Science World Journal Vol. 21(No 1) 2026 https://dx.doi.org/10.4314/swj.v21i1.16
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

Full Length Research Article

GASTROPROTECTIVE EFFECT OF LOCALLY FORMULATED NIGERIAN HERBAL SUPPLEMENT FROM 5 PLANTS

Saheed O. Afolabi[1*], Gideon Gyebi[2], Damilola Raji[3], Olufunke Olorundare[1]

[1]Department of Pharmacology and Therapeutics, Faculty of Basic Clinical Sciences, University of Ilorin, Ilorin, Nigeria
[2]Department of Biotechnology and Food Science, Faculty of Applied Sciences, Durban University of Technology, P.O. Box 1334, Durban 4000, South Africa
[3]Department of Medical Laboratory Sciences, Faculty of Basic Clinical Sciences, University of Ilorin, Ilorin, Nigeria

*Corresponding Author Email Address: afolabi.so@unilorin.edu.ng

ABSTRACT
Gastrointestinal (GI) disorders such as peptic and duodenal ulcers are ranked high amongst several chronic and relapsing disorders. *H. pylori* urease activity is linked to the aetiology of over 75% of peptic ulcer disease (PUD). This study explores the inhibitory role of PHS, a Nigerian polyherbal nutraceutical, against H^+/K^+ Atpase and urease enzyme activity using *in vitro* and *in silico* models. Using ELISA methods, the inhibitory activity of PHS against H^+/K^+ Atpase and urease enzyme was determined. Also, the most active compounds against *Helicobacter pylori* urease enzyme were identified via molecular docking. For the H^+/K^+ Atpase inhibition, the IC_{50} obtained were 100 µg/mL and 30.2 µg/mL for PHS and omeprazole respectively. While for the urease inhibition, IC_{50} obtained were 130.2 µg/mL and 40.5 µg/mL for PHS and Thiourease (a positive control) respectively. Docking analysis against *Helicobacter pylori* urease showed that Cyclotriacontane displayed the highest affinity (−9.1 kcal/mol), followed by β-amyrin and 9,19-cyclolanost-24-en-3-ol (−8.6 kcal/mol). Other sterol and triterpenoid compounds demonstrated favourable docking scores. Overall, these results suggest that the screened natural compounds have strong interaction potential with the urease active site. These preliminary *in vitro* and *in silico* results provide a basis for further investigations into its *in vivo* and possible translational potentials.

Keywords: Molecular docking, nutraceutical, gastroprotective, *Helicobacter pylori*, α-amylase, α- glucosidase.

INTRODUCTION

Peptic ulcer disease (PUD) remains one of the most common, chronic, and recurring gastrointestinal disorders globally, raising major public health concerns (Zhang *et al*., 2025). Its pathogenesis has been linked to several factors, including *Helicobacter pylori* infections, excessive consumption of NSAIDs, consumption of alcohol, burns, and other physiological stressors (Kuna *et al*., 2019). The mechanism underlying this disease is attributed to an imbalance between the aggressive and the protective mechanisms of the GI tract. This occurs when the protective mucosal lining of the stomach or duodenum is disrupted, leading to erosion by gastric acid and pepsin (Badapanda *et al*., 2024). Globally, the incidence of peptic ulcer disease has declined in developed nations but remains significant in developing regions (Azhari et al., 2022). It is estimated that about 5–10% of adults experience peptic ulcers during their lifetime (Xie *et al*., 2022; Zhang *et al*., 2025). *H. pylori* infection affects over 50% of the global population, and its prevalence exceeds 70% in low-income areas such as sub-Saharan Africa and parts of Asia (Smith *et al*., 2019). Among the elderly, the increasing use of NSAIDs and stress-related disorders also contributes to ulcer development (Badapanda *et al*., 2024).

Despite the availability of proton pump inhibitors (PPIs) and antibiotics, ulcer recurrence and *H. pylori* resistance continue to pose serious clinical challenges. Strains of *H. pylori* have developed resistance to commonly used antibiotics such as clarithromycin and metronidazole, reducing eradication success (Megraud *et al.,* 2021). Other factors include unwanted or deleterious drug effects, accessibility, availability, and affordability, especially in resource-limited settings. This creates a need for more tolerable, accessible, and cost-effective alternatives, which are mostly provided by phytomedicines, nutraceuticals, and other herbal supplements.

A major enzyme that plays a key therapeutic role in the management of PUD is the H^+/K^+ ATPase (Gastric Proton Pump) (Shin *et al*., 2009). This enzyme, located in the parietal cells of the stomach lining, is often called the gastric proton pump because it pumps hydrogen ions (H^+) into the stomach lumen in exchange for potassium ions (K^+). This process forms hydrochloric acid (HCl), which helps digest food but, in excess, causes gastric irritation and ulcers. When overactivated (due to stress, H. pylori, NSAIDs, etc.), too much acid (HCl) is secreted, overwhelming the mucosal barrier. Acid and pepsin penetrate the epithelium, leading to erosion and ulceration (Saha *et al*., 2010). Drugs such as omeprazole and lansoprazole are proton pump inhibitors, and they are a major component of the first-line triple regimen employed in the management of PUD (Andrawes *et al*., 2025).

Urease is another enzyme worthy of note in the aetiology of PUD. This is an enzyme produced by *H. pylori* that hydrolyses urea into ammonia (NH_3) and carbon dioxide (CO_2). The released ammonia neutralizes gastric acid around the bacterium, allowing *H. pylori* to survive in the highly acidic stomach environment (Mahernia e*t al*., 2015). However, excess ammonia and reactive oxygen species (ROS) contribute to mucosal inflammation and ulceration (Han *et al*., 2022).

Many developing nations employ polyherbal formulations as supplementary therapies. This can be in the form of nutraceuticals or just bioactive phytochemicals (Moussavi *et al*., 2024; Mafogang *et al*., 2025). These alternative therapies have shown marked efficacy in several disease conditions, and of particular interest in this study is their gastroprotective roles. One major example is Triphala, a traditional polyherbal formula originating from India, which is well known in Ayurveda medicine for its healing prowess. Triphala demonstrates scientifically proven gastroprotective effects through a multi-target mechanism. Inhibiting *H. pylori* urease, it reduces bacterial survival and inflammation while suppressing H^+/K^+ ATPase activity (Zhu et al., 2024).

This study aims to explore the gastroprotective mechanisms of PHS by evaluating H^+/K^+ ATPase (Gastric Proton Pump) and urease inhibitory activity, using both *in vitro* and *in silico* models.

MATERIALS AND METHODS

Preparation of Ethanolic extract of PHS

As previously reported by Afolabi et al. (2023), PHS, a nutraceutical containing the medicinal plants: leaves of *Moringa oleifera* (80%w/w), *Ocimum gratissimum* (5%w/w), *Vernonia amygdalina* (5%w/w); nuts: *Garcinia kola* (bitter kola) (5%w/w) and *Zingiber officianale* (ginger) (5%w/w); was constituted by Biofuel and Natural Product Herbal Supplement; NAPHERBS, Ilorin, Nigeria. PHS (500 g) was macerated in 2.5 L of 50% ethanol successively in 3 phases, each phase was for 72 h, and then filtered using Whatman filter paper 1. The residue was reconstituted in 2.5 L of 50% ethanol for the second and third phases. The filtrate was concentrated using a rotary evaporator at 40°C (BUCHI, Switzerland) with the vacuum Model V-801 EasyVac®Switzerland. The concentrate was weighed and tagged as PHS extract. A percentage yield of 14.01%w/w was extrapolated.

H^+/K^+ Atpase inhibitory assay

PHS extract 7.8 - 1000 µg/ml was incubated in the reaction mixture (40 mM Tris-HCl buffer, pH 7.4, containing 2 mM $MgC1_2$ and 10 µg membrane protein) to make a volume of 1 ml. Then, 2 mM ATP Tris salt was utilized to start the reaction; this preparation was incubated for 20 min at 37 °C. The reaction was terminated by adding 1 ml of ice-cold trichloroacetic acid (10% v/v). The negative control had distilled water, while the same concentration of omeprazole (7.8 - 1000 µg/ml) was also used as the positive control. The amount of inorganic phosphate released from ATP was determined spectrophotometrically at 400 nm (Reyes-Chilpa *et al*., 2006).

For each concentration of the sample, a sample blank was added in parallel.

% inhibition = ([Absorbance of control – Absorbance of samples]/ Absorbance of control) ×100

The IC50 values were determined graphically using the AAT Bioquest online calculator (https://www.aatbio.com/tools/ic50-calculator)

Urease inhibitory assay

Methods were adopted from Mahernia et al. (2015). Briefly, the urease inhibitory activity of PHS was evaluated at the concentrations of 7.8 – 1000 µg/mL, with the modified Berthelot spectrophotometric method at the absorbance of 625 nm. Thiourea served as the positive control with the same concentrations of 7.8 – 1000 µg/mL, and the negative control was distilled water. The assay solution mixture consisted of urea (850 µL), the extract (in the range of 0 to 100 µL), and phosphate buffer (100 mM, pH 7.4) to reach a total volume of 985 µL. The enzymatic reactions started with the addition of 15 µL of urease enzyme and measured via determining ammonia concentration after 60 minutes using 500 µL of solution A (contained 0.5 g phenol and 2.5 mg of sodium nitroprusside in 50 mL of distilled water) and 500 µL of solution B (contained of 250 mg sodium hydroxide and 820 µL of sodium hypochlorite 5% in 50 mL of distilled water) at the temperature of 37 °C for 30 minutes. The activity of uninhibited urease was chosen as the control activity of 100%. Finally, the IC_{50} inhibitory activity of each extract was assessed.

For each concentration of the sample, a sample blank was added in parallel.

% inhibition = ([Absorbance of control – Absorbance of samples]/ Absorbance of control) ×100

The IC50 values were determined graphically using the AAT Bioquest online calculator (https://www.aatbio.com/tools/ic50-calculator)

In silico investigation

Protein structure preparation

The deposited three-dimensional structures of *Helicobacter pylori* urease with inhibitor bound in the active site (PDB ID: 6ZJA, sequence length: 238, and resolution: 2.00 Å) were retrieved from the Protein Data Bank (http://www.rcsb.org). All heteroatoms, co-crystallized ligands, and crystallographic water molecules were removed from all the crystal structures, while missing hydrogen atoms were added using MGL-AutoDockTools (ADT, v1.5.6) (Morris et al., 2009).

Ligand preparation

The GCMS identified phytocompounds from PHS were previously reported by Afolabi et al. (2023). These identified compounds and reference inhibitor (acarbose) were downloaded from the PubChem database (www.pubchem.ncbi.nlm.nih.gov) in Structure Data Format (SDF). To prepare the compounds, they were imported into the Openbabel (O'Boyle, 2011) section of Python Prescription PyRx 0.8 and converted to pdb format. Non-polar hydrogen molecules were merged with the carbons, while the polar hydrogen charges of the Gasteiger-type were assigned to atoms. Furthermore, ligand molecules were converted to dockable PDBQT format with the help of AutoDock Tools.

Molecular docking of phytochemicals with the targeted active site

AutoDock Vina, implemented in PyRx 0.8, was used to carry out molecular docking of the reference inhibitors and the GC-MS-identified compounds against the protein target (Trott & Olson, 2010). After importation of the compounds into the PyRx 0.8's through OpenBabel (O'Boyle, 2011). The energy of the ligand was minimized to achieve stable conformations. The energy minimization parameter and conjugate gradient descent used were the Universal Force Field (UFF) and optimization algorithm, respectively. A blind docking approach was used. Unless otherwise noted, docking calculations were performed using AutoDock Vina with default parameters. Multiple binding poses were generated for each ligand, and the pose with the best orientation within the active site and the lowest score was chosen for additional examination. Predicted score (kcal/mol), hydrophobic contacts, hydrogen bonding interactions, and congruence with known binding site residues were used to assess the docking results.

RESULTS

H^+/K^+ Atpase inhibitory activity

In vitro, the methanolic extract of PHS potently reduced the hydrolysis of ATP by the goat gastric ATPase with IC_{50} of 100 µg/mL. Omeprazole (7.8-1000µg/ mL) used as positive control reduced H+-K+ ATPase activity with an IC_{50} = 30.1 µg/mL (Figure 1).

Science World Journal Vol. 21(No 1) 2026 https://dx.doi.org/10.4314/swj.v21i1.16
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

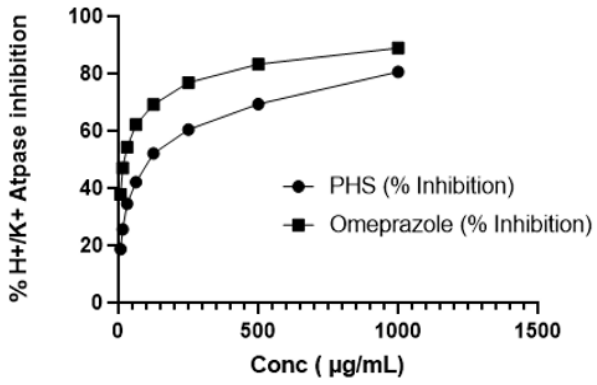

Figure 1: Inhibitory effect of PHS and omeprazole on H+-K+ ATPase activity

Urease inhibitory activity

Urease inhibitory activity was estimated as previously described. PHS inhibited urease activity with an IC_{50} of about 130.2 µg/mL, while the positive control thiourea had an IC_{50} of about 40.5 µg/mL. This is shown in Figure 2.

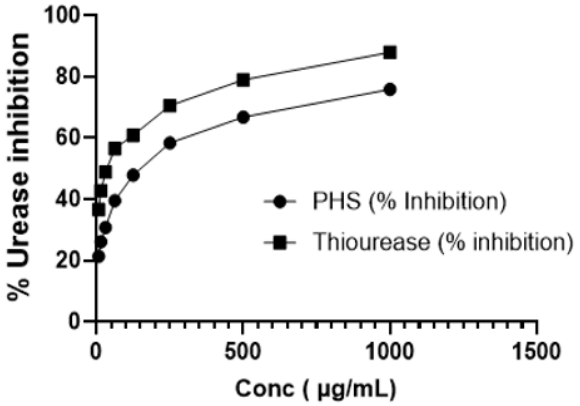

Figure 2: Inhibitory effect of PHS and thiourea on urease activity

In silico studies

Table 1 presents the molecular docking scores of the top 10 GCMS identified compounds against *Helicobacter pylori* urease, expressed in kcal/mol. In docking studies, more negative binding energies (kcal/mol) indicate stronger predicted ligand–protein interactions and, by implication, greater inhibitory potential. Among the screened compounds, cyclotriacontane exhibited the strongest binding affinity with a docking score of –9.1 kcal/mol. Subsequently, β-amyrin and 9,19-cyclolanost-24-en-3-ol (3β) displayed docking scores of -8.6 kcal/mol, whereas β-amyrinol displayed a score of -8.5 kcal/mol. Strong binding was also shown by other substances, such as lanosterol (-8.2 kcal/mol) and bacchotricuneatin C (-8.1 kcal/mol). Ergost-25-ene-3,5,6-triol (–7.8 kcal/mol), stigmasterol (–7.7 kcal/mol), dibenzo[b,f][1,4]oxazepin-11(10H)-one (–7.7 kcal/mol), and campesterin (–7.6 kcal/mol) all had moderate docking scores. Overall, the results indicate that all screened ligands exhibit favorable binding interactions with *H. pylori* urease.

Table 1: Docking scores (kcal/mol) of ligands against *Helicobacter pylori* urease

Compounds	Docking scores (kcal/mol)
Acetohydroxamic acid	-7.6
Cyclotriacontane	-8.1
beta.-Amyrin	-8.6
9,19-Cyclolanost-24-en-3-ol, (3.beta.)	-8.6
beta-Amyrenol	-8.5
Lanosterol	-8.2
Bacchotricuneatin c	-8.1
Ergost-25-ene-3,5,6-triol	-7.8
Stigmasterol	-7.7
Dibenzo[b,f][1,4]oxazepin-11(10H)-one	-7.7
Campesterin	-7.6

Science World Journal Vol. 21(No 1) 2026 https://dx.doi.org/10.4314/swj.v21i1.16
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

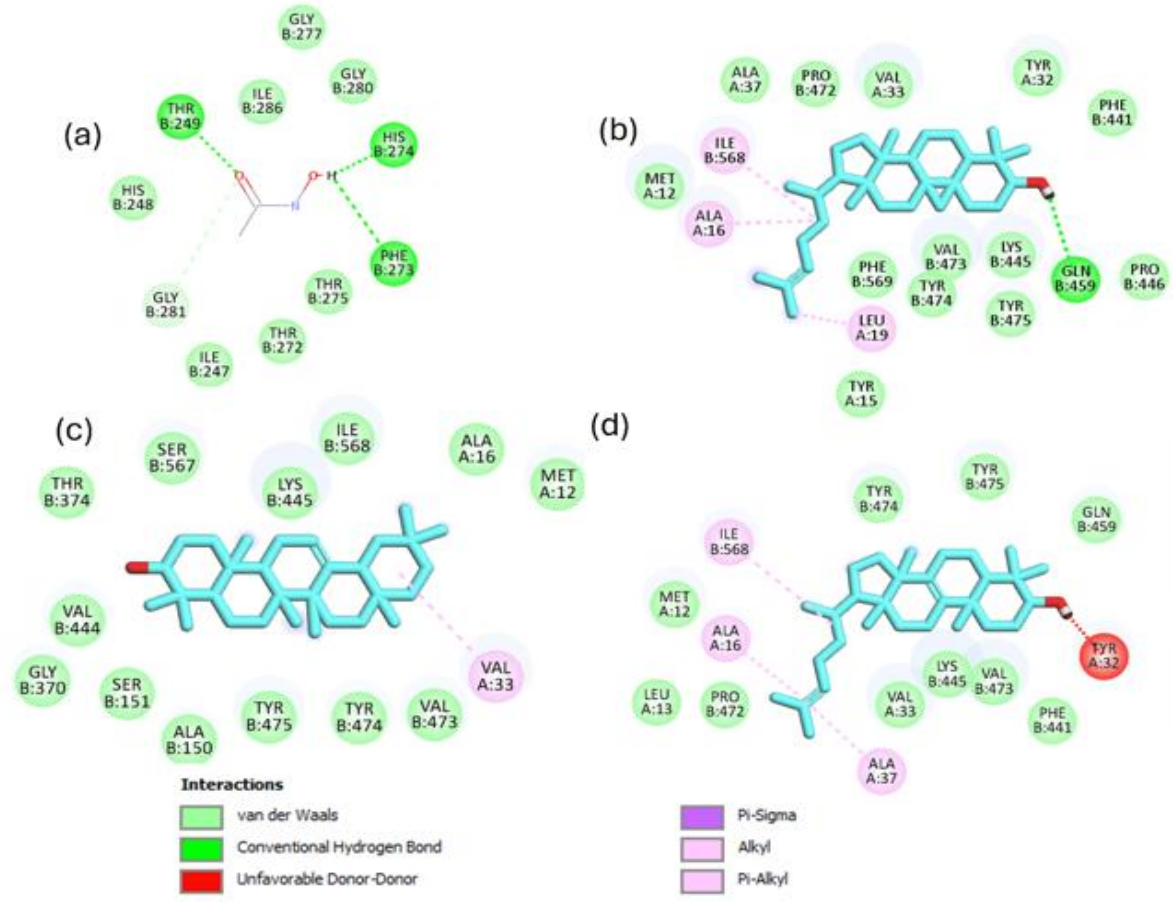

Figure 3: Interactive plots of the top three GCMS identified phytochemicals against *Helicobacter pylori* urease

DISCUSSION

The use of nutraceuticals and medicinal foods has gained a huge subscription in the last couple of years (Vignesh *et al*., 2024). This has been ascribed to their availability, accessibility, and multi-targeting mechanisms in several disease conditions (Puri *et al*., 2022). In spite of this, many of these supplements are mainly used based on folkloric claims and not scientific validation, to ensure efficacy and safety (Starek *et al*., 2025). Thus, the need to explore the mechanisms underlying the use of PHS.

The understanding of the aetiology of several GI disorders provides a lead to discovering novel target-specific agents (Suri *et al*., 2024). GI disorders, particularly peptic ulcer, duodenal ulcer, gastroesophageal disorder, and gastric cancer, are mainly caused as a result of *H. pylori* infection (Majumdar and Looi, 2024). Aside from PUD, *H. pylori* has been linked to several pathologies, including urinary stone formation, pyelonephritis, and hepatic coma (Gong *et al.,* 2025). *H. pylori* accounts for about 80 % of reported PUD. Its survival is critical for the persistence of the disease (Alli and AlHussaini, 2024). The persistence of this bacterium in the acidic medium of the stomach is due to the urease enzyme activity. Urease enzyme buffering activity alters the acidic medium of the stomach to a habitable environment for *H. pylori* survival. This is achieved via neutralizing gastric acid through hydrolysis of urea to form carbon dioxide (CO_2) and ammonia (NH_3) (Clyne *et al*., 1995; Cheok *et al*., 2021). In this study, PHS effectively inhibited the activity of the urease enzyme with an IC_{50} of 130.2 µg/mL. In a previous study by Biglar *et al*. in 2014, about 20 herbal extracts were screened for their urease inhibitory potentials. Amongst the most potent were *Zingiber officinale* (ginger root), *Nigella sativa* (black cumin), *Allium sativum* (garlic), and *Curcuma longa* (turmeric), with corresponding IC_{50} of 48.5, 59.1, 170.4, and 310.5 µg/mL. These have become constituents of polyherbal formulas, where they serve gastroprotective roles (Biglar *et al*., 2014). Thus, suggesting a major role in distorting the survival of *H. pylori*.

In a parallel mechanism, H^+/K^+ Atpase inhibition by PHS was also assessed. The human stomach is lined with numerous gastric pits from which acid is released. One of the cells lining the gastric pits is the parietal cell, which is responsible for the acidification of the stomach (Engevik *et al*., 2020). The H+/K+ Atpase enzyme present in the parietal cell is responsible for the final step in the release of HCl. The therapeutic regimens in the management of PUD must contain one proton pump inhibitor (PPI) or histamine H_2 blocker (Andrawes *et al*., 2025). PHS had a significant inhibitory effect on the H+/K+ Atpase, as judged by its IC_{50}. Although the IC_{50} of PHS (100 µg/mL) was quite higher than that of omeprazole (30 µg/mL), it was comparable with other reported herbal preparations, such as *Acalypha wilkesiana* foliage extract with an IC_{50} of 51.5 µg/mL (Gupta and Hanumanthappa, 2013). PHS may provide some gastroprotective advantage in peptic ulcer disease and other hyperacidity-related GI pathologies. This could be via the inhibition

of urease and the proton pump, H+/K+ Atpase. This is just a preliminary finding that warrants further in vivo and other mechanism-based studies.

Several of the compounds under investigation appear to have substantial inhibitory capability against *H. pylori* urease, an enzyme necessary for bacterial survival in acidic stomach environments, according to the observed docking scores. Because of its extremely hydrophobic nature, which probably encourages stable contacts within nonpolar areas of the urease binding pocket, cyclotriacontane has a higher binding affinity (Kusters *et al*., 2006). Similar to this, the potent effects of sterol-based and triterpenoid compounds like lanosterol, β-amyrin, and β-amyrinol emphasize the significance of large hydrophobic scaffolds with hydroxyl functional groups that can promote van der Waals interactions and hydrogen bonding with important amino acid residues (Kafarski & Talma, 2018). Interestingly, a large number of the tested ligands show binding affinities that are on par with or possibly higher than those commonly reported for well-known urease inhibitors like acetohydroxamic acid. Given the safety and resistance issues with traditional urease inhibitors, this implies that these natural chemicals could be attractive substitute leads (Newman & Cragg, 2020). A structure–activity relationship that favors lipophilic frameworks in urease inhibition is further supported by the constant binding seen among structurally similar sterols. To verify the stability, specificity, and biological significance of these interactions, additional validation via molecular dynamics simulations, binding free energy calculations, and actual enzymatic assays is required, even if the docking data offer insightful initial information (Singh et al., 2025).

Conclusion

Putting these together, PHS may provide some gastroprotective advantage in peptic ulcer disease and other hyperacidity-related GI pathologies. This could be via the inhibition of urease and the proton pump, H+/K+ Atpase. This is just a preliminary finding that warrants further in vivo and other mechanism-based studies. Molecular docking analysis against *Helicobacter pylori* urease revealed that several phytochemical ligands exhibited strong binding affinities, outperforming or comparable to the reference inhibitor. Among the screened compounds, cyclotriacontane, β-amyrin, 9,19-cyclolanost-24-en-3-ol, and β-amyrenol demonstrated the more favourable binding energies. Overall, the docking results indicate that these predominantly hydrophobic natural compounds possess strong interaction potential with the urease active site, suggesting their promise as lead candidates for the development of novel *H. pylori* urease inhibitors.

REFERENCES

Afolabi, S. O., Olorundare, O., Akanbi, O. B., Bello, M. K., Njan, A., Agede, O. A., Oche, J., Akinsola, A. O., Ologe, M., & Ibiyemi, S. (2023). GC/MS Analysis and a 30-day Toxicological Evaluation of a Nigerian Immunomodulatory Polyherbal Supplement (PHS). *Pharmacology and Toxicology of Natural Medicines (ISSN: 2756-6838)*, *3*(2), 1-14.

Ali, A., & AlHussaini, K. I. (2024). Helicobacter pylori: A Contemporary Perspective on Pathogenesis, Diagnosis and Treatment Strategies. Microorganisms, 12(1), 222. https://doi.org/10.3390/microorganisms12010222.

Andrawes, M., Andrawes, W., Das, A., & Siau, K. (2025). Proton Pump Inhibitors (PPIs)—An Evidence-Based Review of Indications, Efficacy, Harms, and Deprescribing. Medicina, 61(9), 1569.

Andrawes, M., Andrawes, W., Das, A., & Siau, K. (2025). Proton Pump Inhibitors (PPIs)—An Evidence-Based Review of Indications, Efficacy, Harms, and Deprescribing. Medicina, 61(9), 1569.

Azhari, H., King, J. A., Coward, S., Windsor, J. W., Ma, C., Shah, S. C., ... & Kaplan, G. G. (2022). The global incidence of peptic ulcer disease is decreasing since the turn of the 21st century: a study of the Organisation for Economic Co-operation and Development (OECD). Official journal of the American College of Gastroenterology| ACG, 117(9), 1419-1427.

Badapanda, S. S., Kaur, A., Jain, D., & Bhatia, D. (2024). Epidemiology, Pathogenesis, and Induction of Peptic Ulcer: A Comprehensive Review. New Emirates Medical Journal, 5(1), e02506882348139.

Biglar, M., Sufi, H., Bagherzadeh, K., Amanlou, M., & Mojab, F. (2014). Screening of 20 commonly used Iranian traditional medicinal plants against urease. Iranian journal of pharmaceutical research: IJPR, 13(Suppl), 195.

Cheok, Y. Y., Lee, C. Y. Q., Cheong, H. C., Vadivelu, J., Looi, C. Y., Abdullah, S., & Wong, W. F. (2021). An overview of Helicobacter pylori survival tactics in the hostile human stomach environment. Microorganisms, 9(12), 2502.

Clyne, M., Labigne, A., & Drumm, B. (1995). Helicobacter pylori requires an acidic environment to survive in the presence of urea. Infection and immunity, 63(5), 1669-1673.

Engevik, A. C., Kaji, I., & Goldenring, J. R. (2020). The physiology of the gastric parietal cell. Physiological reviews, 100(2), 573-602.

Gong, R., Ling, Y., Wang, S., Wang, W., Meng, L., Zeng, J., ... & Xu, S. (2025). Helicobacter Pylori Infection as an Independent Risk Factor for Kidney Stone Formation in China: A Cross-Sectional Study. Infection and Drug Resistance, 2881-2888.

Gupta, R. K. P., & Hanumanthappa, M. (2013). In vitro antioxidant and H+, K+-ATPase inhibition activities of Acalypha wilkesiana foliage extract. Journal of Pharmacy and Bioallied Sciences, 5(3), 214-223.

Han, L., Shu, X., & Wang, J. (2022). Helicobacter pylori-mediated oxidative stress and gastric diseases: a review. Frontiers in microbiology, 13, 811258.

Kafarski, P., & Talma, M. (2018). Recent advances in design of new urease inhibitors: A review. *Journal of advanced research*, *13*, 101-112.

Kuna, L., Jakab, J., Smolic, R., Raguz-Lucic, N., Vcev, A., & Smolic, M. (2019). Peptic ulcer disease: a brief review of conventional therapy and herbal treatment options. Journal of clinical medicine, 8(2), 179.

Kusters, J. G., Van Vliet, A. H., & Kuipers, E. J. (2006). Pathogenesis of Helicobacter pylori infection. *Clinical microbiology reviews*, *19*(3), 449-490.

Mafogang, B., Zingue, S., Kotue, C. T., Djouhou, M., Fomo, F. A. F., Ponka, R., & Fokou, E. (2025). Development and Comparative Evaluation of Two Polyherbal Nutraceuticals, BobyGuards A and B: Phytochemical Composition, Antioxidant Potential, and Nutritional Value. Journal of Food Quality, 2025(1), 1971279.

Mahernia, S., Bagherzadeh, K., Mojab, F., & Amanlou, M. (2015). Urease inhibitory activities of some commonly consumed

herbal medicines. Iranian journal of pharmaceutical research: IJPR, 14(3), 943.

Majumdar, D., & Looi, S. (2024). Helicobacter pylori infection and peptic ulcers. Medicine, 52(3), 152-160.

Megraud, F., Bruyndonckx, R., Coenen, S., Wittkop, L., Huang, T. D., Hoebeke, M., ... & Glupczynski, Y. (2021). Helicobacter pylori resistance to antibiotics in Europe in 2018 and its relationship to antibiotic consumption in the community. Gut, 70(10), 1815-1822.

Morris, G. M., Huey, R., Lindstrom, W., Sanner, M. F., Belew, R. K., Goodsell, D. S., & Olson, A. J. (2009). AutoDock4 and AutoDockTools4: Automated docking with selective receptor flexibility. *Journal of Computational Chemistry*, *30*(16), 2785-2791.

Moussavi, N., Mounkoro, P. P., Dembele, S. M., Ballo, N. N., Togola, A., Diallo, D., ... & Paulsen, B. S. (2024). Polyherbal Combinations Used by Traditional Health Practitioners against Mental Illnesses in Bamako, Mali, West Africa. Plants, 13(3), 454.

Newman, D. J., & Cragg, G. M. (2020). Natural products as sources of new drugs over the nearly four decades from 01/1981 to 09/2019. *Journal of natural products*, *83*(3), 770-803.

O'Boyle, N. (2011). Banck M. James, CA Morley C. Vandermeersch T. Hutchison GR Open Babel: An open chemical toolbox. *J. Cheminf*, *3*(1), 33.

Puri, V., Nagpal, M., Singh, I., Singh, M., Dhingra, G. A., Huanbutta, K., Dheer, D., Sharma, A., & Sangnim, T. (2022). A Comprehensive Review on Nutraceuticals: Therapy Support and Formulation Challenges. Nutrients, 14(21), 4637. https://doi.org/10.3390/nu14214637.

Reyes-Chilpa, R., Baggio, C. H., Alavez-Solano, D., Estrada-Muñiz, E., Kauffman, F. C., Sanchez, R. I., & Mesia-Vela, S. (2006). Inhibition of gastric H+, K+-ATPase activity by flavonoids, coumarins and xanthones isolated from Mexican medicinal plants. *Journal of ethnopharmacology*, *105*(1-2), 167-172.

Saha, A., Hammond, C. E., Beeson, C., Peek, R. M., & Smolka, A. J. (2010). Helicobacter pylori represses proton pump expression and inhibits acid secretion in human gastric mucosa. *Gut*, *59*(7), 874-881.

Shin, J. M., Munson, K., Vagin, O., & Sachs, G. (2009). The gastric HK-ATPase: structure, function, and inhibition. Pflügers Archiv-European Journal of Physiology, 457(3), 609-622.

Singh, D. D., Yadav, D. K., & Shin, D. (2025). Antioxidant Natural Compounds Integrated with Targeted Protein Degradation: A Multi-Modal Strategy for Alzheimer's Disease Therapy. *Antioxidants*, *14*(12), 1426.

Smith, S., Fowora, M., & Pellicano, R. (2019). Infections with Helicobacter pylori and challenges encountered in Africa. World journal of gastroenterology, 25(25), 3183.

Starek, M., Błasiak, M., & Dąbrowska, M. (2025). Insights into dietary supplements as a popular product supporting the diet. Naunyn-Schmiedeberg's Archives of Pharmacology, 1-15.

Suri, C., Pande, B., Sahu, T., Sahithi, L. S., & Verma, H. K. (2024). Revolutionizing gastrointestinal disorder management: cutting-edge advances and future prospects. Journal of Clinical Medicine, 13(13), 3977.

Trott, O., & Olson, A. J. (2010). AutoDock Vina: improving the speed and accuracy of docking with a new scoring function, efficient optimization, and multithreading. *Journal of Computational Chemistry*, *31*(2), 455-461.

Vignesh, A., Amal, T. C., Sarvalingam, A., & Vasanth, K. (2024). A review on the influence of nutraceuticals and functional foods on health. Food Chemistry Advances, 5, 100749.

Xie, X., Ren, K., Zhou, Z., Dang, C., & Zhang, H. (2022). The global, regional, and national burden of peptic ulcer disease from 1990 to 2019: a population-based study. BMC gastroenterology, 22(1), 58.

Zhang, T., Zhang, B., & Tang, X. (2025). Global Burden of Peptic Ulcer Disease in Adolescents and Young Adults: Trends and Disparities from 1990–2021. Archives of Medical Research, 56(8), 103320.

Zhu, Z., Zou, Y., Ou, L., Chen, M., Pang, Y., Li, H., ... & Feng, Z. (2024). Preliminary investigation of the in vitro anti-Helicobacter pylori activity of Triphala. Frontiers in Pharmacology, 15, 1438193.