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PHYTOCHEMICAL PROFILE AND ENZYME INHIBITORY POTENTIAL OF *Allium chinense* G. Don FROM NORTH SUMATERA, INDONESIA

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ABSTRACT

This study investigates the phytochemical composition, antioxidant potential, and enzyme inhibitory activity of *Allium chinense* extracts from North Sumatra, Indonesia. The bulbs were extracted using n-hexane, chloroform, ethyl acetate, and ethanol, and their bioactive compounds were analyzed. Ethanol extraction yielded the highest concentrations of flavonoids, tannins, saponins, and phenolics, correlating with strong biological activity. The antioxidant activity, assessed through DPPH and ABTS radical scavenging assays, showed the ethanolic extract exhibiting the highest inhibition at 78.10 ± 0.65% (DPPH) and 86.45 ± 2.65% (ABTS) at 500 µg/mL. Additionally, the ethanolic extract demonstrated the strongest inhibition of α-amylase (80.96 ± 0.71%) and α-glucosidase (84.51 ± 1.49%) at 600 µg/mL, indicating its potential as a natural antidiabetic agent. Statistical analysis using two-way ANOVA confirmed significant effects of extract type and concentration on enzyme inhibition ($p < 0.05$), while no significant interaction was observed. Tukey's post-hoc test revealed significant differences between solvent extractions, emphasizing the role of polar solvents in extracting enzyme-inhibiting bioactives. The findings support SDG-3 (Good Health and Well-being) and suggest that *A. chinense* could be utilized as a functional food ingredient or phytopharmaceutical for diabetes management. Further research is needed to isolate key active compounds, assess their mechanisms of action, and validate their efficacy in vivo.

Keywords: *Allium chinense*, Phytochemicals, Antioxidant, A-Amylase, A-Glucosidase

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INTRODUCTION

Diabetes mellitus is a serious disease that includes various metabolic disorders characterized by chronic hyperglycemia and is widely found throughout the world.[1] This disease is classified into two types, namely type 1 diabetes (insulin-dependent diabetes), which occurs due to the inability of the pancreas to produce sufficient insulin due to beta cell damage, and type 2 diabetes (non-insulin-dependent diabetes), in which the body's cells become resistant to insulin and no longer respond effectively to it.[2] Currently, there are various synthetic drugs used in the treatment of diabetes, with the main aim of reducing postprandial hyperglycemia. The main mode of action of these drugs is by inhibiting digestive enzymes, especially α-glucosidase in the intestine and α-amylase in the pancreas, or by reducing glucose absorption in the intestine.[3] In recent decades, various natural compounds derived from plants have emerged as potential candidates for inhibiting the activities of α-glucosidase and α-amylase.[4] In addition, recent studies have increasingly emphasized the importance of developing safer and better-tolerated enzyme inhibitors, especially those derived from medicinal plants, fruits, and vegetables, at a lower cost.[5] One potential plant is *Allium chinense*. Several studies have shown that consumption of plants from the Allium family can help in the management of various chronic diseases, including type 2 diabetes.[6-8] However, research on the effectiveness of *A. chinense* as an inhibitor of diabetes-related enzymes is still limited and difficult to access. *Allium chinense* G. Don, known locally as Batak onion, is one of the herbal plants widely used in traditional medicine in North Sumatra, Indonesia.[9] This plant belongs to the Alliaceae family and has special characteristics, such as a pungent aroma and small to medium-sized tubers. In

addition to being used as a kitchen spice, Batak onion is also believed to have various health benefits, especially in the treatment of metabolic diseases such as diabetes and digestive disorders.[10] In traditional pharmacology, Batak onion is often used by the Batak community to increase the body's resistance, overcome inflammation, and treat various infectious diseases.[11] Several studies show that this plant contains various bioactive compounds, including flavonoids, saponins, alkaloids, and sulfur compounds that have potential as antioxidants and anti-diabetic agents [12] Previous research shows the antioxidant activity of the ethanol extract from *A. chinense* that inhibited the DPPH and ABTS radical with inhibitory concentrations 50 (IC_{50}) of 127.085 µg/mL and 270.549 µg/mL, respectively.[13] Therefore, the antioxidant properties of *A. chinense* extract and its active component support that this plant has an inhibitory effect on carbohydrate-digesting enzymes such as α-glucosidase and α-amylase, which play a role in controlling blood sugar levels.[14] Research on this plant is still limited, especially in terms of phytochemical characterization and pharmacological potential in reducing the risk of metabolic diseases. Therefore, this study aims to identify the phytochemical profile of *A. chinense* extract obtained from North Sumatra and evaluate its inhibitory potential against α-glucosidase and α-amylase enzymes. The results of this study are expected to provide further insight into the benefits of Batak onion as a natural agent in managing diabetes and open up opportunities for the development of local plant-based phytopharmaceuticals.

EXPERIMENTAL

Plant Material Collection and Preparation

Fresh *Allium chinense* G. Don (Batak onion) bulbs were collected from North Sumatra, Indonesia. The plant was identified and authenticated at Herbarium Medanese, and a voucher specimen was deposited in the herbarium (Voucher ID: 130/UN5.1.2.8.2/PPM/24). The bulbs were washed thoroughly, dried at room temperature under shade, and then ground into a fine powder using a mechanical grinder. The powdered sample was stored in an airtight container at 4°C until further analysis.

Extraction of *Allium chinense*

The extraction was performed using a sequential maceration method with four different solvents: n-hexane, chloroform, ethyl acetate, and ethanol. Approximately 100 g of dried bulb powder was successively extracted with 500 mL of each solvent, starting with n-hexane, followed by chloroform, ethyl acetate, and finally ethanol. Each extraction was carried out for 72 hours at room temperature with occasional shaking. After each step, the extract was filtered using Whatman No. 1 filter paper, and the solvent was removed under reduced pressure using a rotary evaporator at 40°C. The concentrated extracts were then freeze-dried and stored at 4°C for subsequent phytochemical and enzymatic assays.[15]

Phytochemical Screening

A preliminary phytochemical screening was performed to detect the presence of bioactive compounds such as flavonoids, alkaloids, saponins, tannins, and phenolics using standard qualitative tests. The Liebermann–Burchard test was conducted by adding 2 mL of chloroform to each extract, followed by acetic anhydride and concentrated sulfuric acid (H_2SO_4). The mixture underwent a color change from red to blue and then green, indicating the presence of steroids and terpenoids. To test for alkaloids, the extracts were dissolved in a small amount of 50% hydrochloric acid (HCl), followed by the addition of Mayer's reagent. The formation of a white or yellow precipitate confirmed the presence of alkaloids. For flavonoids, 0.5 g of magnesium ribbon and concentrated HCl were added to each extract, resulting in a pink precipitate, which indicated a positive reaction. The presence of saponins was determined by adding 2 mL of distilled water to each extract in a test tube, followed by vigorous shaking, where the formation of foam signified a positive result. Lastly, the detection of tannins and phenolics was carried out by mixing 2 mL of a 1% (w/v) ferric chloride ($FeCl_3$) solution with the crude extract, where the appearance of a black or blue-green coloration confirmed their presence.[16]

Total Phenolic and Flavonoid Content Determination

The Total Phenolic Content (TPC) was measured using the Folin-Ciocalteu method, with gallic acid as the standard reference compound. The absorbance of the reaction mixture was recorded at 765 nm.

Similarly, the Total Flavonoid Content (TFC) was determined using the aluminum chloride colorimetric assay, employing quercetin as the reference standard. The absorbance was measured at 415 nm. [17]

Antioxidant Activity Assay

The antioxidant potential of *A. chinense* extract was evaluated using DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid)) radical scavenging assays. DPPH Assay: The extract was mixed with DPPH solution and incubated in the dark for 30 minutes, and the absorbance was measured at 517 nm. Meanwhile, ABTS Assay: The ABTS radical cation solution was prepared and reacted with the extract, followed by absorbance measurement at 734 nm [18]

Enzyme Inhibition Assay

The *in vitro* inhibitory activities of *Allium chinense* extract against α-glucosidase and α-amylase were evaluated using standard protocols. α-Glucosidase Inhibition Assay: The assay was performed using p-nitrophenyl-α-D-glucopyranoside (pNPG) as a substrate. The reaction mixture contained α-glucosidase enzyme, phosphate buffer (pH 6.8), extract at different concentrations, and pNPG. The reaction was incubated at 37°C for 30 minutes, and the absorbance was measured at 405 nm. Meanwhile, α-Amylase Inhibition Assay: The assay was conducted using starch as a substrate. The reaction mixture contained α-amylase enzyme, phosphate buffer (pH 6.9), extract at different concentrations, and starch solution. After incubation at 37°C for 10 minutes, the reaction was terminated by adding a dinitrosalicylic acid (DNS) reagent, and the absorbance was measured at 540 nm. The percentage inhibition of both enzymes was calculated using the formula:[19]

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

Where A control is the absorbance of the control reaction without extract, and A sample is the absorbance of the reaction containing the extract.

Statistical Analysis

All experiments were performed in triplicate, and the results were expressed as mean ± standard deviation (SD). Statistical analysis was conducted using one-way ANOVA followed by Tukey's post-hoc test, with significance set at $p < 0.05$.

RESULTS AND DISCUSSION

Yield of Extraction

Figure-1 depicts the extraction process from *A. chinense* dried bulb using polar and non-polar solvents, as well as the extraction yield. Extraction is a fundamental process in natural product research, aiming to isolate bioactive compounds using appropriate solvents.[20] The efficiency of extraction largely depends on the solvent's polarity and the solubility of the targeted compounds.[21] The observed variations in extraction yields can be explained by the following factors, including solvent polarity and compound solubility, extraction efficiency of bioactive compounds, and relevance to pharmacological activity.[22] According to Fig.-1, ethanol is a highly polar solvent that effectively extracts a wide range of bioactive compounds, including flavonoids, phenolics, and saponins, which are predominantly polar in nature. This explains why its significantly higher yield was 30.91%. In addition, ethyl acetate is a moderately polar solvent, primarily extracts semi-polar compounds, such as certain flavonoids and alkaloids, resulting in a moderate yield was 5.65%. Meanwhile, n-hexane is a nonpolar solvent and is mainly efficient in extracting lipophilic compounds such as essential oils, lipids, and terpenoids. Due to the limited presence of these compounds in *A. chinense*, the yield was relatively low, was 5.20%. Therefore, chloroform is a solvent with intermediate polarity but more affinity for lipophilic compounds, resulting in the lowest yield was 3.25%, suggesting that *A. chinense* contains fewer non-polar bioactive compounds. [23-25]

The findings indicate that ethanol is the most effective solvent for extracting bioactive compounds from *A. chinense*, as it resulted in the highest yield. The choice of solvent should align with the targeted compounds: ethanol for phenolics and flavonoids, n-hexane for lipophilic compounds, and ethyl acetate or chloroform for semi-polar bioactives. If the objective is to study antioxidant and anti-diabetic activities,

ethanolic extraction would be the optimal approach. Various extraction methods and solvents have been explored to optimize the yield of bioactive compounds from *Allium* species, particularly garlic (*Allium sativum*).

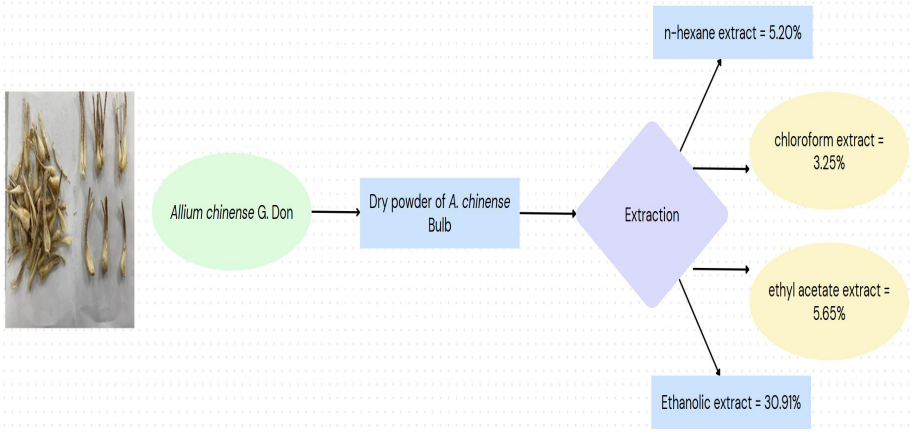


Fig.-1: Extraction Process and Extraction Yield by Different Solvents (n-hexane, chloroform, ethyl acetate, and ethanol) from *A. chinense* Bulb

Conventional techniques, such as Soxhlet extraction with ethanol-water mixtures, have demonstrated high extraction yields, while supercritical CO_2 extraction offers better selectivity for valuable components.[26] Innovative approaches, including subcritical water extraction and ultrasound-assisted micellar extraction, have been shown to enhance the yields of alliin and allicin, respectively.[26,27] Additionally, solvent-free microwave extraction has proven effective for isolating sulfur compounds.[28] The solvent choice also plays a crucial role in bioactive compound recovery. Methanolic extracts have exhibited the highest phenolic and flavonoid content,[29] whereas butanol extracts have demonstrated strong antibacterial activity.[30] Ultimately, the extraction method and solvent selection significantly influence both the yield and bioactivity of the extracts, with each technique offering distinct advantages depending on the target compounds and intended applications.

Qualitative Phytochemical Screening

Table-1 summarizes the secondary metabolites present in *A. chinense* bulb extracts for various solvents. These findings indicate that *A. chinense* bulb is an excellent source of phytochemicals that may detoxify free radicals by lowering oxidative stress. Indeed, ethanolic extract was rich in flavonoids, phenolics, tannins, terpenoids, alkaloids, and saponins. Meanwhile, n-hexane, chloroform, and ethyl acetate extracts were high in steroids and terpenoids, but only the chloroform extract contained alkaloids. Therefore, the ethyl acetate extract is a good solvent to dissolve flavonoid compounds. Overall, our results are consistent with those published in the literature in many countries.[32,33] The results in Table-1 indicate that solvent polarity significantly affects the extraction of secondary metabolites from *A. chinense* bulbs. Among the tested solvents, ethanol proved to be the most effective for extracting a broad spectrum of bioactive compounds, particularly those with antioxidant and antidiabetic properties, such as flavonoids, tannins, and saponins. *Allium* vegetables, especially onions and garlic, are well-known sources of flavonoids, predominantly quercetin derivatives.[34] These compounds offer various health benefits, including antioxidant, anticancer, anti-inflammatory, and antidiabetic effects.[35] In addition, Kwak *et al.* reported that 80–85% of total flavonoids in onion species consist of quercetin glucosides, primarily quercetin-3,4-O-diglucoside (QDC) and quercetin-4-O-monoglucoside (QMG).[36] Additionally, *A. schoenoprasum* green leaves contain 3-β-D-glucosides of quercetin, kaempferol, and isorhamnetin.[37] Further analysis of flavonoid content in *A. fistulosum* and *A. ursinum* using HPLC revealed kaempferol in both non-hydrolyzed and hydrolyzed extracts of *A. fistulosum*, while in *A. ursinum*, it was only present in hydrolyzed flower and leaf samples.[38] Moreover, isoquercetin and quercetin were detected exclusively in *A. fistulosum*.[39] Despite these findings, information on flavonoid content in *A. chinense* remains limited and difficult to obtain, highlighting the need for further research on its phytochemical composition.

Quantitative Phytochemical Screening

Table-2 summarizes the total phenolic content in mg gallic acid equivalent (GAE)/100 g dry weight (DW) and the total flavonoid content in mg quercetin equivalent (QE)/100 g DW of each extract. According to the results, the ethanol extract had the highest yield and contained the most total phenolic compounds (22.43 ± 1.52 mg of GAE/100 g DW) and flavonoids (8.94 ± 0.87 mg of QE/100 g DW).

Table-1: Phytochemical Screening of *A. chinense* Bulb Extracts

Secondary Metabolite	*Allium chinense* bulb extracts			
	n-hexane	Chloroform	Ethyl acetate	Ethanolic
Alkaloid	-	+	-	+
Flavonoids	-	-	+	+
Saponin	-	-	-	+
Tanin	-	-	-	+
Steroid/triterpenoids	+	+	+	+

Although the extracts obtained with ethyl acetate contained the lowest TPC and TFC than the ethanolic extract of 13.64 ± 0.67 mg of GAE/100 g DW and 3.57 ± 0.23 mg of QE/100 g DW, respectively. Certainly, because of its lipophilic nature, n-hexane extract contained none of these compounds, whereas chloroform extract contained a lower amount of flavonoids.

Table-2: Quantitative Phytochemical Screening of *A. chinense* Bulb Extracts

Solvent Extract	Total Phenol Content	Total Flavonoid Content
n-hexane	-	-
Chloroform	-	1.12 ± 0.12
Ethyl acetate	13.64 ± 0.67	3.57 ± 0.23
Ethanol	22.43 ± 1.52	8.94 ± 0.87

*in mg gallic acid equivalent (GAE) per 100 g of dry sample, **in mg quercetin equivalent (QE) per 100 g of dry sample

The TPC obtained from the results of this study was much higher than that reported by Anggriani and Anggarani (2022), which was 1.68 mg GAE/g sample.[40] Meanwhile, the TFC obtained in this study was also higher than TF in other types of Allium, such as *Allium mongolicum* reported by Wang *et al.* (2019), containing TFC of 4.02 mg QE/g sample.[41] In addition, it is also higher than *Allium cepa,* based on a report from Nurcahyo *et al.* (2020) of 2.715 mg QE/g sample.[42] various factors can affect the differences in the amount of TPC and TFC in samples, including factors originating from the plant itself such as genetic variation, growing place, age and condition of the plant, and interaction of plants with soil microbes, while other factors include the drying method applied, the extraction method used, and human resource factors that determine the total phenol content of the sample.[43] Overall, the measured total phenol content indicates that the ethanol extract of Batak onion has the potential to be developed as a health supplement or antioxidant-based pharmaceutical raw material. Further research is needed to confirm its biological effectiveness through specific antioxidant activity tests, such as DPPH and ABTS assays, as well as other pharmacological tests to evaluate its clinical benefits.

Antioxidant Activity Assay

The antioxidant activity of *A. chinense* was evaluated using different solvent extracts, including n-hexane, chloroform, ethyl acetate, and ethanol, at concentrations ranging from 100 to 500 µg/mL, as can be seen in Fig.-2A. The results demonstrated that the ethanolic extract exhibited the highest antioxidant activity, followed by ethyl acetate, chloroform, and n-hexane extracts. The activity increased with increasing concentration, indicating a dose-dependent effect ($p < 0.05$). The ethanolic extract at 500 µg/mL displayed the highest activity at 78.10 ± 0.65%, suggesting that polar compounds present in the extract contributed significantly to its antioxidant potential. Meanwhile, the effect of extracts to inhibit the radical ABTS is presented in Fig.-2B. The ABTS radical scavenging activity was measured to further assess the antioxidant potential of *A. chinense* extracts. The results showed a similar trend to the DPPH antioxidant activity, with ethanolic extract demonstrating the highest inhibition of ABTS radicals. At 500 µg/mL, the

ethanolic extract achieved an inhibition percentage of 86.45 ± 2.65%, followed by ethyl acetate extract (64.67 ± 1.72%), chloroform extract (44.07 ± 0.55%), and n-hexane extract (39.83 ± 0.53%). This confirms that the more polar solvents extracted a higher concentration of antioxidant compounds, leading to greater radical scavenging activity.[44]

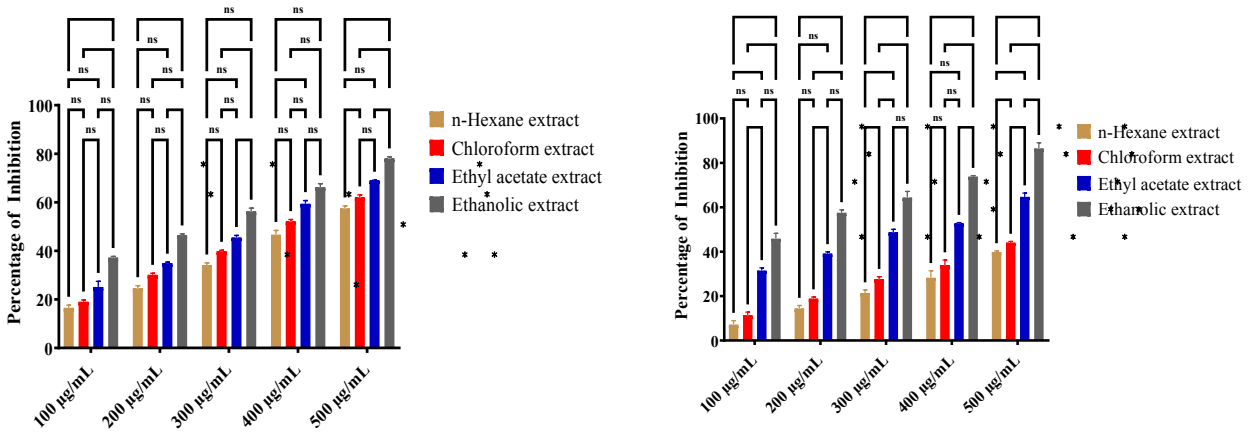
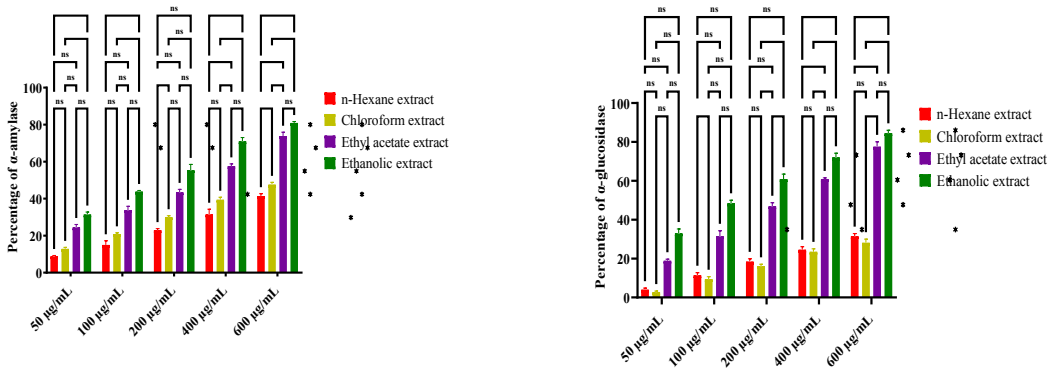


Fig-2: Percentage Inhibition of DPPH (A) and ABTS Radical (B) after Administration of *A. chinense* Extracts on a Range of Concentrations between 100 µg/mL to 500 µg/mL. *Indicates the Group Test is significantly different with $p < 0.05$, and ^{ns} indicates the Group Test is not Significantly Different with $p > 0.05$.

Therefore, a two-way ANOVA test was performed to analyze the statistical significance of the differences in DPPH and ABTS radical scavenging among the extracts. The analysis revealed a significant effect of both the extract type and concentration on DPPH radical scavenging activity ($p < 0.05$). Post-hoc comparisons indicated that ethanolic and ethyl acetate extracts had significantly higher activity than n-hexane and chloroform extracts across all tested concentrations, with $p < 0.05$, respectively. Similarly, ABTS radical scavenging activity was significantly influenced by both factors ($p < 0.05$), with ethanol extracts consistently showing the strongest effect. The interaction between extract type and concentration was also significant, indicating that the response to increasing concentrations varied among different extracts. The higher antioxidant activity of the ethanolic extract suggests that polar compounds, such as flavonoids and phenolic acids, are the main contributors to the antioxidant capacity of *A. chinense*. Ethanol, as a polar solvent, is known to extract these bioactive compounds effectively, explaining the superior activity observed.[45] In contrast, n-hexane, being a nonpolar solvent, extracted fewer antioxidant compounds, leading to lower activity.[46] The strong correlation between DPPH and ABTS radical scavenging further supports this finding, as both methods indicated the highest efficacy in ethanol extracts. Previous studies have highlighted the significant health benefits of Allium species, primarily attributed to their high content of bioactive compounds with antioxidant properties.[47,48] Dai *et al.* (2024) reported that *Allium schoenoprasum* exhibited the highest total phenolic content and antioxidant activity among various Allium species.[49] Similarly, Matrella *et al.* (2022) found that red onion extracts demonstrated the strongest DPPH and ABTS scavenging capacities, indicating a direct correlation between antioxidant activity and phenolic and flavonoid content.[50] Kaur *et al.* (2016) further confirmed that methanol and aqueous extracts of *Allium cepa* possessed notable antioxidant activity, with methanol extracts proving more effective.[51] Aydın *et al.* (2015) highlighted the potent antioxidant properties of endemic *Allium* species from Turkey.[52] Supporting this, Beretta *et al.* (2017) established a positive correlation between phenolic content and antioxidant activity across multiple *Allium* species.[53] Meanwhile, Dhurrotul Lu'ma & Anggarani (2022) reported moderate antioxidant activity in *Allium cepa*,[54] while Kovarovič *et al.* (2017) emphasized the broad health benefits of various *Allium* species due to their rich bioactive composition.[55] Additionally, Kurnia *et al.* (2021) reviewed the antioxidant properties and bioactivities of *Allium* species, reinforcing their medicinal potential.[56]

α-Amylase and α-Glucosidase Inhibitor Activity

The inhibitory effects of different *A. Chinese* extracts on α-amylase and α-glucosidase were evaluated across various concentrations (50–600 µg/mL). The results indicate that the solvent type significantly influences the extraction efficiency of bioactive compounds, which subsequently affects enzyme inhibition activity and can be seen in Fig. 3A-B. Among the tested extracts, the ethanolic extract consistently demonstrated the highest inhibition for both α-amylase and α-glucosidase, suggesting its strong potential as an antidiabetic agent. At 600 µg/mL, the ethanolic extract exhibited 80.96 ± 0.71% inhibition for α-amylase and 84.51 ± 1.49% inhibition for α-glucosidase, confirming its superior activity. Ethyl acetate extract followed as the second most effective extract, while chloroform and n-hexane extracts showed weaker inhibition, with n-hexane being the least effective against both enzymes.



(A) (B)

Fig-3: Percentage Inhibition of α-amylase (A) and α-glucosidase (B) after Administration of *A. chinense* Extracts on a Range of Concentrations between 50 µg/mL to 600 µg/mL. *Indicates the Group Test is Significantly Different with $p < 0.05$, and ns Indicates the Group Test is Not Significantly Different with $p > 0.05$

A two-way repeated-measures ANOVA was conducted to assess the impact of extract type and concentration on both α-amylase and α-glucosidase inhibition. The results showed that Extract type and concentration significantly influenced enzyme inhibition ($p < 0.05$ for both enzymes). On the other hand, no significant interaction effect ($p > 0.05$) was observed between extract type and concentration, indicating that their effects were independent. Therefore, Tukey's post-hoc analysis revealed significant differences between certain extract pairs ($p < 0.05$), particularly between n-hexane and more polar extracts like ethanol and ethyl acetate. These findings reinforce the importance of solvent polarity in extracting enzyme-inhibiting bioactive compounds, with polar solvents such as ethanol yielding the highest inhibition levels [57] While both α-amylase and α-glucosidase play essential roles in carbohydrate metabolism, their inhibition mechanisms differ slightly.[58] The results showed that ethanolic and ethyl acetate extracts exhibited comparable inhibition levels for both enzymes, indicating that similar bioactive compounds might be responsible for their effects. However, the inhibition of α-glucosidase was generally stronger than that of α-amylase, particularly in the ethanolic and ethyl acetate extracts. This suggests that certain flavonoids, tannins, and saponins extracted in polar solvents are more effective in targeting α-glucosidase, an enzyme primarily involved in the final stages of carbohydrate digestion.[59] The high inhibition activity observed in ethanolic extracts aligns with previous studies that highlight the presence of quercetin derivatives, kaempferol, and other flavonoids in *Allium* species. These compounds have been shown to inhibit carbohydrate-hydrolyzing enzymes by interacting with their active sites, thereby reducing glucose absorption and postprandial blood sugar spikes.[60] The stronger inhibition of α-glucosidase relative to α-amylase suggests that some bioactive compounds might have a higher binding affinity for this enzyme. Additionally, recent studies have highlighted the potential of *Allium* species in inhibiting key enzymes associated with diabetes and hypertension [61] *A. sativum* and *A. cepa* oils have demonstrated competitive inhibition of α-amylase, with *A. sativum* exhibiting superior efficacy.[61] Several *Allium* species, including *A. tripedale, A. hooshidaryae,* and *A. stipitatum*, have shown α-glucosidase inhibitory activity alongside strong antioxidant properties.[62] Similarly, *Allium odorum* extracts have

exhibited significant α-amylase inhibition and antioxidant effects.[63] Further research identified quercetin-4'-O-glucoside, a flavonoid derived from *Allium cepa* peel, as a potent α-glucosidase inhibitor.[64] The incorporation of *A. sativum* into yogurt was found to enhance its inhibitory effects on diabetes- and hypertension-associated enzymes.[65] On the other hand, the choice of extraction solvent significantly influenced enzyme inhibition activity in *Allium cepa* and other vegetables.[66] These findings underscore the potential of *Allium* species as natural therapeutic agents for managing diabetes and related metabolic disorders, warranting further investigation into their bioactive compounds and mechanisms of action.

CONCLUSION

This study highlights the phytochemical composition, antioxidant properties, and enzyme inhibitory potential of *A. chinense* extracts from North Sumatra, Indonesia. Among the tested solvents, ethanol emerged as the most effective extraction medium, yielding the highest concentrations of phenolics, flavonoids, tannins, and saponins, which are known for their bioactive properties. The ethanolic extract demonstrated the strongest antioxidant activity, as well as the highest inhibition of α-amylase (80.96 ± 0.71%) and α-glucosidase (84.51 ± 1.49%) at 600 µg/mL, reinforcing its potential as a natural antidiabetic agent. The two-way ANOVA analysis confirmed that both extract type and concentration significantly influenced enzyme inhibition, while no significant interaction effect was observed, indicating that their effects were independent. The findings suggest that *A. chinense* could be developed as a functional food ingredient or phytopharmaceutical for diabetes management, offering a safer and cost-effective alternative to synthetic enzyme inhibitors. Importantly, this research supports Sustainable Development Goal (SDG) 3, Good Health and Well-being, by promoting the utilization of plant-based antidiabetics as safer alternatives to synthetic agents, contributing to preventive healthcare and nutraceutical development.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

The present work is related to *SDG-3: Good Health and Well-being*. All the authors contributed significantly to this manuscript, participated in reviewing/editing, and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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