



The Anti-Allergic And Anti-Inflammatory Effect Of Fingerroot (*Boesenbergia Rotunda*) Rhizome Extract In Male White Wistar Rats Induced By Ovalbumin

*Diah Hermayanti ¹, Hawin Nurdiana², Alifia Salsabila Teka³, Vania Nabila Putri B⁴,
Yosiene Dhea Elfita⁵

¹Clinical Pathology Departement, Medical Faculty, University of Muhammadiyah Malang,
Indonesia, JL. Bendungan Sutami 188A, Malang, East Java

²Pediatric Departement, Medical Faculty, University of Muhammadiyah Malang,
Indonesia, Medical Faculty, University Muhammadiyah Malang,
JL. Bendungan Sutami 188A, Malang, East Java

³⁴⁵Student of Medical Faculty, University of Muhammadiyah Malang, Indonesia

Corresponding Author : Diah Hermayanti

Email: diahhermayanti_umm@yahoo.com

Received : February 17th2025. Revised : March 25th2025. Published: June 30th2025

DOI : <https://doi.org/10.22219/sm.Vol21.SMUMM1.41001>

ABSTRACT

Background: In type 1 hypersensitivity reactions there is an increase in pro-inflammatory cytokines and recruitment of eosinophil cells which will cause inflammation. The fingerroot rhizomes (*Boesenbergia rotunda*) contain flavonoids which are thought to improve allergic and inflammatory reactions.

Aims: to determine the effect of *Boesenbergia rotunda* rhizome extract (BRE) on levels of IgE, TNF- α , number of peribronchial eosinophil cells (PEC) and level of peribronchial tissue necrosis (PTN), proliferation of alveoli cells (PAC) in male Wistar white rats induced by ovalbumin.

Methods: true experimental research using post test only control group design. The research objects were male white rats (*Rattus norvegicus* Wistar strain) which were divided into negative and positive control groups, as well as three treatment groups. Ovalbumin induction was given intraperitoneally on days 0 and 7, and by inhalation on days 19-22. BRE was given orally on days 15-22 at a dose of 350, 7500, 1,400 mg/kg BW/day.

Results and discussion: One-way ANOVA test for TNF- α levels p.0.015, PEC p.0.013, PTN p.0.000, and PAC p.0.007. Kruskal-Wallis test for IgE levels p.0.056. Pearson correlation test for NEC was -0.805 (p.0.002), PTN -0.799 (p.0.02), PAC -0.701 (p.0.01). BRE contains panduratin A and hydroxypanduratin A, which have anti-allergic and anti-inflammatory effects.

Conclusion: BRE has anti-allergic and anti-inflammatory effect in male white wistar rats induced by ovalbumin

Keywords: Type 1 hypersensitivity, *Boesenbergia rotunda*, immunoglobulin E, TNF- α , eosinophils, necrosis, alveoli cell proliferation

Copyright © 2025, Diah Hermayanti et al

This is an open access article under the CC-BY-SA license

INTRODUCTION

The prevalence of asthma in Indonesia based on Basic Health Research (Riskesdas) in 2018 was highest in DIY (4.5.8%), North Sumatra (2.5%), and East Java (2.9%). This is still above the prevalence of asthma in Indonesia (2.5%) (Kemenkes RI, 2018; Kartina et al., 2020).

Asthma is associated with innate and adaptive immunity mediated by immune cells (Zhu et al., 2020). Asthma is an allergic disease, type 1 hypersensitivity immune reaction, due to exposure to allergens, which will cause pathological conditions. Hypersensitivity is classified based on its immunological mechanism, namely type 1 reaction or rapid reaction; type 2 reactions are reactions mediated by antibodies; type antibody complexes mediate 3 reactions; and reaction 4 is mediated by T cells (Abbas, 2021)

In type 1 hypersensitivity reactions, the reaction can occur immediately after the body is exposed to the allergen within 15-30 minutes and sometimes 6-8 hours from the time of exposure to the antigen. This reaction is mediated by immunoglobulin E (IgE) and mast cells. Allergen exposure causes a rapid vascular and smooth muscle reaction to the allergen, which develops within minutes after exposure. In the sensitization phases of type-1 hypersensitivity, the host encounters an asymptomatic contact with the antigen. The next impact phases, in this stage, the pre-sensitized host is re-introduced to the antigen which leads to type-I anaphylactic or atopic immune responses (Kiruthika, 2023)(Wang et al., 2023)

Allergic asthma is associated with T helper2 (Th2) cell responses. Upon recognizing allergens, allergen specific Th2 cells produce type 2 cytokines (interleukin (IL)-4, IL-5, IL-9, and IL-13), that lead to the accumulation of high number of eosinophil in the airway wall, mucus overproduction, and synthesis of IgE by allergen-specific B cells, which can be detected in the serum or through a positive skin-prick test (Hammad and Lambrecht, 2021). Th2 cells also secrete the cytokine Interleukin 5 (IL-5) to activate the increase in eosinophils in the blood, resulting in eosinophilic inflammation in tissues affected by allergies (Abbas, Lichtman and Pillai, 2020).

There are two types of IgE receptors : the high-affinity receptor (FcεRI) mainly found in large numbers on the mast cells and basophils, and the low-affinity receptor (FcεRII or CD23) found on NK cells, macrophages, dendritic cells, eosinophils, and platelets. (Kiruthika, 2023). Furthermore, mast cells release mediator that involve inflammatory reaction. These mediators include histamine, serotonin, proteases, proteoglycans, and inflammatory cytokines (eg., TNFα). This phase is followed by the release of diverse mediators newly synthesized from membrane phospholipid, which include prostaglandins (PGs), leukotrienes (LTs), and platelet activating factor (PAF), as well as variety of cytokines and chemokines that facilitate the activation and recruitment of others cells of the immune system, leading to the late phase of the immune response that typically occurs between 2-6 hours after exposure to an allergen (González-Deolano and Álvarez-Twose, 2018).

Boesenbergia Rotunda, or what is often referred to as the Fingerroot rhizome, is a species that various groups widely use as an ingredient in herbal medicines such as antibacterial, antiparasitic, treating oral infections, intestinal infections, anticancer, anti-inflammatory, and so on (Rosdianto AM et al., 2022)(Mohan et al., 2020)(Kanjanasirirat et al., 2020). The Fingerroot rhizome itself is a native plant from Indonesia and is currently found on the islands of Sumatra and Java (Priyadi et al., 2021).

Fingerroot rhizome contains phytochemicals which can be classified into two large groups, namely flavonoids such as panduratin A, 4-hydroxypanduratin, cardamonin, 2',4',6'-trihydroxychalcone, uvangoletin, panduratin C, boesenbergin, 2',6'- dihydroxy-4'-methoxy chalcone, (-)-isoppanduratin A, (+)-krachaizin B, (-)-kracaizin B, quercetin, and kaempferol and chalcone derivatives such as pinocembrin, pinostrombin, alpinetin, panduratin, cardamonin, quercetin and kaempferol. (Rosdianto et al., 2020). In this study, it is hoped that the Fingerroot rhizome can inhibit the emergence of hypersensitivity and inflammatory reactions in male Wistar strain white rats induced by respiratory tract allergies with ovalbumin.

Ovalbumin (OVA) is protein obtained from chicken egg whites. Induction of ovalbumin in murin by inhalation can induce asthmatic inflammation exacerbated. The challenge with OVA increased airway hyperresponsiveness and inflammatory cell infiltration into the lung tissue (Kim et al., 2022).

METHOD

Study design

This research uses an experimental design with a post-test-only control group design method. The object of this research was an active male white rat (*Rattus norvegicus* strain Wistar), 2-3 months old, weighing 150-200 grams. The study was divided into five groups: positive control group (+), negative control (-), and three treatment groups. The sample replication size in research is determined using the formula in Sample Size Calculation in Animal Studies. In this study, 15 mice were used. The negative control group was only given standard feed, the positive control was given ovalbumin (OVA) without *Boesenbergia rotunda* extract (BRE), and three treatment groups were given OVA and BRE at doses of 350 mg/kgBW/day, 700 mg/kgBW/day, 1,400 mg /kgBW/day. BRE is given from day fifteen to day thirty. On the 23rd day, all treatments offered were stopped. Next, the mice were killed, and blood serum was taken to measure the levels of IgE, TNF- α , and peribronchial tissue to calculate the number of eosinophil cells, the level of necrosis, and the proliferation of alveoli cells.

Ovalbumin induction

Making ovalbumin solution as an allergen using purebred chicken egg whites. 50 ml of purebred chicken egg white is stirred until there are no lumps. The sensitization stage in mice was carried out by administering 70 μ g of ovalbumin using a micro pipette and 14 mg of Al(OH)₃ in 1.4 cc of normal saline which was then injected intra-peritoneally. Inhalation administration is carried out by administering 7% ovalbumin in 10 ml of normal saline. On day 0, day 7 and day 14, sensitization was carried out by administering ovalbumin (OVA) 70 μ g intraperitoneally. Next, repeat sensitization by administering 7% OVA in 10 ml of normal saline using a nebulizer for 30 minutes on the nineteenth to the twenty-second day.

Fingerroot extract (*Boesenbergia rotunda*)

The Fingerroot (*Boesenbergia pandurata*) rhizome comes from Batu Medika Material. The rhizomes are dried, then ground and extracted with 95% ethanol. *Boesenbergia rotunda* extract is obtained through filtration followed by solvent evaporation.

Parameter measurement

Mice were euthanized with per inhalation chloroform anesthesia. Blood was taken from the rat's heart ventricles. Lung organs were taken and fixed with buffered neutral formalin (BNF) for 24 hours; then paraffin blocks were made. Afterward, the paraffin block was cut using a microtome and placed on a glass object. The preparations were stained with Hematoxylin-Eosin (HE). The finished preparations were examined under a light microscope at 100x magnification to determine the field of view to be observed, 400x magnification to keep the histopathological picture of the lungs, and count the number of eosinophils in the lung peribronchial tissue in five fields of view.

The parameters are:

1. Immunoglobulin E (IgE). The blood was put into a vacutainer without anticoagulant, and then the mouse blood serum was measured for IgE levels using the ELISA technique.
2. TNF- α . The blood was put into a vacutainer without anticoagulant, and then the mouse blood serum was measured for TNF- α levels using the ELISA technique.
3. The number of lung peribronchial eosinophil cells was calculated from lung tissue preparations in the peribronchial area. Tissue preparations were stained with Hematoxylin-Eosin (HE) and examined under a light microscope at 400x magnification to count the number of eosinophils in five fields of view.
4. The lung peribronchial tissue necrosis level was examined from lung tissue preparations in the peribronchial area. Tissue preparations were stained with Hematoxylin-Eosin (HE) and examined under a light microscope at 400x magnification. The level of necrosis is determined by the Hansel and Barnes (2004) score: score 0 = no necrosis, score 1 = low <25% visual field, score 2 = moderate 25-50% visual field, and score 3 = high 50-75% visual field look.
5. The pulmonary alveoli cell proliferation level was examined from lung tissue preparations in the peribronchial area. Tissue preparations were stained with Hematoxylin-Eosin (HE) and examined under a light microscope at 400x magnification. The level of pulmonary alveoli cell proliferation was determined by the Hansel and Barnes score. Score 0 = no proliferation, score 1 = low <25% proliferation, score 2 = medium 25-50% proliferation, score 3 = high 50-75% proliferation.

RESULT AND DISCUSSION

In this study, induction of ovalbumin (OVA) in mice by peritoneal injection and per inhalation resulted in less increase in $\text{TNF-}\alpha$, immunoglobulin E (IgE), and the number of eosinophil cells in peribronchial tissue in the positive control group, compared to the negative control group. However, in this study, there was a significant difference in the administration of ovalbumin induction by peritoneal injection and perinhalation in the mean necrosis score ($p.0.000$) and mean alveolar cell proliferation score ($p.0.034$) between the negative and positive control groups. In this study, administration of ovalbumin appeared to have a significant effect on the damage and proliferation of alveoli cells in the peribronchial tissue of rat lungs. In IgE measurements, the P3 treatment group had the lowest mean IgE levels compared to all other groups (5.47 ng/ml), while the P1 group had the highest mean (15.11 ng/ml).

The Kruskal-Wallis test on the mean value of IgE levels for all groups was $p.0.056$, but if the one way anova test was carried out only on the K- group and the treatment group it was $p.0.015$ (<0.05). One Way Anova test on the mean value of $\text{TNF-}\alpha$ levels in all groups was $p.0.015$ (<0.05). Furthermore, in the Post Hoc Bonferroni test, it appeared that the K- group was not significantly different from the K+, P1, and P3 groups, but was significantly different from P2 ($p.0.26$).

One Way Anova test on the mean value of the number of eosinophil cells in peribronchial tissue in all groups was $p.0.013$ (<0.05). The Bonferroni Post Hoc Test showed no difference between the K- and other groups. The K+ group differed significantly from P3 but not from the other treatment groups. Group P1 is not substantially different from P2 but is quite different from P3. The P3 group was not very diverse from the K- and P2 groups but significantly different from the K+ and P1 groups. Pearson correlation test is -0.805 $p.0.002$ (<0.05). One Way Anova Test on the average value of the level (score) of necrosis was $p.0.00$ (<0.05). In the Bonferroni post hoc test, the K- group was significantly different from all groups; the K+ group was not significantly different from P1 and P2 but was significantly different from P3. The three treatment groups did not appear to be significantly different. The Pearson correlation test shows a correlation of -0.799 with $p.0.02$ (<0.05). One way anova test on the mean value of alveoli cell proliferation level (score) was $p.0.007$ (<0.05). In the Bonferroni post hoc test, it appears that K- is significantly different from K+ and P1, but not significantly different from groups P2 and P3. The K+ group was not significantly different from the three treatment groups. The three treatment groups did not differ significantly. In the Pearson correlation test, a correlation of -0.701 with $p.0.011$ (<0.05) appears.

Type-I hypersensitivity reactions are mediated by Immunoglobulin-E (Ig-E) antibodies and mast cells. Exposure to allergens will cause rapid vascular and smooth muscle reactions within minutes. In the advanced phase, cytokines will cause local inflammation. Mast cells will produce pro-inflammatory cytokines, namely Tumor Necrosis Factor- α ($\text{TNF-}\alpha$) and Interleukin-4 (IL-4) which will cause inflammation. This cytokine will stimulate the release of leukocytes (eosinophils,

neutrophils and T helper-2 cells) and will cause the onset of the slow phase. Late phase reactions may occur 2 to 24 hours later (Abbas, Abul K., Andrew H. Lichtman, 2021). TNF- α is a proinflammatory cytokine is produced by macrophage, monocytes, T cells, smooth muscle cells, fibroblasts, or adipocytes (Harvanová et al, 2023).

In this study, it is possible that the rats in the random positive control group may be did not have allergic genetic factors. However, OVA induction in rat appeared to have the effect of peribronchial tissue necrosis and pulmonary alveoli cell proliferation. There was no increase in the parameters of TNF- α and IgE, in the positive control group, which is not by other studies. Research by Liu et al., who induced mice with 1 mg aluminum hydroxide diluted with 200 μ L normal saline intraperitoneally on days 0 and 14, and continued orally on days 28 to 38, showed results There was a significant difference in TNF- α levels in the negative and positive control groups. (Liu et al., 2022). In the variable number of eosinophil cells in the lung peribronchial tissue, the positive control group had the highest number of eosinophil cells. It was not significantly different from groups P1 and P2 but was significantly different from P3. The P3 group experienced a decrease in the number of eosinophil cells and was not significantly different from the negative control group. The Pearson correlation test was -0,805 p.0.002 (<0.05), which shows that increasing EBR levels strongly correlates with decreasing the number of peribronchial eosinophil cells. Eosinophilia is a hallmark of airway allergic inflammation (Dileepan et al., 2020). There were significant differences between all groups in the additional variables of alveolar cell necrosis and proliferation, and the negative control group was significantly different from the positive control group. In this study, OVA induction significantly affected alveoli cell necrosis and proliferation. The P3 group experienced a decrease in necrosis, significantly different from the positive control group. Groups P2 and P3 experienced a decrease in alveolar cell proliferation and were not significantly different from the negative control group. In this study, giving BRE to OVA-induced mice reduced alveolar cell necrosis and proliferation. In the Pearson correlation test, the variable level of lung tissue necrosis was found to be -0.799 with p.0.02 (<0.05), and the alveoli cell proliferation level was -0.701 with p.0.011 (<0.05). The value means that in OVA-induced mice, there is a strong correlation between increasing the dose of EBR and a decrease in lung peribronchial tissue necrosis and the level of pulmonary alveoli cell proliferation.

Table 1. The Level of Immunoglobulin-E and TNF- α

Group	IgE levels (ng/ml)			Mean $\pm$ SD
	1	2	3	
K-	14,08	10,16	14,35	12,86 $\pm$ 2,34
K+	13,80	13,40	13,70	13,63 $\pm$ 0,21
P1	15,36	15,54	14,44	15,11 $\pm$ 0,58
P2	12,66	18,07	6,61	12,44 $\pm$ 5,73
P3	5,60	5,56	5,27	5,47 $\pm$ 0,18

Group	TNF- α Level (pg/ml)			Mean $\pm$ SD
	1	2	3	
K-	81,85	81,03	75,97	79,61 $\pm$ 3,18
K+	81,72	89,55	98,94	90,07 $\pm$ 8,62
P1	101,06	88,29	99,23	96,19 $\pm$ 6,90
P2	110,94	116,04	90,63	105,87 $\pm$ 13,44
P3	81,11	85,89	79,21	82,07 $\pm$ 3,44

Notes:

K- : Negative control

K+: Positive control (ovalbumin induction)

P1 : Induction ovalbumin + Fingerroot rhizome extract (*Boesenbergia rotunda*) 350 mg/KgBWP2 : Induction ovalbumin + Fingerroot rhizome extract (*Boesenbergia rotunda*) 700 mg/KgBWP3 : Induction ovalbumin + Fingerroot rhizome extract (*Boesenbergia rotunda*) 1400 mg/KgBW**Table 2.** The Number of Eosinophil Cells, Peribronchial Tissue Necrosis, and Alveoli Cell Proliferation in Lung Peribronchial Tissue

Group	Number of Eosinophil Cells (cells/fv)			Mean $\pm$ SD
	1	2	3	
K-	11,20	10,80	8,20	10,07 $\pm$ 1,62
K+	10,80	11,20	13,20	11,73 $\pm$ 1,28
P1	9,00	14,00	10,80	11,27 $\pm$ 2,53
P2	6,80	10,20	10,80	9,27 $\pm$ 2,51
P3	5,60	5,20	6,20	5,67 $\pm$ 0,50

Group	Lung Peribronchial Tissue Necrosis Score			Mean $\pm$ SD
	1	2	3	

K-	0,2	0,2	0	0,13 ± 0,11
K+	2,4	2,2	2,4	2,33 ± 0,11
P1	1,8	1,8	2,6	2,06 ± 0,46
P2	1,6	2,2	1,8	1,86 ± 0,30
P3	1,6	1,2	1,4	1,40 ± 0,20

Group	Alveoli Cell Proliferation Score			Mean ± SD
	1	2	3	
K-	1,8	1,2	1,2	1,4 ± 0,34
K+	2,4	2,2	2,0	2,26 ± 0,11
P1	2,0	2,6	2,6	2,4 ± 0,34
P2	2,0	1,8	2,2	2,00 ± 0,20
P3	1,6	1,4	2,0	1,66 ± 0,30

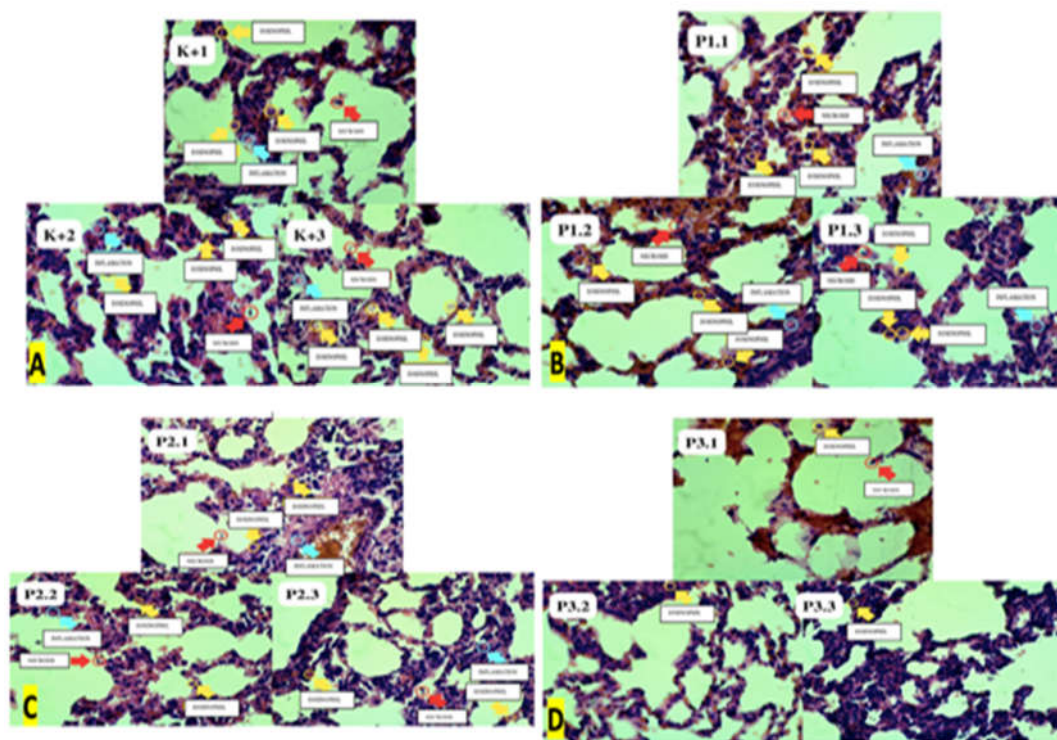


Figure 1. Histology of Lung Peribronchial Tissue : A. Positive Control Group; B. P1 Treatment Group; C. P2 Treatment Group; P3 Treatment Group (400x Hematoxylin-Eosin Staining)

In the extract of the *Boesenbergia rotunda*) rhizome, flavonoids were found, namely panduratin A, 4-hydroxy panduratin A, uvangoletin, panduratin C, boesenbergin A, 2'4'6'-tri hydroxy chalcone, cardamonine, 2'6' -dihydroxy-4'-methoxy chalcone, (+)-krachaizin B, (-)-krachaizin B, (-)-isopanduratin A, hydroxypanduratin A, quercetin, kaempferol. It has been researched that the

flavonoid content can work as an anti-inflammatory (Rosdianto et al., 2020). Research by Mohan et al., showed the results of the prophylactic effect of *Boesenbergia rotunda* on ethanol-induced gastric damage in rats, where there was a decrease in GSH, MDA, an increase in non-protein sulphydryl levels, a reduction of nitric oxide levels, and a decrease in the pro-inflammatory cytokines TNF- α and IL-6 (Mohan et al., 2020). Won et al, studied that after oral administration of *Boesenbergia pandurata* extract, the panduratin were found in the following order (highest first) : skin, lung, heart, gum, liver, spleen, kidney, and brain. Further research is needed to determine its efficacy (Won et al., 2021).

CONCLUSION

Administration of Fingerroot extract (*Boesenbergia rotunda*) to male *Ratus norvegicus* mice induced by ovalbumin had a significant effect on reducing the number of eosinophil cells, the level of necrosis in the lung peribronchial tissue, and the level of alveoli cell proliferation, but less significantly on lowering the levels of TNF- α and Immunoglobulin E.

REFERENCE

- Abbas, A.K. (2021). *Imunologi Dasar Abbas*. Elsevier. <https://doi.org/10.1016/C2018-0-00753-2>
- Abbas, A.K., Lichtman, A.H., & Pillai, S. (2020). *Cellular and Molecular Immunology*. Elsevier. <https://doi.org/10.1016/C2018-0-00752-0>
- Ashfiyah, B.A. (2016). Soursop leaf decoction against head lice activity. UMM Dissertation. (No DOI)
- Dileepan, M. et al. (2019). Mast cell–eosinophil interactions in allergic disease. *Allergy*, 74(6), 1060–1072. <https://doi.org/10.1111/all.13726>
- Dileepan, M. et al. (2020). Regulation of eosinophil recruitment and allergic airway inflammation by tropomyosin receptor kinase A. *J Immunol*, 204(3), 682–693. <https://doi.org/10.4049/jimmunol.1900786>
- González-Deolano, D., & Álvarez-Twose, I. (2018). Mast cells as key players in allergy and inflammation. *J Investig Allergol Clin Immunol*, 28(6), 365–378. <https://doi.org/10.18176/jiaci.0327>
- Hammad, H., & Lambrecht, B.N. (2021). The basic immunology of asthma. *Cell*, 184(6), 1469–1485. <https://doi.org/10.1016/j.cell.2021.02.016>
- Hapsari, R. (2020). Prevalence of pediculosis capitis in Malang. *Jurnal Kedokteran*, 9(1), 22–27. <https://doi.org/10.22219/jk.v9i1.10849>
- Harvanová, G. et al. (2023). The role of cytokines and chemokines in the inflammatory response. *Polish J Allergol*, 210–219. <https://doi.org/10.5114/pja.2023.131708>
- Imron, M. (2021). Potential of saponins from lerak fruit as natural insecticides. *J Biol Tropis*, 21(2), 102–108. <https://doi.org/10.29303/jbt.v21i2.2122>

- Kanjanasirirat, P. et al. (2020). High-content screening of Thai medicinal plants against SARS-CoV-2. *Sci Rep*, 10, 19963. <https://doi.org/10.1038/s41598-020-77002-0>
- Kim, H.J. et al. (2022). BRL-50481 effects on OVA-induced lung inflammation. *Arch Pharm Res*, 45(1), 51–62. <https://doi.org/10.1007/s12272-021-01367-x>
- Kiruthika, A. (2023). Hypersensitivity reactions: a type of immune response. *Immunol Rev*, 314(2), 45–58. <https://doi.org/10.1111/imr.13245>
- Li, J., & Monje-Galvan, V. (2023). Antimicrobial saponins: in vitro and in silico studies. *Processes*, 11(10), 2856. <https://doi.org/10.3390/pr11102856>
- Liu, P. et al. (2022). Effects of avenanthramide on OVA-induced allergy model. *Int J Mol Sci*, 23(23), 15229. <https://doi.org/10.3390/ijms232315229>
- Mohan, S. et al. (2020). Ameliorative effect of Boesenbergin A on oxidative stress in gastric ulcer. *J Ethnopharmacol*, 261, 113104. <https://doi.org/10.1016/j.jep.2020.113104>
- Nadira, R. (2019). Prevalence of pediculosis capitis in Jember. *J Epidemiol Kesehatan*, 7(2), 78–84. <https://doi.org/10.20473/jek.v7i2.2019.78-84>
- Pradana, M.S. et al. (2023). Effectiveness of soursop leaf extract on lice mortality. *J Sains Kesehatan*, 5(1), 55–63. <https://doi.org/10.21831/jsk.v5i1.42121>
- Priyadi, M. et al. (2021). Phytochemical profile of Boesenbergia rotunda. *J Pharmascience*, 8(1), 45. <https://doi.org/10.20527/jps.v8i1.9725>
- Rosdianto, A.M. et al. (2020). Bioactive compounds of Boesenbergia sp. *J Appl Pharm Sci*, 10(7), 116–126. <https://doi.org/10.7324/JAPS.2020.10715>
- Rosdianto, A.M. et al. (2022). Inhibitory effects of Indonesian fingerroot extract on nitric oxide. *World Acad Sci J*, 4(3), 173. <https://doi.org/10.3892/wasj.2022.173>
- Singh, R., & Sharma, B. (2019). *Pharmacological activities of Sapindus spp.* Springer Singapore. https://doi.org/10.1007/978-981-32-9189-8_6
- Wang, J. et al. (2023). Pathogenesis of allergic diseases. *Signal Transduct Target Ther*, 8, 144. <https://doi.org/10.1038/s41392-023-01344-4>
- Won, J. et al. (2021). Pharmacokinetics of panduratin A in rats. *J Food Drug Anal*, 29(4), 701–708. <https://doi.org/10.38212/2224-6614.3382>
- Zhu, X. et al. (2020). T cells and macrophages in asthma pathogenesis. *Mediators Inflamm*, 2020, 7835284. <https://doi.org/10.1155/2020/7835284>