



INVESTIGATING THE ANTI-INFLAMMATORY ACTIVITY OF AN ETHANOLIC EXTRACT FROM *ARTOCARPUS TONKINENSIS* LEAVES USING A COLLAGEN ANTIBODY-INDUCED ARTHRITIC MOUSE MODEL

Tran Duc Quan^{1,2}, Dao Duc Thien^{1,2}, Nguyen Thanh Tam^{1,2},
Nguyen Thi Hoang Anh^{1,2}, Nguyen Thi Cuc³, Nguyen Thi Nga³,
Tran Van Sung¹, Le Thi Hong Nhung⁴, Nguyen Hoang Sa^{2,3},
Sabrina Adoriso⁶, Domenico V. Delfino⁶, Do Thi Thao^{2,3}, Trinh Thi Thuy^{1,2,*}

¹*Institute of Chemistry, VAST, 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Viet Nam*

²*Graduate University of Science and Technology, VAST, 18 Hoang Quoc Viet, Ha Noi, Viet Nam*

³*Institute of Biotechnology, VAST, 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Viet Nam*

⁴*Hanoi University of Industry, 298 Cau Dien, Bac Tu Liem, Ha Noi, Viet Nam*

⁵*Khanh Hoa University, 01 Nguyen Chanh, Nha Trang, Khanh Hoa, Viet Nam*

⁶*University of Perugia, Piazzale Severi, S. Andrea delle Fratte, 06132 Perugia, Italy*

*Email: thuy@ich.vast.vn

Received: 25 January 2018; Accepted for publication: 20 April 2018

ABSTRACT

This study was contrived for evaluating the *in vitro* and *in vivo* anti-inflammatory effects of an aqueous ethanolic leaf extract of the Vietnamese *Artocarpustonkinensis* A. Chev. exGagnep. using lipopolysaccharide-stimulated RAW 264.7 macrophages and a collagen antibody-induced arthritic mouse model as well. The obtained results here demonstrate that the 70 % ethanolic leaf extract of *A. tonkinensis* (AT2), traditionally used in Vietnamese folk medicine for treating arthritic symptoms, has beneficial effects on pro-inflammatory cytokine inhibition and in an experimental arthritic mouse model. LPS-stimulated RAW 264.7 macrophages treated with AT2 showed a significant decrease in the production of IL-6 and TNF α at concentrations of 12.5, 25 and 50 $\mu\text{g/mL}$ ($P < 0.05$), indicating its potential anti-inflammatory properties. The treatment of CAIA mice with AT2 also led to diminish the incidence of arthritis at doses of 200 and 300 mg/kg body weight.

Keywords: *Artocarpustonkinensis*, autoimmune, interleukin 6, inflammation, rheumatoid arthritis.

Classification numbers: 1.1.1; 1.2.1

1. INTRODUCTION

Inflammation is involved in the development of conditions such as autoimmune disease [1, 2] and rheumatoid arthritis [3, 4]. The major classes of drugs used to suppress inflammation are nonsteroidal anti-inflammatory agents and corticosteroids, but their toxic adverse effects such as epigastric distress, peptic ulceration and osteoporosis have limited their use [5]. Considering that different medicinal compounds, derived from plant sources, such as flavonoids, flavonoid glycosides, stilbenoids and saponins, may represent new anti-inflammatory agents more efficacious, safer, affordable, and accessible for patients, this path of searching for new drugs should be taken in serious consideration.

Artocarpus tonkinensis A. Chev. ex Gagnep. is a tree currently found in North Vietnam. The decoction of its leaves and roots is used in traditional knowledge to treat backache, arthritis and joint disorders. Our previous phytochemical analysis of the *A. tonkinensis* leaves revealed the presence of flavonoid compounds such as auronol, kaempferol, quercetin and their glycosides [6-8]. Of them, two auronol glucosides (**1** and **2**) were found to have potent immunomodulatory, anti-proliferative and anti-inflammatory activities [9-11]. For a possible use of 70% ethanolic extract of *A. tonkinensis* leaves as alternative herb medicines to treat human disease, this study was undertaken to evaluate its possible anti-inflammatory activities *in vitro* using LPS-stimulated RAW 264.7 macrophages and *in vivo* using a collagen antibody-induced arthritic BALB/c mouse model.

2. MATERIALS AND METHODS

2.1. Chemicals

Dulbecco's Modified Eagle's Medium (DMEM) and antibiotic - antimycotic were purchased from Invitrogen (Carlsbad, CA, USA). Fetal bovine serum (FBS), lipopolysaccharides (LPS) and 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) were obtained from Sigma Chemical Co. (St. Louis, MO., USA). TNF-alpha and IL-6 ELISA kits were purchased from Biovision (Chester Springs, PA, USA). The collagen antibody cocktail was purchased from Modi Quest Research (Nijmegen, The Netherlands).

2.2. Preparation of ethanolic extract of *A. tonkinensis* leaves (AT2)

Leaves of *A. tonkinensis* were collected in Hanoi, Vietnam (October 2016) and identified by the taxonomist – Ngo Van Trai (National Institute of Medicinal Materials, Hanoi, Vietnam). The voucher specimen (Nr. 1482-AT-2016) was deposited in the Institute of Chemistry, Vietnam Academy of Science and Technology (ICH, VAST) for further reference.

In a pre-experiment, it was found that application of 70 % ethanol to extract the dried leaves of *A. tonkinensis* possessed high total phenolic content. Thus, 70 % ethanol was used for this extraction. Dried ground of *A. tonkinensis* leaves (600g) were extracted with 70 % EtOH, each 3 litres, overnight, x3 times) at RT. The extract was filtered and concentrated under reduced pressure in a rotary evaporator at 50-60 °C until the aqueous volume reduced to one third of its original volume and then freeze-dried. The crude ethanolic extract (110 g) was a brown powder, of which the obtained yield was 18.3 % (w/w).

2.3. Phytochemical analysis of AT2

To obtain the purified flavonoids for the chemical structural analysis, a large-scale isolation was carried out as previously described and their structures were confirmed by comparing their ESI-MS, ^1H and ^{13}C NMR data with reported data [6, 8]. AT2 was fractionated by a classical chromatography methodology. Columns packed with DIAION HP-20 and Sephadex LH-20 adsorbents were efficient for the isolation of nine compounds. Two auronolglucosidemaesopsin 4-*O*- β -glucopyranoside (hovetrichoside C, **1**), alphononin-*O*- β -glucopyranoside (**2**), as well as kaempferol (**3**), astragalol (**4**), kaempferol 3-*O*- β -rutinoside (**5**), kaempferol 3-*O*- β -neohesperidoside (**6**), quercetin, quercetin 3-*O*- β -glucopyranoside (**7**), afzelechin-(4 α →8'')-catechin-3-*O*- β -glucopyranoside (**8**) and catechin (**9**) were identified [6, 8]. The AT2 extract was analyzed for the presence of various phytochemical constituents employing screening TLC. The detailed qualitative analyses of AT2 extract was performed with HPLC method. The presence of flavonoids **1-9** (Figure 1) in AT2 was examined by high-performance liquid chromatography coupled with mass spectrum (HPLC-MS), with UV detection.

Table 1. The MS data of isolated compounds from ethanolic extract of *A. tonkinensis* leaves (AT2)^a

Comp.	Name of compounds ^b	Molecular formula	Molecular ion (<i>m/z</i>)	Rt ^c (min .)
1	hovetrichoside C	C ₂₁ H ₂₂ O ₁₁	473[M+Na] ⁺	10.89
2	alphononin- <i>O</i> - β -D-glucopyranoside	C ₂₁ H ₂₂ O ₁₂	489[M+Na] ⁺	9.41
3	kaempferol	C ₁₅ H ₁₀ O ₆	287 [M+H] ⁺	16.29
4	astragalol	C ₂₁ H ₂₀ O ₁₁	449 [M+H] ⁺	14.70
5	kaempferol 3- <i>O</i> - β -rutinoside	C ₂₇ H ₃₀ O ₁₅	617 [M+Na] ⁺	^c
6	kaempferol 3- <i>O</i> - β -neohesperidoside	C ₂₇ H ₃₀ O ₁₅	593 [M-H] ⁻	^c
7	quercetin 3- <i>O</i> - β -D-glucopyranoside	C ₂₁ H ₂₀ O ₁₂	465 [M+H] ⁺	13.85
8	afzelechin-(4 α →8'')-catechin-3- <i>O</i> - β -glucopyranoside	C ₃₆ H ₃₆ O ₁₆	747 [M+Na] ⁺ 725 [M+H] ⁺	12.60
9	catechin	C ₁₅ H ₁₄ O ₆	291[M+H] ⁺	16.88

^aUPLC/MS/MSXevo-TQ, Waters, USA. UPLC C18 column (150 mm×2.1 mm i.d.) at 25°C. UV spectrum was recorded from 190 nm to 400 nm. The mobile phase consisted of A, water containing 0.1 % formic acid, and B, methanol containing 0.1 % formic acid. The elution gradient was performed using a pump from 10 % to 100 % B for 25 min at a flow rate of 0.25 mL/min. Detection was carried over 30 min at a flow rate of 0.25 mL/min. Detection was carried out at 290 and 294 nm. The injection volume was 5 μL . ESI-MS (positive ion), fullscan(*m/z* from 100 to 1300).

^bConfirmed by comparison to authentic standards; ^cOverlapped.

2.4. Biological tests

2.4.1. Cell culture

The RAW 264.7 mouse macrophage cell line was obtained from the American Type Culture Collection (ATCC) (Manassas, VA, USA) and cultured in Dulbecco's Modified Eagle's Medium

(DMEM) supplemented with 10 % fetal bovine serum, 1 % penicillin and 1 % streptomycin. Cells were incubated in a humidified incubator with an atmosphere of 5 % CO₂ at 37 °C.

2.4.2. Cell viability assay

The MTT assay was used to evaluate the effects of AT2 on cell viability. In brief, cells were seeded into 96-well plates at a density of 1×10^5 cells/mL. Cells were treated with different concentrations (0, 3.125, 6.25, 12.5, 25, and 50 µg/mL) of AT2 for 1 h, followed by stimulation with LPS (1 µg/mL) for 24 h. After incubation, 30 µL MTT (5 mg/mL) was added to each well and incubated for another 4 h. After replacing the culture supernatant with 100 µL dimethyl sulfoxide (DMSO), the optical density of the plates was read at a wavelength of 490 nm using a microplate reader (TECAN, Austria).

2.4.3. Pro-inflammatory cytokine determination assay

RAW 264.7 cells were pretreated with various concentrations (0, 3.125, 6.25, 12.5, 25, and 50 µg/mL) of AT2 for 24 h before stimulating with LPS (1 µg/mL). After 18 h incubation, the levels of pro-inflammatory cytokines TNF-alpha and IL-6 were measured in the supernatant using commercial ELISA kits (Biovision, Chester Springs, PA, USA) following the manufacturer's protocols.

2.4.4. Evaluating AT2 extract-reduced arthritis using a model of collagen antibody-induced arthritis (CAIA)

The male mice used in this study were of 10-11 weeks of age. The anti-collagen antibody cocktail was purchased from Modi Quest Research (Nijmegen, The Netherlands) and used according to the manufacturer's instructions. Briefly, mice were intraperitoneally (IP) injected with 3 mg of the cocktail of anti-collagen antibodies. On days 3 and 9, the mice were IP injected with 25 µg LPS (Sigma, St. Louis, MO) to trigger the development of arthritis. Dosing began on day 4 after the mice had initial symptoms of arthritis. Thirty mice were assigned equally into five groups: the positive control (Group 1) orally received dexamethasone at a dose of 0.5 mg/kg body weight (bw) daily for 9 days; the negative control (Group 2) received water daily for 9 days; The experimented groups, of which were group 3, 4 and 5, was orally administered with AT2 at different doses for 9 days. Accordingly, group 3 was treated with AT2 at a dose of 300 mg/kg bw daily; Group 4 was treated with AT2 at a dose of 200 mg/kg bw daily; and Group 5 was treated with AT2 at a dose of 100 mg/kg bw daily. The mice were scored for clinical arthritis by two observers who were blinded to the group assignments. Each paw was scored on a scale of 0-2 based on the signs of swelling and inflammation. Serum was collected from each mouse injected with anti-collagen antibodies on days 0, 4, 6, 8, 10, and 12 and stored at -20 °C until use. The levels of TNF-alpha and IL-6 in the sera were measured as already described.

3. RESULTS AND DISCUSSION

3.1. Phytochemical analysis

In our previous studies, we prepared an ethyl acetate (EtOAc) extract from the leaves of the *A.tonkinensis* plant and tested its anti-inflammatory properties in a collagen-induced arthritis

(CIA) model, and showed that the EtOAc extract of *A. tonkinensis* had beneficial effects [9]. Phytochemical analysis indicated that the EtOAc extract contains potentially bioactive glucosides such as hovetrichoside C (**1**), alphonin-*O*- β -D-glucoside (**2**), artonin-4'-*O*- β -D-glucopyranoside and astragaloside (**4**). All four compounds were found to have potent anti-proliferative and anti-inflammatory effects *in vitro* model [7, 9]. The main compound **1** inhibited also the growth of OCI-AML cells [10]. Moreover, gene expression profiling identified 19 genes modulated by compound **1** and among them, *HMOX1* and *SRXN1* genes were consistently and highly up-regulated [10]. To examine the more polar components from *A. tonkinensis*, AT2 was prepared from 70 % ethanol extraction of *A. tonkinensis* leaves. The use of 70 % ethanol for extraction resulted in higher yield of crude extract (18.3 %, w/w). On the other hand, AT2 contains significant amounts of the same glucosides as in EtOAc extract, which are responsible for anticancer and anti-inflammatory activities [8, 11]. Thus, in this study, AT2 was evaluated for potential at reducing arthritis using a CAIA model.

Phytochemical studies using the 70 % ethanolic extract of AT2 revealed the presence of nine flavonoids **1-9**. Their structures were elucidated by electrospray ionization mass spectrometry (ESI-MS) and ^1H -, ^{13}C NMR spectral analysis. Nine compounds **1-9** are identified, including maesopsin 4-*O*- β -glucopyranoside (**1**), alphonin 4-*O*- β -glucopyranoside (**2**), kaempferol (**3**), astragaloside (**4**), kaempferol 3-*O*- β -rutinoside (**5**), kaempferol 3-*O*- β -neohesperidoside (**6**), quercetin 3-*O*- β -glucopyranoside (**7**), afzelechin-(4 α \rightarrow 8'')-catechin-3-*O*- β -glucopyranoside (**8**) and catechin (**9**) (Figure 1). The detailed qualitative analyses of AT2 extract were performed with HPLC and HPLC-MS methods. Constituents of AT2 were confirmed by comparing HPLC-MS data of standard isolated compounds (Table 1) [8]. At present, it is difficult to attribute the observed effects of the leaves of *A. tonkinensis* to any one particular chemical moiety.

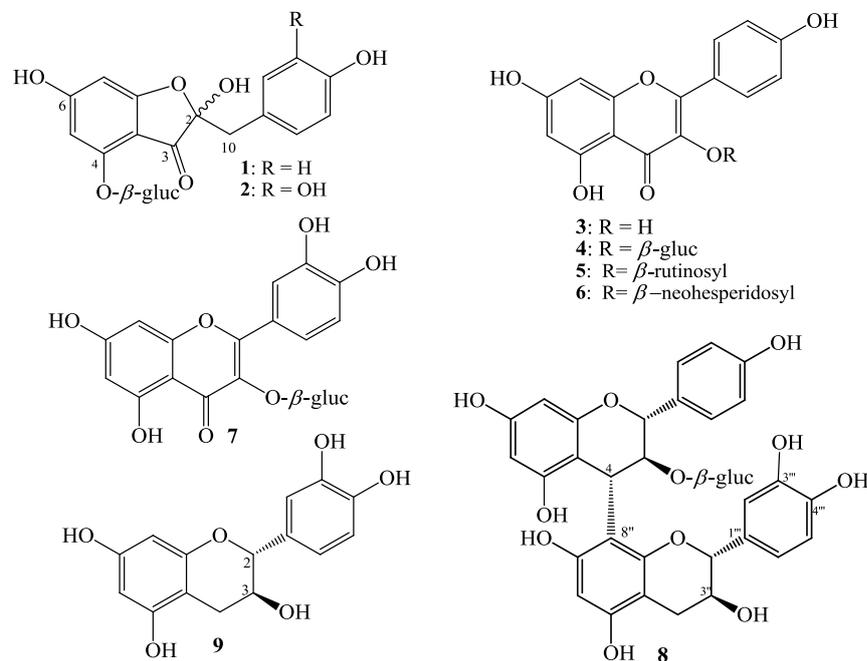


Figure 1. Structures of flavonoids (**1-9**) from 70% ethanolic extract of *A. tonkinensis* leaves (AT2).

3.2. *A. tonkinensis* leaf extract (AT2) inhibited pro-inflammatory cytokines releasing in LPS-stimulated RAW 264.7 macrophages

There were no significant changes in cell viability following AT2 treatment at the tested concentrations (Figure 2). Therefore, non-toxic concentrations (3.125, 6.25, 12.5, 25, and 50 $\mu\text{g/mL}$) of AT2 were used in the cytokine inhibition experiment, allowing the determination of the effects of AT2 on the production of pro-inflammatory cytokines in LPS-stimulated macrophages. Treatment with LPS resulted in a significant increase in TNF-alpha and IL-6 production compared with the control. However, treatment with AT2 (12.5, 25 and 50 $\mu\text{g/mL}$) remarkably inhibited LPS-induced TNF-alpha and IL-6 production in a dose-dependent manner ($P < 0.05$) (Figure 3). This led us to conclude that AT2 might have anti-inflammatory properties caused by the inhibition of cytokine production in LPS-induced macrophages.

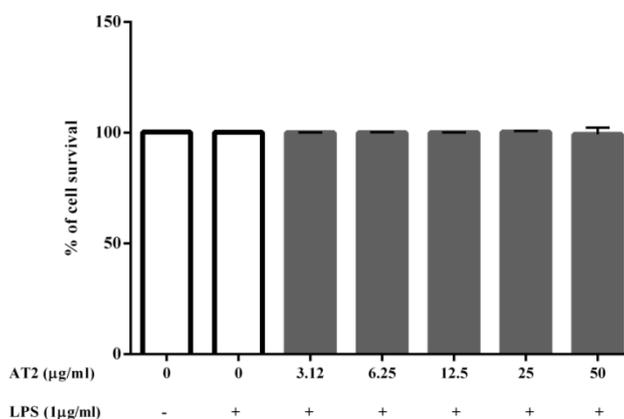


Figure 2. Effects of AT2 extract on cell viability in LPS-treated RAW 264.7 mouse macrophages. RAW 264.7 cells were cultured with AT2 extract in the presence of LPS (1 $\mu\text{g/mL}$) for 24 h. Cell viability was tested by MTT reduction assays. Values are presented as the mean \pm standard deviation (SD) of three independent experiments.

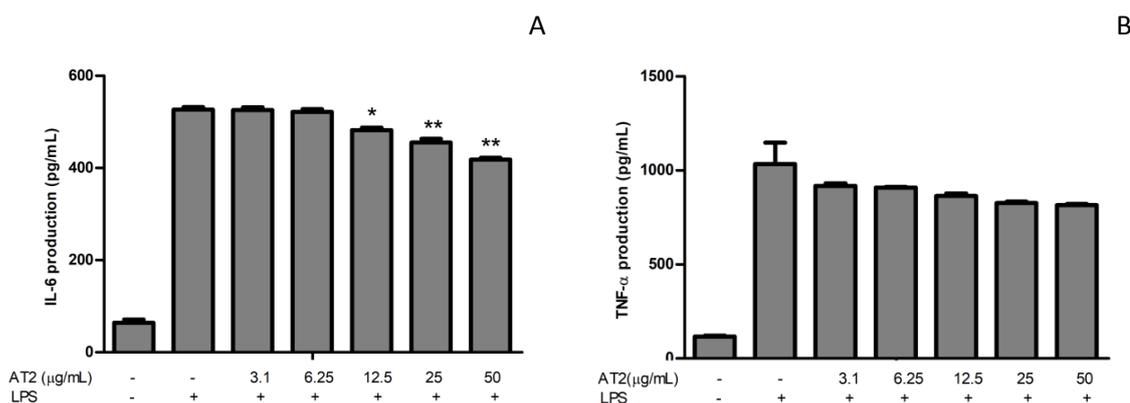


Figure 3. Effects of AT2 extract on the production of IL-6 (A) and TNF-alpha (B) in LPS-stimulated RAW 264.7 cells. Cells were treated with LPS alone or LPS plus various concentrations (3.125, 6.25, 12.5, 25, and 50 $\mu\text{g/mL}$) of AT2 extract for 24 h. * $P < 0.05$, ** $P < 0.01$ compared to LPS stimulated cells. Values represent the mean \pm SD of three independent experiments.

3.3. The *in vivo* effect of *A. tonkinensis* leaf extract on CAIA

For a possible use of 70 % ethanolic extract of *A. tonkinensis* leaves as alternative herb medicines to treat human disease, it was undertaken to evaluate its potential at reducing arthritis using a CAIA model. Previous toxicological studies have shown that AT2 exerted no effects on survival, clinical observations, macroscopic examination of organs, body weight or food, or water consumption in mice up to 14.50 g/kg bw (oral administration) dose. In addition, from sub-chronic toxic tests, AT2 did not change the behavior, body weight or histopathological assessment of the kidney or liver at doses of 0.6 and 1.8 g/kg body weight for 8 weeks (data not shown); hence doses of 100, 200 and 300 mg/kg bw were selected for the present study.

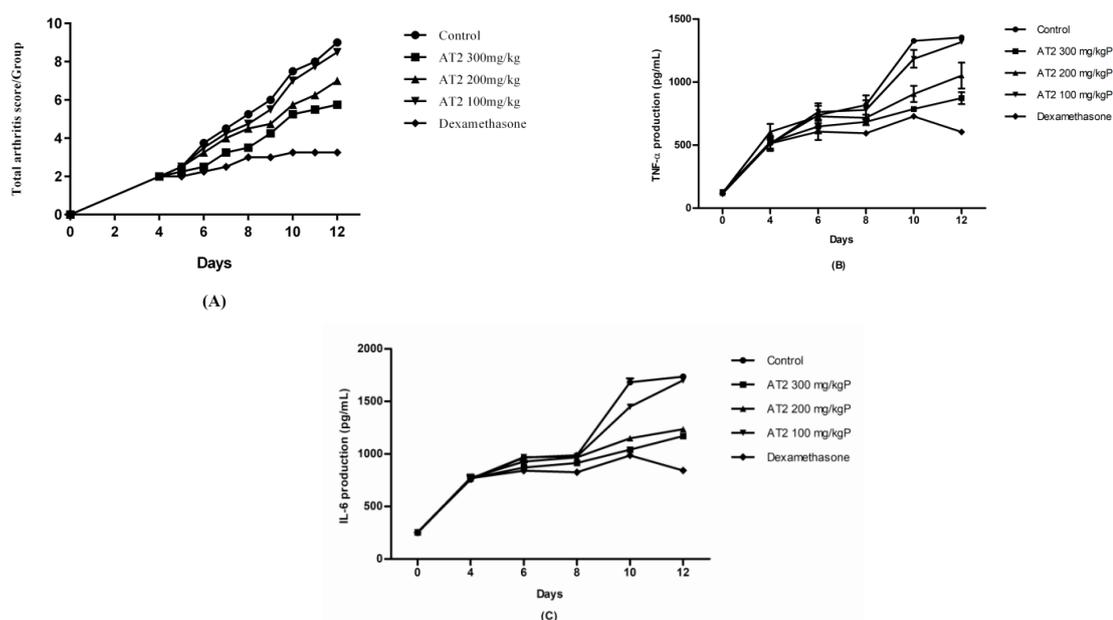


Figure 4. Effect of AT2 administration at high doses caused statistically significant reductions in the arthritis scores compared with the vehicle-treated controls ($P < 0.05$) (A). TNF- α was measured in the sera of AT2-treated mice at difference doses (100, 200 and 300 mg/kg body weight), together with negative (vehicle-treated) and positive (dexamethasone) groups (B). IL-6 levels in compliance with TNF- α measured from AT2-treated groups and other control groups (C).

The effect of the AT2 extract on signs of arthritis in the CAIA model was evaluated. Initial experiments were performed using the BALB/c mouse model because of its higher susceptibility to CAIA. On days 0 and 3, BALB/c mice were injected with 3 mg collagen antibody cocktail and 25 μ g LPS, respectively. Animals were treated with AT2 at different concentrations from day 4. AT2 administration at doses of 300 mg/kg and 200 mg/kg bw caused statistically significant reductions in the arthritis scores compared with the vehicle-treated controls ($p < 0.05$) (Figure 4A). The arthritis scores were reduced from 9 in the control group to 5.75 and 7 at doses of 300 mg/kg and 200 mg/kg bw, respectively. Accordingly, these scores showed the average reduction of arthritis symptomatic scores to be 36.11 % and 22.22 %, respectively. In addition, mice treated with a daily oral dose of dexamethasone at a dose of 0.5 mg/kg bw (positive control) had excellent dose responsive inhibition of paw swelling over time, with activity peaking at 63.89 % inhibition of arthritis scores (Figure 4A). The IL-6 and TNF- α levels in the collected sera were also significantly decreased by AT2 extract at doses of 300 mg/kg and

200 mg/kg bw compared with those of untreated mice (Figure 4B and 4C). The data were entirely consistent with the level of rheumatoid arthritis symptoms shown in those mouse groups.

The results indicate that the aqueous EtOH extract from *A. tonkinensis* leaves exerts its anti-inflammatory activity through decreasing arthritis scores. Moreover, reductions in arthritis scores were dose-related and statistically significant at doses of 200 and 300 mg/kg bw. Accordingly, the level of IL-6 and TNF-alpha pro-inflammatory cytokines in the sera of AT2 extract-treated mice showed a relevant reduction.

Flavonoids and their glycosides exhibit their anti-inflammatory effects by several mechanisms [14], along with a wide spectrum of other pharmacological effects such as analgesic, antioxidant, antimicrobial, antiviral, anticancer, antidiabetic, and antiplatelet activities [15, 16]. Kaempferol, quercetin, alphitonin and their glycosidic derivatives are considered potent immunomodulatory, anticancer, anti-inflammatory activities and antioxidant ability [17, 18]. Therefore, the anti-inflammatory activity of AT2 may be attributed to its total flavonoids. These results suggest that AT2 can inhibit the inflammatory response and may represent a potential therapeutic candidate for the treatment of chronic inflammatory diseases.

4. CONCLUSIONS

The results of the present study indicate that the 70 % ethanol extract from *A. tonkinensis* leaves exerts anti-inflammatory activity when tested *in vitro* and *in vivo*. The *in vivo* tests indicate that the arthritis scores and pro-inflammatory cytokines were significantly reduced at doses of 200 and 300 mg/kg body weight ($P < 0.05$). These promising results demonstrate that this plant is valuable for preparing functional foods and pharmaceutical medicines to treat inflammatory, rheumatism and joint disorders.

Acknowledgements. The research was supported by a grant (NDT.33.ITA/17) from Vietnam Ministry of Science and Technology and by the Italian Ministero degli Affari Esteri della Cooperazione Internazionale (MAECI).

REFERENCES

1. Tabas I, Glass C. K. - Anti-inflammatory therapy in chronic disease: challenges and opportunities. *Science* **339** (6116) (2013) 166-172.
2. Guilherme L., Kalil J. - Rheumatic heart disease: Molecules involved in valve tissue inflammation leading to the autoimmune process and anti-s. pyogenes vaccine, *Front Immunol* **4** (2013) 352.
3. Shrivastava A. K., Pandey A. - Inflammation and rheumatoid arthritis, *J. Physiol Biochem.* **69** (2) (2013) 335-347.
4. Christodoulou C., Choy E. - Joint inflammation and cytokine inhibition in rheumatoid arthritis, *Clin. Exp. Med.* **6** (1) (2006) 13-19.
5. Gullick N. J., Scott D. L. - Drug therapy of inflammatory arthritis, *Clin. Med.* **12** (4) (2012), 357-363.
6. Thuy T. T., Kamperdick C., Ninh P. T., Lien T. T. P., Thao T. T. P., Sung T. V. - Immunosuppressive auronol glycosides from *Artocarpus tonkinensis*, *Pharmazie* **59** (2004) 297-300.

7. Dang D. T., Eriste E., Liepinsh E., Trinh T. T., Erlandsson-Harris H., Sillard R., Lasson P. - A novel anti-inflammatory compound, artonkin-4'-O-glucoside, from the leaves of *Artocarpus tonkinensis* suppresses experimentally induced arthritis, *Scand J Immunol* **69** (2009) 110-118.
8. Thuy T. T., Thien D. D., Hung T. Q., Tam N. T., Anh N. T. H., L. K. Dung, T. V. Sung, Delfino D. V. - Flavonol and proanthocyanidin glycosides from the leaves of *Artocarpustonkinensis*, *Chem. Nat. Compd.* **53** (2017) 759-763.
9. Ngoc D.D., Catrina A. I., Lundberg K., Harris H. E., Ha N. T., Anh P. T., Larsson P. - Inhibition by *Artocarpus tonkinensis* of the development of collagen-induced arthritis in rats, *Scand J Immunol* **61** (2005) 234-241.
10. Pozzesi N., Pierangeli S., Vacca C., Falchi L., Pettorossi V., Martelli M.P., Thuy T. T., Ninh P.T., Liberati A.M., Riccardi C., Sung T.V., Delfino D. V.- Maesopsin 4-O-beta-D-glucoside, a natural compound isolated from the leaves of *Artocarpus tonkinensis*, inhibits proliferation and up-regulates HMOX1, SRXN1 and BCAS3 in acute myeloid leukemia, *J. Chemother* **23** (2011) 150-157.
11. Thuy T. T., Thien D. D., Hung T. Q., Tam N. T., Anh N. T. H., Nga N. T., Mai L. P., Sung T. V., Delfino D. V., Thao D. T. - *In vivo* anticancer activity of maesopsin 4-O- β -glucoside isolated from leaves of *Artocarpus tonkinensis* A, *Chev. Ex Gagnep, Asian Pac. J. Trop. Med.* **9** (2016) 351-356.
12. Pulichino AM, Rowland S, Wu T, Clark P, Xu D, Mathieu MC, Riendeau D, Audoly LP. - Prostacyclin antagonism reduces pain and inflammation in rodent models of hyperalgesia and chronic arthritis, *J. Pharmacol Exp. Ther.* **319** (3) (2006) 1043-1050.
13. Moore A. R., Alden S., Bourne T., Denis M. C., Kranidioti K., Okoye R., Sotsios Y., Stelcel Z., Vugler A., Watt G., Shaw S. - Collagen II antibody-induced arthritis in Tg1278TNFko mice: optimization of a novel model to assess treatments targeting human TNF α in rheumatoid arthritis, *J. Transl. Med.* **12** (1) (2014) 1-10.
14. Romano B., Pagano E., Montanaro V., Fortunato A. L., Milic N., Borrelli F. - Novel insights into the pharmacology of flavonoids, *Phytother Res* **27** (2013) 1588-1596.
15. Xiao J., Chen T., Cao H. - Flavonoid glycosylation and biological benefits, *Biotechnol Adv* **196** (2014) 4103-4110.
16. Zhao M., Yang B., Wang J., Liu Y., Yu L., Jiang Y. -Immunomodulatory and anticancer activities of flavonoids extracted from litchi (*Litchi chinensis* Sonn.) pericarp, *Int Immunopharmacol* **7** (2007) 162-166.
17. Kotani M., Matsumoto M., Fujita A., Higa S., Wang W., Suemura M., Kishimoto T., Tanaka T. - Persimmon leaf extract and astragaloside inhibit development of dermatitis and IgE elevation in NC/Nga mice, *J. Allergy ClinImmunol* **106** (1) (2000) 159-166.
18. Kampkötter A., Timpel C., Zurawski R. F., Ruhl S., Chovolou Y., Proksch P., Watjen W. - Increase of stress resistance and lifespan of *Caenorhabditis elegans* by quercetin, *Comparative biochemistry and Physiology Part B: Biochemistry and Molecular Biology* **149** (2008) 314-323.