Phytochemical Composition, *in vitro* Studies on \( \alpha \)-Amylase and \( \alpha \)-Glucosidase Inhibitory Activity of Selected Mangrove Plants

**Ranjana***, B. L. *Jadhav*

*Department of Life Sciences, University of Mumbai, Vidyanagari Campus, Santacruz (East)-400098, Mumbai, India*

**ABSTRACT**

The purpose of this study is to show the phytochemical composition and *in vitro* antidiabetic potential in the leaves of *Ceriops tagal*, *Bruguiera cylindrica*, and *Salvadora persica* mangrove plants. The phytochemical composition was studied by qualitative analysis. To determine *in vitro* antidiabetic activity leaves were subjected to solvent extraction by the Soxhlet method using methanol, ethanol, ethyl acetate, and pet ether and \( \alpha \)-amylase, \( \alpha \)-glucosidase inhibition assays were performed. The findings indicate that alkaloid, steroid, flavonoid, terpenoid, glycosides, tannin, saponin, phenol, quinones and coumarin principles are present in the leaves of selected mangrove species. Among the selected mangrove species *C. tagal* leaves recorded the highest antidiabetic activity for both the assay followed by *B. cylindrica* and *S. persica*. Overall *C. tagal* was found highly potent in the antidiabetic activity.

**Keywords:** Mangroves, *In vitro*, Antidiabetic activity, \( \alpha \)-glucosidase, \( \alpha \)-amylase.

**DOI:** 10.25004/IJPSDR.2019.110505

**INTRODUCTION**

Diabetes mellitus, characterized by both elevated production and low utilization of glucose, could be a major endocrine disorder touching nearly 10\% of the population throughout the world. \[1\] It is a long lasting condition that solemnly affects a person's life, characterized by metabolic disorders in carbohydrate, fat, and protein and resulting in hyperglycemia. \[2\] Since centuries, plants are consistently been an admirable source of medicines and drugs available today, which are derived from plants to overcome a wide variety of clinical diseases. Mangroves are woody plants growing in marshy areas in tropical and subtropical regions where they do exist in relatively high salinity, utmost tides, robust winds, high temperatures and filthy, anaerobic soils. \[3\]-\[4\] To thrive in these extreme conditions, they synthesize diverse classes of secondary metabolites responsible for various medicinal properties. Mangrove plants are used traditionally in folk medicines to treat various diseases such as skin disorders, sores, leprosy, angina pectoris, asthma, tuberculosis, constipation, convulsions, diarrhoea, dysentery, elephantiasis, eye ailments, fever, headaches, haemorrhage, inflammation, malaria, jaundice, fungal infections, kidney stones, lesions, malignancies, rheumatism, sore throat, and syphilis. They are also used as an astringent, emmenagogue, hemostat, styptic, expectorant, and tonic. \[5\] A few
species like Acanthus ilicifolius [6], C. tagal [7-8], Rhizophora mucronata [8-10], Diospyros peregrina [11] and Hetrilera fomes [12] are used as folklore medicine to cure diabetes. Besides folklore uses, many mangrove species like R. mucronata [13-14], Xylocarpus molluccensis [15], Sonneratia apetala [16], Drosera heterophylla and S. alba [17], C. decandra [18] scientifically proved active against the hyperglycaemic activity. Mangrove plants are the major source of phytoconstituents like phenolic compounds, flavonoids, terpenoids, saponin, coumarins, glycopeptid, alkaloids, tannin, essential oils, anthraglycosides [19-22] and other constituents rich in plant products tend to show a reduction in blood glucose levels. [23] They can also maintain the function of β-cells by hampering the formation of diabetes-induced reactive oxygen species. [24] Mangrove possesses secondary metabolites in abundance such as alkaloid, saponin, flavonoid, tannin and they are proved to have antidiabetic activity. [25-28] We have selected C. tagal, B. cylindrica and S. persica mangrove species, thereunder studied their phytochemical compositions and in vitro antidiabetic potential in this study.

MATERIALS AND METHODS

Plant Material

Three mangrove plants C. tagal, B. cylindrica, and S. persica leaves were collected in May from the Gorai beach area located at 19°15’0” N and 72°46’59”E Borivali, Mumbai, Maharashtra, India and recognised by a taxonomist. The leaves were washed under running water to get them free from dust and other contaminants followed by oven-drying at 40°C to remove any moisture, ground, and the powder was sieved through a muslin cloth for further uses of the extract preparation.

Extract Preparation

Different solvent leaves extracts were prepared from the selected plants’ leaves. 10 g leaf powder of all the three mangroves was added with the 200ml methanol, ethanol, ethyl acetate and pet ether (polar to non-polar) using the Soxhlet apparatus. The extracts obtained were concentrated using a rotary flash evaporator (Buchi, Japan) to get the residues and used for antidiabetic activity.

Phytochemical Analysis

The qualitative estimation of secondary metabolites in methanol leaf extract was studied as per Harborne. [29] The tests for various classes of secondary metabolites were as follows.

Alkaloids: 0.2 ml extract was taken and 0.2 ml HCl was added. 2-3 drops of Dragendorff’s reagent was added to the mixture and then the orange or red precipitate and turbid solution indicate the presence of alkaloids.

Tannins: 2 ml of water was added to 0.2 ml extract followed by heating on a water bath for 10 min. The mixture was filtered; FeCl₃ was added to the filtrate and observed for the dark green solution which indicates the presence of tannin.

Terpenoids: In a test tube, 0.2 ml extract was mixed with 0.2 ml chloroform. Conc. H₂SO₄ was added to this cautiously to form a layer. The presence of reddish-brown colour at the interface indicated that terpenoids are present.

Glycosides: 0.2 ml extract was mixed with 0.2 ml acetic acid and 0.2 ml of chloroform and then it was chilled on ice. H₂SO₄ was added carefully and the colour change from violet to blue and then to green confirmed the existence of the steroidal nucleus (Aglycone portion of glycoside).

Steroids: 0.2 ml extract was added to 0.2 ml chloroform followed by 0.2 ml Conc. H₂SO₄. The red colour in the lower layer of chloroform indicated the presence of steroids.

Saponins: A mixture of 0.2 ml extract and 5 ml distilled water was shaken vigorously and was observed for a stable persistent froth. After adding 3 drops of olive oil, the formation of stable foam confirmed the presence of saponins.

Flavonoids: 0.2 ml plant extract was mixed with dilute NaOH solution followed by dilute HCl. The change of yellow solution into a colourless one indicates the presence of flavonoids.

Phlobatannins: The red precipitate after mixing 2 ml extract in 1% aqueous HCl, witnessed the presence of phlobatannin.

Anthocyanins: 2 ml extract was added in 2 ml 2N HCl containing ammonia. Pink-red color turns into blue-violet which shows the presence of anthocyanins.

Coumarins: The yellow colour solution after adding 2 ml extract in 10% NaOH confirms the presence of coumarins.

Phenolics: Addition of 1 ml extract in 0.5 ml 1% Lead acetate and 1% FeCl₃ gave a blue-black and green-brown precipitate respectively.

Quinones: 3 ml Conc. HCl was added in the 2 ml extract. The green color was obtained, indicating quinones are present in the extracts.

In vitro Antidiabetic Activity

The antidiabetic activity was estimated by α-amylase and α-glucosidase inhibition assays as described below:

α-amylase Inhibition Assay

A mixture of 100µL plant extract and 100µL 0.02 M sodium phosphate buffer (pH 6.9) containing α-amylase solution was kept for incubation at 37°C for 30 min. In each tube, 800µL 1% starch solution in 0.02 M sodium phosphate buffer (pH 6.9) was added and kept again for incubation at 37°C for 15 min followed by addition of 1 ml dinitrosalicylic acid (DNSA) reagent. All the test tubes were then placed in a boiling water bath for 5 min and the optical density was measured at 540 nm.

α-glucosidase Inhibition Assay

A mixture containing plant extract, 1 ml starch substrate (2% w/v maltose) and 0.2 M Tris buffer (pH 8.0) was kept for incubation at 37°C for 5 min. The addition of 1 ml of α-glucosidase enzyme (1U/ml) followed by incubation at 35°C for 40 min initiates the
reaction and further addition of 2 ml 6N HCl terminates the reaction. Thereafter absorbance of the resultant colour was measured at 540 nm.

**Inhibitory Concentration (IC₅₀)**

Half-maximal Inhibitory concentration (IC₅₀) is the amount of a substance required to inhibit a biological process such as an enzyme, cell, cell receptor or microorganism by half. The IC₅₀ value was calculated by non-linear regression analysis of % inhibition recorded for different concentrations of test substances/standard. The relative activity of the sample was determined by comparing the IC₅₀ value of a sample with the standard. Higher the IC₅₀ value, lower will be the relative activity in comparison to standard and vice-versa.

Acarbose was used as the standard and all tests were carried out in triplicate. Percentage inhibition (I %) was calculated by:

\[
\text{% Inhibition} = \left( \frac{\text{Absorbance}_{\text{control}} - \text{Absorbance}_{\text{sample}}}{\text{Absorbance}_{\text{control}}} \right) \times 100
\]

Where Absorbance_{control} = absorbance of the solution with no extract

Absorbance_{sample} = absorbance of the solution containing extract and enzyme solution

**Statistical analysis**

All the data are means of three independently performed experiments and shown as means ± SD. Their significance was tested by one-way ANOVA (SPSS ver-21; IBM Japan Ltd., Tokyo, Japan) followed by Post hoc Duncan’s test at significance level \( P < 0.05 \).

**RESULTS**

The result of phytochemical analysis has shown the presence of alkaloid, steroid, flavonoid, terpenoid, glycosides, tannin, saponin, phenol, quinones and coumarin in all the selected mangrove species (Table 1). The α-amylase inhibition assay of C. tagal leaves has shown a gradual increase in percent inhibition as concentration increases for all the extracts. In this plant best percent inhibition was recorded in methanol extract (73.26%) followed by ethanol (62.76%), ethyl acetate (61.83%) and pet ether (54.55%) extracts at highest concentration (5 mg/ml) (Table 2). The percent inhibition and IC₅₀ value for standard drug acarbose was 89.39% and 0.095 mg/ml respectively. Similarly, α-glucosidase assay has shown the best percent inhibition (66.13%) and IC₅₀ value (2.448 mg/ml) for methanol extract (Table 5).

**DISCUSSION**

In the present study selected mangrove species C. tagal, B. cylindrica and S. persica have shown the presence of alkaloid, steroid, flavonoid, terpenoid, glycosides, tannin, saponin, phenol, quinones and coumarin. This indicates selected mangroves contain diverse classes of phytochemicals. Similar classes of secondary metabolites were seen in L. racemosa [19], S. alba [20], C. tagal [21], S. aptevala [22] mangrove species. These results are in agreement with the present finding, therefore it is suggested that mangroves are affluent in a diverse range of phytoconstituents. In the present study, we have made leaves extracts of methanol, ethanol, ethyl acetate and pet ether of selected mangrove species and determined its antidiabetic activity using in vitro antidiabetic assays i.e. α-amylase and α-glucosidase inhibition assays.

### Table 1: Phytochemical composition of selected mangrove species.

| Phytochemical constituents | C. tagal | B. cylindrica | S. persica |
|---------------------------|----------|---------------|------------|
| Alkaloids                 | +        | +             | -          |
| Tannins                   | +        | +             | +          |
| Terpenoids                | +        | +             | +          |
| Glycosides                | +        | +             | +          |
| Steroids                  | +        | -             | +          |
| Saponins                  | +        | +             | +          |
| Flavonoids                | +        | +             | +          |
| Phlobatannins             | +        | -             | +          |
| Anthocyanins              | +        | +             | +          |
| Coumarins                 | +        | +             | +          |
| Phenolics                 | +        | +             | +          |
| Quinones                  | +        | +             | +          |

### Table 2: The percent inhibition of α-amylase by methanol, ethanol, ethyl acetate and pet ether extracts of C. tagal leaves at varying concentrations.

| Conc. (mg/ml) | Acarbose | Methanol | Ethanol | Ethyl acetate | Pet ether |
|--------------|----------|----------|---------|---------------|-----------|
| 0.5          | 50.32±0.292 | 21.06±0.106 | 17.52±0.476 | 15.63±0.186 | 8.383±0.673 |
| 1.0          | 57.1±0.165  | 38.97±0.529 | 32.58±0.181 | 27.53±0.252 | 14.22±0.277 |
| 2.0          | 70.25±0.16  | 46.84±0.274 | 39.04±0.474 | 36.42±0.296 | 24.98±0.296 |
| 3.0          | 82.02±0.111  | 55.33±0.528 | 53.54±0.159 | 45.76±0.345 | 35.58±0.212 |
| 4.0          | 88.09±0.037  | 65.03±0.049 | 62.05±0.337 | 60.24±0.061 | 50.24±0.465 |
| 5.0          | 89.39±0.87   | 73.26±0.571 | 62.76±0.219 | 61.83±0.223 | 54.45±0.106 |
Table 3: The percent inhibition of α-amylase by methanol, ethanol, ethyl acetate and pet ether extracts of *C. cylindrica* leaves at varying concentrations.

| Conc. (mg/ml) | Acarbose IC₅₀ | Methanol IC₅₀ | Ethanol IC₅₀ | Ethyl acetate IC₅₀ | Pet ether IC₅₀ |
|---------------|----------------|----------------|---------------|---------------------|---------------|
| 0.5           | 50.32 ± 0.292  | 19.34 ± 0.329  | 15.86 ± 0.048 | 12.53 ± 0.261       | 3.33 ± 0.177  |
| 1.0           | 57.1 ± 0.165   | 29.53 ± 0.345  | 23.66 ± 0.458 | 18.08 ± 0.191       | 12.77 ± 0.308 |
| 2.0           | 70.25 ± 0.16   | 33.63 ± 0.172  | 3.027 ± 0.245 | 3.455 ± 0.797       | 3.681 ± 0.107 |
| 3.0           | 80.22 ± 0.113  | 35.90 ± 0.457  | 0.026          | 0.013               | 0.022         |
| 4.0           | 88.09 ± 0.037  | 63.98 ± 0.099  | 59.00 ± 0.458  | 58.04 ± 0.274       | 49.34 ± 0.237 |
| 5.0           | 89.39 ± 0.87   | 69.23 ± 0.618  | 62.12 ± 0.554  | 60.15 ± 0.587       | 55.19 ± 0.149 |

Table 4: The percent inhibition of α-amylase by methanol, ethanol, ethyl acetate and pet ether extracts of *S. persica* leaves at varying concentrations.

| Conc. (mg/ml) | Acarbose IC₅₀ | Methanol IC₅₀ | Ethanol IC₅₀ | Ethyl acetate IC₅₀ | Pet ether IC₅₀ |
|---------------|----------------|----------------|---------------|---------------------|---------------|
| 0.5           | 50.32 ± 0.292  | 18.84 ± 0.553  | 11.24 ± 0.144 | 10.39 ± 0.432       | 8.26 ± 0.025  |
| 1.0           | 57.1 ± 0.165   | 23.21 ± 0.306  | 18.11 ± 0.031 | 16.43 ± 0.637       | 10.70 ± 0.488 |
| 2.0           | 70.25 ± 0.16   | 33.23 ± 0.553  | 27.81 ± 0.735 | 4.047 ± 0.292       | 22.67 ± 0.046 |
| 3.0           | 80.22 ± 0.113  | 45.71 ± 0.737  | 34.82 ± 0.392 | 29.87 ± 0.062       | 26.88 ± 0.141 |
| 4.0           | 88.09 ± 0.037  | 57.32 ± 0.484  | 54.99 ± 0.733 | 49.58 ± 0.125       | 43.28 ± 0.538 |
| 5.0           | 89.39 ± 0.87   | 59.82 ± 0.307  | 58.08 ± 0.309 | 51.95 ± 0.330       | 47.42 ± 0.375 |

Table 5: The percent inhibition of α-glucosidase by methanol, ethanol, ethyl acetate and pet ether extracts of *T. tagal* leaves at varying concentrations.

| Conc. (mg/ml) | Acarbose IC₅₀ | Methanol IC₅₀ | Ethanol IC₅₀ | Ethyl acetate IC₅₀ | Pet ether IC₅₀ |
|---------------|----------------|---------------|---------------|---------------------|---------------|
| 0.5           | 50.61 ± 0.429  | 51.38 ± 0.421 | 16.22 ± 0.314 | 13.65 ± 0.182       | 6.39 ± 0.479  |
| 1.0           | 56.86 ± 0.494  | 40.31 ± 0.420 | 29.35 ± 0.103 | 26.06 ± 0.282       | 14.59 ± 0.579 |
| 2.0           | 70.23 ± 0.399  | 49.14 ± 0.359 | 24.48 ± 0.147 | 36.61 ± 0.464       | 30.40 ± 0.455 |
| 3.0           | 82.00 ± 1.525  | 56.33 ± 0.295 | 76.78 ± 0.441 | 43.49 ± 0.486       | 36.47 ± 0.331 |
| 4.0           | 86.67 ± 0.587  | 62.96 ± 0.461 | 60.87 ± 0.353 | 57.27 ± 0.324       | 50.21 ± 0.454 |
| 5.0           | 89.26 ± 0.156  | 66.13 ± 0.419 | 61.80 ± 0.352 | 61.76 ± 0.443       | 54.80 ± 0.498 |

Table 6: The percent inhibition of α-glucosidase by methanol, ethanol, ethyl acetate and pet ether extracts of *B. cylindrica* leaves at varying concentrations.

| Conc. (mg/ml) | Acarbose IC₅₀ | Methanol IC₅₀ | Ethanol IC₅₀ | Ethyl acetate IC₅₀ | Pet ether IC₅₀ |
|---------------|----------------|---------------|---------------|---------------------|---------------|
| 0.5           | 50.61 ± 0.429  | 13.87 ± 0.543 | 10.84 ± 0.441 | 9.09 ± 0.084        | 7.51 ± 0.199  |
| 1.0           | 56.86 ± 0.494  | 24.71 ± 0.613 | 21.55 ± 1.08  | 20.78 ± 0.444       | 17.81 ± 0.091 |
| 2.0           | 70.23 ± 0.399  | 32.99 ± 0.410 | 3.797 ± 0.245 | 29.65 ± 0.645       | 27.45 ± 0.506 |
| 3.0           | 82.00 ± 1.525  | 43.83 ± 0.567 | 36.05 ± 0.517 | 32.21 ± 0.177       | 32.10 ± 0.546 |
| 4.0           | 86.67 ± 0.587  | 56.19 ± 0.385 | 56.17 ± 0.468 | 49.99 ± 0.366       | 43.11 ± 0.504 |
| 5.0           | 89.26 ± 0.156  | 62.41 ± 0.140 | 59.29 ± 0.413 | 52.19 ± 0.464       | 47.61 ± 0.527 |

Overall, the best activity was recorded in *C. tagal* leaves followed by leaves of *B. cylindrica* and *S. persica*. In *C. tagal* best α-amylase inhibition was recorded in methanol extract (73.26%) followed by ethanol (62.76%), ethyl acetate (61.83%) and pet ether (54.45%) at higher concentration (Table 2). Results of similar magnitude were recorded for α-glucosidase assay. These results indicate that methanol is the best solvent for the extraction of antidiabetic principle in this plant. There are no reports on *in vitro* antidiabetic activity in this plant however; *in vivo* antidiabetic activity has been recorded in the leaves of *C. tagal* [31]. This confirms antidiabetic potential in leaves of *C. tagal*. In *B. cylindrica* also the highest α-amylase inhibition was recorded in methanol extract than other solvent extracts. Similar results were recorded for α-glucosidase assay. Like-wise lower α-amylase inhibition was recorded in methanol extract of *S. persica* than other solvents at higher concentrations. The result of the plant indicates slightly lower antidiabetic activity in the leaves of *B. cylindrica* and *S. persica* than *C. tagal*. Overall highest in vitro antidiabetic potential indicated in *C. tagal* followed by *B. cylindrica* and *S. persica* besides this methanol was found to be the best solvent for the extraction of antidiabetic principle.

Int. J. Pharm. Sci. Drug Res. September-October, 2019, Vol 11, Issue 5 (181-186)
Antidiabetic potential of the plants is related to the presence of alkaloid, flavonoid, saponin, terpenoids classes of secondary metabolites [25-28], which all are seen in C. tagal, B. cylindrica and S. persica in this study. Therefore, the antidiabetic potential of the selected mangroves can be related to these phytochemicals. However the quantity and quality of these phytochemicals may be responsible for the antidiabetic potency of selected mangrove species.

This study proves that C. tagal exhibited maximum inhibitory activity in both the assays out of the mangrove species selected, thus establish a good relationship with the antidiabetic properties. This implicates the probability of containing some herbal bioactive compounds in plant which are inhibiting the activity of the enzyme, so in future; the identification of the bioactive constituents needs isolation, structural elucidation, and characterization.

ACKNOWLEDGMENT

The author expresses immense gratitude to University Grant Commission for providing financial support. We are also thankful to the Department of Life Sciences, University of Mumbai for instrumental help.

REFERENCES

1. Burke JP, Williams K, Narayan KV, Leibson C, Haffner SM, Stern MP. A population perspective on diabetes prevention: whom should we target for preventing weight gain? Diabetes care. 2003 Jul 1;26(7):1999-2004.
2. Parks M, Rosebraugh C. Weighing risks and benefits of liraglutide—the FDA's review of a new antidiabetic therapy. New England Journal of Medicine. 2010 Mar 4;362(9):774-7.
3. Kathiresan K, Bingham BL. Biology of mangroves and mangrove ecosystems. Advances in Marine Biology. 2001; 81-251.
4. Das SK, Patra JK, Thatoi H. Antioxidative response to abiotic and biotic stresses in mangrove plants: A review. International Review of Hydrobiology. 2016 Apr;101(1-2):3-19.
5. Revathi P, Thirumalaiakolundusubramanian P, Prabhu N. Medicinal properties of mangrove plants—an overview. International Journal of Bioassays. 2013 Dec 1(2):1597-608.
6. Agbiliak NV, Naik VR, Abraham GJ, Reddy CV, Naqvo SW, Mitral PK. Analgesic anti-inflammatory activity of Acacia nilotica Linn. Indian journal of experimental biology. 1979 Nov;17(11):1257-8.
7. Perry LM, Metzger J. Medicinal plants of East and Southeast Asia: attributed properties and uses. MIT press; 1980.
8. Santos AC, Santos GA. Obligacion MB. Philippine plants and their contained natural products: biological and pharmacological literature survey. National Research Council of the Philippines (NRCP), Bicutan, Taguig. Metro Manila. 1981.
9. Duke JA, Wain KK. Medicinal Plants of the World. 3 vol. Computer index with more than 85,000 entries. Plants genetics and germplasm Institute. Agriculture Research Service, Beltsville, Maryland. 1981.
10. Adhikari A, Ray M, Sur TK, Biswas S, Das AK. Comparative evaluation of antidiabetic activity of fresh juice and ethanolic extract of Sudanberg mangrove Rhizophora mcrornata Lam. leaves in animal model. International Journal of Basic and Clinical Pharmacology 2017; 6:2193-2198.
11. Islam MS, Rahman MF, Raja MA, Parveez M, Rakib HH, Shome B. A review on traditional ayurvedic medicinal plants used in the sundarban mangrove forest in Bangladesh. International Journal of Research in Pharmacology and Pharmacotheuraputics. 2015;4(1), 37-44.
12. Mahmud I, Islam MK, Saha S, Barman AK, Rahman MM, Anisuzzaman M, Rahmatullah M. Pharmacological and ethnomedical overview of Heritiera fomes: Future Prospects. International Scholarly Research Notices. 2014; 2014:1-12.
13. Lawlg IL, Aguinaldo AM, Naheed S, Moshuhammadz H, Manzor MM. α- Glucosidase inhibitory activity of selected Philippine plants. International Journal of Ethnopharmacology. 2012 Oct 31;144(1):217-9.
14. Hagie M, Ahmed A, Nasrin S, Rahman MM, Raisuzzaman S. Revelation of mechanism of action of Rizhiphora mcrornata bark extracts for its antidiabetic activity by gut perfusion and six segment method in long evan rats. International Research Journal of Pharmacy. 2013; 4:1-4.
15. Srivastava SP, Mishra A, Lakshmi V, Tamrakar AK, Srivastava MN, Srivastava AK. Antidiabetic and antidysslipidemic activity of ethyl acetate fractions of Xylocarpus granatum and Xylocarpus molluccensis on high fructose high fat AND high sucrose high fat fed-low does streptozotocin treated diabetic rats. International Journal of Pharmacy and Pharmaceutical Sciences. 2015; (7), 537-543.
16. Patra JK, Das SK, Thatoi H. Phytochemical profiling and bioactivity of a mangrove plant, Sonneratia apetala, from Odisha Coast of India. Chinese journal of integrative medicine. 2015 Apr 1;21(4):274-85.
17. Morada NJ, Mettilo EB, Uy MM, Oclarit JM. Anti-diabetic polysaccharide from mangrove plant, Sonneratia alba Sm. International Conference on Asia Agriculture and Animal. International Proceedings of Chemical, Biological and Environmental Engineering 2011 July; 13:197-200.
18. Nabeel MA, Kathiresan, K, Manivannan S. Antidiabetic activity of the mangrove species Ceriops decandra in alloxan induced diabetic rats. Journal of Diabetes. 2010(2), 97-103.
19. Ranjana, Jadhav BL, Dhawan PP, Patel P. In vitro antidiabetic activity and phytochemical analysis of Lumnitzera racemosa leaves. International Research Journal of Pharmacy 2019;10(4):220-227.
20. Gawali P, Jadhav BL. Antioxidant activity and phytochemical analysis of mangrove species Sonneratia alba and Bruguiera cylindrica. Asian Journal of Microbiology, Biotechnology and Environmental Sciences. 2011;13(2):257-261.
21. Jadhav BL, Quaraishi FM, Pagare BG. “Evaluation of Antioxidant Properties and Phytochemical analysis in the stem and leaves of Ceriops tagal mangroves.” Research journal of Biotechnology. 2013;8(9), 28-31.
22. Maurya BR. Studies on the bioactive components of alcoholic stem extract of Sonneratia apetala. Ph.D. Thesis (Life Sciences), Mumbai University, Mumbai; 2007.
23. Crozier A, Jaganath IB, Clifford MN. Dietary phenolics: Chemistry, bioavailability and effects on health. Natural Product Reports 2009;26(8):1001-1043.
24. Shyam T, Ganapaty S. Evaluation of antidiabetic activity and phytochemical analysis of methanolic extracts from the aerial parts of Barleria montana in streptozotocin induced diabetic rats. Journal of Pharmacognosy and Phytochemistry 2013;2:187-92.
25. Wangensteen H, Dang HC, Uddin SJ, Alamgiir M, Malterud KE. Antioxidant and antimicrobial effects of the mangrove tree Heritiera fomes. Natural Product Communications 2009 Mar; 4(3):371-376.
26. Li MY, Xiao Q, Pan JY, Wu J. Natural products from semi-mangrove flora: source, chemistry and bioactivities. Natural Product Reports 2009; 26:281-298.
27. Cheng F, Zhou Y, Wu J. Chemical constituents of fruit of Xylocarpus granatum. Journal of Chinese Medicinal Materials 2009; 32:1220-1223.
28. Nebula M, Harisanh KS, Chandramohanakumar N. Metabolites and bioactivities of Rhizophoraceae mangroves. Natural Products and Bioprospecting 2013; 3:207-232.
29. Harborne JB. Phytochemical methods: a guide to modern techniques of plant analysis. 2nd Ed. London (GB): Chapman and Hall Ltd; 1973.
30. Adisakwattana S, Ruengsamran T, Kampa P, Sompong W. In vitro inhibitory effects of plant-based foods and their combinations on intestinal α-glucosidase and pancreatic α-
Ranjana et al. / Phytochemical Composition, in vitro Studies on α-Amylase and α-Glucosidase Inhibitory……

amylase. BMC Complementary and Alternative Medicine 2012; 12(1):110.

31. Krishnaveni S, Balasubramanian T, Sadasivam S. Sugar distribution in sweet stalk sorghum. Food Chemistry 1984; 15(3):229-232.

32. Quraishi F, Studies on the Antioxidant properties and phytochemical analysis of selected mangrove species, Ph.D. Thesis, University Of Mumbai, 2017.

33. Tiwari P, Tamrakar AK, Ahmad R, Srivastava MN, Kumar R, Lakshmi V, Srivastava AK. Antihyperglycaemic activity of Ceriops tagal in normoglycaemic and streptozotocin-induced diabetic rats. Medicinal Chemistry Research. 2008 Jun 1;17(2-7):74-84.

HOW TO CITE THIS ARTICLE: Ranjana, Jadhav BL. Phytochemical Composition, in vitro Studies on α-Amylase and α-Glucosidase Inhibitory Activity of Selected Mangrove Plants. Int. J. Pharm. Sci. Drug Res. 2019; 11(5): 181-186. DOI: 10.25004/IJPSDR.2019.110505