Original Article

In-vitro α-amylase and α-glucosidase inhibitory activity of coccinia grandis fruits and hyptis suaveolens seeds extracts

Jagannath Narumalla[1]*, Dr.D.Sheela[2], Dr.Rohit Dixit [3]

[1]PhD scholar, Department of Pharmacology, Saveetha University, Chennai, Tamilnadu,
[2]Associate professor, Department of Pharmacology. Saveetha Medical College, Chennai, Tamilnadu, India
[3]Professor, Department of pharmacology, S.V.S medical college, mahabubnagar, Telangana.

Corresponding author
Jagannath Narumalla*
Department of Pharmacology,
Saveetha University, Chennai, Tamilnadu
Email: Jagan.jae@gmail.com
DOI: 10.47750/pnr.2023.14.03.408

Abstract

Introduction

Diabetes mellitus is a chronic metabolic illness that has a significant health and economic impact on society. Current diabetes treatments are expensive and reported to have side effects on long-term use. The use of ethnomedicinal plants has showed promise in the creation of less expensive, cost-effective anti-diabetic medicines with fewer adverse effects. The plants Coccinia grandis and Hyptis suaveolens have been used in Ayurvedic medicine to treat microbial infections, gastrointestinal issues, inflammation, diabetes, helminthiasis, and hyperuricemic conditions.

Methods: Hydro alcoholic extracts of Coccinia grandis fruits and Seeds of Hyptis suaveolens were prepared and their inhibitory actions of these extracts on α-amylase and α-glucosidase inhibitory activities was determined in vitro.

Results: The results indicated concentration-dependent inhibitory action with both the extracts on the enzyme alpha amylase and alpha glucosidase However, coccinia grandis fruit extract exhibited more α-amylase and α -glucosidase enzyme inhibition when compared with hyptis suaveolens seed extract.

Conclusion: The results show that hydroalcoholic extracts of Coccinia grandis fruits and seeds of Hyptis suaveolens significant α-amylase and α -glucosidase inhibitory actions in vitro, according to the current research.

Keywords: α-amylase, α-glucosidase, coccinia grandis fruits, hyptis suaveolens seeds

INTRODUCTION

Diabetes mellitus is a metabolic condition characterized by chronic hyperglycemia and abnormalities in carbohydrate, lipid, and protein metabolism caused by abnormalities in insulin production (type 1 DM), insulin action (type 2 DM), or both. [1]

Type 2 diabetes mellitus is a prevalent metabolic problem, and maintaining normal blood glucose levels after meals is one of the therapeutic approaches for this disease. Postprandial hyperglycemia is a major contributor to the development of type 2 diabetes and its associated consequences [2].

Hence, lowering postprandial hyperglycemia to limit glucose absorption with carbohydrate digesting enzyme inhibitors is essential [3]. Postprandial hyperglycemia is primarily caused by two carbohydrate hydrolyzing enzymes (α-amylase and α -glucosidase)[4].α-amylase initiates carbohydrate digestion by hydrolyzing 1, 4-

glycosidic bonds of polysaccharides (starch, glycogen) to disaccharides, and α-glucosidase catalyses disaccharides to monosaccharides, resulting in postprandial hyperglycemia[5].

One of the treatment strategies for reducing postprandial hyperglycemia is the capacity of a medication or diet to delay the synthesis or absorption of glucose by inhibiting carbohydrate hydrolyzing enzymes like α -amylase and α – glucosidase[6]. Although acarbose—a dual inhibitor of " α -amylase and " α -glucosidase" is already accessible for the treatment of DM, its clinical use is still limited in some developing countries due to its comparatively high cost when compared to other regularly used anti-diabetic drugs like glibenclamide and metformin. Natural inhibitors of carbohydrate-degrading enzymes (α-amylase and α-glycosidase), particularly those derived from plants, offer an appealing treatment option for postprandial hyperglycemia. In vitro studies can be used as preliminary screening methods to evaluate a drug's α -amylase and α -glycosidase inhibitor activity, allowing researchers to investigate a wide range of potential therapeutic options [7].

According to ethnobotanical statistics, there are over 1200 plants worldwide that may have anti-diabetic properties [8-11]. The edible plant Coccinia grandis belongs to the family Curcubitaceae, which has been used in Ayurvedic medicine to treat microbial infections, gastrointestinal issues, inflammation, and diabetes. The leaves and stems of Coccinia grandis are pressed to extract a juice that is then used as an alternative medicine to treat diabetes [12, 13]. Streptozotocin- and alloxan-induced diabetic rats showed significant reductions in fasting plasma glucose levels when treated with methanolic and ethanolic leaf extracts of the plant, respectively [14–16]. Methanolic extracts of the plant's leaves, were found to be inhibitors of " **α** -amylase and " **α** -glucosidase enzymes in vitro [13]. Fruits have traditionally been used to cure leprosy, fever, asthma, bronchitis, and jaundice. The fruit has anti-anaphylactic, antihistaminic, and mast cell-stabilizing properties [17].

Hyptis suaveolens belongs to the family Lamiaceae is an annual, perennial herb that grows in subtropical, tropical and disturbed habitat. Traditionally, In vivo gastroprotective efficacy of an ethanol extract of H. suaveolens aerial component has been demonstrated [18]. Previous chemical studies on H. suaveolens seed concentrated primarily on protein [19], oligo- and polysaccharides [20 and 21] and antihyperuricemic nutraceutical [22].

The purpose of this study was to see if hydroalcohol extracts of Hyptis suaveolens seeds and Coccinia grandis fruits influenced the in vitro activities of the enzymes "**α**- amylase" and "**α**- glucosidase."

MATERIAL AND METHOD

Plant material and extraction

The Hyptis suaveolens and the Coccinia grandis plants were collected from the local market. Identified and authenticated by a botanist, S.V University, Tirupati with voucher numbers 0709 and 0579 for Hyptis suaveolens and the Coccinia grandis respectively.

Freshly collected Hyptis suaveolens (L.) Poit seeds and Coccinia grandis fruits were shade-dried and coarsely powdered. The powder was passed through sieve no. 40, and the sieved powder was stored in an airtight container for further use. Initially, 100 g of each dried plant material powder was macerated with hydro alcohol 70% ethanol for 7 days. It was then filtered, and the solvent was evaporated and stored in desiccators until further use.

In-vitro α-amylase inhibitory activity

The inhibiting activity of alpha-amylase was performed according to the method by González-Montoya et al. 2018[23] and Ramana Murty Kadali SLDV et al. 2017[24] with some modifications. The reaction mixture contained 1mL of acarbose (positive control) or test samples (the plants extracts and its solvent partitions) at concentrations of 62.5,125,250,500 and 1000ug/ml and 1 ml of 0.02M sodium phosphate buffer (pH6.9) containing α-amylase solution (0.5mg/ml) was pre -incubated at 25°C for 30 min. Then 1mL of 1% starch solution in 0.02M sodium phosphate buffer (pH -6.9) were added to the reaction and the reaction was allowed to be carried out at 25°C for 10 min to react with the alpha-amylase solution. Then finally the reaction was terminated by adding 1 mL of the DNS solution (12.0 g of sodium potassium tartrate tetrahydrate in 8 ml of 2M NaOH and 96 mM of 3, 5-dinitrosalicylic acid solution) and the tube were covered and heated in boiling water for 5 min. Then the reaction mixture was diluted by adding 10 ml of distilled water after cooling the tubes at room temperature. The α-amylase activity was determined my measuring the intensity of color at 540 nm.

Absorbance of the positive control which contain only the enzyme but doesn't contain any test sample was performed in similar way (100% enzyme activity). Besides, a blank which contain only the test samples in their respective concentration in the absence of the enzyme was prepared and assay was performed to observe any possible intrinsic absorbance produced by the test samples. The samples and the standard drug (acarbose) were compared with the control (100% enzyme activity) by using the equation given below to obtain the percentage inhibition (I %) :

% Inhibition = [(Absorbance $_{control}$ – Absorbance $_{test\ sample}$) / Absorbance $_{control}$] × 100

Table 1: α-Amylase test samples with concentrations

Sl. No.	Test samples	Concentrations
1	Acarbose	5(62.5,125,250,500,1000ug/ml)
2	Hydro alcoholic extract of Coccina grandis fruits	5(62.5,125,250,500,1000ug/ml)
3	Hydro alcoholic extract Hyptis suaveolens seeds	5(62.5,125,250,500,1000ug/ml)

In-vitro α-glucosidase inhibitory activity

The alpha-glucosidase inhibiting activity was performed according to a method described by Pandithurai et al. 2015[25]. 1mL of 2% w/v of sucrose solution was added as the substrate in 0.2 M of Tris buffer (pH 8.0). 1mL of acarbose (positive control) or test samples (the plants extracts and its solvent partitions) at concentrations of 62.5,125,250,500 and 1000ug/ml was added to the reaction mixture and incubated for 5 minute at room temperature. The reaction was started after the incubation period by adding 1 ml of alpha-glucosidase enzyme (1 U/ml) to it and then incubating it for 40 min at 35°C. The reaction was terminated by the addition of 2 mL of 6N HCl. The α- glucosidase activity was determined my measuring the intensity of color at 540 nm. Acarbose was used a positive control (standard). The following formula was used to obtain the percentage inhibition (I%):

% Inhibition = [(Absorbance $_{control}$ – Absorbance $_{test\ sample}$) / Absorbance $_{control}$] × 100

Table 2: α-glucosidase research samples with concentrations

Sl. No.	Test samples	Concentrations
1	Acarbose	5(62.5,125,250,500,1000ug/ml)
2	Hydro alcoholic extract of Coccina grandis fruits	5(62.5,125,250,500,1000ug/ml)
3	Hydro alcoholic extract Hyptis suaveolens seeds	5(62.5,125,250,500,1000ug/ml)

RESULTS

Alpha-amylase enzyme inhibiting activity

In the present study, test Compounds namely Hydro alcoholic extracts of Coccina grandis fruits (HACG), Hyptis suaveolens seeds (HAHS) at Concentrations 62.5,125,250,500 and 1000ug/ml exhibited α-amylase inhibitory activity 11.54%, 22.78%, 33.56%, 55.95% and 96.58% respectively whereas hydro alcoholic extract of Hyptis suaveolens seeds at same concentrations showed α-amylase inhibitory activity 1.91%, 8.77%, 17.63%, 27.50% and 55.97% respectively. Acarbose showed 30.34%, 38.55%, 47.95%, 65.93% and 99.06% α-amylase of inhibitory activity at the mentioned Concentrations respectively showed in figure 1.The standard reference drug Acarbose which showed α-amylase inhibitory activity with an IC50 value of 298 ug/ml. Among the test samples, Coccina grandis fruits has shown the prominent α-amylase enzyme inhibitory activity with IC50 455 ug/ml when compared to Hyptis suaveolens seeds with 889 ug/ml showed in figure 2

.

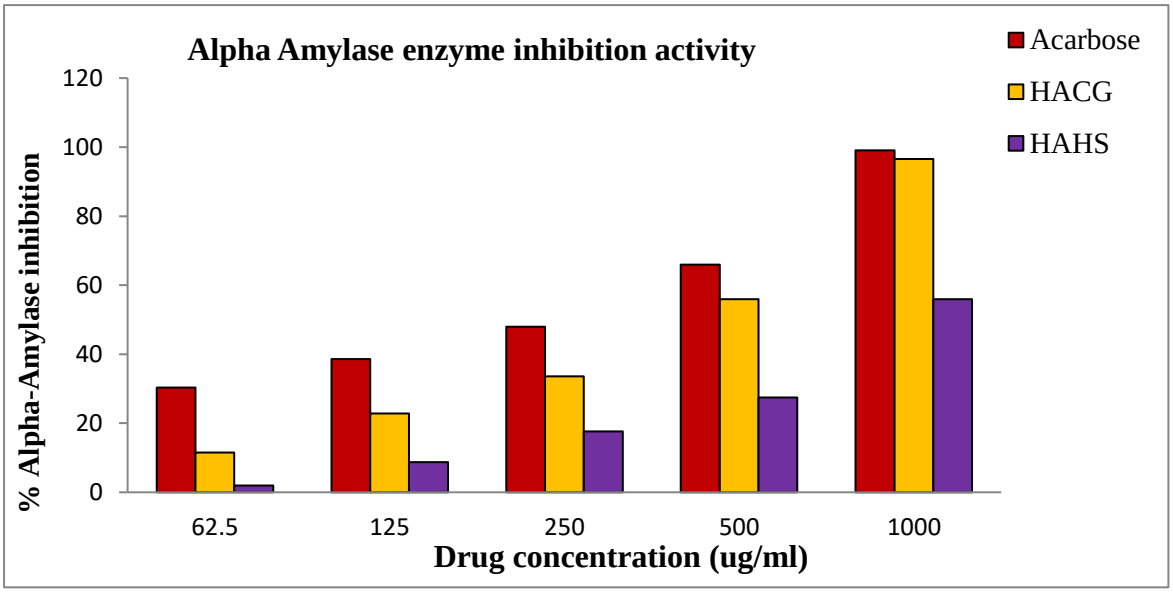

Figure 1: α-amylase inhibition by Hydro alcoholic extracts of Coccina grandis fruits (HACG), Hyptis suaveolens seeds (HAHS)) and acarbose.

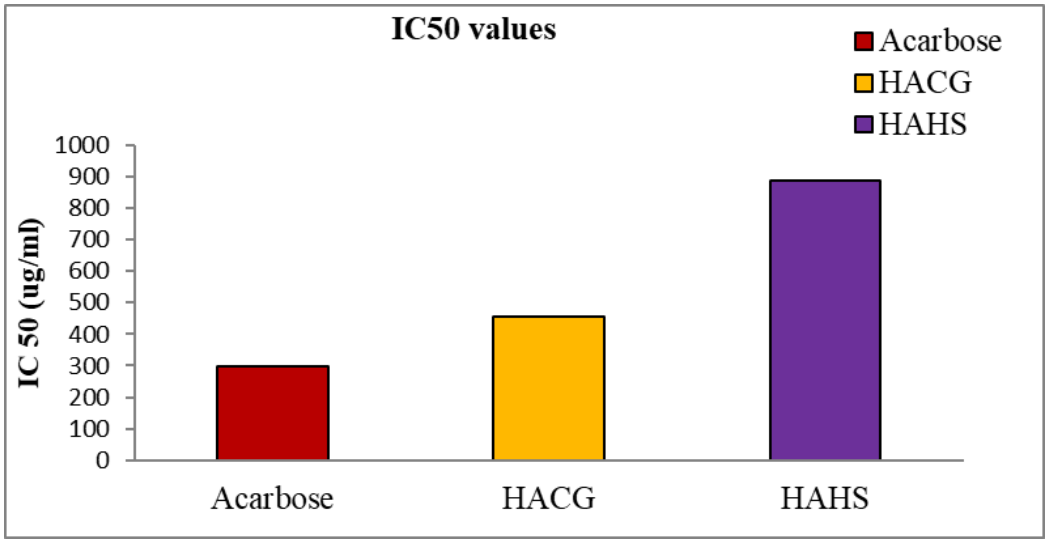

Figure 2: IC50 values of Hydro alcoholic extracts of Coccina grandis fruits (HACG), Hyptis suaveolens seeds (HAHS) on α-amylase in comparison with Acarbose

Alpha-glucosidase enzyme inhibiting activity

In the present study, test Compounds namely Hydro alcoholic extracts of Coccina grandis fruits (HACG), Hyptis suaveolens seeds (HAHS) at Concentrations 62.5,125,250,500 and 1000ug/ml exhibited α-amylase inhibitory activity 0.89%, 6.59%, 18.82%, 41.32% and 86.54% respectively whereas hydro alcoholic extract of Hyptis suaveolens seeds at same concentrations showed α-amylase inhibitory activity 1.19%, 4.48%, 11.36%, 26.54% and 58.09% respectively. Acarbose showed 30.37%, 38.65%, 47.91%, 62.45% and 95.27% α-amylase of inhibitory activity at the mentioned Concentrations respectively shown in figure 3.

The Acarbose which showed Alpha-glucosidase inhibitory activity with an IC50 value of 313.62 ug/ml. Among the test samples, Coccina grandis fruits has exhibited the prominent Alpha-glucosidase enzyme inhibitory activity with IC50 498 ug/ml and 765 in comparison of Hyptis suaveolens seeds with 889 ug/ml shown in figure 4.

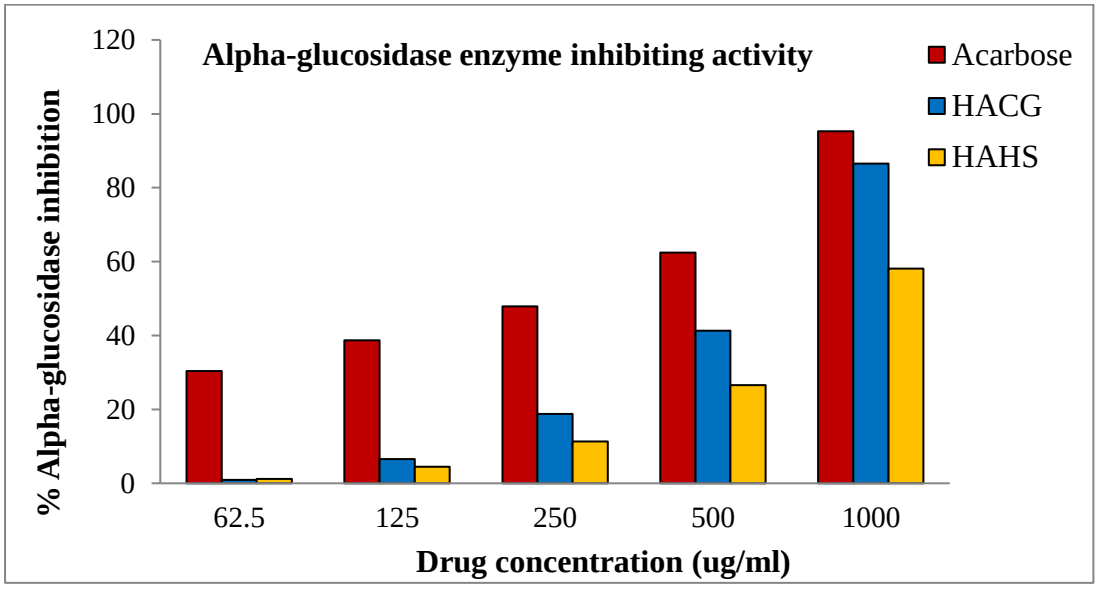

Figure 3. α-glucosidase inhibition by Hydro alcoholic extracts of Coccina grandis fruits (HACG), Hyptis suaveolens seeds (HAHS)) and Acarbose.

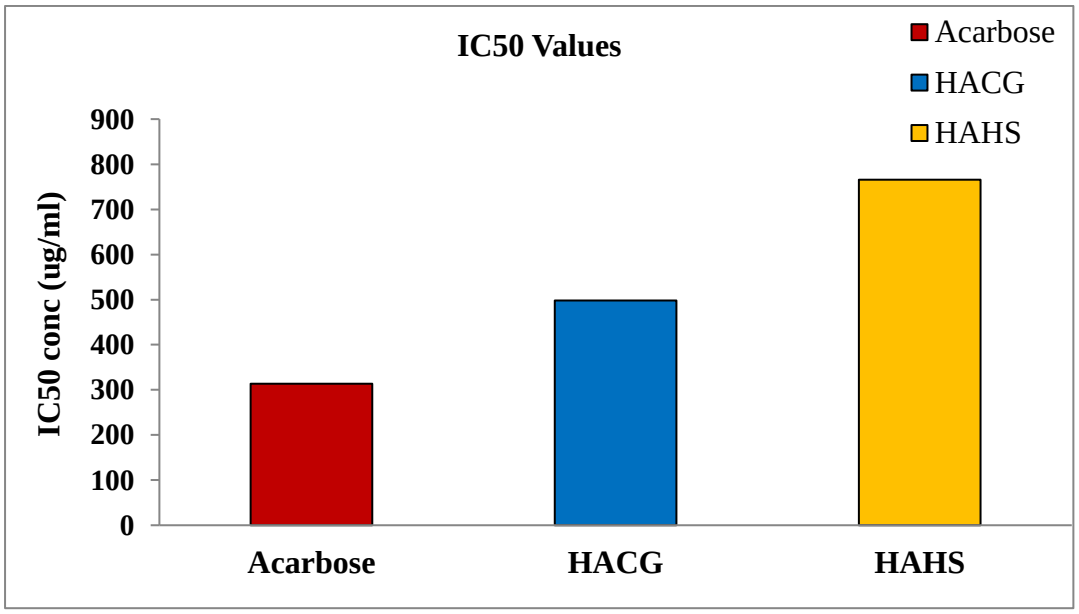

Figure 4: IC50 values of Hydro alcoholic extracts of Coccina grandis fruits (HACG), Hyptis suaveolens seeds (HAHS) on α-amylase in comparison with Acarbose

DISCUSSION

Hyperglycemia is a situation in which an excessive amount of glucose circulates in the blood plasma as a result of insufficient secretion or impaired action of insulin [26], hence maintaining glucose levels is critical. The enzyme alpha-amylase and alpha-glucosidase are essential for managing blood glucose levels by delaying carbohydrate breakdown and absorption [27]. In this work, we looked into the efficacy of Coccinia grandis fruits and Hyptis suveolens seeds to prevent the enzymatic activity of the alpha-amylase and alpha –glucosidase.

Coccinia grandis commonly known as ivy guard has been used traditionally from so many years for treating various disorders [28]. Various parts of Hyptis suveolens commonly known "Chan/Wilayathi tulsi" is used

for treating various disorders [29]. Several studies are reported on various pharmacological activities of hyptis suveolens and coccinia grandis [30-34].

The results obtained in the present study proves that hydroalcoholic extract of both hyptis suveolens seeds and coccinia grandis fruits have marked dose dependent ability to inhibit alpha amylase and alpha glucosidase activity. In present study IC50 values of C.G fruit and H.S seeds for alpha amylase activity were 455 ug/ml and 889 ug/ml respectively, whereas standard Acarbose, which exhibited an IC50 concentration of 298ug/ml (figure 2). Given Test compounds of C.G fruits and H.S seeds extracts for alpha glucosidase activity showed the IC50 concentrations at 498.06 ug/ml and 765.73ug/ml, respectively, in comparison to the standard drug acarbose, which showed the IC50 concentration to be 313.62 ug/ml. (figure 4)

The results indicated concentration-dependent inhibitory action with both the extracts on the enzyme alpha amylase and alpha glucosidase. The highest percentage of inhibition having with highest concentration. However, coccinia grandis fruit extract exhibited more Alpha amylase and Alpha-glucosidase enzyme inhibition when compared with hyptis suaveolens seed extract showed in (figure 1and3).

Several investigations have demonstrated that polyphenols, flavonoids, and alkaloids are known to limit carbohydrate enzyme activity [35, 36]. There are some studies that have demonstrated that flavonoids and alkaloids are powerful alpha glucosidase enzyme inhibitors [37]. Many investigations have revealed that flavonoids and alkaloids are effective alpha-amylase inhibitors [27, 35, and 38]. From the earlier studies it has been reported that presence of flavonoids and alkaloids along with other active constituents in both coccinia grandis fruit and seeds of hyptis suaveolens [28, 29].

A study conducted by Beidokhti MN, on anti-diabetic potential of Psidium guajava L using alpha glucosidase and alpha amylase assays reported the ability of the plant to inhibit alpha amylase and alpha glucosidase enzymes which may be responsible for their anti-hyperglycaemic effects [39]. This study results showed similar trend of results as the present study. Tela. Total showed potency of methanolic extracts of lingerie ciliate, Phyllanthus reticulatus and bambina vulgaris to inhibit alpha amylase and alpha glucosidase activities, which has therapeutic potential for the management of postprandial hyperglycemia [40]. This study strongly supports the analysis of present study.

Hence, the results suggest that the extract's dose depended inhibitory activities on enzymes alpha - amylase and alpha - glucosidase which may contribute to its anti-hyperglycaemic action. The findings further imply that the extract could be clinically effective in the treatment of postprandial hyperglycemia.

CONCLUSION

Form the results, it can be concluded that the hydro-alcoholic extracts of both hyptis suveolens seeds and coccinia grandis fruits have α -glucosidase and α-amylase inhibitory actions in vitro. The phytoconstituents present in extracts may contribute to in vitro enzyme inhibitory actions. Consequently, our investigation demonstrates that both extracts can reduce postprandial hyperglycemia and help with diabetic complications. Further research is needed to support the plant's usage as an anti- diabetic medication.

Conflict of Interest:

None

Funding Support:

Nil

REFERENCES

[1] Ishnava KB, Motisariya DM. In vitro studies on alpha-amylase inhibitory activity of selected ethnobotanical plant extracts and its herbal formulations. Int J Pharmacogn Chinese Med. 2018;2(3):1-11.

[2] Hind L, Nabila B, Sara A, Rabah D. In vitro alpha-amylase and alpha-glucosidase inhibitory activity of Ononis angustissima extracts. J Appl Pharma Sci. 2017;7(2):191-8.

[3] Bhuvaneshwari, Khanam S, Devi K. In vitro enzyme inhibition studies for antidiabetic activity of mature and tender leaves of

Mangifera indica var totapuri. J Microbiol Biotechn 2014;3(3):36–41.
[4] Hara Y, Honda M. The inhibition of alpha amylase by tea polyphenols. Agric Biol Chem. 1990; 54:1939–45.
[5] Matsui T, Tanaka T, Tamura S, Toshima A, Tamaya K, Miyata Y, et al. Alpha-glucosidase inhibitory profile of catechins and theaflavins. J Agric Food Chem. 2007; 55:99–105.
[6] Tiwari AK, Rao JM. Diabetes mellitus and multiple therapeutic approaches of phytochemicals: Present status and future prospects. Curr Sci. 2002; 83:30–8.
[7] Roy A, Geetha RV. In vitro α-amylase and α-glucosidase inhibitory activities of the ethanolic extract of dioscorea villosa tubers. Int J Pharm Bio Sci. 2013;4(4):49-54.
[8] Arumugam, G., Manjula, P., Paari, N., A review: anti diabetic medicinal plants used for diabetes mellitus. Journal of Acute Disease. 2013: 2(3):196–200
[9] Bnouham, M., Ziyyat, A., Mekhfi, H., Tahri, A., Legssyer, A. Medicinal plants with potential antidiabetic activity—a review of ten years of herbal medicine research (1990–2000). International Journal of Diabetes and Metabolism. 2006; 14:1–25.
[10] Wadkar, K.A., Magdum, C.S., Patil, S.S., Naikwade, N.S. Anti-diabetic potential and Indian medicinal plants. Journal of Herbal Medicine and Toxicology. 2008; 2: 45–50.
[11] Tundis, R., Loizzo, M.R., Menichini, F. Natural products as α-amylase and α-glucosidase inhibitors and their hypoglycemic potential in the treatment of diabetes: an update. Mini Reviews in Medicinal Chemistry. 2010; 10: 315–331
[12] Manikandan R, Anand AV, Kumar S. Phytochemical and in vitro Antidiabetic activity of Psidium Guajava leaves. Pharmacognosy Journal. 2016; 8(4).
[13] Manikandan R, Anand AV, Muthumani GD. Phytochemical and in vitro anti-diabetic activity of methanolic extract of Psidium guajava leaves. Int. J. Curr. Microbiol. App. Sci. 2013;2(2):15-9.
[14] Godebo A, Makonnen E, Mekonnen N. Hypoglycemic and antihyperglycemic effect of leaves extracts of Psidium guajava in normoglycemic and streptozotocin-induced diabetic mice. International Journal of Pharmacognosy. 2017;4(8):262-8.
[15] Simamora A, Paramita L, Azreen N, Santoso AW, Timotius KH. in vitro Antidiabetic and Antioxidant Activities of Aqueous Extract from the Leaf and Fruit of Psidium guajava L. The Indonesian Biomedical Journal. 2018 Aug 2;10(2):156-64.
[16] Tella T, Masola B, Mukaratirwa S. Anti-diabetic potential of Psidium guajava leaf in streptozotocin induced diabetic rats. Phytomedicine Plus. 2022 May 1;2(2):100254.
[17] Taur DJ, Patil RY. Mast cell stabilizing, anti-anaphylactic and antihistaminic activity of Coccinia grandis fruits in asthma. Chin J Nat Med. 2011;9:359-62. doi: 10.3724/SP.J.1009.2011.00359.
[18] Jesus NZ, Falcao HS, Lima GR, Caldas Filho MR, Sales IR, Gomes IF, et al. Hyptis suaveolens (L.) Poit (Lamiaceae), a medicinal plant protects the stomach against several gastric ulcer models. J Ethnopharmacology. 2013; 150:982e8.
[19] Bojorquez-Velazquez E, Lino-Lopez GJ, Huerta-Ocampo JA, Barrera-Pacheco A, Barba de la Rosa AP, Moreno A, et al. Purification and biochemical characterization of 11S globulin from chan (Hyptis suaveolens L. Poit) seeds. Food Chem 2016; 192:203e11.
[20] Mueller M, Čavarkapa A, Unger FM, Viernstein H, Praznik W. Prebiotic potential of neutral oligo- and polysaccharides from seed mucilage of Hyptis suaveolens. Food Chem. 2017 Apr 15; 221:508-514
[21] Praznik W, Cavarkapa A, Unger FM, Loeppert R, Holzer W, Viernstein H, et al. Molecular dimensions and structural features of neutral polysaccharides from the seed mucilage of Hyptis suaveolens L. Food Chem 2017;221:1997e2004.
[22] Fu-Chun Hsu, Sheng-Fa Tsai, Shoei-Sheng Lee. Chemical investigation of Hyptis suaveolens seed, a potential antihyperuricemic nutraceutical, with assistance of HPLC-SPE-NMR. Journal of Food and Drug Analysis 2019;17(4);897-05.
[23] González-Montoya M, Hernández-Ledesma B, Mora-Escobedo R, Martínez Villaluenga C. Bioactive Peptides from Germinated Soybean with Anti-Diabetic Potential by Inhibition of Dipeptidyl Peptidase-IV, α-Amylase, and α-Glucosidase Enzymes. International journal of molecular sciences. 2018; 19(10): e2883. https://doi.org/10.3390/ ijms19102883
[24] Ramana Murty Kadali SLDV, Das MC, Vijayaraghavan R, Shanmukha I. In vitro evaluation of antidiabetic activity of aqueous and ethanolic leaves extracts of Chloroxylon swietenia. Natl J Physiol Pharm Pharmacol 2017;7(5):486-490
[25] Pandithurai M, Murugesan S, Bhuvaneswari S, Thennarasan S. In-vitro alpha-amylase and alpha glucosidase inhibition activity of methanolic extract of marine brown alga Spatoglossum asperum. Advances in Pharmaceutics. 2015; 4(5).
[26] Kortykowski M, McDonnell ME, Umpierrez GE, Zonszein J. Patient Guide to Managing Hyperglycemia (High Blood Sugar) in the Hospital. The Journal of Clinical Endocrinology Metabolism. 2012; 97(1): 27A–28A. https://doi.org/10.1210/jcem.97.1.zeg27a
[27] Telagari M, Hullatti K. In-vitro α-amylase and α-glucosidase inhibitory activity of Adiantum caudatum Linn. And Celosia argentea Linn. extracts and fractions. Indian journal of pharmacology. 2015 47(4): 425–429. https://doi.org/10.4103/0253-7613.161270
[28] Sakharkar P, Chauhan B. Antibacterial, antioxidant and cell proliferative properties of Coccinia grandis fruits. Avicenna J Phytomed, 2017; 7 (4): 295-307.
[29] S. M. Sankara Malathi, S. L. Sidde Lahari, P. S. P. Sahithya, P. R. R. P. Ramalingeswar Reddy, and K. L. K.Sai Lakshimi, "anthelmintic and primer phytochemical examination of dissolvable concentrates of hyptis suaveolens from seeds", Int J Indig Herb Drug 2019 Dec; 1-5.
[30] Racheal M. Agenyi. Phytochemical Analysis of Hyptis Suaveolens Extract and Its Effects on the Growth of Disease-Causing Parasites. Int. J. Adv. Res.2021; 9(05):555-560.
[31] Bankole Abimbola E , Umebese Caroline E. Light Intensity Alters the Growth and Quality of Volatile Components from Hexane Extracts of Hyptis suaveolens (Family Lamiaceae): A Medicinal Plant. Asian Journal of Biological and Life Sciences 2022;11(3):812-818.
[32] Hadi Ghaffari, Behrouz Jalali Ghassam et.al. Antioxidant and Neuroprotective Activities of Hyptis Suaveolens (L.) Poit. Against Oxidative Stress-Induced Neurotoxicity. Cell Mol Neurobiol 2014; 34:323–331.
[33] Poommaree Namchaiw , Yamaratee Jaisin, Cholticha Niwaspragrit et.al. The Leaf Extract of Coccinia Grandis (L.) Voigt Accelerated In Vitro Wound Healing By Reducing Oxidative Stress Injury. Oxidative Medicine and Cellular Longevity vol. 2021, Article ID 3963510, 10 pages, 2021. https://doi.org/10.1155/2021/3963510
[34] Prashant Sakharkar, Balwantsinh Chauhan. Antibacterial, antioxidant and cell proliferative properties of Coccinia grandis fruits. Avicenna J Phytomed. 2017 Jul-Aug; 7(4): 295–307.

[35] Kidane Y, Bokrezion T, Mebrahtu J, Mehari M, Gebreab Y, Fessehaye N, Achila O. In Vitro Inhibition of α-Amylase and α-Glucosidase by Extracts from Psiadia punctulata and Meriandra bengalensis. Evidence- Based Complementary and Alternative Medicine. 2018; 1–9. https:// doi.org/10.1155/2018/2164345

[36] Unuofin J, Otunola G, Afolayan A. In vitro α-amylase, α-glucosidase, lipase inhibitory and cytotoxic activities of tuber extracts of Kedrostis africana (L.) Cogn. Heliyon. 2018; 4(9): e00810. https://doi.org/10.1016/j.heliyon.2018.e00810

[37] Yin Z, Zhang W, Feng F, Zhang Y, Kang W. α-Glucosidase inhibitors isolated from medicinal plants. Food Science and Human Wellness. 2014; 3(3–4): 136–174. https://doi.org/10.1016/j.fshw.2014.11.003

[38] Somtimuang C, Olatunji O, Ovatlarnporn C. Evaluation of in Vitro α-Amylase and α-Glucosidase Inhibitory Potentials of 14 Medicinal Plants Constituted in Thai Folk Antidiabetic Formularies. Chemistry & Biodiversity. 2018; 15(4):e1800025. https://doi.org/10.1002/cbdv.201800025

[39] .Beidokhti MN, Eid HM, Villavicencio ML, Jäger AK, Lobbens ES, Rasoanaivo PR, McNair LM, Haddad PS, Staerk D. Evaluation of the antidiabetic potential of Psidium guajava L.(Myrtaceae) using assays for α-glucosidase, α-amylase, muscle glucose uptake, liver glucose production, and triglyceride accumulation in adipocytes. Journal of ethnopharmacology. 2020 Jul; 15; 257:112877.

[40] Tella T, Masola B, Mukaratirwa S. The effect of Psidium guajava aqueous leaf extract on liver glycogen enzymes, hormone sensitive lipase and serum lipid profile in diabetic rats. Biomedicine & Pharmacotherapy 109 (2019) 2441–2446.