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(RESEARCH ARTICLE)

Antioxidant and antidiabetic activities of cinnamon bark (*Cinnamomum burmannii*) Extracts *In Vitro*

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Abstract

Cinnamomum burmannii belongs to the Lauraceae family. This herbal plant can potentially lower blood glucose and ward off free radicals. It can be a candidate for diabetes mellitus therapy. This study aims to determine the phytochemical profiles and antioxidant and antidiabetic activities in vitro of *C burmanii* powder as a basis for pharmacological testing of the bioactive compounds contained therein. This study took place in several stages, namely the manufacture of simplicia, extraction, phytochemical screening, and *in vitro* antioxidant and antidiabetic activity tests. The results showed that the yield of water solvent is 7.57 ± 1.18% and ethanol solvent is 6.67 ± 0.39%. Phytochemical screening revealed the presence of flavonoids, saponins, tannins, terpenoids, alkaloids, and steroids. The cinnamon extract contained phenolic compounds of 116,79±2,84 mg GAE/g extract in a higher mount than the Aqueous extract 69,37± 2,84 mg GAE/g extract. The antioxidant activity with Aqueous extracts was 68.86±10.89 and 114,98±7.89 ppm, and the inhibition of α-glucosidase activity of 478±17,78 ppm of aqueous extract, 271±14,22 ppm of Ethanol extract and acarbose 223±8,54. Conclusion: *C. Burmanii* has a sweet taste, distinctive odor, and yellowish color. It contains flavonoid compounds, saponin, tannin, and terpenoid, and has antioxidant and antidiabetic activity.

Keywords: *Cinnamomum burmanii*; Phytocemistry; Phenol; Antioxidant activity; Inhibition α-glucosidase

1 Introduction

Diabetes is a degenerative disease characterized by high blood sugar levels (hyperglycemia) due to abnormalities in insulin secretion, insulin action, or both (1). Hyperglycemia is indicated by blood glucose levels above 200 mg/dl and fasting blood glucose above 126 mg/dl (2). An addition to increased blood sugar levels, diabetes due to oxidative stress. Oxidative stress is an imbalance between antioxidants and oxidants in the body (3). The incidence of diabetes continues to increase every year. Patients with diabetes mellitus 463 million, and will continue to grow to 700 people in 2045 Indonesia ranks seventh (4). With the high number of cases of Diabetes Mellitus in the world, the development of disease treatment has shifted to using natural or herbal ingredients. The choice of using herbal medicine is preferred over using synthetic drugs because herbal drug therapy has few side effects (5). Herbal plants that function to lower blood glucose are cinnamon (*Cinnamomum burmannii Ness*) of the genus Cinnamomum, Lauraceae family. Compounds in cinnamon that have potential as antidiabetics as Methylhydroxy Calcone Polymer (MHCP), cinnamaldehyde, and polymer procyanidin type-ApolymID Fers (6,7,8). Cinnamaldehyde in cinnamon can reduce the effects of oxidative stress in people with Diabetes Mellitus by counteracting free radicals (9). Antioxidants are antidotes to the adverse effects of oxidants, the mechanism of replenishing lost oxidant electrons so that they are stable and do not harm the body (10). In addition to antioxidants, α-glucosidase enzyme inhibitors also have the potential to reduce glucose in the blood (11). The enzyme can lessen carbohydrate hydrolysis and α-D glucose absorption so that postprandial blood glucose levels

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drop (12). Some studies show that ethanol extracts and water extracts can inhibit α-glucosidase enzymes by 94.88% and 94.51%, respectively (13). In addition, the results of a mixture of cinnamon (28%) with red betel leaves (42%), red ginger (15%), and lime (15%) have the potential as an α-glucosidase inhibitor of 88.7% (11). Based on this information, cinnamon extract has potential as a raw material for antidiabetic traditional medicine, so this study aims to determine the yield, total phenolic, DPPH free radical silencing, and α-glucosidase enzyme inhibitory activity in ethanol extract of cinnamon bark (*Cinnamomum burmannii*).

2 Material and methods

A *Cinnamomum burmannii*, methanol, Folin-Ciocalteu reagent 10%, Na CO_2 10%, gallic acid, DPPH solution, ascorbic Iacid, phosphate buffer 0.1 M pH 7.0, an α-glucosidase enzyme from *Bacillus stearothermophilus* (SIGMA), p-NPG powder, acarbose.

2.1 Extract preparation

Extraction of simplesia *Cinnamomum burmanii* by maceration method using water and ethanol solvents. A simplesia (500 mg) was added solvent in a ratio of 1:4 (b:v). the solution was soaked for thirty minutes at a sonicator. The solution was shaken using a shaker incubator at room temperature for two hours. The solution was centrifuged, and the dissolved phase was filtered using Whatman paper no 1. The extract was calculated. as the yields.

$$\% \text{ Yield} = (\text{gram of extract/gram of cinnamon simplesia}) \times 100$$

2.2 Phytochemical Analysis

Phytochemical screening that includes qualitative analysis of tannins, alkaloids, flavonoids, saponins, and triterpenoids was carried out according to standard methods contained in Materia Medika Indonesia.

2.3 Determination of total phenolic content

Water extracts and ethanol extracts were each dissolved in water and ethanol solvents (1000 ppm). A sample (1 ml) was mixed with 4 mL of sodium carbonate solution (75 g/L) in a 10 mL volumetric flask and then shaken. Add Folin-Ciocalteu reagent (2mL) and distilled water. The mixture was allowed to stand in a dark room at room temperature for one hour. The absorbance was measured at a wavelength of 760 nm using a Shimadzu UV-160 spectrophotometer. A standard was using a gallic acid solution. Total phenolics obtained were expressed as gallic acid equivalents (GAE) in mg per gram of dry extract.

2.4 Antioxidant capacity analysis of the DPPH method

The free radical scavenging test was using the DPPH method. The several-concentration extract (2mL) was added to 1.0 mL of 0.5 mM DPPH in ethanol. The mixture was shaken and left at 25°C in the dark for 25 min. A blank solution for each sample solution by mixing 2 mL of sample solution and 1.0 mL of ethanol. As a negative control, 1.0 mL of 0.5 mM DPPH solution was added to 2.0 mL of ethanol. Absorbance (Abs) was measured at a wavelength of 518 nm using a spectrophotometer.

$$\% \text{ inhibition} = [1-(\text{Abs sample/Abs control})] \times 100$$

The IC50 value was calculated at the regression equation from the curve between percent inhibition versus concentrations.

2.5 Assay of α-glucosidase inhibitor activity

The reagent mixture used contained 50 µL phosphate buffer 0.1 M (pH 7.0), 25 µL 4-nitrophenyl α-D-glucopyranoside 0.5 mM, 10 µL test samples at various concentrations (50-1000 ppm) and 25 µL α-glucosidase solution (0.2 units/mL), and incubated at 37°C for 30 minutes. The reaction stopped by 100 µL of 0.2 M sodium carbonate solution. Enzymatic hydrolysis of the substrate was calculated based on the amount of p-nitrophenol produced. The result for absorbance at 410 nm wavelength. Blank by replacing the enzyme with buffer. Controls used solvents (water or ethanol). Acarbose as a positive control. Percentage inhibition α-glucosidase calculated by the formula.

$$\% \text{ inhibition} = [1-(\text{Abs sample /Abs control})] \times 100$$

The IC50 value was calculated at the regression equation from the curve between percent inhibition versus concentrations.

2.6 Statistical analysis

All analyses are in triplicate. All results as mean ± SD. Data analysis was performed using descriptive analysis and comparative analysis of mean values. Comparative analysis of mean values was performed using one sample t-test.

3 Results and discussion

3.1 Yield Extract *Cinnamomum burmanii*

Extraction of *Cinnmomum burmanii* with water solvent gives a yield of 7.57 ± 1.18% while for ethanol solvent gives a yield of 6.67 ± 0.39%. Based on the one-sample t-test statistical test, there is a significant difference between the two types of solvents where extraction using water solvents provides a greater extract yield compared to ethanol solvents. The yield is the ratio between the dry weight of the extract of a sample and the weight of the raw material (simplisia) of a sample (14). Calculation of extract yield can determine how many bioactive components are found in an extract (9,15) . Other studies show different results from this study. Research with the infusa method gave a yield of 18.83% (16,17). Another method using soxhlet with methanol solvent gave a yield of 9.8% (18). The difference in results is influenced by several factors such as temperature, extraction time, extraction method, and solvents used during extraction.

3.2 Phytochemical screening

The phytochemicals compounds of aqueous and ethanol extracts of *Cinnamomum burmanii* (Table 1). The phytochemical compounds in ethanol extracts alkaloids, tannins, phenolics, flavonoids, and triterpenoids. The aqueous extracts such as alkaloids, phenolics, and triterpenoids. All types of compounds are known to have antioxidant activity.

Tabel 1 Screening phytochemical of etanolik ectract and aqueous of *Cinnamomum burmanii*

No	Test	Extract		Information
		Aqueous	Etanolic	
1	Alkaloid	+++	++	++++ very strong positive +++ strong positive ++ positive + weak positive
2	Saponin	+	+	
3	Tanin	+	++	
4	Phenolic	++	+++	
5	Flavonoid	-	+++	
6	Terpenoid	++++	++++	
7	Steroid	+	+	

3.3 Total phenolics

The results showed that the ethanol extract of the cinnamon extract contained phenolic compounds of 116,79±2,84 mg GAE/g extract in a higher amount than the Aqueous extract 69,37± 2,84 mg GAE/g extract (Figure 1A). The polyphenolic compounds in plants are multifunctional in reducing and donating hydrogen atoms as antioxidants and absorbers of singlet oxygen formation. The nature of the polyphenol group has its ability as an antioxidant. A total phenolic in this study using Folin-Ciocalteau reagent. This method of the phenolic hydroxy group. All phenolic compounds can react with the Folin Ciocalteau reagent. The presence of aromatic in phenolic compounds (phenolic hydroxy groups) can reduce phosphomolybdate phosphotungstate to molybdenum are blue. Polyphenolic compounds have antioxidant activity. The antioxidant activity of polyphenolic compounds is the high activity as hydrogen or electron donors and the ability to stabilize or move unpaired electrons and chelate transition metals (19,20). Phenolic compounds are secondary metabolites in plants consisting of aromatic rings and one or more hydroxyl groups (21). The phenolic compounds have a function on the free radicals (22). The test to determine the total phenolic content in this study used the Folin-Ciocalteu method. Other studies have shown that the phenolic-hydroxyl group in the extract reacts with the Folin-Ciocalteu reagent to form a blue phosphotungstate-phosphomolybdate complex (23). The phenolic of the aqueous extract of *C. burmannii* with yields of 4.61%. The total phenolics in this study, namely 93-100 mg GAE g-1(16), cinnamon methanol

extract (*C. burmannii*) results are 119 mg GAE / g extract (24). The difference is due to the use of different solvents. Phenolic levels in methanol extracts are higher than in aqueous extracts because methanol has hydroxyl groups (polar) and methyl groups (non-polar) (25). Research on *Eleutherine palmifolia* plants belongs to the genus Iridaceae. Species of the genus Iris (Iridaceae) have a long history in traditional medicine in the world and have long been known to contain many secondary metabolites, especially phenolic compounds such as flavonoids (26). In a study of ethanol extracts of *Eleutherine americana* grown in Thailand, the total phenol of the extract was 4.56 µmol gallic acid equivalent/g dry extract and could inhibit DPPH free radical activity with an IC50 value of 8.4 µg/mL (27). The relationship between total phenol content and antioxidant activity (28). The antioxidant activity determined by DPPH and ABTS methods of the 10 Croatian wines studied with their total phenol content with correlation coefficients of 0.9926 and 0.0938.

3.4 Antioxidant activity

The free radical scavenging was obtained with the standard antioxidant ascorbic acid (Table 2 and Figure 1B). The activity of the ethanol extract was greater than that of the water extract. The IC50 is the concentration of a compound that causes 50% inhibition of a given system, and the DPPH free radical scavenging activity, the IC50 value can be interpreted as the concentration of the extract that causes a 50% decrease in DPPH concentration from the initial DPPH concentration (29). The IC50 for ethanol and Aqueous extracts were 68.86±10.89 and 114,98±7.89 ppm, respectively (Figure 1B). The effectiveness of phenolic compounds as antioxidants depends on their structure, hydrophobicity, biological activity, and oxidative activity. The ability of radical chain reactions by phenol compounds. The presence of two o-hydroxyl groups on the B ring. The formation of intramolecular hydrogen bonds between hydroxyl groups the stability of phenoxyl radicals (30). The Phenol compounds are a 3',4'-dihydroxy group on the B ring and/or have a 3-OH group next to the 4-keto have antiradical activity (31). In addition to phenol and polyphenol compounds, triterpenoid compounds have antioxidant activity (32). In diabetes mellitus, a strengthening of the production of Radical Oxygen Species results in the body experiencing oxidative stress (33). Oxidative stress is a condition in which the content of oxidants or free radicals in the body is more than antioxidants. Antioxidants play a role in preventing complications in DM patients. Non-enzymatic protection systems against oxidative stress can be vitamin C, vitamin E, carotenoids, and polyphenols. The Carotenoids such as free radical quenchers. Polyphenols can donate hydrogen atoms, free radical scavengers, and metal ion chelators(34).

Tabel 2 Antioxtidant of standart, extract etanol, and aqueous of ekxtract etanolic *C. burmanii*

Antioksidan Activity(equivalent/gram extracts	**Aqueous Extract**	**Etanol Extract**
Mg ascorbic acid equivalent/g extract	68.86 ±10.89	114,98 ± 7.89
Mg BHT equivalent/gram extract	114 41 25,57	215.32 20,82
Mg trolox equivalent/g extract	113.87 20.04	187.09 13.14

3.5 Inhibition of α-glucosidase activity

The inhibibition of α-glucosidase activity of aquous extravt is 478±17,78, ethanol extract is 271±14,22 Ethanol extract, and acarbose is 223±8,54. The hypoglycemic potential of cinnamon bark extract was tested in vitro by α-glucosidase enzyme activity. The Acarbose is used as a comparator. The α-glucosidase enzyme inhibition is a concentration-dependent activity (Figure 1C). Determination of IC50 values of aqueous extract, ethanol extract, and acarbose in inhibiting α-glucosidase enzyme activity (Figure 1D). Acarbose is an oligosaccharide compound that works at the brush border to break down starch, dextrin, maltose, and sucrose to produce digestible monosaccharides (35). The α-glucosidase is an enzyme that catalyzes the cutting of glycosidic bonds in oligosaccharides (36). The phytochemical compounds can inhibit the work of α-glucosidase enzymes, such as compounds from the alkaloid group (37), triterpenes (38), and flavonoids (26). Phenolic compounds such as flavonols can inhibit α-glucosidase (34). Luteolin, myricetin, and quercetin (39). The α-glucosidase inhibitors work by mimicking the transition position of the pyranosidic unit of the natural glucosidase substrate (40), The higher activity of α-glucosidase enzyme inhibition in ethanol extracts is related to the content of phenolic compounds.

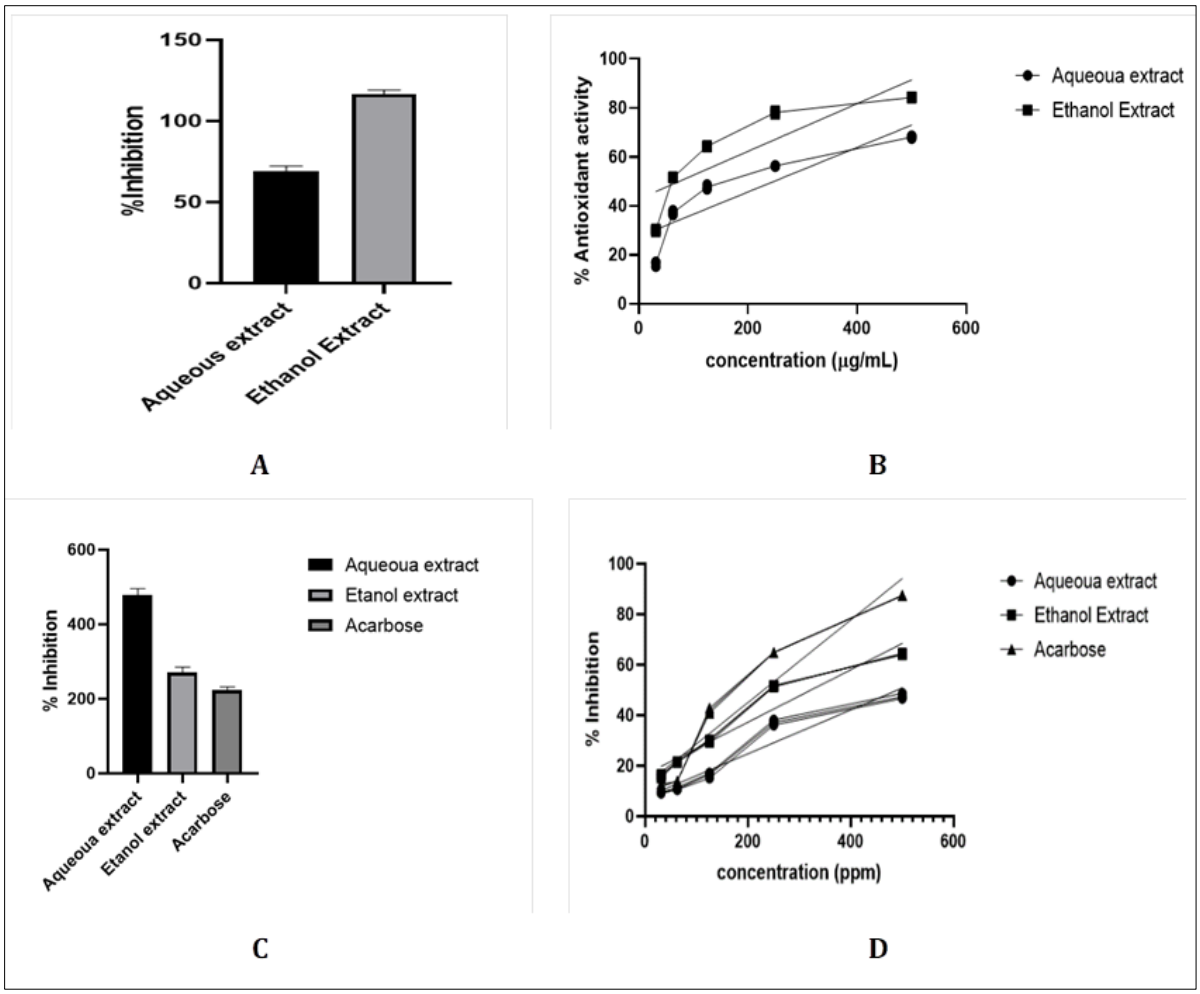

Figure 1 The Total Fenol, antioxidant activity n inhibition α-glikosidase of Ektract Aqueous and extract ethanol of *Cinnamomum burmanii.* A. Persen total henol, B, % antioxidant activity n % Inhibition α-glikosidase

4 Conclusion

Cinnamomum burmanii contains flavonoids, phenols, saponins, tannins, terpenoids, alkaloids, and steroids with total phenols in the aqueous extract of 69.37 ± 2.84 mg GAE/g extract. The antioxidant activity with Aqueous extracts is 68.86±10.89 and 114.98±7.89 ppm and has antioxidant and antidiabetic activity.

Compliance with ethical standards

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Disclosure of conflict of interest

All authors declare that they have no conflict of interest.

References

[1] RN F. Type 2 diabetes mellitus. Major J. 2015;4(1):93–101.

[2] DW H. Factors associated with compliance with dietary management in outpatients with type 2 diabetes mellitus in Semarang city. J Heal Educ. 2017;2(1):138–45.

[3] Dompeipen EJ S. Antidiabetic and antioxidant activities of endophytic molds from mahogany (Swietenia macrohylla King) plants. BIOPROPAL Ind. 2015;6:7–17.

[4] Federation ID. International Diabetes Federation. في: IDF Atlas. Ninth edit. 2019.

[5] DF H. Analysis of the use of herbal medicine for type II diabetes mellitus patients in Langsa city. JUMANTIK J. 2019;4(2):169–77.

[6] Purbowatingrum, Ngadiwiyana, Fachriyah, E., Ariestiani B and K. Antidiabetic activity from cinnamaldydhe encapsulated by nanochitosan'. IOP Conf Ser Mater Sci Eng. 2019;349(1).

[7] Medagama AB. The glycaemic outcomes of Cinnamon, a review of the experimental evidence and clinical trials. Nutr J. 2015;14:108.

[8] Emilda. Effects of cinnamon (*Cinnamomum burmanii* NEES EX.BL.) bioactive compounds on diabetes mellitus: a literature review. Indones Phytopharm J. 2018;5:246–52.

[9] Kusumaningtyas, Ika Dewi; Fajariyah, Susantin; Utami ET. The Effect of Cinnamon (*Cinnamomum burmanii*) Aqueous Extract on Pancreas Structure of Diabetic Mice (Mus musculus) Strain Balb-C. J ILMU DASAR. 2015;15(2):69–73.

[10] Sayuti K YR. Natural and Synthetic Antioxidants. 1 . adang: Andalas University Press; 2015. 124–135 ص.

[11] Safithri M, Kurniawati A S. Formula of Piper crocatum, *Cinnamomum burmanii*, and *Zingiber oficinale* extract as a functional beverage for diabetics. Int Food Res J. 2016;13:1123–30.

[12] Hossain U, Das AK, Ghosh S SP. An overview on the role of bioactive α-glucosidase inhibitors in ameliorating diabetic complications. Food Chem Toxicol. 2017;145:1-15.

[13] Anggriawan MB, Roswiem AP NW. Potential of water and ethanol extracts of cinnamon bark (*Cinnamomum Burmanii*) against α-glucosidase enzyme activity. J Yars Med. 2015;23:91–102.

[14] Senduk TW, Montolalu LADY D V. Yield of boiled water extract of old leaves of *Sonneratia alba* mangrove. J Trop Fish Mar. 2020;11:9–15.

[15] Utami NF, Nurdayanty SM, Sutanto SU. Effect of various extraction methods on the determination of flavonoid content of ethanol extract of iler leaves (*Plectranthus scutellarioides*). Fitofarmaka Sci J Pharm. 2020;10:76-83.

[16] Ervina M, Lie HS, Diva J, Caroline, Tewfik S TI. Optimization of water extract of *Cinnamomum burmani* bark to ascertain its in vitro antidiabetic and antioxidant activities. Biocatal Agric Biotechnol. 2019;19:1–7.

[17] Ervina M, Nawu YE ES. Comparison of in vitro antioxidant activity of infusion, extract and fractions of Indonesian cinnamon (*Cinnamomum burmannii*) bark. Int Food Res J. 2016;23:1346–50.

[18] Daker M, Lin VY, Akowuah GA, Yam MF AM. Inhibitory effect of *Cinnamomum burmannii* blume stem bark extract and trans¬-cinnamaldehyde on nasopharyngeal carcinoma cells; synergism with cisplatin. Exp Ther Med. 2013;5(2):1701–9.

[19] Febriansah R. Pemberdayaan Kelompok Tanaman Obat Keluarga Menuju Keluarga Sehat Di Desa Sumberadi, Mlati, Sleman. BERDIKARI J Inov Dan Penerapan Ipteks. 2018;5(2):80–90.

[20] Afifi, H.S., Hashim, I.B., & Altubji SI. Optimizing Extraction Conditions Of Crude Fiber, Phenolic Compounds, Flavonoids And Antioxidant Activity of Date Seed Powder. J Food Sci Technol موجود. 4161–54:4149;2017]. انترنت[في: https://doi.org/10.1007/s13197-017-2854-7

[21] Wijewardhana US, Gunathilaka UGSA NS. Detemination of total phenolic content, radical scavenging activity and total antioxidant capacity of cinnamon bark, black cumin seeds and garlic. Int Res J Adv Eng Sci. 2019;4:55–7.

[22] Diniyah N LS. Phenol compound composition and antioxidant potential of legumes. J Agrotechnology. 2020;14:91–102.

[23] Khadijah, Jayali AM, Umar S SI. Determination of total phenolic and antioxidant activities of ethanolic extract of samama (*Anthocephalus macrophylus*) leaves from ternate, Maluku. J Agrotechnology. 2017;4(1):216–23.

[24] Shan B, Zhong Cai Y, Brooks JD CH. The in vitro antibacterial activity of dietary spice and medicinal herb extracts. Int J Food Microbiol. 2007;11:112–9.

[25] Romadanu, Rachmawati SH LS. Testing the antioxidant activity of lotus flower extract (*Nelumbo nucifera*). J FishtecH. 2014;3:1-7.

[26] Guo, L.P., Jiang, T.F., Lv, Z.H., & Wang Y. Screening alpha-glucosidase inhibitors from traditional Chinese drugs by capillary electrophoresis with electrophoretically mediated microanalysis. J Pharm Biomed Anal. 2010;53(1):1250–1253.

[27] Ifesan BOT, Siripongvutikom S, Hutadilok-Towatana N VS. Evaluation of the ability of *Eleutherine americana* crude extract as natural food additive in cooked pork. J Food Sci. 2009;74:M352–7.

[28] Vrcek IV, Bojic M, Zuntar I, Mendas G M-SM. Phenol content, antioxidant activity and metal composition of croatian wines deriving from organically and conventionally grown grapes. J Food Chem. 2011;124:354–61.

[29] Nurkhasanah, Minangsari DNI, Yulianny VA. The combination of rosella (*Hibiscus Sabdariffa,* L) and Stevia (*Stevia Rebaudiana*) extracts increase the antioxidant activity and stability. Int J Pharm Pharm Sci. 2016;8(5):7–8.

[30] Majewska M, Skrzycki M, Podsiad M CH. Evaluation of antioxidant potential of flavonoids: an in vitro study. Acta Pol Pharm. 2011;68:611–5.

[31] Amic D, Davidovic-Amic D, Beslo D TN. Structure-radical scavenging activity relationships of flavonoids. Croat Chem Acta. 2028;76:55–61.

[32] Grace-Lynn C, Darah I, Chen Y, Latha LY, Jothy SL SS. In vitro antioxidant activity potential of lantadene A, a pentacyclic triterpenid of lantana plants. Molecules. 2012;17:11185–98.

[33] Rathee, P., Chaudhary, H., Rathee, S., Rathee, D., Kumar, V., Kohli K. Mechanism of action of flavonoids as anti-inflammatory agents: a review. Inflamm Allergy Drug Targets. 2009;8(3):229–135.

[34] Lee SY, Mediana A, Ashikin NAH, Azliana ABS AF. Antioxidant and α-glucosidase inhibitory activities of the leaf and stem of selected traditional medicinal plants. Int Food Res J. 2014;21(1):165–172.

[35] Hollander P, Pi-Sunyer X CR. Acarbose in the treatment of type 1 diabetes. Diabetes Care. 1997;20:248–53.

[36] Bernardo MA , Elisabeth Santos, Margarida Maria Moncada, José Brito, Luis Proença, Jaipaul Singh and MF de M. Research Article: Effect of Cinnamon Tea on Postprandial Glucose Concentration. Journal of Diabetes Research. J Diabetes Res. 2015;126(3):1–6.

[37] Patel MB MS. Magnoflorine from Tinospora cordifolia stem inhibits α-glucosidase and is antiglycemic in rats. J Funct Foods. 2012;4:79–86.

[38] Lai YC, Chen CK, Tsai SF LS. Triterpenes as α-glucosidase inhibitors from Fagus hayatae. Phytochemistry. 2012;74:206–11.

[39] Tadera K, Minami Y, Takamatsu K MT. Inhibition of α-glucosidase and α-amylase by flavonoids. J Nutr Sci Vitaminol. 2026;52:149–53.

[40] Kim, S.Y., & Moon A-R. Drug-Induced Nephrotoxicity And Its Biomarkers. Biomol Ther (Seoul). 2012;20(2):268–272.