ANTI-ALLERGY POTENTIAL OF AVERRHOA BILIMBI LINN. FRUIT WATER EXTRACT SHOWN BY ITS SUPPRESSIVE EFFECT ON THE DEGRANULATION OF RBL-2H3 CELLS

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ABSTRACT

Allergy rhinitis (AR), as reported by the World Allergy Organization (WAO), is one of the highest prevalence allergies affecting 10-30% of all adults and up to 40% of children. In Indonesia, current evidence showed that the prevalence of AR is increasing. Averrhoa bilimbi Linn. fruit (AF), or locally known as belimbing wuluh has potentials to treat many diseases due to the abundant of polyphenol content, including to the treatment of allergies. Therefore, this study was aimed to investigate the anti-allergy potential of AF in vitro. The anti-allergy effect of Averrhoa bilimbi Linn. fruit water extract (AFWE) was examined using RBL-2H3 cells. At first, the cytotoxicity effect of AFWE was determined by WST-8 assay. The release of β-hexosaminidase by RBL-2H3 cells was also measured to evaluate degranulation suppression activity of AFWE. Lastly, calcium assay was employed to investigate the intracellular calcium concentration ([Ca2+]i). Results demonstrated that AFWE does not show any cytotoxicity at any given concentration. In addition, AFWE at 1.25 mg/mL showed sufficient inhibitory effect towards degranulation by RBL-2H3 cells. Moreover, the degranulation-suppressing activity of AFWE was resulted from the inhibition of calcium-dependent signaling pathways. Unfortunately, the properties of active substances from AFWE have not been investigated. To conclude, this study indicated that AFWE has potential as an alternative treatment for allergic diseases.

Keywords: Allergic rhinitis, anti-allergy, averrhoa bilimbi, beta-hexosaminidase, RBL-2H3 cells

ABSTRAK

Rinitis alergi (AR), sebagai salah satu alergi dengan prevalensi tertinggi yang mempengaruhi 10-30% orang dewasa dan 40% anak-anak. Di Indonesia, bukti terkini menunjukan terjadinya peningkatan prevalensi AR. Buah Averrhoa bilimbi Linn. (AF), atau yang dikenal sebagai belimbing wuluh, berpotensi untuk mencegah atau mereduksi risiko beberapa penyakit, termasuk pada penyakit alergi, karena melimpahnya kandungan polifenol. Oleh sebab itu, studi ini bertujuan untuk menginvestigasi potensi anti-alergi AF secara in vitro. Pengujian efek anti-alergi dari ekstrak air buah Averrhoa bilimbi Linn. (AFWE) dilakukan pada sel RBL-2H3. Efek sitotoksitas dari AFWE diuji menggunakan metode WST-8. Lalu, pelepasan β-hexosaminidase dari sel RBL-2H3 diukur untuk mengevaluasi aktivitas penekanan degranulasi dari AFWE. Terakhir, uji kalsium dilakukan untuk menginvestigasi konsentrasi kalsium intraseluler ([Ca2+]i). Hasil studi menunjukkan bahwa AFWE tidak memiliki efek sitotoksik di setiap konsentrasi yang diujikan. Selain itu, AFWE pada konsentrasi 1,25 mg/mL menunjukkan efek penghambatan yang cukup terhadap degranulasi sel RBL-2H3. Aktivitas penekanan degranulasi oleh AFWE dihasilkan dari adanya penghambatan pada calcium-dependent signaling pathway. Akan tetapi, properti kandungan aktif dari AFWE belum dapat terinvestigasi. Sebagai kesimpulan, studi ini mengindikasikan bahwa AFWE memiliki potensi sebagai sumber pangan alternatif untuk memperbaiki kondisi pasien dengan penyakit alergi.

Kata kunci: Anti-alergi, averrhoa bilimbi, beta-hexosaminidase, rinitis alergi, sel RBL-2H3.
INTRODUCTION

Allergic rhinitis (AR) is defined as an inflammation of the membrane lining in the nasal cavity which is indicated by one or more symptoms such as sneezing, nasal itching, nasal congestion, and nasal discharge (Bousquet et al., 2008). As reported by World Allergy Organization (WAO), AR affected 10-30% of the total population and up to 40% of children worldwide (Pawankar et al., 2011). In Indonesia, the latest national report by International Study of Asthma and Allergies in Childhood (ISAAC) found that the prevalence of AR was less than 5% (Mallol et al., 2013). However, current evidence showed that the prevalence is increasing, particularly in the big cities, including Bandung and Surabaya to 38% and 23%, respectively (Fauzi et al., 2015; Soegiarto et al., 2019).

AR is stimulated by the cross-link of antigen to immunoglobulin E (IgE) bound on high-affinity IgE receptors, known as FceRI (Ishida et al., 2013). This action stimulates the calcium dependent signaling pathway (Lyn-Syk-LAT-PLCγ) in FceRI receptor-expressing-cells, such as mast cells and basophils, which leads to Ca\(^{2+}\) liberation from endoplasmic reticulum (ER) (Sun et al., 2014). As the results, the cells are degranulated and chemical mediators are released such as β-hexosaminidase, histamine, and inflammatory cytokines, inducing acute allergic responses (Metcalfe et al., 2009).

Averrhoa bilimbi Linn. is a Southeast Asian endemic plant species, which is underutilized. It is used as one of food ingredients in Indonesian traditional dishes, such as garang asam, sayur asem, and asem-asem. Averrhoa bilimbi Linn. fruit (AF) is also used as ethnomedicine for skin care (Ahmed and Alhassan, 2016), to treat syphilis (Samuel et al., 2010), whooping cough, obesity, hypertension, and diabetes (Ahmed and Alhassan, 2016). Besides, scientific studies revealed the capability of AF as antihypertensive (Lestari et al., 2018), antihyperlipidemic (John and Pta, 2019), antidiabetic (Kurup and Mini, 2014), antimicrobial (Mokhtar and Aziz, 2016), anti-inflammatory (Suluvoy et al., 2017), and anticancer (Nair et al., 2016). However, assessment of AF for its anti-allergic potentials has not been done to date.

In phytochemical studies conducted by Hasanuzzaman et al. (2013) and Yan et al. (2013), AF was reported to be a promising source of polyphenols, which include phenolic acids, flavonoids, and tannins. Hasanuzzaman and colleagues also found that the polyphenols are present in aqueous extract of AF. Polyphenols, particularly flavonoids, have been strongly associated with the alleviation and prevention of IgE-mediated allergic diseases. Polyphenol-induced alleviation of allergic reactions is done through the reduction of expression of MHC-II on dendritic cells, causing the reduction the antigen presentation from dendritic cells to T\(\text{H}2\) cells. This action leads to the suppression of inflammatory cytokines (IL-4 and IL-13) released by T\(\text{H}2\) cells, resulting in the reduction of B cells recruitment and the reduction of antigen specific IgE production (Singh et al., 2011; Tanaka and Takahashi, 2013).

To analyze anti-allergy potential of AF water extract (AFWE), Rat Basophilic Leukemia (RBL)-2H3 cells were used in this in vitro study. RBL-2H3 cells mimic the properties of mast cells and express high levels of FceRI on the surface of the cells when activated by IgE-allergen complex (Fu et al., 2019).

MATERIALS AND METHOD

This study was performed at Animal Cell Technology Laboratory, Ehime University, Japan and at Indonesia International Institute for Life Sciences (i3L), Jakarta, Indonesia. The cytotoxicity effect, suppression of β-Hexosaminidase release, and suppression of intracellular Ca\(^{2+}\) concentration ([Ca\(^{2+}\)]\(i\)) were investigated. In this study, unnotated materials were purchased from either Nacalai Tesque (Kyoto, Japan) or Fujifilm Wako Pure Chemical (Osaka, Japan).

Sample preparation

Averrhoa bilimbi Linn. fruits were from Tangerang, Indonesia, and randomly sampled. The fruits were washed and freeze-dried at Pilot Plant, i3L. The freeze-dried fruits (the whole fruit, including flesh, peel and seeds) were made into powder and soaked in distilled water (DW) at concentration of 2 g/mL overnight at room
temperature. The extract was centrifuged twice at 4,000 rpm for 3 min and 15,000 rpm for 20 min, sequentially. pH of the supernatant was adjusted to 7.4 using 0.1 M of NaOH and the supernatant was filtered. The solution was freeze-dried again to obtain the water-soluble substances in the extract. The dried form of the water-soluble extract was rehydrated with DW at 20 mg/mL. The extract solution was sterilized using a 0.22 µm filter syringe in sterile condition and stored at -35°C until further used. Prior to use, the extract was further diluted into 10.00, 5.00, 2.50, and 1.25 mg/mL. The processed extract was then brought to Japan for further analysis.

**RBL-2H3 cells seeding and sample treatment**

RBL-2H3 cells seeding was performed according to Ishida et al. (2013) with minor modification. Cells were seeded into 96-well plate in Dulbecco’s Modified Eagle Medium (DMEM; Sigma-Aldrich, St. Louis, MO, USA) containing 100 µg/mL of streptomycin, 100 U/mL of penicillin, and 5% of fetal bovine serum (FBS; SAFC Biosciences, Lenexa, KS, USA) at 4 x 10^4 cells/well. The cells were sensitized with DNP-IgE (Sigma-Aldrich, St. Louis, MO, USA) and incubated overnight at 37°C in a humidified 5% of CO₂ incubator. The cells were washed using modified Tyrode’s buffer (1.8 mM CaCl₂, 5.6 mM glucose, 20 mM HEPES, 5mM KCl, 1 mM MgCl₂, 135 mM NaCl, and 0.05% BSA, pH 7.4) twice and treated with AFWE at different concentration for 10 min. Cells degranulation was induced by adding 10 µL of DNP-HSA diluted in modified Tyrode’s Buffer, and the cells were incubated for 30 min.

**Cytotoxicity assay**

Cytotoxicity of AFWE on RBL-2H3 cells were measured using WST-8 assay kit (Kishida Chemical, Osaka, Japan) according to the manufacturer’s instruction. In brief, after RBL-2H3 cells were seeded in a 96 well plate, they were treated with AFWE and were degranulated (as induced by DNP-HSA). The cells were then washed once with 200 µL of phosphate buffered saline (PBS). Then, 110 µL of 5% PBS-DMEM containing 5% of WST-8 solution was added to each well. After that, the cells were incubated for 25 min at 37°C. Cells viability was measured through absorbance measurement using microplate reader (Model 680; Bio-Rad Laboratories, Hercules, CA, USA) at 450 nm.

**β-Hexosaminidase assay**

β-Hexosaminidase assay was performed according to Ishida et al. (2013) with minor modification. In brief, after 30-min of incubation following the degranulation of the cells, the degranulation process was terminated by incubating the cells on ice for 10 min. Supernatant was collected, and the cells were lysed by using a hand sonicator in a 0.1% Triton X-100 Tyrode’s buffer for 5 s. The cell lysate and supernatant were transferred into a new 96-well plate, and 100 µL of 0.1 mM citrate buffer (pH 4.5) containing 3.3 mM p-nitrophenyl-2-acetoamid-2-deoxy-β-d-glucopyranoside (Wako Pure Chemical Industries) was added to each well. The microplate was incubated at 37°C for 25 min, and the reaction was terminated by adding 100 µL of 2 M glycine buffer (pH 10.4). β-Hexosaminidase release was measured using microplate reader (Model 550; Bio-Rad Laboratories) at 405 nm and the rate of release was calculated according to the formula: β-Hexosaminidase Release (%) = \{A_{supernatant} - A_{blank of supernatant}\} / \{(A_{cell lyse} - A_{blank of cell lyse}) + (A_{supernatant} - A_{blank of supernatant})\}.

**Calcium assay**

Intracellular Ca²⁺ concentration was measured using Calcium Kit-Fluo 3 AM (Dojindo Laboratories, Kumamoto, Japan). Following RBL-2H3 cells sensitization with DNP-IgE, the cells were washed twice with PBS and were labeled using 100 µL of Fluo-3 AM fluorescence dye. The cells were incubated for 1 h. Labeled cells were rinsed with PBS and treated with AFWE at different concentrations. Then, the cells were degranulated by adding DNP-HSA and the [Ca²⁺]j was measured by using fluorescence microplate reader (SH-8000 Lab; Corona Electric, Ibaraki, Japan) at λex = 480 nm, λem = 530 nm for 2 min, in which fluorescent intensity was monitored every 10 s.
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Statistical analysis

All experiments in this study were conducted in two batches with triplication in each batch. The data were presented as mean ± standard error mean (SEM). One-way analysis of variance (ANOVA) and Tukey’s test were conducted to obtain the statistical significance between AFWE and control.

RESULTS

In this study, the effect of AFWE on viability of RBL-2H3 cells was first to be examined by treating the cells with different concentrations AFWE ranging from 1.25 to 10.00 mg/mL. As shown in Figure 1, AFWE did not show any cytotoxicity at any given concentration on RBL-2H3 cells. These results indicated that all concentrations of AFWE can be further analyzed for its anti-allergy effect.

![Figure 1. RBL-2H3 cells viability. Results were presented as the mean ± SEM (n = 6). Data were collected in two batches (independent measurement) with three replications in each batch.](image1)

The anti-allergy effect of AFWE was examined through β-Hexosaminidase assay to check its capability to suppress the release of β-Hexosaminidase by the degranulated cells (Figure 2). The suppression effect of AFWE towards β-Hexosaminidase release was reported as the ratio of β-Hexosaminidase that was released-to-supernatant to the total of β-Hexosaminidase presence in both supernatant and lysed cells. The results showed that AFWE significantly suppresses β-Hexosaminidase release in a dose dependent manner, suggesting that AFWE has a degranulation-suppressing activity. Moreover, the results demonstrated that 1.25 mg/mL of AFWE was sufficient to inhibit β-Hexosaminidase release from RBL-2H3 cells. However, 2.50 mg/mL of AFWE showed more potent inhibition.

![Figure 2. β-Hexosaminidase release. Results were presented as the mean ± SEM (n = 6). Data were collected in two batches (independent measurement) with three replications in each batch. Statistically significant differences between samples are represented by different alphabets (p < 0.05).](image2)

In order to investigate the effect of AFWE to calcium dependent signaling pathway, [Ca^{2+}]i was examined. As shown in Figure 3, [Ca^{2+}]i is rapidly elevated in non-treated RBL-2H3 cells, while the elevation of [Ca^{2+}]i was suppressed by the addition of AFWE. These results suggested that the degranulation-suppressing activity of AFWE was resulted from the inhibition of calcium dependent signaling pathways.

DISCUSSION

Averrhoa bilimbi Linn. is an underutilized natural source that is commonly found in Indonesia and other tropical countries, such as Malaysia and Philippines. Its leaves and fruits are used as food ingredients and ethnomedicine (Ahmed and Alhassan, 2016), and recently, scientific studies...
showed that *Averrhoa bilimbi* Linn. fruit (AF) has high potentials to be a functional food, because it was reported to exert several beneficial health effects, such as antihypertensive (Lestari et al., 2018), antihyperlipidemic (John and Pta, 2019), antidiabetic (Kurup and Mini, 2014), antimicrobial (Mokhtar and Aziz, 2016), anti-inflammatory (Suluvoy et al., 2017), and anticancer (Nair et al., 2016). Phytochemical studies also revealed the abundance content of polyphenols in AF, especially flavonoids, tannins, and phenolic compounds. Previously, numerous studies revealed the association of polyphenols with anti-allergy (Juríková et al., 2015; Magarone and Jirillo, 2012; Tanaka et al., 2019). Therefore, the potential benefits of AFWE as an anti-allergy is important to be investigated.

The anti-allergy effect of AFWE might be because of the presence of polyphenols, particularly flavonoids. Previous studies revealed the mode of action of polyphenols as anti-allergy is done through the reduction of expression of MHC-II on dendritic cells (Singh et al., 2011). This action leads to the reduction of antigen presented from dendritic cells to Tn2 cells, causing suppression of inflammatory cytokines released by Tn2 cells. This results in the suppression of IgE production from B cells (Tanaka and Takahashi, 2013). In study by Yoo et al. (2014), aged black garlic extract fraction rich in polyphenols and flavonoids were reported to have potent inhibitory effect towards β-Hexosaminidase release. In addition, polyphenols from apple such as apple condensed tannins was also reported to have strong inhibitory effect toward β-Hexosaminidase release from RBL-2H3 cells (Kanda et al., 1998). The polyphenols content in AF have not been fully identified yet. However, study by Muhamad et al. (2015) mentioned the presence of catechin in AF. Previously, it has been reported that the consumption of tea containing catechin has successfully alleviated the symptoms of mouse with Japanese cedar pollinosis (Maeda-Yamamoto et al., 2007). The consumption of catechin and its derivatives was previously reported to have significant effects on inhibiting IgE-mediated allergy through the prevention of tyrosine phosphorylation (Maeda-Yamamoto et al., 2004) and the production of IL-4 and IL-13 released by Tn2 cells (Singh et al., 2011). Besides that, ethyl acetate fraction of AF also reported to contain quercetin (Kurup and Mini, 2017). Previously, quercetin has been elaborated for its potential to inhibit histamine release from FcεRI receptor expressing-cells (Scheller et al., 2011), and to inhibit the activation of MHC-II in APCs (Gong and Chen, 2003). A study by Kempuraj et al. (2005) showed that quercetin and kaempferol suppress [Ca^{2+}]i in the mast cells. However, the presence of kaempferol and other flavonoids such as chrysin and apigenin in AF have not been identified yet, especially in aqueous extract.

![Figure 3](image-url) [Ca^{2+}]i level in RBL-2H3 cells following the treatment by control and AFWE. Results were presented as the mean ± SEM (n = 6). Data were collected in two batches (independent measurement) with three replications in each batch.

In this study, the cytotoxic effect of AFWE was first examined and results showed that AFWE does not possess cytotoxic effect toward RBL-2H3 cells. After the safety of AFWE towards RBL-2H3 cells was confirmed, the potential of AFWE to inhibit degranulation of RBL-2H3 cells was examined. The results demonstrated that AFWE successfully suppresses degranulation on RBL-2H3 cells in a dose dependent manner, denoted by the suppression of β-Hexosaminidase release (Figure 2). Moreover, as shown in Figure 3, the suppression of β-Hexosaminidase release by AFWE was caused by the suppression of intracellular Ca^{2+} concentration ([Ca^{2+}]i). These results suggested that AFWE has a good potential as an anti-allergy.
Unfortunately, the molecular mechanism on how AFWE suppresses degranulation of RBL-2H3 cells is still unknown. Referring to the previous study, Lyn and Syk are frequently utilized as protein biomarkers in immunoblotting analysis as both of this proteins are responsible for $[\text{Ca}^{2+}]i$ liberation, the activation of mitogen-activated protein kinases (MAPKs), and also the degranulation of the mast cells (Yoo et al., 2014). Since the Lyn and Syk pathway induce the activation of MAPKs pathway, then the utilization of MAPKs, including p38 mitogen activated protein kinase, c-Jun N-terminal kinase (JNK), and extracellular signal-regulated protein kinase (ERK), can also be alternative biomarkers (Lian et al., 2015). In a study by Ishida et al. in 2013, PLCγ was also one of the biomarkers in the immunoblotting test. PLCγ has an important role in Ca$^{2+}$ signaling (Putney and Tomita, 2012).

In addition, Fyn and Gab2 are also candidates for protein biomarkers. Besides its responsibility for accumulation of PI3K, study by Nishida et al. (2005) showed that Fyn and Gab2 are also responsible for the formation of microtubules in mast cells. In this case, the microtubule leads to the translocation of granules to the plasma membrane and results in the degranulation of the cells. Therefore, further investigations are required to clarify the mechanism underlying the inhibitory activity of AFWE on degranulation of RBL-2H3 cells.

CONCLUSION

AFWE successfully demonstrated its anti-allergy potential through in vitro experiment using RBL-2H3 cells. Results showed that AFWE inhibit the release of $\beta$-Hexosaminidase from RBL-2H3 cells through the suppression of intracellular Ca$^{2+}$ ion $[\text{Ca}^{2+}]i$ concentration. These findings indicate the potential of Averrhoa bilimbi fruit as an alternative for patients with allergic rhinitis and/or other IgE-mediated allergies. Further investigation is needed to identify the active substance in AFWE and to elucidate its mode of actions.

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REFERENCES

Ahmed, Q. and Alhassan, A. 2016. Averrhoa bilimbi linn: a review of its ethnomedicinal uses, phytochemistry, and pharmacology. Journal of Pharmacy and Bioallied Science. 8(4). pp.265.

Ambili, S., Subramoniam, A. and Nagarajan, N. 2008. Studies on the antihyperlipidemic properties of Averrhoa bilimbi fruit in rats. Planta Medica. 75(01). pp.55-58.

Bousquet, J., Khaltuev, N., Cruz, A., Denburg, J., Fokkens, W., and Togias, A. et al. 2008. Allergic rhinitis and its impact of asthma (ARIA) 2008*. Allergy. 63. pp.8-160.

Fauzi, Sudiro, M. and Lestari, B. 2015. Prevalence of allergic rhinitis based on world health organization (aria-who) questionnaire among batch 2010 students of the Faculty of Medicine, Universitas Padjajaran. Althea Medical Journal. 2(4).

Fu, L., Cherayil, B., Shi, H., Wang, Y., and Zhu, Y. 2019. Food allergy: from molecular mechanisms to control strategies. 1st ed. Singapore: Springer Singapore.

Gong, J. and Chen, S. 2003. Polyphenolic antioxidants inhibit peptide presentation by antigen-presenting cells. International Immunopharmacology. 3(13-14). pp.1841-1852.

Hasanuzzaman, M., Ali, M., Hossain, M., Kuri, S. and Islam, M. 2013. Evaluation of total phenolic content, free radical scavenging activity and phytochemical screening of different extracts of Averrhoa bilimbi (fruits). International Current Pharmaceutical Journal. 2(4). pp.92-96

Ishida, M., Nishi, K., Watanabe, H. and Sugahara, T. 2013. Inhibitory effect of aqueous spinach extract on degranulation of RBL-2H3 cells. Food Chemistry. 136(2). pp.322-327.
ANTI-ALLERGY POTENTIAL OF AVERROHA BILIMBI LINN. FRUIT WATER EXTRACT SHOWN BY ITS SUPPRESSIVE EFFECT ON THE DEGRANULATION OF RBL-2H3 CELLS

John, P. and Pta, U. 2019. Effect of Averrhoa bilimbi fruit powder on histopathology and the functional indices of the liver and kidney of rats fed with high fat diet. The Pharma Innovation Journal. 8(1). pp.48-51.

Juriková, T., Mlček, J., Sochor, J. and Hegedűsová, A. 2015. Polyphenols and their mechanism of action in allergic immune response. Global Journal of Allergy. 1(2). pp.037-039.

Kanda, T., Akiyama, H., Yanagida, A., Tanabe, M., Goda, Y., Toyoda, M., Teshida, R. et al. 1998. Inhibitory effects of apple polyphenol on induced histamine release from RBL-2H3 cells and rat mast cells. Bioscience, Biotechnology, and Biochemistry. 62(7). pp.1284-1289.

Kempuraj, D., Madhappan, B., Christodoulou, S., Boucher, W., Cao, J., Papadopulou, N. et al. 2005. Flavonoids inhibit proinflammatory mediator release, intracellular calcium ion levels and protein kinase C theta phosphorylation in human mast cells. British Journal of Pharmacology. 145(7). pp.934-944.

Kurup, S. and Mini, S. 2014. Attenuation of hyperglycemia and oxidative stress in streptozotocin-induced diabetic rats by aqueous extract of Averrhoa bilimbi Linn. fruits. International Journal of Pharmaceutical Sciences and Research. 5(11). pp.4981-4988.

Kurup, S. and Mini, S. 2017. Averrhoa bilimbi fruits attenuate hyperglycemia-mediated oxidative stress in streptozotocin-induced diabetic rats. Journal of Food and Drug Analysis. 25(2). pp.360-368.

Lestari, I., Melania, A. and Prasetyo, B. 2018. Potency water stew of Averrhoa bilimbi L. for antihypertensive. International Journal of Nursing and Midwifery Science. 2(01). pp.55-61.

Lian, Q., Cheng, Y., Zhong, C. and Wang, F. 2015. Inhibition of the IgE-mediated activation of RBL-2H3 cells by TIPP, a novel thymic immunosuppressive pentapeptide. International Journal of Molecular Sciences. 16(1). pp.2252-2268.

Maeda-Yamamoto, M., Ema, K. and Shibuichi, I. 2007. In vitro and in vivo anti-allergic effects of ‘benifuuki’ green tea containing O-methylated catechin and ginger extract enhancement. Cytotechnology. 55(2-3). pp.125-142.

Maeda-Yamamoto, M., Inagaki, N., Kitaura, J., Chikumoto, T., Kawahara, H., Kawakami, Y., Sano, M. et al. 2004. O-methylated catechins from tea leaves inhibit multiple protein kinases in mast cells. The Journal of Immunology. 172(7).

Magrone, T. and Jirillo, E. 2012. Influence of polyphenols on allergic immune reactions: mechanisms of action. Proceedings of the Nutrition Society. 71(2). pp.316-321.

Mallol, J., Crane, J., von Mutius, E., Odhiambo, J., Keil, U. and Stewart, A. 2013. The international study of asthma and allergies in childhood (ISAAC) phase three: a global synthesis. Allergologia et Immunopathologia. 41(2). pp.73-85.

Metcalfe, D., Peavy, R. and Gilfillan, A. 2009. Mechanisms of mast cell signaling in anaphylaxis. Journal of Allergy and Clinical Immunology. 124(4). pp.639-646.

Mokhtar, S. I. and Aziz, N. A. A. 2016. Antimicrobial properties of Averrhoa bilimbi extracts at different maturity stages. Journal of Medical Microbiology & Diagnosis. 5(233).

Muhammad, N., Yusoff, M. M. and Gim bun, J. 2015. Thermal degradation kinetics of nicotinic acid, pantothenic acid and catechin derived from Averrhoa bilimbi fruits. RSC advances. 5(90). pp.74132-74137.
Anti-allergy potential of Averrhoa bilimbi Linn. fruit water extract shown by its suppressive effect on the degranulation of RBL-2H3 cells

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Nair, M. S., Soren, K., Singh, V. and Boro, B. 2016. Anticancer activity of fruit and leaf extracts of Averrhoa bilimbi on MCF-7 human breast cancer cell lines: a preliminary study. Austin Journal of Pharmacology and Therapeutics. 4(2).

Nishida, K., Yamasaki, S., Ito, Y., Kabu, K., Hattori, K. and Tezuka, T. et al. 2005. FcεRI-mediated mast cell degranulation requires calcium-independent microtubule-dependent translocation of granules to the plasma membrane. Journal of Cell Biology. 170(1). pp.115-126.

Patel, G., Kern, R., Bernstein, J., Hae-Sim, P. and Peters, A. 2020. Current and future treatments of rhinitis and sinusitis. The Journal of Allergy and Clinical Immunology: In Practice. 8(5). pp.1522-1531.

Pawankar, R., Canonica, G., Holgate, S. and Lockey, R. 2011. WAO White Book of Allergy. Milwaukee: World Allergy Organization.

Putney, J. and Tomita, T. 2012. Phospholipase C signaling and calcium influx. Advances in Biological Regulation. 46(3). pp.152-164.

Samuel, A., Kalusalingam, A., Chellappan, D., Gopinath, R., Radhamami, S. and Husain, H. et al. 2010. Ethnomedical survey of plants used by the orang asli in Kampung Bawong, Perak, West Malaysia. Journal of Ethnobiology and Ethnomedicine. 6(1).

Scheller S., Dworniczak, S., Pogorzelska, T., Rajca, M. and Shani, J. 2011. Effect of quercetin, caffeic acid and caffeic acid phenylethyl ester, solubilized in non-ionic surfactants, on histamine release in vivo and in vitro. Arzneimittelforschung. 50(01). pp.72-76.

Singh, A., Holvoet, S. and Mercenier, A. 2011. Dietary polyphenols in the prevention and treatment of allergic diseases. Clinical & Experimental Allergy. 41(10). pp.1346-1359.

Soegiarto, G., Abdullah, M. S., Damayanti, L. A., Suseno, A. and Effendi, C. 2019. The prevalence of allergic diseases in school children of metropolitan city in Indonesia shows a similar pattern to that of developed countries. Asia Pacific Allergy. 9(2).

Sun, N., Zhou, C., Zhou, X., Sun, L. and Che, H. 2014. Use of a rat basophil leukemia (RBL) cell-based immunological assay for allergen identification, clinical diagnosis of allergy, and identification of anti-allergy agents for use in immunotherapy. Journal of Immunotoxicology. 12(2). pp.199-205.

Suluvoy, J. K., Sakhivel, K. M., Guruvayoorappan, C. and Grace, V. M. B. 2017. Protective effect of Averrhoa bilimbi L. fruit extract on ulcerative colitis in wistar rats via regulation of inflammatory mediators and cytokines. Biomedicine and Pharmacotherapy. 91. pp.1113-1121.

Tanaka, T., Iuchi, A., Harada, H. and Hashimoto, S. 2019. Potential beneficial effects of wine flavonoids on allergic diseases. Diseases. 7(1). pp.8.

Tanaka, T. and Takahashi, R. 2013. Flavonoids and asthma. Nutrients. 5(6). pp.2128-2143.

Yan, S., Ramasamy, R., Alitheen, N. and Rahmat, A. 2013. A comparative assessment of nutritional composition, total phenolic, total flavonoid, antioxidant capacity, and antioxidant vitamins of two types of Malaysian underutilized fruits (Averrhoa bilimbi and Averrhoa carambola). International Journal of Food Properties. 16(6). pp.1231-1244.

Yoo, J., Sok, D. and Kim, M. 2014. Anti-allergic action of aged black garlic extract in RBL-2H3 cells and passive cutaneous anaphylaxis reaction in mice. Journal of Medicinal Food. 17(1). pp.92-102.