youness et al., 2021). Phenolic rich extracts demonstrate strong anti-oxidative properties which potentially ameliorate chronic conditions associated with oxidative stress including neurodegenerative diseases, cardiovascular disorders and type-2 diabetes (Cory et al., 2018). Monosodium urate crystals in gouty arthritis trigger inflammatory responses by the activation of $NLRP_3$ inflammasome, and as such the anti-oxidant phytochemicals such as flavonoids have been reported to have inhibitory effects against the $NLRP_3$ inflammasome-mediated cellular oxidative stress, which reduces the severity of the disease (Jhang et al., 2018). Alkaloids have diverse pharmacological properties that have made them suitable drug candidates in clinics, such as analgesic morphine, antimalarial quinine, bronchodilator ephedrine and anticancer vinca alkaloids (Thawabteh et al., 2019). Galanthamine which is an Amaryllidaceae alkaloid acts as an acetylcholinesterase (AChE) inhibitor, and is currently used as an effective drug to manage early and intermediate stages of Alzheimer's disease (Scott and Goa 2000). Saponins, most of which have been isolated from the plant extracts particularly distributed in Asian countries, possess diverse structures that contain hydrophilic carbohydrate moiety with hydrophobic sapogenin (triterpenoid or steroid aglycon). These molecules show inhibitory effects in different disease models that include anti-diabetic, anti-cancer and anti-inflammatory responses (Grzywacz et al., 2020). The myriad action mechanisms observed in studies on plant extracts in biological systems may reflect the significance of a single molecule which can be isolated for targeted therapy or it may be the result of a synergistic action of different phytochemical constituents. Such synergistic effects have been effectively exploited to enhance the efficacy of certain drugs or to overcome the drug resistance.

Ochradenus baccatus extract is redox-active as displayed by scavenging of DPPH radicals & superoxide anions in a dose-dependent manner and reduction of Cu (II) to Cu (I)

Oxidative stress is a hallmark of majority of the chronic diseases including cancer, cardiovascular disease, neurodegenerative disorders and metabolic syndromes such as type-2 diabetes (Sharifi-Rad et al., 2020). It is believed that the therapeutic approaches for the treatment of these diseases may benefit from the antioxidant properties of the natural products. The antioxidant potential of the extract was examined by DPPH radical scavenging assay and NBT assay for superoxide anions. As shown in fig. 2 and 3, the extract caused a progressive inhibition of DPPH radical and also neutralizes superoxide anions in a dose-dependent manner. Antioxidants preserve the cellular redox homeostasis by their ability to readily participate in electron transfer reactions to subdue the damaging potential of free radicals and reactive oxygen species against cellular biomolecules. Fig. 4, displays the redox-activity of the extract by means of its ability to reduce Cu (II) to Cu (I) that is detected using bathocuproine, a Cu (I)-specific sequestering agent. Bathocuproine binds specifically to Cu (I) which is the reduced form of copper, but not to Cu (II), the oxidized form. Studies have reported that the antioxidant activities of plant extracts show an incremental variation in direct proportion to the concentration of polyphenolic compounds which possess redox properties (Adedapo et al., 2008; Farhan and

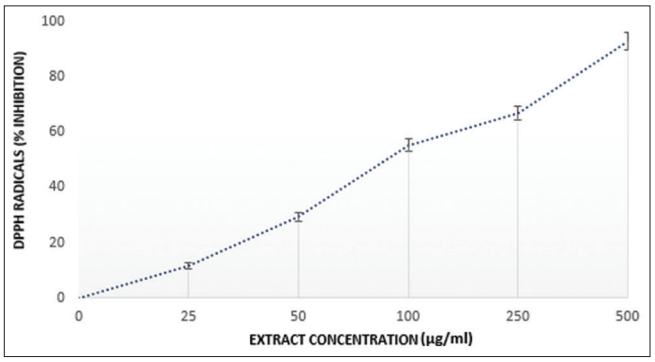

Fig 2. The extract shows dose-dependent inhibition of DPPH radicals. The values reported are the mean ± SEM of three independent experiments. **p ≤ 0.05: significant when compared with the control in the absence of the extract.

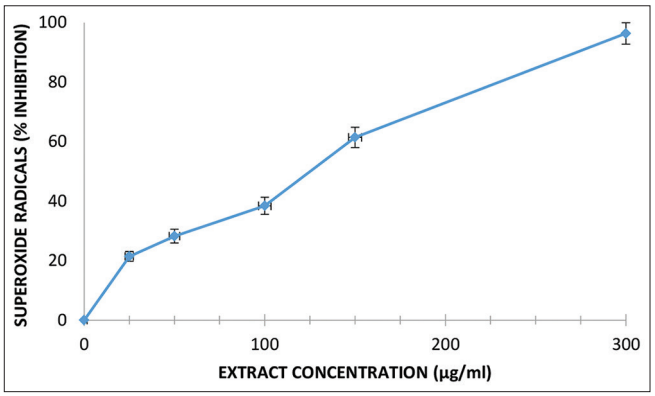

Fig 3. The extract shows dose-dependent scavenging of superoxide ($O2^{\cdot-}$) anion. The values reported are the mean ± SEM of three independent experiments. **p ≤ 0.05: significant when compared with the control in the absence of the extract.

Rizvi 2022). Reactive oxygen species which include oxygen ions such as superoxide anions or oxygen-containing radicals such as hydroxyl radicals or their products such as hydrogen peroxide are generated in abundance when the oxygen readily accepts electrons leaked from the normal oxidative metabolism. However. Cellular anti-oxidant system which also includes enzymes, neutralize these reactive species to eliminate the risk of detrimental consequences if these interact with cellular molecules and structures. An imbalance between the ROS and cell's counter mechanism may result in an oxidative stress and associated abnormal signalling and damaging effects, which leads to a diseased state. Protein oxidation and nitrosylation causing impairment of cellular functions; lipid peroxidation associated to cell membrane injury; nucleic acid oxidation leading to DNA breaks are related to premature aging and chronic conditions such as inflammation, respiratory disorders, type-2 diabetes, nerve-damage and neoplastic disease (Auten and Davis 2009). Several cell signalling pathways such as NF-kB, JNK, NRF2 and AMPK are influenced by ROS-mediated redox activity which may be protective in normal physiology but detrimental in an imbalanced abnormal state (Forrester et al., 2018). Natural antioxidants present in diet or traditional herbs help to mitigate the endogenous antioxidant depletion and restore the redox balance in pathophysiological conditions (Liu et. al., 2018). As presented in the results, the *Ochradenus baccatus* extract show significant anti-oxidative properties, which as stated above is an essential requirement of therapeutic approaches in chronic diseases.

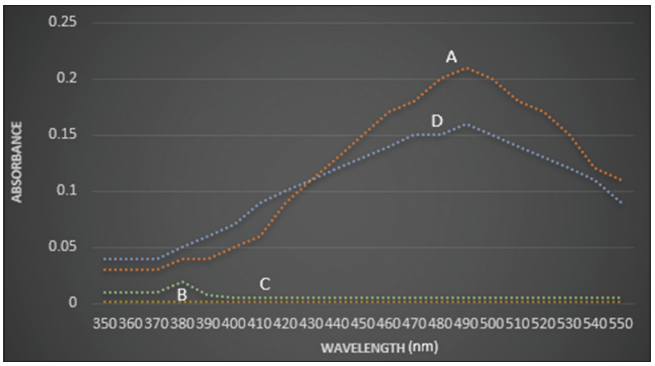

Fig 4. The redox activity of the extract assessed by its ability to reduce C (II) to Cu (i). A- Bathocuproine + Cu (I) B- Bathocuproine + Cu (II) C- Bathocuproine + Extract D-Bathocuproine + Extract + Cu (II).

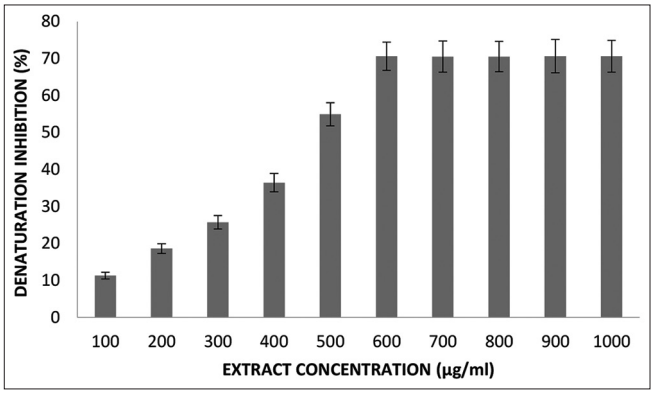

Fig 5. Inhibition of albumin protein denaturation by varying concentrations of the extract. The values reported are the mean ± SEM of three independent experiments. **p ≤ 0.05: significant when compared with the control in the absence of the extract.

Pre-incubation of bovine serum albumin with the *Ochradenus baccatus* extract progressively restrained the denaturation of the protein

It has been often realized that ROS mediated oxidative-stress, protein denaturation and inflammation are intertwined in chronic diseases. The denaturation of proteins by the loss of tertiary structure causes functional impairments, which effects several pathways where a protein is an effector molecule. In addition, the denaturation of proteins in chronic conditions also illicit inflammatory responses and biological consequences that are detrimental to normal cellular phenotype (Fersht 2013). Some mutations that contribute to certain metabolic diseases also cause protein to denature at physiological temperature. As reported in Fig. 5, progressive doses of the extracts inhibit the denaturation of protein with maximum inhibition of 70.6% observed at concentration of 600 µg/ml, after which the effect plateaued for further doses. The standard drug aspirin showed 78.6% inhibition at 100 µg/ml. Inflammatory bowel disease is a common inflammatory condition related to colonic mucosa, which includes Crohn's disease and ulcerative colitis. These are a kind of autoimmune disease characterized by relatively high degree of inflammation in the small and large intestines, caused due to host-microbial interactions. The mainstream treatment strategy for this condition involves various nutritional and therapeutic approaches that could reduce the inflammation in the intestinal lining and keep it restrained to relieve the symptoms and discomfort. *In vivo* study have previously shown that the ethanolic extract of *Ochradenus baccatus* resulted in a significant reduction of inflammation associated with paw swelling and ulcerative colitis in rats (Alqasoumi et al., 2012). It is a universal observation that invading pathogens causing infections are resisted by host defence such as innate immunity (inflammation) which is a common response for all pathogens, in addition to adaptive immunity, which is specific in nature. Such inflammatory and post-inflammatory events cause release of pro-inflammatory agents by pathogens, damaged host cells, and immune cells, which in a synergistic manner destroy the host cells, leading to conditions that are difficult to manage even when the infection has subdued or cleared (Ginsburg et al., 2019). These stages often require anti-inflammatory therapy with conventional, traditional and dietary approaches. Molecular mechanisms structuring inflammatory tumor microenvironment with cancer cells, stromal cells and

inflammatory cells play a pivotal role in pro-tumorigenic inflammation, which is implicated in the initiation, growth, progression, and metastasis of cancer (Greten et al., 2019). Inflammation is increasingly being associated with tumor-permissive state within a complex network of cellular signalling. Since a long time, diabetes has been considered a metabolic disorder with complexities driven by various factors including genetics, ageing, ethnicity, obesity, diet and other lifestyle factors. Interestingly, emerging evidences point towards a substantial role of inflammatory pathways as dominant mediators of pathogenetic course of both T1DM and T2DM with the above listed factors acting as stimulatory triggers that are associated with higher risk of the disease (Tsalamandris et al., 2019). Patients suffering from gout disease, an inflammatory arthritis have also been found to benefit from anti-inflammatory therapies that include NSAIDs, which are deleterious in long-term use, and natural products that are relatively safer (So and Martinon 2017).

The dose-dependent inhibition of xanthine oxidase by the *Ochradenus baccatus* extract shows a curve indicative of a progressive loss of enzymatic activity

Xanthine oxidase is a key enzyme in the metabolic pathway of nitrogenous compounds that leads to the formation of uric acid (Dawson and Walters 2006). Gout is a condition of inflammatory arthritis, which results due to hyperuricemia in which the serum urate levels are in excess of 7mg/l, forming monosodium urate crystals that are deposited in the joints, triggering the elements of innate immunity. It results in IL1β–mediated inflammation through a complex molecular mechanism that involves inflammasome, a key effector inflammatory complex in a number of pathological conditions (So and Martinon 2017). The condition also impairs kidney functions by promoting uric acid nephrolithiasis (Wiederkehr and Moe 2011). Advanced age, high consumption of seafood and non-vegetarian diet, as well as obesity is some of the risk factors that have been identified for this metabolic disorder. Inhibition of xanthine oxidase reduce the hyperuricemia in these patients and alleviate the tendency of salt accumulation in the joints and kidney; and relieves the associated symptoms. Our results show a progressive inhibitory property of the *Ochradenus baccatus* extract against the enzymatic activity of xanthine oxidase with a maximum inhibition of 66% observed at a dose of 300 µg/ml (Fig. 6). The study used allopurinol as the standard drug, which is a well-known inhibitor of the enzyme. The preventive strategies for hyperuricemia engages treatments that reduce the formation of uric acid or enhance the excretion of the metabolite. However, it is observed that in comparison to uricosuric and anti-inflammatory medications, inhibitors of xanthine oxidase have milder side effects in long-term use. Several laboratories are currently exploring natural

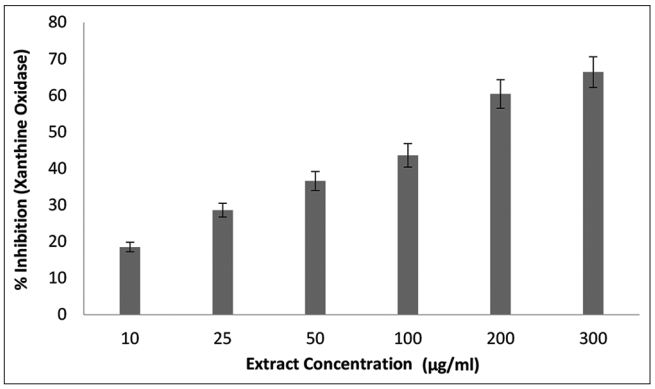

Fig 6. The dose- dependent inhibition of mammalian xanthine oxidase by increasing concentrations of the extract. The values reported are the mean ± SEM of three independent experiments. *p ≤ 0.05: significant when compared with the control in the absence of the extract.

products for lead molecules in the treatment of this metabolic disorder as unlike drugs, natural products have a higher safety index (Samuel et al., 2020). These complex plant-derived agents including polyphenols have been reported to ameliorate such hyperuricemic disorder by multiple pathways that includes reduction in the synthesis of uric acid, interfering with urate renal reabsorption and enhancing its excretion (El-Tantawy et al., 2021; Mehmood et al., 2019). These natural compounds have hydroxyl groups at C-5 & C-7, which may competitively replace the C-2 and C-6 hydroxyl groups of xanthine at the enzyme's active site or some such as quercetin and chrysin form complexes with the hydrophobic moieties in the active site, forming an inactive enzyme-inhibitor complex (Mehmood et al., 2019). Colchicine, a natural compound that has a long history of use as herbal medication for joint pain, dating back to early 1800, was approved by FDA in 2009; and serves as a highly effective regimen when given early in an acute gouty condition (Dasgeb et al., 2018). Hence, it is understood that the preventive approaches for hyperuricemia and related disorders may benefit from the natural products such as *Ochradenus baccatus,* which display multitude of pharmacological properties including anti-oxidative, anti-inflammatory and xanthine oxidase inhibitory activities.

CONCLUSION

Plants have been the source of pharmaceutically active molecules since ancient times when the human civilizations started accumulating sophisticated knowledge from the environmental cues for treating various illnesses. It is believed that still in the modern times 25% of drugs prescribed for various ailments worldwide are plant-derivatives (Rates, 2001). The Nobel Prize 2015 for artemisinin has rekindled the interest in natural product pharmacology. Moreover, the interest in the natural products pharmacology is also

escalating due to the affordability, accessibility and higher safety index. In recent years exploring novel bioactive properties in plants of interest is a significant stride from the traditional knowledge to evidence-based practice (Fernandez et al., 2022; Santini 2022).

CONFLICT OF INTEREST

Author declares no conflict of interest

ACKNOWLEDGEMENT

The author acknowledges the support of Prof. Faisel Abuduhier and Dr. Showket Bhat for the plant collection and that of Dr. Mohammad Nasir for the authentication of the plant. The technical support from Dr. Shazia Usmani, College of Pharmacy, Integral University (India) is also thankfully acknowledged.

FUNDING

The study did not receive any external funding. The charges incurred on some technical services and APC has been borne by the author.

Author contribution

M.F.Ullah conceived the study design, experimental work and contributed in compiling the results and writing of the manuscript.

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