WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.084
Volume 12, Issue 21, 910-924. Research Article ISSN 2277–7105

EXPLORING THE POTENTIAL ANTI-DIABETIC PHYTOCONSTITUENTS OF PORTULACA OLERACEA L: AN IN-SILICO STUDY

Yenumala Vamshidhar Reddy*

Department of Pharmacy, Osmania University, Hyderabad.

Article Received on
19 October 2023,

Revised on 09 Nov. 2023,
Accepted on 30 Nov. 2023

DOI: 10.20959/wjpr202321-30209

***Corresponding Author**
Yenumala Vamshidhar Reddy
Department of Pharmacy,
Osmania University,
Hyderabad.

ABSTRACT

'Portulaca oleracea L' is commonly known as purslane, because of to its nutritional and medicinal advantages. It has important anti-diabetic ability and it is a rich source of vitamins, minerals and various health-beneficial Secondary Metabolites like Flavonoids and Terpenoids. The Insilco study may be significant for developing potent anti-diabetic medications from this plant. The goal of the current study was to employ an in-silico method to determine the best bioactive components of *Portulaca oleracea L* as potential therapeutic agents against Diabetes mellitus. Phytoconstituents were obtained and docked to a targeted Protein. Finally, six Phytoconstituents - Isoharmnetin, Kaempferol, Luteolin, Apigenin, Portulene, and Genistein were chosen because they effectively bind to the targeted Protein active binding site. According to the research, *Portulaca oleracea L* screened Phytoconstituents can be exploited as potential therapeutic medication candidates to treat diabetes mellitus.

KEYWORDS: *Portulaca oleracea L,* Phytoconstituents, Molecular Docking, Anti-Diabetic agent, Insilico Study.

1. INTRODCUTION

Portulaca oleracea L. is also known as Common purslane, little hogweed or parsley belongs to Portulacaceae Family. The word "Portulaca" refers to the presence of milky juice in the plant and is derived from two Latin words ('Porto' means "to carry" and "lac" means "milk").[1] It is an annual herbaceous plant with reddish stems and alternate leaves which is often found throughout the world, but it's most common in tropical and subtropical areas.

With green or yellow leaved varieties, it has been widely utilised as a potherb.[2] Since ancient times, purslane has been used as traditional food and folk medicine in various regions of the world.[3] According to various ethnobotanical research, indigenous populations use it as a significant medication to treat a wide range of illnesses, including diabetes, urinary infections, kidney and cardiovascular problems, diarrhoea, headache, and ulcers, to mention a few, as well as to treat snake and insect bites.[4],[5] The Purslane Plant is given in Figure 1.

Figure 1: Purslane Plant (https://www.google.co.in/).

In Central Europe, Asia, and the Mediterranean region, purslane is widely used as a herb. It is a key ingredient in green salads, and its tender stem and leaves are eaten raw, either by alone or in combination with other greens. Additionally, purslane can be cooked with or preserved as a pickle. Its use to treat burns, headaches, disorders of the colon, liver, and stomach, cough, shortness of breath, and arthritis is evidence of its medical usage.[6] Its use in herbal medicine as a purgative, heart tonic, emollient, muscle relaxant, anti-inflammatory, and diuretic therapy makes it significant. Purslane has also been used to treat psoriasis and osteoporosis.[7],[8],[9]

Its reported use as an medicinal plant across practically all continents indicates its enormous significance in the healthcare of indigenous peoples. Several hundred metabolites from different parts of the purslane have been identified because of recent advances in the quantitative methods for phytochemical research.[10],[11] Even though its anti-diabetic properties are yet to be proven scientifically, people still make use of it for this purpose. In an investigation, purslane's crude polysaccharides were extracted in order to examine their potential for lowering blood sugar levels in diabetic individuals through experiments using animals.[12]

Portulaca oleracea L. contains Carbohydrates, Proteins, Fats, Alkaloids, Flavonoids, Terpenoids, Phenolic acids, Anthocyanins, Lignans, Fatty Acids, Vitamin-A,C, Vitamin-B

complex Electrolytes and Minerals.[5],[13],[14],[15],[16],[17],[18],[19],[20],[21] Diverse Phytoconstituents belonging to different classes are given in Table 1.

Table 1: Different Phytoconstituents and Medicinal Uses of *Portulaca oleracea L.*

Sl.No	Phytoconstituents		Medicinal Uses
1	Alkaloids	Oleracein-A,B,C,D,E,K,L	Diarrhoea, Throat infections, Asthma, Anti-Hypoglycemic agent, urinary infections, kidney diseases, cardiovascular diseases, Headache, Ulcers, Anti-Oxidant, Anti-Inflammatory.
		Scopolectin	
		Aurantiamide	
		Aurantiamide acetate	
		N-cis-Feruloyloctopamine	
		N-trans-Feruloyloctopamine	
		N-cis-Feruloyltyramine	
		N-trans-Feruloyltyramine	
		Indole-3-aldehyde	
2	Lignans	(+)- Syringaresinol	
		(+)- Lirioresinol-A	
3	Fatty acids	Linoleic acid	
		α-Linolenic acid	
		Omega-3-fatty acid	
4	Phenolic acids	Caffeic acid	
		Gentisic acid	
		Ferulic acid	
		p-coumaric acid	
		Gallic acid	
		Vanillic acid	
		Benzoic acid	
5	Terpenoids	Lupeol	
		Friedelane	
		Portuloside-A	
		Taraxerol	
		Portulene	
6	Anthocyanins	Delphinidin-3-glucoside	
		Pelargonidin-3-glucoside	
		Cyanidin-3-glucoside	
		Lupeol	
7	Flavonoids	Isoharmnetin	
		Genistin	
		Naringenin	
		Kaemferol	
		Genistein	
		Myricetin	
		Luteolin	
		Quercetin	
		Apigenin	
8	Electrolytes	Sodium	
		Potassium	
9	Vitamins	Vitamin-A	

		Vitamin-B complex	
		Vitamin-C	
10	Minerals	Calcium	
		Magnesium	
		Zinc	
		Iron	
		Manganese	
		Selenium	
		Phosphorus	
		Copper	

The symptoms of type 2 diabetes, formerly known as adult-onset diabetes, include elevated blood sugar, insulin resistance, and a relative lack of insulin. Increased thirst, frequent urination, and unexplained weight loss are typical symptoms. The prevalence of type-2 diabetes is rising globally. An comprehensive study of Portulaca oleracea L. various metabolites as an anti-diabetic drug. As a result, we screened several of this plant's main phytochemicals and docked them with the diabetes mellitus protein.

2. MATERIALS AND METHODS

2.1 DISEASE SELECTION

Diabetes Mellitus (DM) was chosen as the target condition for investigating *Portulaca oleracea L* anti-diabetic properties. The worldwide rate of Diabetes mellitus, a chronic metabolic condition, is increasing quickly. For this medical issue, there is presently no adequate or effective treatment available.[22] The inability to produce insulin is one of the many extra medical issues that diabetic patients frequently deal with. Type 2 diabetes mellitus, commonly known as non-insulin dependent diabetes, is a medical disorder in which the beta cells of the pancreas, which generate insulin, get exhausted or malfunction.

2.2 SELECTION OF PLANT

Due to its extensive nutritional profile and bioactive components, *Portulaca oleracea L* also known as purslane, has a variety of health-beneficial characteristics. Purslane makes a substantial contribution to general wellbeing since it is rich in important nutrients including the vitamins C, A, and different B vitamins, as well as minerals like calcium, magnesium, and potassium. It is notable for being one of the few plant sources of alpha-linolenic acid, an essential omega-3-fatty acid with beneficial effects on the heart and inflammation. By protecting cells from oxidative stress and the hazards that come with it, antioxidants like beta-carotene, vitamin C, and flavonoids further increase their ability to promote health.[23] Additionally, its anti-inflammatory properties have attracted scientific interest, and early

research points to potential advantages in reducing chronic inflammation. The heart-healthy omega-3-fatty acids in purslane may help with cholesterol control, blood pressure control, and general cardiovascular support. Additionally, new research suggests that it may help regulate blood sugar levels by enhancing insulin sensitivity, however more thorough research is necessary. Dietary fibre from this rich plant supports digestion and regular bowel movement while also perhaps fostering good gut flora, contributing to overall gastrointestinal health. The historical usage of purslane for skin disorders in several cultures indicates that it may have wound-healing and anti-inflammatory properties.

2.3 PROTEIN PREPARATION

The insulin receptor is metabolically essential in lowering glucose homeostasis, and disturbance of glucose homeostasis can result in major diseases including diabetes. The insulin receptor's protein structure was obtained by using the RCSB PDB(https://www.rcsb.org/). The protein was gathered and obtained from essential crystal structure of the insulin receptor kinase (PDB ID: 5HHW) with resolution: 1.79Å. Crystal structure of insulin receptor kinase in complex with cis-(R)-7-(3-(azetidin-1-ylmethyl) cyclobutyl)-5-(3-((tetrahydro-2H-pyran-2-yl)methoxy)phenyl)-7H-pyrrolo[2,3-*d*]pyrimidin-4-amine was obtained**.**

The protein preparation workflow was employed to add missing hydrogen, fill in loop gaps, adjust side chain protonation states, and remove water molecules from the crystal structures. The heavy atoms were assigned hydrogens, charges and bond orders were assigned, selenomethionines were converted to methionines and all waters were eliminated. Prior to additional processing for grid creation, the specified protein was digested. After that, the receptor grid was created around the co-crystallized enzyme ligand to show the binding site.[24]

2.4 LIGAND PREPARATION

Compounds were retrieved from PubChem databases (https://pubchem.ncbi.nlm.nih.gov/) i.e. Oleracein-A,B,C,D,E,K,L, Scopoletin, Aurantiamide, Aurantiamide acetate, N-cis-Feruloyloctopamine, N-trans-Feruloyloctopamine, N-cis-Feruloyltyramine, N-trans-Feruloyltyramine, Indole-3-aldehyde, Kaempferol, Apigenin, Luteolin, Myricetin, Quercetin, Genistein, Genistin, 2,2′-Dihydroxy-4′,6′-dimethoxychalcone, Isorhamnetin, Naringenin, Portuloside-A, Portulene, Friedelane, Taraxerol, Lupeol, Caffeic acid, p-coumaric acid, Ferulic acid, Gallic acid, Gentisic acid, Anisic acid, Vanillic acid, Delphinidin-3-glucoside,

Cyanidin-3-glucoside, Pelargonidin-3-glucoside, (+)-Syringaresinol, (+)-Lirioresinol-A, α-linolenic acid and Linoleic acid.[25],[26] Then the Ligands were prepared by Schrödinger-Maestro v13.5. All ligands 3D structures were generated using the Schrödinger Maestro application. Using the LigPrep and Epik modules from the Schrodinger's suite, the ligands were generated under physiological pH conditions (7.0 ± 2.0). The ligands were converted to their three-dimensional (3D) structures, and the OPLS4 force field was used for ionisation to generate tautomeric states.[27],[28]

2.5 TOXICITY IDENTIFICATION

ProTox-II was used to calculate the toxic characteristics of the phytochemicals isolated from *Portulaca oleracea L.*(https://tox-new.charite.de/protox_II/). From all the Phytoconstituents, only twelve constituents i.e., Scopoletin, Kaempferol, Apigenin, Luteolin, Genistein, Isorhamnetin, Portuloside –A, Portulene, Caffeic acid, p-Coumaric acid, Gentisic acid, Anisic acid were chosen for further analysis was based on the toxicity class and Phytoconstituents having Toxicity Class-V, VI were selected. [Class V: may be harmful if swallowed (2000mg/kg < LD50 ≤ 5000mg/kg), Class VI: non-toxic (LD50 > 5000mg/kg)].[29]

2.6 LIGAND DOCKING

The target protein was docked with the top six phytochemicals which fulfilled the Lipinski rule of five. In Glide of Schrödinger-Maestro v 13.5, XP (Extra Precision) flexible ligand docking was performed and non-cis/trans amide bonds were penalized.[30] For ligand atoms, 0.15 and 0.80 were chosen as the partial charge cutoff and vanderWaals scaling factor respectively.[31] For each of the predefined functional groups, bias sampling of torsions is performed and docking score is increased by adding Epik state penalties.[32] Energy-minimized poses were used for final scoring, which was shown as a docking score. For each ligand, the best-docked position with the lowest Docking score value was determined.

3. RESULTS

MOLECULAR DOCKING ANALYSIS

The Protein Insulin receptor kinase (5HHW) has total structural weight of 35.45 kDa with Atom Count of 2800, Residue Count of 307 and has only one unique protein chain. The 5HHW protein depicted two mutations. The Crystal structure of Insulin receptor kinase in complexed with cis-(R)-7-(3-(azetidin-1-ylmethyl)cyclobutyl)-5-(3-((tetrahydro-2H-pyran-2-yl)methoxy) phenyl)-7H-pyrrolo[2,3-*d*]pyrimidin-4-amine was shown in Figure 2.

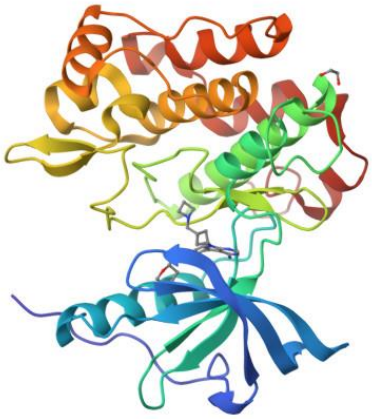
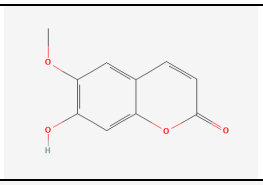
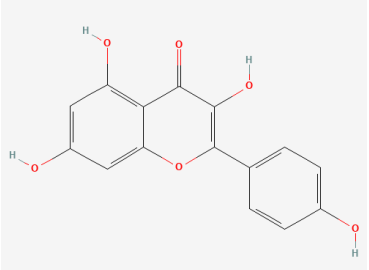
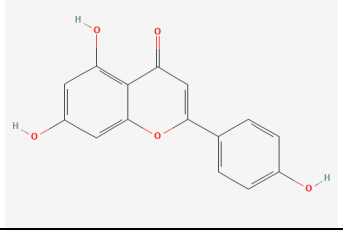
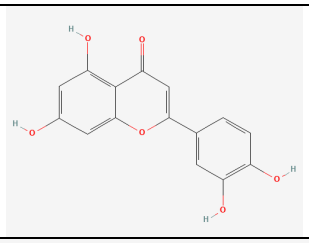
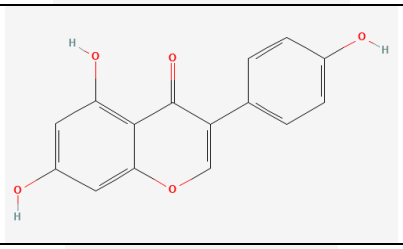
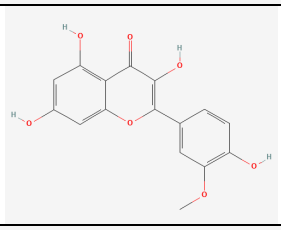
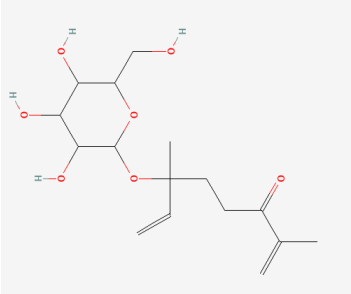
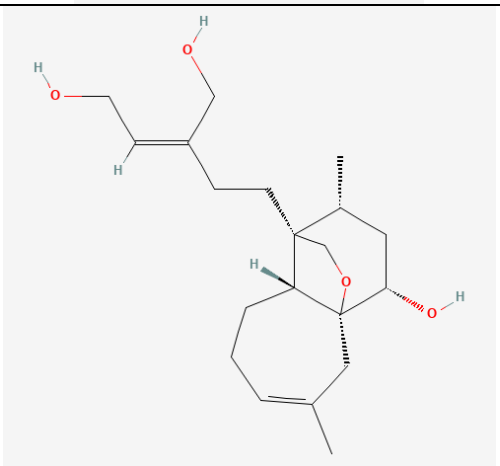
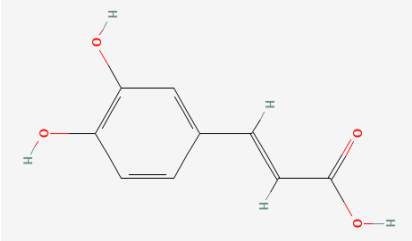


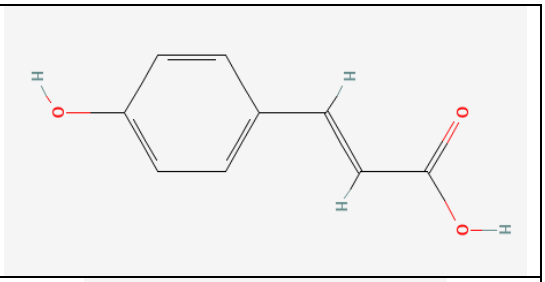
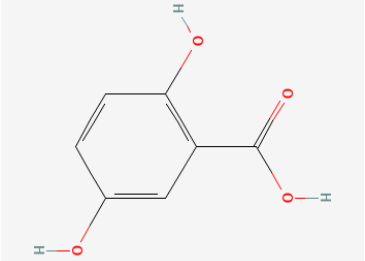
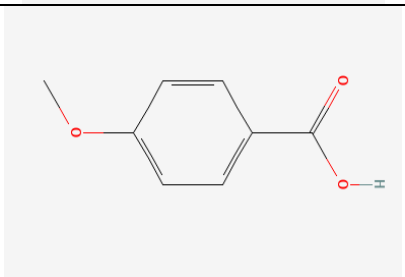
Figure 2: Crystal structure of Insulin receptor kinase(5HHW).

Structures of Phytoconstituents i.e. Scopoletin, Kaempferol, Apigenin, Luteolin, Genistein, Isorhamnetin, Portuloside-A, Portulene, Caffeic acid, p-Coumaric acid, Gentisic acid and Anisic acid present in *Portulaca oleracea L* were extracted and analyzed using PubChem. The 2D structures of Phytoconstituents of Portulaca oleracea L. are given in Table 2.

Table 2: The 2D structures of Phytoconstituents of *Portulaca oleracea L.*

SL.No	Phytoconstituents	Molecular Formula	Structure
1.	Scopoletin (Alkaloid)	$C_{10}H_8O_4$	
2.	Kaempferol (Flavonoid)	$C_{15}H_{10}O_6$	
3.	Apigenin (Flavonoid)	$C_{15}H_{10}O_5$	

4.	Luteolin (Flavonoid)	$C_{15}H_{10}O_6$	
5.	Genistein (Flavonoid)	$C_{15}H_{10}O_5$ $C_{15}H_{10}O_6$	
6.	Isorhamnetin (Flavonoid)	$C_{16}H_{12}O_7$	
7.	Portuloside –A **(**Terpenoids)	$C_{16}H_{26}O_7$	
8.	Portulene **(**Terpenoids)	$C_{20}H_{32}O_4$	
9.	Caffeic acid (Phenolic acid)	$C_9H_8O_4$	

10.	p-Coumaric acid (Phenolicacid)	$C_9H_8O_3$	
11.	Gentisic acid (Phenolic acid)	$C_7H_6O_4$	
12.	Anisic acid (Phenolic acid)	$C_8H_8O_3$	

The Top Phytoconstituents with good Docking score, when Phytoconstituents interact with Insulin Kinase Receptor (PBD ID: 5HHW) are given in Table 3.

Table 3: Docking results of Isoharmnrtin, Kaempferol, Luteolin, Apigenin, Portulene and Genistein with Insulin receptor kinase (PDB: 5HHW).

SL.No	Phytocnstituents	PubChem ID	Docking score (Kcal/mol)
1	Isoharmnetin	5281654	-8.376
2	Kaempferol	5280863	-8.145
3	Luteolin	5280445	-8.033
4	Apigenin	5280443	-8.022
5	Portulene	46902093	-7.274
6	Genistein	5280961	-7.236

The Phytoconstituents which follow Lipinski rule of five: Hydrogen bond donors (HBD) not greater than 5, Hydrogen bond acceptors (HBA) not greater than 10, Molecular weight (MW) not greater than 500 Daltons, Octanol-water partition coefficient (log P) not greater than 5 and Toxicity Classes(TC) are given in Table 4.

Table 4: Phytochemicals of following Lipinski rule of 5 and toxicity class.

Phytoconstituents	MW	HBA	HBD	TC	LogP
Scopoletin	192.17	4	1	5	1.51
Kaempferol	286.24	6	4	5	2.28
Apigenin	270.24	5	3	5	2.58
Luteolin	286.24	6	4	5	2.28
Genistein	270.24	5	3	5	2.58
Isorhamnetin	316.26	7	4	5	2.29
Portuloside –A	330.37	7	4	6	2.28
Portulene	336.47	4	3	5	2.58
Caffeic acid	180.16	4	3	5	1.20
p-Coumaric acid	164.16	3	2	5	1.49
Gentisic acid	154.12	4	3	5	0.80
Anisic acid	152.15	3	1	5	1.39

By using computational analysis and glide docking, the binding of insulin receptor kinase was studied in the present study. The flexible Ligand docking with extra precision (XP) had been carried out. The top docked Phytoconstituents were Isoharmnetin, Kaempferol, Luteolin, Apigenin, Portulene and Genistein with docking scores of -8.376 Kcal mol^{-1} (XP mode), −8.145 (XP mode), −8.033 (XP mode), −8.022 (XP mode), −7.274 (XP mode), −7.236 (XP mode) respectively. The results of docking analysis were described in Table 2 and the docking figure showed in Figure 3,4,5,6,7 & 8. Among all the compounds, Isoharmnetin showed good docking score against insulin receptor kinase.

Results of Docking of 6 Phytoconstituents of Portulaca oleracea L with the binding region of targeted Protein (5HHW) indicate that, Isoharmnetin(Flavonoid) was interacting with GLU:1104, MET:1106, LYS:1057, SER:1033, ASP:1177, ARG:1163 (Figure.3), while Kaempferol (Flavonoid) was found to be interacting with GLU:1104, MET:1106, LYS:1057, SER:1033, ASP:1177, ARG:1163 (Figure.4). Likewise, Luteolin(Flavonoid) was interacting with GLU:1104, LYS1057, SER:1033, ASP:1177 (Figure.5), Apigenin (Flavonoid) was interacting with GLU:1104, LYS:1057, SER:1033, ASP:1177, ARG:1163, MET:1106 (Figure.6), Portulene (Terpenoid) was interacting with ASP:1177, SER:1033, LYS:1057 (Figure.7), Genistein (Flavonoid) was interacting with LYS:1057(Figure.8).

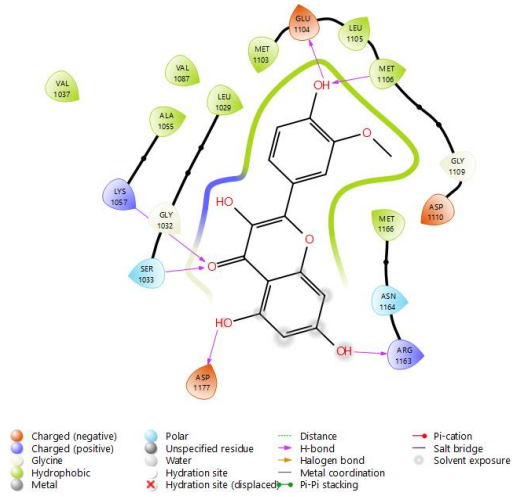


Figure 3: 2-D docking conformation of Isoharmnetin with 5HHW.

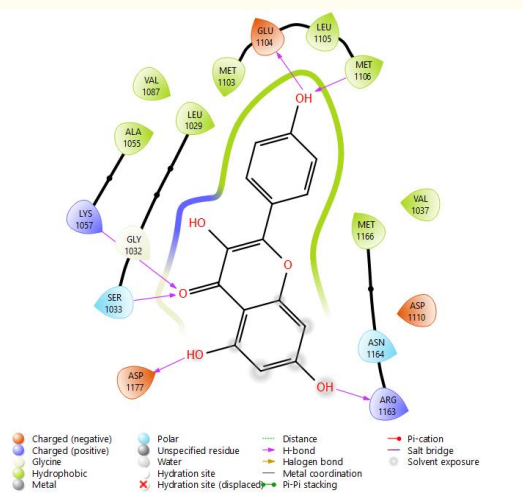


Figure 4: 2-D docking conformation of Kaempferol with 5HHW.

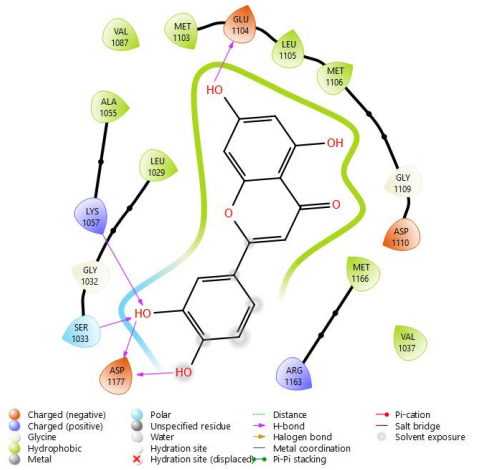


Figure 5: 2-D docking conformation of Luteolin with 5HHW.

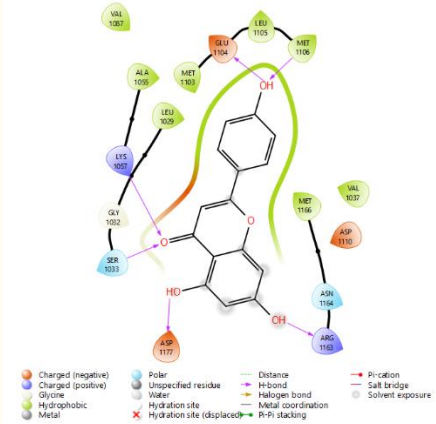


Figure 6: 2-D docking conformation of Apigenin with 5HHW.

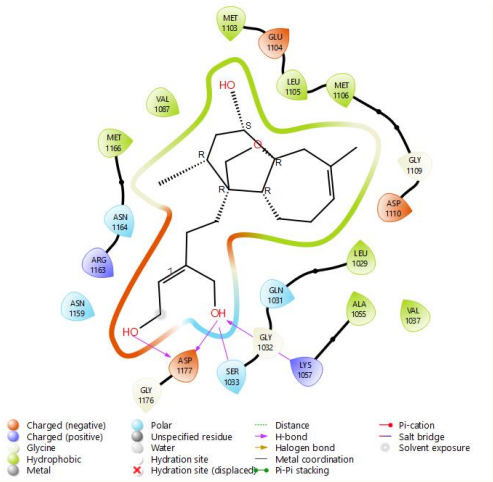


Figure 7: 2-D docking conformation of Portulene with 5HHW.

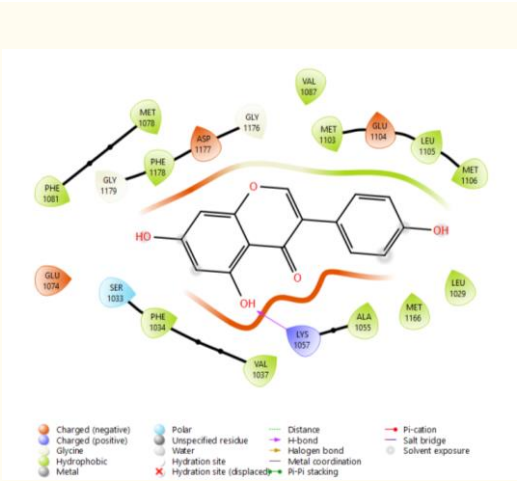


Figure 8: 2-D docking conformation of Genistein with 5HHW.

4. DISCUSSION

Different diseases have been treated with various kinds of medicinal plants. A transmembrane receptor, the insulin receptor kinase gets activated by insulin. Metabolically, the regulation of glucose homeostasis is greatly influenced by the insulin receptor. Genistein from *Portulaca oleracea L* had the lowest docking score against Insulin receptor kinase (5HHW), which is -7.236 Kcal/mol, as determined by Schrödinger-Maestro v 13.5 docking studies. Isoharmnetin from *Portulaca oleracea L* was shown to have a significant docking score of -8.376 Kcal/mol, which suggests that it may be an effective anti-diabetic medication. The more potent the compound, the lower the docking value.

Plant-based substances can improve lipid metabolism, antioxidant activity, capillary function, and blood pressure while also decreasing cholesterol levels and enhancing overall wellness of diabetes individuals. These screened phytochemicals were extremely selective and shown potent interactions with the Protein of diabetes according to in silico molecular docking. The phytochemical analysis of *Portulaca oleracea L* revealed the presence of Flavonoids which can increase the uptake of glucose in peripheral tissues and control the activity of the enzymes responsible for carbohydrate metabolism. By regulating multiple pathways, flavonoids can help to increase insulin secretion and decrease diabetic complications. The aim of the current investigation was to evaluate the anti-diabetic properties of phytochemicals from *Portulaca oleracea L.*

5. CONCLUSION

Isoharmnetin showed the best docking score for insulin receptor kinase out of all the compounds. Due to its higher molecular docking value, Isoharmnetin is the ideal molecule for treating diabetes. Insulin receptor kinase activity of isolated compounds from *Portulaca oleracea L* has to be determined by further in vitro and in vivo research. These findings could serve as the basis for the synthetic modification of bioactive phytochemicals, the structural designs and further research into Phytoconstituents. The simulated complexes demonstrated stability and ligands remained within the modified proteins active binding site. According to the results of this study, these examined phytochemicals have the potential to be exploited as therapeutic medication candidate for preventing against diabetes.

REFERENCES

1. Chugh, V., Mishra, V., Dwivedi, S. V., & Sharma, K. D. (2019). Purslane (Portulaca oleracea L.): An underutilized wonder plant with potential pharmacological value. *The pharma innovation journal*, *8*(6): 236-246.
2. Ocampo, G., & Columbus, J. T. (2012). Molecular phylogenetics, historical biogeography, and chromosome number evolution of Portulaca (Portulacaceae). *Molecular phylogenetics and evolution*, *63*(1): 97-112.
3. Xiang, L., Guo, D., Rui, J. U., Bin, M. A., Lei, F., & Lijun, D. U. (1994). Cyclic dipeptides from Portulaca oleracea. *Chinese Traditional and Herbal Drugs*, (11).
4. Belcheff, E. (2012). *A medical intuitive reveals the wonders of Purslane*. Polished Publishing Group.
5. Nemzer, B., Al-Taher, F., & Abshiru, N. (2020). Phytochemical composition and nutritional value of different plant parts in two cultivated and wild purslane (Portulaca oleracea L.) genotypes. *Food chemistry*, *320*: 126621.
6. Simopoulos, A. P., Norman, H. A., & Gillaspy, J. E. (1995). Purslane in human nutrition and its potential for world agriculture. *Plants in human nutrition*, *77*: 47-74.
7. Zhu, H., Wang, Y., Liu, Y., Xia, Y., & Tang, T. (2010). Analysis of flavonoids in Portulaca oleracea L. by UV–vis spectrophotometry with comparative study on different extraction technologies. *Food Analytical Methods*, *3*: 90-97.
8. Chen, C. J., Wang, W. Y., Wang, X. L., Dong, L. W., Yue, Y. T., Xin, H. L., ... & Li, M. (2009). Anti-hypoxic activity of the ethanol extract from Portulaca oleracea in mice. *Journal of ethnopharmacology*, *124*(2): 246-250.

9. Uddin, M. K., Juraimi, A. S., Hossain, M. S., Nahar, M., Un, A., Ali, M. E., & Rahman, M. M. (2014). Purslane weed (Portulaca oleracea): a prospective plant source of nutrition, omega-3 fatty acid, and antioxidant attributes. *The Scientific World Journal*, *2014*.
10. Mohamed, A. I., & Hussein, A. S. (1994). Chemical composition of purslane (Portulaca oleracea). *Plant Foods for Human Nutrition*, *45*: 1-9.
11. Siriamornpun, S., & Suttajit, M. (2010). Microchemical components and antioxidant activity of different morphological parts of Thai wild purslane (Portulaca oleracea). *Weed science*, *58*(3): 182-188.
12. Simopoulos, A. P. (2004). Omega-3 fatty acids and antioxidants in edible wild plants. *Biological research*, *37*(2): 263-277.
13. Xiang, L., Xing, D., Wang, W., Wang, R., Ding, Y., & Du, L. (2005). Alkaloids from Portulaca oleracea L. *Phytochemistry*, *66*(21): 2595-2601.
14. Jiao, Z. Z., Yue, S., Sun, H. X., Jin, T. Y., Wang, H. N., Zhu, R. X., & Xiang, L. (2015). Indoline amide glucosides from Portulaca oleracea: isolation, structure, and DPPH radical scavenging activity. *Journal of natural products*, *78*(11): 2588-2597.
15. Zhou, Y. X., Xin, H. L., Rahman, K., Wang, S. J., Peng, C., & Zhang, H. (2015). Portulaca oleracea L.: a review of phytochemistry and pharmacological effects. *BioMed research international*, *2015*.
16. Elkhayat, E. S., Ibrahim, S. R., & Aziz, M. A. (2008). Portulene, a new diterpene from Portulaca oleracea L. *Journal of Asian natural products research*, *10*(11): 1039-1043.
17. Sicari, V., Loizzo, M. R., Tundis, R., Mincione, A., & Pellicano, T. M. (2018). Portulaca oleracea L.(Purslane) extracts display antioxidant and hypoglycaemic effects. *J. Appl. Bot. Food Qual*, *91*(1): 39-46.
18. Ma, Y., Bao, Y., Zhang, W., Ying, X., & Stien, D. (2020). Four lignans from Portulaca oleracea L. and its antioxidant activities. *Natural product research*, *34*(16): 2276-2282.
19. Palaniswamy, U. R., McAvoy, R. J., & Bible, B. B. (2001). Stage of harvest and polyunsaturated essential fatty acid concentrations in purslane (Portulaca oleraceae) leaves. *Journal of Agricultural and Food Chemistry*, *49*(7): 3490-3493.
20. Uddin, M. K., Juraimi, A. S., Ali, M. E., & Ismail, M. R. (2012). Evaluation of antioxidant properties and mineral composition of purslane (Portulaca oleracea L.) at different growth stages. *International journal of molecular sciences*, *13*(8): 10257-10267.
21. Dkhil, M. A., Moniem, A. E. A., Al-Quraishy, S., & Saleh, R. A. Antioxidant effect of purslane. *Portulaca oleracea*, 1563-89.

22. Melichova, J., Sivco, P., Rusnak, M., Phuong Truc, P., & Majdan, M. (2023). International evidence-based guidelines on hypertension and type 2 diabetes mellitus: A systematic review. *Journal of Public Health Research*, *12*(1): 22799036221146913.
23. Jafari, N., Bahreini, N., Dehghani, A., Lak, Y., Mirmohammadali, S. N., Samavat, S., ... & Asbaghi, O. (2023). The effects of purslane consumption on lipid profile and C-reactive protein: A systematic review and dose–response meta-analysis. *Food Science & Nutrition*.
24. Bhachoo, J., & Beuming, T. (2017). Investigating protein–peptide interactions using the Schrödinger computational suite. *Modeling peptide-protein interactions: methods and protocols*, 235-254.
25. Petropoulos, S., Karkanis, A., Martins, N., & Ferreira, I. C. (2016). Phytochemical composition and bioactive compounds of common purslane (Portulaca oleracea L.) as affected by crop management practices. *Trends in food science & technology*, *55*: 1-10.
26. Binici, H. I., ŞAT, İ. G., & Aoudeh, E. (2021). The effect of different drying methods on nutritional composition and antioxidantactivity of purslane (Portulaca oleracea). *Turkish Journal of Agriculture and Forestry*, *45*(5): 680-689.
27. Harder, E., Damm, W., Maple, J., Wu, C., Reboul, M., Xiang, J. Y., ... & Friesner, R. A. (2016). OPLS3: a force field providing broad coverage of drug-like small molecules and proteins. *Journal of chemical theory and computation*, *12*(1): 281-296.
28. Sastry, G. M., Adzhigirey, M., Day, T., & Annabhimoju, R. ligand preparation: Parameters, protocols, and influence on virtual screening enrichments., 2013, 27. *DOI: https://doi. org/10.1007/s10822-013-9644-8.PMID:https://www.ncbi.nlm.nih. gov/pubmed/23579614*, 221-234.
29. Banerjee, P., Eckert, A. O., Schrey, A. K., & Preissner, R. (2018). ProTox-II: a webserver for the prediction of toxicity of chemicals. *Nucleic acids research*, *46*(W1), W257-W263.
30. Friesner, R. A., Murphy, R. B., Repasky, M. P., Frye, L. L., Greenwood, J. R., Halgren, T. A., ... & Mainz, D. T. (2006). Extra precision glide: Docking and scoring incorporating a model of hydrophobic enclosure for protein− ligand complexes. *Journal of medicinal chemistry*, *49*(21): 6177-6196.
31. Bell, J. A., Cao, Y., Gunn, J. R., Day, T., Gallicchio, E., Zhou, Z., ... & Farid, R. (2012). PrimeX and the Schrödinger computational chemistry suite of programs.
32. Elokely, K. M., & Doerksen, R. J. (2013). Docking challenge: protein sampling and molecular docking performance. *Journal of chemical information and modeling*, *53*(8): 1934-1945.