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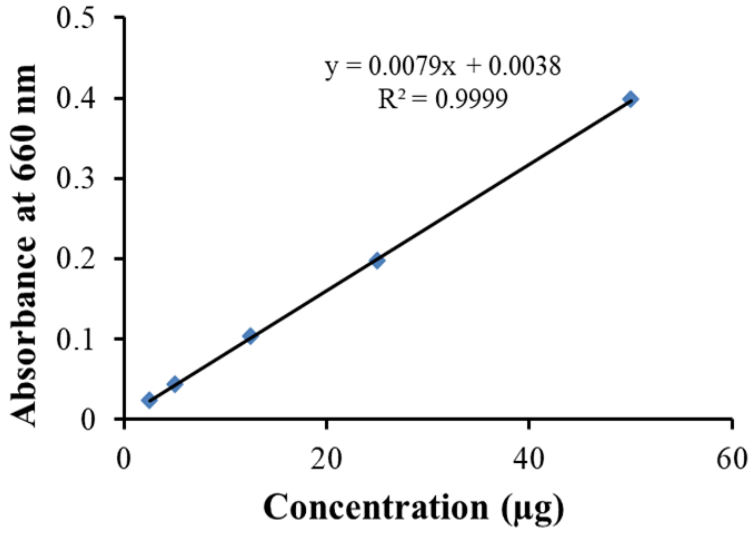
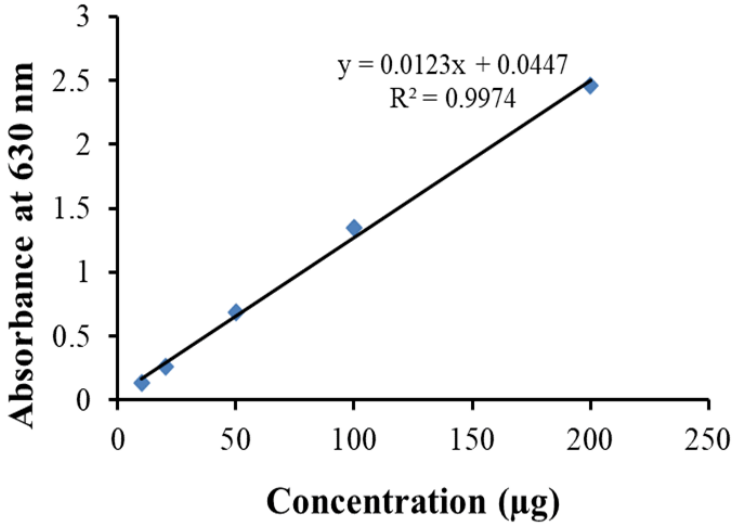
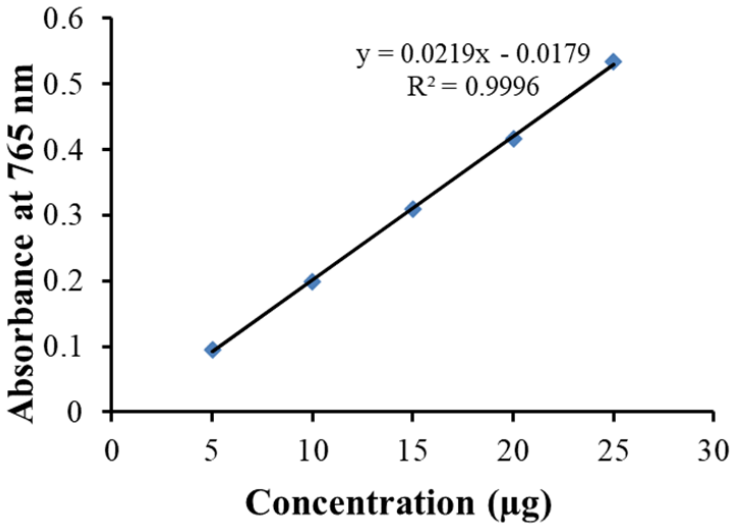
ANNEXURE-I



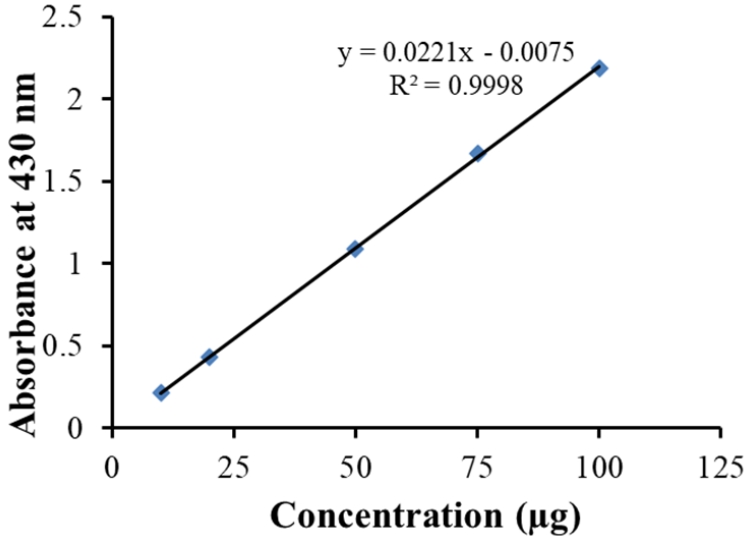
A. Standard curves of Bovine serum albumin. Values are expressed as mean ± standard deviation (SD), n = 3



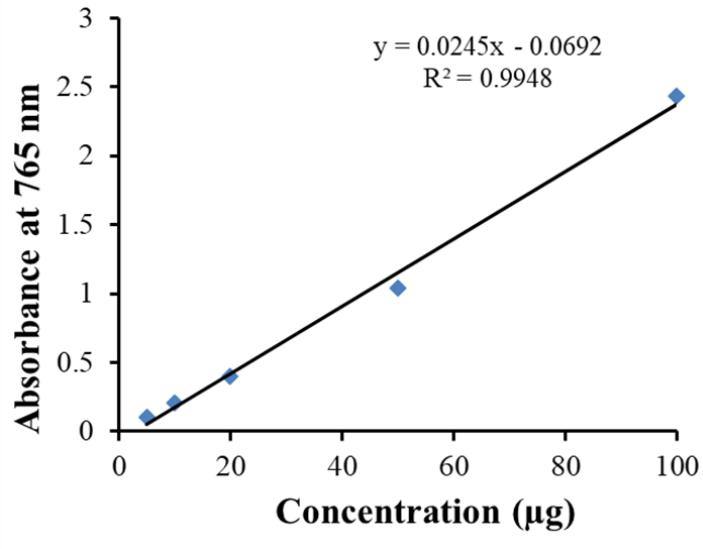
B. Standard curve of Glucose. Values are expressed as mean ± standard deviation (SD), n = 3



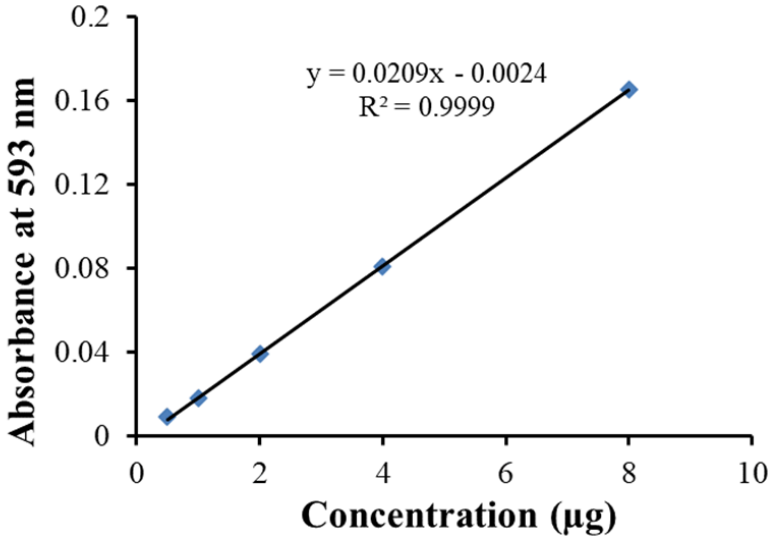
C. Standard curve Gallic acid for total phenolic content. Values are expressed as mean ± standard deviation (SD), n = 3



D. Standard curve of Quercetin, for total flavonoid content. Values are expressed as mean ± standard deviation (SD), n = 3



E. Standard curve of Ascorbic acid for total antioxidant activity by phosphomolybdate assay. Values are expressed as mean ± standard deviation (SD), n = 3



F. Standard curve of $FeSO_4$ for FRAP assay. Values are expressed as mean ± standard deviation (SD), n = 3

ANNEXURE-II

ETHICAL CLEARANCE CERTIFICATE

INSTITUTIONAL ANIMAL ETHICS COMMITTEE
Bodoland University, Kokrajhar, Assam, India
PIN – 783370, Phone No.03661-277183

Ref No. IAEC/ZOOL/2019/1 **Date:** 14.12.2019

CERTIFICATE

This is to certify that Miss Manita Daimari, Ph.D. scholar under the guidance of Dr. Ananta Swargiary, Assistant Professor, Department of Zoology, Bodoland University has presented the protocol regarding the use of Animal model (Wister Albino male Rat) for her research work entitled **"Study of anti-hyperglycemic property of traditionally used medicinal plants of Kokrajhar District, Assam"** on13th December 2019. The protocol was presented before the members of Institutional Animal Ethics Committee, Bodoland University. The Committee has approved the protocol and allowed to use animal model in the research proposal.

The Committee did not find any objectionable/unethical *vis-a-vis* animal subjects in this research proposal. The proposed research work is, therefore awarded ethical clearance.

Sarmah 14/12/2019

(JATIN SARMAH)
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ANNEXURE-III

List of publications

Daimari M, Roy MK, Swargiary A, Baruah S, Basumatary S (2019) An ethnobotanical survey of antidiabetic medicinal plants used by the Bodo tribe of Kokrajhar district, Assam. Indian Journal of Traditional knowledge

Daimari M, Swargiary A (2020) Study of phytochemical content and antioxidant properties of Musa balbisiana corm extract. Indian Journal of Pharmaceutical Science, 82(4): 707-712.

Swargiary A, **Daimari M** (2020) Identification of bioactive compounds by GC-MS and α-amylase and α-glucosidase inhibitory activity of *Rauvolfia tetraphylla* L. and *Oroxylum indicum* (L.) Kurz: an in vitro and in silico approach. Clinical Phytoscience, 6 (2020): 1-11.

Swargiary A, Verma A K, Singh S, Roy M K, **Daimari M** (2021) Antioxidant and antiproliferative activity of selected medicinal plants of lower Assam, India: An in vitro and in silico study. Anti-Cancer Agents in Medicinal Chemistry (Formerly Current Medicinal Chemistry-Anti-Cancer Agents), 21(2): 267-277.

Swargiary A, **Daimari M** (2021) GC–MS analysis of phytocompounds and antihyperglycemic property of *Hydrocotyle sibthorpioides* Lam. SN Applied Sciences 3 (1): 36.

Swargiary A, **Daimari M** (2022) Identification of major compounds and α-amylase and α-glucosidase inhibitory activity of rhizome of *Musa balbisiana* Colla: An in-vitro and in-silico study. Combinatorial Chemistry & High Throughput Screening 25(1): 139-148.

Swargiary A, Roy MK, **Daimari M** (2022) Gas Chromatography-Mass Spectrometry Analysis and Antihyperglycemic Property of *Lindernia crustacea* (L.) F. Muell. Indian Journal of Pharmaceutical Sciences, 84(3).

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An ethnobotanical survey of antidiabetic medicinal plants used by the Bodo tribe of Kokrajhar district, Assam

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Diabetes mellitus (DM) belongs to the group of diseases causing major health problems in India and world at large. Natural products including medicinal plants are known to treat various diseases worldwide since ancient times. It is well known that plants are a great source of bioactive compounds having tremendous medicinal properties and can be used to discover plant-based drugs with lesser side effects. A survey was carried out among the Bodo community of Kokrajhar district of Assam to explore the traditional knowledge on medicinal plants against diabetes using semi-structured interviews among the local healers and elderly people. A total of 54 informants were interviewed in a face-to-face manner following readymade questionnaire, of which 15 healers were known to have knowledge regarding antidiabetic medicinal plants. A total of 37 medicinal plants, belonging to 24 families and 33 genera were found to be used by traditional healers of Kokrajhar district to cure diabetes. The mostly cited plant was found to be *Hodgsonia heteroclita* (Roxb.) followed by *Andrographis paniculata* (Burm. f.) Nees. Out of the 24 families, Apocynaceae was found to be the most popular plant family with four numbers of plants.

Keywords: Antidiabetic, Bodo tribe, Ethnomedicine, Kokrajhar
IPC Code: Int. Cl.[19]: A61P 3/10, A61K 36/00, A61K 36/185, A61K 36/00

The world is fertile with natural and medicinal plants. Medicinal plants continue to be an important therapeutic aid for alleviating ailments of mankind[1]. Approximately 80% of the people in the developing countries rely on traditionally used medicinal plants for their primary health care needs[2]. Plants have always been an exemplary source of drugs since ancient times. Many of the currently available drugs have been derived directly or indirectly from plant source[3]. Plants are a rich source of bioactive compounds (secondary metabolites) and are of great value for developing novel therapeutic agents[4]. Since ancient times, plants and its derivatives have been traditionally used as medicine for the treatment of various diseases. Many plants such as *Tylophora indica*, *Dioscorea bulbifera* etc. are used for the treatment of common health problem such as asthma, piles, dysentery, etc[5].

DM is a metabolic disorder characterized by hyperglycemia resulting from defects in either insulin secretion or insulin resistance or both[1]. There are two major forms of diabetes- Type-1 (insulin-dependent DM) and Type-2 (noninsulin-dependent DM). Type-I DM occurs when the human immune system destroys pancreatic β-cells, which are responsible for secreting insulin. Insulin concentration can efficiently be managed through continuous injection in timely dosages. Elevated post-prandial blood glucose levels are widely recognized as one of the earliest disease markers in the prediction of subsequent microvascular and macrovascular complications that can progress to full symptomatic Type-2 Diabetes (T2DM). Type-2 DM accounts for about 90% of the diabetic cases and typically begins as insulin resistance until the pancreas slowly loses its ability to produce insulin[6]. Globally, an estimated of 422 million adults were living with diabetes in 2014, rising from 4.7% to 8.5% in adult population[7]. It is the most common and very prevalent disease affecting the citizens of both developed and developing countries all around the world. It is estimated 25% of the world's population is currently being affected by this disease[8]. Currently available therapy for diabetes and the use of orthodox drugs in the management of DM

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Study of Phytochemical Content and Antioxidant Properties of *Musa Balbisiana* Corm Extract

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***Musa balbisiana* colla is an important plant native to India and many other Asian countries. Parts of this plant such as seeds, fruit pulp, inflorescence, pseudo-stem, and corm have been known to possess several medicinal values. In Kokrajhar district of Assam, the decoction of corm part of the plant is traditionally used as antidiabetic medicine. The present study was aimed to investigate the phytochemicals, antioxidants, trace element, and major compounds of the corm part of *Musa balbisiana*. Phenolic and flavonoid contents were estimated following standard protocols. The antioxidant activity of the plant was studied by ferric reducing antioxidant power assay, total antioxidant capacity, 1,1-diphenyl-2-picryl-hydrazyl, and lipid peroxidation scavenging assay. The phytochemical study revealed that the corm extract is rich in protein, carbohydrates, phenolics, and flavonoid content. Antioxidant study revealed strong free radical scavenging property of the crude corm extract of *Musa balbisiana*. The elemental analysis showed highest Zn content (0.2993 ppm) followed by Ni, Cu, and Mn. Pb, Cd, and Cr were not detected in the extract. GC-MS analysis showed difluroisocyanotophosphine to be the major compound of *Musa balbisiana* corm extract**

Key words: Phytochemicals, antioxidants, trace elements, gc-ms, musa balbisiana, kokrajhar

Natural products play an important role in the treatment of various diseases and drug discovery processes. Plants have been used in ethnomedicine system since ancient times to cure many diseases including diabetes[1]. Many therapeutically active plants are known to be used in the preparation of herbal medicine. Plants are rich sources of pharmacologically active substances which can be helpful in designing therapeutically active medicines for treating various ailments. Phytochemical content such as phenols or their oxygen substituted derivatives such as tannins while some may contain nitrogen or sulfur that are biologically active and useful for

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ORIGINAL CONTRIBUTION Open Access

Identification of bioactive compounds by GC-MS and α-amylase and α-glucosidase inhibitory activity of *Rauvolfia tetraphylla* L. and *Oroxylum indicum* (L.) Kurz: an in vitro and in silico approach

Ananta Swargiary* and Manita Daimari

Abstract

Background: The practice of ethnomedicine remains to be the primary source of healthcare in many parts of the world, especially among the tribal communities. However, there is a lack of scientific outlook and investigation to authenticate and validate their medicinal values.

Objective: The present study investigated the trace and heavy metal content, bioactive compounds, α-amylase, and α-glucosidase inhibitory activity of *Rauvolfia tetraphylla* and *Oroxylum indicum* using in vitro and in silico methods.

Methods: Trace and heavy metal content of *Rauvolfia tetraphylla* and *Oroxylum indicum* were detected using Atomic Absorption Spectroscopy. Bioactive compounds were analyzed and identified by the GC-MS technique. α-Amylase and α-glucosidase inhibitory activity of the plants were studied using the spectrophotometric method using UV/VIS-Spectrophotometer. In silico molecular docking was carried out in AutoDock vina and the structures visualized using PyMol and Biovia Discovery Studio software. Statistical and graphical representations were performed using Excel and OriginPro.

Results: The trace and heavy metallic content such as Zn, Ni, Pb, Cr, Cu, and Mn were reported from both the plant. No Cd was detected in both the plants. GC-MS analysis revealed four major compounds in *R. tetraphylla* and seven in *O. indicum*. Biochemical studies showed that the leaf extract of *O. indicum* posses the strongest α-amylase and α-glucosidase inhibitory activity. *R. tetraphylla* showed weaker enzyme inhibition. Molecular docking study revealed that three compounds from *O. indicum* (O2, O3, and O6) and two from *R. tetraphylla* (R1 and R2) showed strong binding affinity to α-amylase and α-glucosidase. However, leaf extract of *O. indicum* showed better binding affinity with the enzymes compared to *R. tetraphylla*.

Conclusion: Inhibition of α-amylase and α-glucosidase in an important strategy of diabetes control. The present study revealed the in vitro α-amylase and α-glucosidase inhibitory activity of *Rauvolfia tetraphylla* and *Oroxylum indicum*. In conclusion, the study identified that the leaf extract of *O. indicum* as a potential inhibitor of glucose metabolizing enzymes and could be a source of antidiabetic agents.

Keywords: α-Amylase, α-Glucosidase, *Rauvolfia tetraphylla*, *Oroxylum indicum*, GC-MS, Docking

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Research Article

GC–MS analysis of phytocompounds and antihyperglycemic property of *Hydrocotyle sibthorpioides* Lam.

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Abstract
Hydrocotyle sibthorpioides Lam. is a popular medicinal plant of Assam having several ethnomedicinal values. The present study investigated the metallic content, phytochemical contents, α-amylase, and α-glucosidase enzymes inhibitory property of *H. sibthorpioides* using in-vitro and in-silico methods. Heavy metal contents were analyzed using Atomic Absorption Spectroscopy. GC–MS was used to analyze the phytochemical compounds of the plant. Enzyme inhibition study was carried out by Spectrophotometry methods. The drug-likeness and toxicity properties of the phytocompounds were studied using SwissADME and ADMETlab databases. Docking and molecular visualizations were performed in AutoDock vina and Discovery studio tools. The study found that the extract of *H. sibthorpioides* contains a negligible amount of toxic elements. GC–MS analysis detected four compounds from the methanolic extract of the plant. Biochemical study showed considerable α-amylase and α-glucosidase enzyme inhibitory property of the crude extract of *H. sibthorpioides*. The IC_{50} of the plant extracts were found to be 1.27 mg/ml and 430.39 µg/ml for α-amylase and α-glucosidase enzymes, respectively. All four compounds were predicted to have potential drug-likeness properties with high cell membrane permeability, intestinal absorption, and less toxic effects. The docking study also showed strong binding affinities between the plant compounds and enzymes. Plant compound C2 showed an almost similar binding affinity with the α-amylase enzyme as compared to standard acarbose. The present study, thus, suggests the antihyperglycemic property of *H. sibthorpioides* and can be a potential source of antidiabetic drug candidates.

Keywords *Hydrocotyle sibthorpioides* Lam. · α-Amylase · α-Glucosidase · GC–MS · Docking

1 Introduction

Type-2 diabetes (T2D) is a metabolic disorder characterized by high blood glucose leading to several complications including cardiovascular and kidney-related diseases [1, 2]. According to the WHO report, about 422 million people worldwide have diabetes and about 1.6 million deaths were directly or indirectly caused by diabetes in 2016, making it the seventh leading cause of death globally [3]. There are several control measures to T2D including dietary changes, exercise, and medications. In recent years, there is a growing interest in the dietary and plant-based therapeutic approaches to maintain normal blood glucose levels [4]. Inhibition of carbohydrate metabolizing enzymes is one of the most important chemotherapeutic targets of diabetes treatment. α-Amylase and α-glucosidase enzymes are two of the major carbohydrate metabolizing enzymes inhibition of which slows down the carbohydrate digestion and reduces the rate of glucose absorption, and thus decreases the postprandial plasma glucose level [5].

Plants have been the source of medicines since ancient times. Several modern drugs of present-day use are either directly or indirectly derived from plant sources. Phytomedicines or plant-derived compounds are safer, cheaper, easily available, and sometimes more

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Research Paper

Gas Chromatography-Mass Spectrometry Analysis and Antihyperglycemic Property of *Lindernia crustacea* (L.) F. Muell.

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***Lindernia crustacea* (L.) F. Muell is a small herbaceous plant with several ethnomedicinal values. The present study investigated the phytochemical content and alpha-amylase and alpha-glucosidase inhibitory property of *Lindernia crustacea*. Methanolic crude extract of plant was obtained following the Soxhlet method. The crude extract was studied for alpha-amylase and alpha-glucosidase inhibitory activity. Phytochemical analysis was carried out using the gas chromatography-mass spectrometry technique. Furthermore, docking study was carried out with the phytocompounds to see the binding affinity with the enzymes. *In silico* drug-likeness and pharmacological properties were also carried out using Swiss absorption, distribution, metabolism and excretion, and absorption, distribution, metabolism, excretion and toxicity lab tools. The plant extracts showed concentration-dependent inhibition of enzyme activities with half-maximal inhibitory concentration values of 3.11 mg/ml and 548.9 µg/ml for alpha-amylase and alpha-glucosidase, respectively. Gas chromatography-mass spectrometry study identified ten phytocompounds with molecular weights ranging from 264.4 to 561 g/mol. Docking study showed 1-(4-Hydroxybenzoyl)-6,7-dimethoxyisoquinoline as the best binding compound with the enzymes. Phytocompounds identified from *Lindernia crustacea* were predicted to have substantial drug-likeness and absorption, distribution, metabolism, excretion and toxicity properties. The enzyme inhibition study and binding interactions of phytocompounds suggest promising alpha-amylase and alpha-glucosidase inhibitory activity of *Lindernia crustacea*. Therefore, the aerial part of *Lindernia crustacea* may be further investigated to know the exact mode of biological actions.**

Key words: *Lindernia crustacea*, alpha-amylase, alpha-glucosidase, docking, drug-likeness

Type-2 Diabetes (T2D) is a major health problem of the contemporary world affecting millions of people. According to World Health Organization (WHO), globally, about 422 million people had diabetes in 2014, with about 1.6 million deaths, most of them are from low and middle-income countries[1]. International Diabetes Federation estimated about 578 million adults with diabetes by 2030 and 700 million by 2045[2]. South-East Asia, including India, Sri Lanka and Bangladesh, accounted for more than 70 million cases of diabetes in 2013 and is expected to reach up to 135 million by 2035[3]. There are many reasons for diabetes, including abnormal insulin secretion by pancreatic cells, insulin resistance or both[4,5]. Influenced by both genetic and environmental factors, T2D is a multifactorial disorder. Today, several medications are used to lower the blood glucose level and diabetes management[6,7]. Inhibition of carbohydrate-hydrolyzing enzyme is one of the most important therapeutic approaches in diabetes management. Human alpha (α)-amylase (EC 3.2.1.1) and α-glucosidase (EC 3.2.1.20) are two crucial enzymes that catalyze the release of glucose from polysaccharides[8]. Inhibition of these enzymes, therefore, reduces blood glucose levels in the body[9]. However, the use of antidiabetic drugs is reported to have undesirable effects[7]. Plants and plant products have several medicinal values and have been used as medicines since ancient times[10-12]. Plant-derived medicines are safer, cheaper and sometimes more effective than synthetic drugs. In recent times, several plants have been investigated for their antidiabetic and antihyperglycemic properties[13,14].

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RESEARCH ARTICLE

Antioxidant and Antiproliferative Activity of Selected Medicinal Plants of Lower Assam, India: An *In Vitro* and *In Silico* Study

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Abstract: ***Background*:** The use of medicinal plants for general wellbeing and disease treatment is a common practice among tribal communities of Kokrajhar districts of Assam. However, little works have been done to study the pharmacological aspect of the plants.

***Objectives*:** The present study intends to study the antioxidant and antiproliferative properties of selected medicinal plants used by the tribal communities of the Kokrajhar district of Assam since ancient times.

***Methods*:** Five traditionally important medicinal plants, namely, *Cassia fistula, Citrus grandis, Lindernia crustacea, Sacciolepis myosuroides,* and *Zingiber zerumbet* were investigated for antioxidant, antiproliferative (cytotoxic) and apoptosis-inducing potential in the malignant cancer cell line. Phytochemical content, such as phenolic and flavonoid content, were estimated following standard protocol. The methanolic extract of plants was investigated following the phosphomolybdate method (TAC), FRAP, DPPH, ABTS, and TBARS assays. Antiproliferative activities of the plants were carried out by MTT assay in DL and PBMC cells. The apoptotic study was carried out following the acridine orange and ethidium bromide staining method and fluorescent microscopic imaging. Based on the significant ($P \leq 0.05$) high apoptotic inducing potential of the plant and to further dissect the molecular mode of action, including downstream biological action, major phytochemicals derived from *L. crustacea* were investigated for its prospective binding affinity with anti-apoptotic cancer target proteins.

***Results*:** Antioxidant studies by FRAP, DPPH, ABTS, and TBARS assay revealed that all five plants contain considerable free radical scavenging activity. *C. fistula* showed the strongest free radical scavenging activity while the fruit peel extract of *C. grandis* showed poor activity. The overall antioxidant activities of plants such as TAC, FRAP, DPPH, ABTS, and TBARS may be arranged in decreasing activity as *C. fistula* > *Z. zerumbet* > *L. crustacea* > *S. myosuroides* > *C. grandis*. MTT based cell proliferation study showed that all the plants extract significantly ($P \leq 0.05$) inhibited cell viability with negligible cytotoxicity (~5-12%) in normal cells. Moreover, *L. crustacea* showed promising antiproliferative and apoptosis-inducing ability against Dalton's lymphoma. It is worth mentioning that the major bioactive compounds of the most potent plant extract, *L. crustacea* interacted with anti-apoptotic proteins (cancer target) with *higher affinity* and the results are compared with reference inhibitors.

***Conclusion*:** It is worth noting that these plants have the potential to consider for further scientific studies in different cell lines and animal models. Furthermore, isolation and characterization of bioactive compound(s) may promise the discovery of new and valuable drugs candidate to tackle various human diseases.

Keyword: Antioxidant, antiproliferative, apoptosis, docking, ethnomedicine, Kokrajhar.

1. INTRODUCTION

The use of medicinal plants against diseases is an ancient practice which, in recent times, has fascinated the global attraction towards plant-based drug discovery. Many modern drugs (about 50%) of today's healthcare sector are directly or indirectly derived from the plant source. According to the World Health Organisation, about 80% of the population living in tropical and sub-tropical countries still rely on traditional medicines (TM) as the primary source of health care [1]. The rich natural phytochemicals and secondary metabolites of plants are known to provide relief to many diseases including malaria, jaundice, wound healing, inflammation, bacterial, cancer, diabetes, helminthiasis, and many other viral infections [2, 3]. Scientific studies revealed that there are about 2.5 lakh species of flowering plants globally, out of which merely 6% are screened for their pharmacological activity [4]. The use of chemically synthesized medicines is the common practice of disease treatment for many decades. However, the side effects of prescribed drugs, host resistance against the drugs, high costs as well as limited availability to the rural areas have empowered the researchers to look into alternative medicines that are eco-friendly, cost-effective, and readily available to everyone. TM system acts as an eye-opener in this regard and the only source of medicinal information, giving plenty of opportunities to the humankind to investigate and design new therapeutic drugs.

The state of Assam is the gateway to north-east India and is endowed with rich flora and fauna. Ethnic groups of this region have been practicing TM system since ancient times. Living far

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Identification of Major Compounds and α-Amylase and α-Glucosidase Inhibitory Activity of Rhizome of *Musa balbisiana* Colla: An *In-vitro* and *in-silico* Study

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Abstract: ***Background*:** α-Amylase and α-glucosidase inhibitors are widely used to suppress postprandial glycemia in the treatment of type 2 diabetes.

***Objectives*:** To evaluate the metallic content, major phytoconstituents, and α-amylase and α-glucosidase inhibitory activity of *Musa balbisiana* rhizome using *in-vitro* and *in-silico* methods.

***Materials and Methods*:** Heavy metal content was detected by AAS following standard protocol. Major phytochemicals of the plant were analysed by GC-MS technique. Enzyme inhibition study was carried out by UV/VIS spectrophotometric methods. The druglikeness and bioavailability properties of major compounds were carried out using computer-aided tools – SwissADME and ADMElab. Docking and visualization were performed in AutoDock vina and Discovery studio tools.

***Results*:** The study found that the fruits of *M. balbisiana* contain negligible amount toxic elements. GC-MS analysis showed five major compounds from the rhizome of *M. balbisiana*. *In-vitro* enzyme assays revealed strong α-amylase and α-glucosidase inhibitory property of the plant. All the five compounds were predicted to have druglikeness property with high cell membrane permeability and bioavailability. The compounds were also predicted to have low to moderate toxicity property. The Docking study showed strong binding affinities of plant compounds with α-amylase and α-glucosidase. Out of five compounds, C5 showed best binding affinity with active pockets of α-amylase and α-glucosidase.

***Conclusion*:** The present *in-vitro* and *in-silico* study suggests the antihyperglycemic property of the rhizome of *Musa balbisiana* and possible candidate for therapeutic antidiabetic agent(s).

Keywords: *Musa balbisiana*, rhizome, α-amylase, α-glucosidase, docking, ADMET

1. INTRODUCTION

Diabetes is one of the most prevalent and a major endocrine disorder characterized by high blood glucose level leading serious complications to heart, blood vessels, eyes, kidneys, and nerves [1]. Today, it is one of the most common non-communicable

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ADDITIONAL WORKS:

1. Swargiary A, Roy MK, **Daimari M** (2019) Survey and documentation of ethnobotanicals used in the traditional medicines system of tribal communities of Chirang district of Assam against helminthiasis. Biomedical and Pharmacology Journal 12 (4): 1923-1935.
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Survey and Documentation of Ethnobotanicals used in the Traditional Medicines System of Tribal Communities of Chirang District of Assam Against Helminthiasis

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Abstract

Ethnobotanical knowledge has been the backbone of rural healthcare since ancient times. Many diseases including helminthiasis are cured by traditional medicine in many parts of the world. The present study aims at exploring the ethnobotanicals used as anthelmintic medicines by the tribal communities of Chirang district of Assam. The present study was conducted in different villages under Chirang district of Assam, India. A face-to-face interview was carried out during survey work along with readymade questionnaire. In our survey work, 20 neighbouring villages were taken as a single cluster and one sample informant was collected. Information regarding the plant and plant parts used, methodology of use as well as informant demography such as age, sex, education was also collected. A total of 20 villages were surveyed and information was gathered from 27 informants, 23 kaviraja and 4 elderly people, 15 male and 12 female. The information collected revealed 43

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Survey and documentation of putative anthelmintic plants used in ethnomedicinal systems of tribal communities of Baksa District of Assam

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Abstract

The use of ethnomedicine system is a common practice to the people of Assam for curing common ailments. The present study aimed at documenting the plants used by the tribal communities of Baksa district of Assam against helminthiasis. Survey was carried out in different villages of Baksa district in a face-to-face interview manner with the help of readymade questionnaire. Informer's bio-data, plants local names, parts used, mode of formulation etc. were recorded. A total of 26 villages were surveyed and 27 informants were interviewed. We found that most of the informants were illiterate and aged but have rich ethnomedicine knowledge. To cure helminth infection, 70 plants belonging to 58 genera and 39 families were reported to be used. To study the importance and popularity of the plants, Frequency of Citations (FC), Relative FC and Family importance value (FIV) were calculated. *Andrographis paniculata* was the most common plant followed by *Ananas comosus*, *Hydrocotyle asiatica*, *H. sibthorpioides*, and *Azadirachta indica*. Family Acanthaceae was having the highest FIV value followed by Apiaceae, Araliaceae, Bromeliaceae, Apocynaceae and Maliaceae. Leaves were seen to be the most common parts used in traditional herbal preparations and were mostly consumed orally as raw material.

Top

Keywords

Ethnomedicine, anthelmintic, tribal community, Baksa district, Assam.

Top

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Evaluation of phytochemical properties and larvicidal activities of *Cynodon dactylon*, *Clerodendrum viscosum*, *Spilanthes acmella* and *Terminalia chebula* against *Aedes aegypti*

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ABSTRACT

Objective: To investigate the phytochemical, antioxidant and larvicidal property of *Cynodon dactylon*, *Clerodendrum viscosum*, *Spilanthes acmella* and *Terminalia chebula* against *Aedes aegypti*.

Methods: Antioxidant capacity of methanolic extract of the plants was studied by 2,2-Diphenyl-1-picryl-hydrazyl-hydrate (DPPH) assay, ferric reducing antioxidant power assay, 2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonate) assay (ABTS), thiobarbituric acid reactive substance (TBARS) assay, superoxide anion scavenging activity and total antioxidant activity assay following standard protocol. Total phenolic content, total flavonoid content, carbohydrate, and plant protein were also estimated following standard protocols. Larvicidal property of plant extracts were determined following World Health Organization standard protocol. Additionally, glutathione-s-transferase (GST) and acetylcholinesterase (AchE) inhibitory property was also tested biochemically.

Results: Phytochemically, high protein, carbohydrate and phenolic were found in *Terminalia chebula*, while *Cynodon dactylon* showed high flavonoid contents. Similarly, high antioxidant activity was found in *Terminalia chebula* with IC_{50} values at 13.7, 2.9, 45.2 and 46.0 μg/mL in DPPH, ABTS, TBARS and superoxide anion scavenging activity, respectively. Larvicidal study showed strongest activity in *Spilanthes acmella* followed by *Cynodon dactylon*, and *Clerodendrum viscosum* and *Terminalia chebula*. GST and AchE of *Aedes aegypti* larvae showed reduced enzyme activity when pre-incubated with *Cynadon dactylon* and *Spilanthes acmella*.

Conclusions: The methanolic crude extracts of *Cynodon dactylon*, *Clerodendrum viscosum*, *Spilanthes acmella* and *Terminalia chebula* possess strong antioxidant and larvicidal property against *Aedes aegypti* and therefore, may be further investigated for the molecular mode of action.

1. Introduction

Mosquito borne diseases (MBD) such as malaria, dengue, *etc*. are among the major health problems that account more than 17% of all the infectious diseases causing millions of death globally[1]. Dengue is among the most common MDBs causing huge economic losses. According to World Health Organization, more than 3.9 billion people from over 128 countries are at risk of dengue infection. With about 100 million cases, dengue virus is the most

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Survey and documentation of anthelmintic plants used in traditional medicine system of tribal communities of Udalguri district of Assam, India

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Key words:
Anthelmintic, ethnomedicine, traditional healer, Udalguri, Assam.

ABSTRACT

The present study was aimed to survey and document the anthelmintic medicinal plants traditionally used by the tribal communities of Udalguri district of Assam. The survey was conducted in different villages of the district following a face-to-face interview and a readymade questionnaire. The study found that a total of 75 plant species belonging to 67 genera and 44 plant families were used as deworming agents. The result showed that *Andrographis paniculata*, *Ananas comosus*, *Hydrocotyle sibthorpioides*, and *Centella asiatica* were the most popular plant species. Acanthaceae family was found to be most common among the traditional healers. The leaves were found to be commonly used plant parts for herbal preparation. Decoction, infusion, and raw preparations were found to be the most commonly used traditional formulation methodologies. The present study could be used to identify the potential anthelmintic plants and in designing new anthelmintic drug having better property and efficacy.

INTRODUCTION

Nature has always been an exemplary source of drugs since ancient times. Medicinal plants continued to be an important therapeutic aid for alleviating ailments of human kind. Ethnobotanical studies are often significant in revealing locally important plant species, especially for the discovery of crude drugs (Muthee *et al*., 2015). Ethnomedicinal survey of medicinal plants used by traditional medicinal practitioners can form a rich source of data for knowledge about medicinal plants and the ailments for which they are used. Scientists have often found that the herbs themselves, which possess unique combinations of chemical components, are more effective than the chemical derivatives (Shikov *et al*., 2014). Many developing countries like India rely on plants-based products for treating various diseases, including helminth infection. Medicinal plants are a viable source of parasiticides (Wangchuk *et al*., 2016). India is a country based on agriculture, and livestock play a significant role for the farmers. The infection with helminthes is still a big problem mainly due to warm temperatures, in association with poor management practices and inadequate control measures (Akhtar *et al*., 2000). The main goal of present study was the documentation of anthelmintic plants used in traditional medicine system of tribal communities of Udalguri district of Assam, India.

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METHODS AND MATERIALS

Study area and its description

The present study was carried out in different villages under Udalguri district of Assam. Geographically, it covers an area of 1,852.16 sq. km. According to the 2011 Census report of India, Udalguri district has 802 villages (791 human inhabited and 11 uninhabited) and population size of 832,769, more than 95% living in the rural areas.

Data collection and identification of plant samples

The survey was done during the months of May to November, 2018 and information regarding the anthelmintic plants traditionally used by tribal communities of Udalguri district was collected. The information was collected from different community development block (CDB) with the help

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Simeprevir and Eltrombopag as Potential Inhibitors of SARS-CoV2 Proteases: A Molecular Docking and Virtual Screening Approach to Combat COVID-19

Ananta Swargiary, AKALESH Verma, Manita Daimari, Mritunjoy Kumar Roy

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The present study investigates the binding affinities of 61 FDA approved drugs against two key proteases of SARS-COV2, 3-chymotrypsin-like protease and papain-like protease. We also investigates the ADMET properties of the top 10 besting binding drugs to understand the drug likeness property.

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Study of phytochemical content, antioxidant and larvicidal property of different solvent extracts of *Clerodendrum infortunatum* and *Citrus grandis*

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The present study was carried out to investigate the phytochemical, antioxidant and larvicidal property of different solvent extracts of leaves of *Clerodendrum infortunatum* and fruit peel of *Citrus grandis*. The antioxidant property was studied by ferric reducing antioxidant power (FRAP), total antioxidant capacity (TAC), 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonate) (ABTS) and thiobarbituric acid reactive species (TBARS) assays. The total phenolic and flavonoid contents of the extracts were estimated following standard protocols. Larvicidal activity of the plant extracts were evaluated following standard WHO protocol. In a series of test doses (100 to 2000 µg/mL), 20 numbers of *Aedes aegypti* larvae were exposed and the mortality was recorded after 24 h and LC_{50} were calculated. The study showed that the *C. grandis* extracts have better phytochemical, antioxidant and larvicidal activity compared to *C. infortunatum*. Among the four solvent fractions, diethyl ether extract showed higher activity in both the plants. The present study thus showed potential larvicidal property of the plants against *A. aegypti*. However, further characterization and identification of active compound (s) need to be carried out to study the exact mode of action.

Keywords: Antioxidant, *Aedes aegypti*, *Clerodendrum infortunatum*, *Citrus grandis*, Larvicidal activity
IPC Code: Int Cl.[21]: A61K 9/00, A61K 8/97, A61K 36/752, A01H 5/10

Mosquitoes are one of the most important insects that are involved in the transmission of many diseases. Today, there are about 3500 known species of mosquitoes globally with highest density in tropical and sub-tropical countries[1]. Major vector-borne diseases (VBD) such as malaria, dengue, chikungunya, yellow fever, etc. are transmitted from one infected person to the other by mosquitoes[2,3]. Along with malaria and others vector-borne diseases, dengue is one of the major VBDs causing huge economy losses. According to WHO, dengue causes an estimate of about 390 million infections every year worldwide out of which 2.5% of the people die[4]. *Aedes aegypti* (L.) belonging to the Family *Culicidae* is a vector for the transmission of dengue fever which is endemic to many countries including Asia, Africa and America[2]. Over the last few years, there is an increasing trend of dengue cases in India spreading the length and breadth of the country because of drastic climatic changes, urbanization, inadequate vector control measures, mass migration and most importantly the insecticide resistance capacity developed by *Aedes* mosquitoes. The use of commercial insecticides such as organochlorines, organophosphates, pyrethroids, or carbamates has been the most common mosquito control strategy since long time. However, repeated exposure to same insecticides has developed insecticide resistance capacity in many mosquito populations[5]. Moreover, the use of commercial insecticides has several side-effects and imposes serious threat not only to the human health but also to the ecosystem. Like many other mosquito vectors, the development of insecticide resistance has also been reported by many researchers in *A. aegypti* mosquitoes[1,3].

Plants have been used as medicines since ancient times in many parts of the world. Because of its rich bioactive compounds and lesser side-effects there is a growing attention for plant-derived medicines throughout the world. Many researchers have showed potential larvicidal activities of several plant extracts and isolated complounds[6,7]. North East India is one of the biodiversity hotspots of the world with rich in flora and fauna. The use of medicinal plants for curing common health problems has been the tradition of many ethnic groups of NE India. The

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Putative Anthelmintic Plants Used in Traditional Medicine System of Kokrajhar District, India

Ananta Swargiary*, Manita Daimari and Mritunjoy Kumar Roy

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Ethnobotany Research & Applications 22:10 (2021)

Research

Abstract

Background: Traditional medicine (TM) is a common practice among tribal communities of India. The present study has been designed to collect the ethnomedicinal plants used by the Bodo community of Kokrajhar district of India traditionally consumed to cure helminth infection.

Methods: A total of 54 villages were surveyed from the Kokrajhar district. Twenty adjacent villages were taken as a cluster, and one informant was interviewed face-to-face with the help of a readymade questionnaire. Traditional knowledge system of anthelmintic herbal medicines such as the name of the plants, parts used, methods of formulation, and mode of uses was collected. The demography of the informants was also collected.

Results: Total of 64 species of traditionally used anthelmintic plants belonging to 38 families were documented from Kokrajhar district, India. *Andrographis paniculata* was the most popular plant, followed by *Alstonia scholaris*, *Ananas comosus*, and *Azadirachta indica*. Poaceae was the most popular plant family with six species of anthelmintic plants. The leaves were the most commonly used plant-part (63%), followed by barks and tubers. Raw, decoction and infusion were the standard method of traditional formulations reported from the district. Fresh and raw plant parts in the form of paste or balls and oral consumption were the primary means of administration. Demographically, most of the knowledge bearers were found to be illiterate and aged above 50 years of age.

Conclusions: The medicinal plants reported in the present study could be a source of important medicines. A proper scientific study needs to be carried out to study the efficacy of the traditional formulations to ascertain their bioactivity.

Keywords: Ethnomedicine, Anthelmintic, Tribal Community, Kokrajhar

Background

The traditional use of plants and animals as medicines to cure diseases is an age-old practice throughout the world. Ethnomedicinal knowledge systems are transferred from one generation to the next without any formal means of communication (Samy & Ignacimuthu 2000; Verpoorte *et al.* 2005; Vitalini *et al.* 2013). Despite better healthcare facilities of the contemporary world, there is growing attention towards plant-derived compounds and their biological properties. According to the WHO Traditional Medicinal Strategy 2014-23 (WHO 2013), there is a rising

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Phytochemical analysis, antiproliferative and apoptosis-inducing properties of *Persicaria strigosa* Nakai

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Persicaria strigosa, antiproliferative, anti-apoptosis, GC-MS, docking, drug-likeness, ADMET.

ABSTRACT

Persicaria strigosa is an important medicinal plant having several ethnomedicinal values. This study investigated the phytochemical contents, antiproliferative, and apoptosis-inducing properties of *P. strigosa*. The phytocompounds were identified by the Gas Chromatography Mass Spectrometry (GC-MS) technique. Antiproliferative and apoptosis-inducing properties were conducted in Dalton's lymphoma cells. *In-silico* molecular docking, drug-likeness, and absorption, distribution, metabolism, excretion, and toxicity (ADMET) were carried out to study the binding affinity and drug-likeness of the compounds. The study revealed a dose-dependent antiproliferative activity of the plant. GC-MS study identified 12 compounds from the ethyl acetate extract. Phytompounds **C2**, **C5**, **C6**, **C7**, and **C12** showed the best binding affinity with the anti-apoptotic proteins. The phytocompounds were predicted to possess drug-likeness properties and a good ADMET profile. The findings suggest that *P. strigosa* could be a potential source of anticancer agents.

INTRODUCTION

Cancer is a terrible disease that can start in any body organ from an abnormal genome function leading to the proliferation of cells at inappropriate times and locations. Cells acquire mutations that abolish the regulation of cell division and multiply continuously, forming tumors and invading new body parts (Weinberg, 2015). According to WHO, about 18.1 million cancer patients worldwide and about 10 million deaths in 2020 are due to cancer. Today, one of the six deaths is due to cancer, the second-largest killer in the world (https://www.who.int/news-room/fact-sheets/detail/cancer). Despite significant improvements in healthcare facilities, the cancer burden grows to cause tremendous financial strain to the human populace. At the same time, poor accessibility of quality medicines, high cost, off-the-target drug resistance, and the severity of the side effects remain significant challenges to successful cancer treatment. Exploring new anticancer compounds from plants and other biological sources could be a good choice. Plant-derived compounds are readily available, possess lesser side effects, and are sometimes more efficacious than the existing drugs (Atanasov *et al*., 2015).

Plant and plant-derived compounds serve as a promising source of medicine for several diseases (Basu *et al*., 2020; Fahad *et al*., 2021; Swargiary and Daimari, 2021). Since ancient times, searching for natural medicines from plants and organisms has remained an essential aspect of drug discovery. Today, about 60% of the approved anticancer drugs are directly or indirectly derived from plant sources (Fridlender *et al*., 2015). Several phytocompounds, such as paclitaxel, etoposide, camptothecin, vinblastine, vincristine, uvaribonin, 22-epicalamistrin, etc. are plant-derived natural products with considerable anticancer activity (Cragg *et al*., 2009; Pettit *et al*., 2008). *Persicaria strigosa* (R.Br.) Nakai belonging to the family Polygonaceae is a creeping herb that grows well in marshy places. Stems are greenish-brown

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Identification of phytocompounds as potent inhibitors of sodium/glucose cotransporter-2 leading to diabetes treatment

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ABSTRACT

Type-II diabetes, a major metabolic disorder has threatened the very existence of a healthy life since long ago. Commercially available antidiabetic drugs are known for several adverse effects. The present study attempted to identify potential phytocompounds as inhibitors of sodium/glucose cotransporter-2 (SGLT2), a major protein that helps in glucose re-absorption from renal tubules. A total of 28 phytocompounds were collected based on the literature survey. 3D co-ordinates of phytocompounds were collected from PubChem database. Molecular docking was carried out with SGLT2 protein and the best 3 docking complexes were subjected to molecular dynamics simulation for 100 ns. Free energy changes were also analyzed using MM/PBSA analysis. Phytocompounds were also analyzed for their drug-likeness and ADMET properties. Docking study observed a strong binding affinity of phytocompounds (> −7.0 kcal/mol). More than 10 phytocompounds showed better binding affinity compared to reference drugs. Further analysis of three best docking complexes when analyzed by MD simulation showed better stability and compactness of the complexes compared to reference drug, empagliflozin. MM/PBSA analysis also revealed that van der Waals force and electrostatic energy are the major binding energy involved in the complex formation. Like docking energy, free energy analysis also observed stronger binding energies (ΔGGAS) in SGLT2-phytocompound complexes compared to empagliflozin complex. All the phytocompounds showed drug-likeness and considerable ADMET properties. The study, therefore, suggests that Trifolirhizin-6′-monoacetate, Aspalathin, and Quercetin-3-glucoside could be a possible inhibitor of SGLT2 protein. However, further studies need to be carried out to reveal the exact mode of activity.

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KEYWORDS
Diabetes; phytocompounds; sodium/glucose cotransporter-2; docking; molecular dynamics simulation; ADMET

1. Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by abnormal regulation of carbohydrates, proteins, and lipids metabolism leading to the impairment in insulin regulation or loss of function of pancreatic β-cells (Mul et al., 2015; Szkudelski & Szkudelska, 2019). Today, DM is the 9th leading cause of death affecting over 537 million people worldwide, and is predicted to rise to 645 million by 2030 (IDF, 2021; Zheng et al., 2018). Increasing blood glucose level or hyperglycemia is the main symptom of diabetes, which when left untreated causes various micro- and macrovascular complications (Beckman & Creager, 2016). The treatment regime of diabetes mainly depends on the use of insulin, the most commonly used medicine. However, the use of insulin is not always far from side effects, especially hypoglycemia, diabetic nephropathy, or cardiovascular diseases (Herman et al., 2017; Jingi et al., 2017; Søndergaard et al., 2023). Currently, there are several antihyperglycemic drugs in the market which is classified as biguanide, α-glucosidase inhibitors, sulfonylureas, thiazolidinediones, glucagon-like peptide-1 (GLP-1) analogs, GLP-1 receptor agonists, inhibitors of dipeptidyl peptidase 4 (DPP-4), sodium/glucose transporter-2 (SGLT2), etc. (Neumiller et al., 2017; Rosenzweig & Sampson, 2021). Biguanides act on gluconeogenesis by inhibiting the expression of gluconeogenic enzymes and thereby decreasing liver-glucose production (Hunter et al., 2018). α-Glucosidase enzymes are present in the jejunum of the small intestine and are responsible for breaking down carbohydrates into glucose. Inhibition of α-glucosidase decreases the plasma glucose concentration (Lebovitz, 1997). Sulfonylurea is a class of drugs that helps release insulin by acting on ATP-sensitive K-channel. Thiazolidinediones increase insulin sensitivity, decrease hepatic gluconeogenesis, and increase insulin-dependent glucose uptake in muscle and fat (Eggleton & Jialal, 2019; Gor et al., 2020). GLP-1 acts as an incretin hormone that stimulates the release of insulin from the pancreas (Shaefer et al., 2015). DPP-4 is another important multifunctional protein that is known for its catalytic activity. An important glucose homeostasis hormone known as incretin hormone; GLP-1 is cleaved by the DPP-4 molecule thereby inactivating GLP-1. Inactivation of GLP-1 decreases insulin secretion resulting in elevated blood glucose levels. DPP4 inhibitors stabilize GLP-1, which induces

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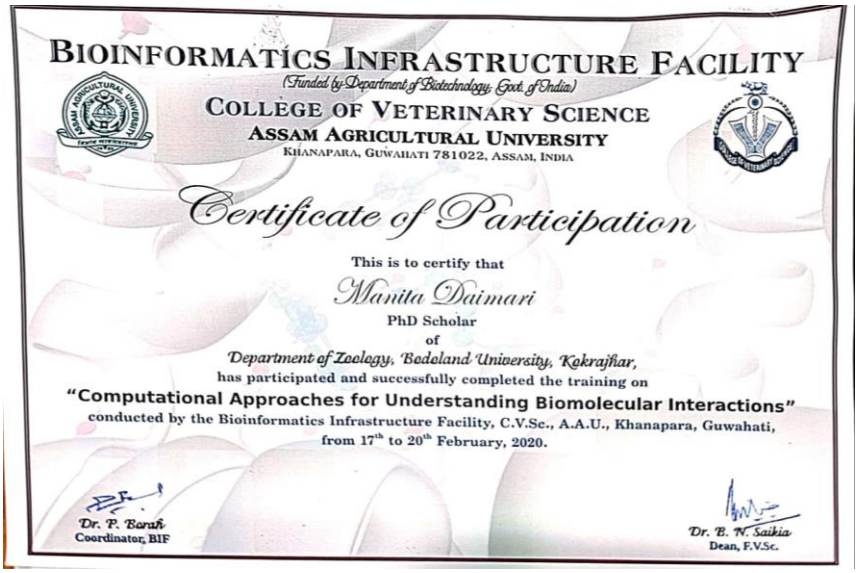
ANNEXURE-IV

WORKSHOPS AND SEMINARS

1. 5 days workshop on '**Computational approaches for understanding Biomolecular interactions**' Conducted by Bioinformatics infrastructure facility, College of Veterinary Science Assam Agricultural University, Khanapara, Guwahati, from 17th to 20th February, 2020.
2. Oral presentation on '**Survey and documentation of traditionally used medicinal plants of Kokrajhar district Assam'** at National Seminar on Advances in Aquaculture and Biodiversity (NSAAB-19) organised by Department of Zoology, Gauhati University 28th and 29th November, 2019
3. Oral presentation on **Phytochemical analysis and free radical scavenging properties of *Phlogacanthus tubiflorus* Nees'** at National Conference on Science & Technology for sustainable development' organised by Science College Kokrajhar, held on 9th and 10th September, 2022.



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Certificate of Participation

This is to certify that

Manita Daimari

PhD Scholar

of

Department of Zoology, Bodoland University, Kokrajhar,

has participated and successfully completed the training on

"Computational Approaches for Understanding Biomolecular Interactions"

conducted by the Bioinformatics Infrastructure Facility, C.V.Sc., A.A.U., Khanapara, Guwahati,

from 17th to 20th February, 2020.

Dr. P. Barah
Coordinator, BIF

Dr. B. N. Saikia
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This is to certify that Prof./Dr/Mr./Ms. Manita Daimari of Deptt. of Zoology, Bodoland University has participated / presented a paper entitled "Survey, documentation district of Assam, India" in the UGC-Sponsored "National Seminar on Advances in Aquaculture & Biodiversity (NSAAB-2019)" under SAP (DRS-III) program at the Department of Zoology, Gauhati University, Guwahati held on 28th and 29th November, 2019.

(Prof. Prasanta Kumar Saikia)
Head, Department of Zoology
&
Chairperson, NSAAB-2019

(Prof. Dandadhar Sarma)
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Certificate of Presentation

This is to certify that

Miss. Manita Daimari

of

Bodoland University, Kokrajhar

has presented a paper entitled "*Phytochemical analysis and free radical scavenging properties of Phlogacanthus tubiflorus Nees*" in the National Conference on "Science & Technology for Sustainable Development (STSD-2022)" held on 9th-10th September, 2022 at Science College, Kokrajhar, Assam, India.

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An ethnobotanical survey of antidiabetic medicinal plants used by the Bodo tribe of Kokrajhar district

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An ethnobotanical survey of antidiabetic medicinal plants used by the Bodo tribe of Kokrajhar district, Assam

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Diabetes mellitus (DM) belongs to the group of diseases causing major health problems in India and world at large. Natural products including medicinal plants are known to treat various diseases worldwide since ancient times. It is well known that plants are a great source of bioactive compounds having tremendous medicinal properties and can be used to discover plant-based drugs with lesser side effects. A survey was carried out among the Bodo community of Kokrajhar district of Assam to explore the traditional knowledge on medicinal plants against diabetes using semi-structured interviews among the local healers and elderly people. A total of 54 informants were interviewed in a face-to-face manner following readymade questionnaire, of which 15 healers were known to have knowledge regarding antidiabetic medicinal plants. A total of 37 medicinal plants, belonging to 24 families and 33 genera were found to be used by traditional healers of Kokrajhar district to cure diabetes. The mostly cited plant was found to be *Hodgsonia heteroclita* (Roxb.) followed by *Andrographis paniculata* (Burm. f.) Nees. Out of the 24 families, Apocynaceae was found to be the most popular plant family with four numbers of plants.

Keywords: Antidiabetic, Bodo tribe, Ethnomedicine, Kokrajhar
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The world is fertile with natural and medicinal plants. Medicinal plants continue to be an important therapeutic aid for alleviating ailments of mankind[1]. Approximately 80% of the people in the developing countries rely on traditionally used medicinal plants for their primary health care needs[2]. Plants have always been an exemplary source of drugs since ancient times. Many of the currently available drugs have been derived directly or indirectly from plant source[3]. Plants are a rich source of bioactive compounds (secondary metabolites) and are of great value for developing novel therapeutic agents[4]. Since ancient times, plants and its derivatives have been traditionally used as medicine for the treatment of various diseases. Many plants such as *Tylophora indica*, *Dioscorea bulbifera* etc. are used for the treatment of common health problem such as asthma, piles, dysentery, etc[5].

DM is a metabolic disorder characterized by hyperglycemia resulting from defects in either insulin secretion or insulin resistance or both[1]. There are two major forms of diabetes- Type-1 (insulin-dependent DM) and Type-2 (noninsulin-dependent DM). Type-I DM occurs when the human immune system destroys pancreatic β-cells, which are responsible for secreting insulin. Insulin concentration can efficiently be managed through continuous injection in timely dosages. Elevated post-prandial blood glucose levels are widely recognized as one of the earliest disease markers in the prediction of subsequent microvascular and macrovascular complications that can progress to full symptomatic Type-2 Diabetes (T2DM). Type-2 DM accounts for about 90% of the diabetic cases and typically begins as insulin resistance until the pancreas slowly loses its ability to produce insulin[6]. Globally, an estimated of 422 million adults were living with diabetes in 2014, rising from 4.7% to 8.5% in adult population[7]. It is the most common and very prevalent disease affecting the citizens of both developed and developing countries all around the world. It is estimated 25% of the world's population is currently being affected by this disease[8]. Currently available therapy for diabetes and the use of orthodox drugs in the management of DM

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has not improved the situation but are reported to produce serious adverse side effects such as liver problems, lactic acidosis and diarrhoea. Plants are well known in traditional medicine for their hypoglycaemic activities. Available literature indicates that there are more than 800 plants species showing hypoglycaemic activity[9]. There has been increasing demand for the use of plant products with antidiabetic activity due to low cost, easy availability and lesser side effects[1]. Currently medicinal plants continue to play an important role in the management of diabetes milletus. Recently, the World Health Organization (WHO) recommended the use of medicinal plants for the management of DM and further encouraged the expansion of the frontiers of scientific evaluation of the hypoglycaemic properties of diverse plant species[10].

North east India is blessed with rich flora and fauna. The favourable climate condition in this part of India, provide various endemic plants and animals to sustain their lives, making it the biodiversity hot spot area. It comprises of eight states viz; Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. Bodoland Territorial Council (BTC) consist of areas located in extreme north of north bank of river Brahmaputra in the state of Assam, at the foothills of Bhutan and Arunachal Pradesh. It is the gateway to the north eastern region of India, which was created in February, 2003 by curving eight districts out of Assam namely Kokrajhar, Dhubri, Bongaigaon, Barpeta, Nalbari, Kamrup, Darrang and Sonitpur within the state of Assam. Geographically, it covers an area of 8,795 sq. km (provisional) that includes Bodoland Territorial Area Districts administered by the BTC, an autonomous administrative unit constituted under the sixth schedule of constitution[11]. This part of India is full of medicinal plants. Several medicinal plants are traditionally being used as medicines against many diseases. Although a large number of plants are used as medicine, no scientific work has been carried out comprehensively in this part of India. Keeping this view in mind, the present study has been designed to study the medicinal plants traditionally being used as antihyperglycemic agent by the Bodo people of Kokrajhar district of Assam.

Materials and methods

A survey was carried out in Kokrajhar district which is predominantly inhabited by the Bodo tribe, and covers an area of 3169.22 km^2, geographical location of 89˚46' East to 90˚38' East and 26˚19' North to 26˚54'North. It is located in the extreme north of the river Brahmaputra, and is rich in various flora and fauna. For administrative purpose, the district is divided into 11 Community Development Blocks (CDBs) and has a total of 1068 villages, of which 15 is uninhabited forest villages. The names of CDBs are: (1) Kachugaon, (2) Gossaigaon, (3) Hatidhura, (4) Dotma, (5) Kokrajhar, (6) Golakganj, (7) Rupsi, (8) Debitola, (9) Mahamaya, (10) Bilasipara and (11) Chappar-Salkocha.

The survey was done from the month of April to October 2018. The demographic data and information about the medicinal plants was collected with the help of local healers and elderly people having knowledge about medicinal plants. Within every CDB, approximately 20 adjacent villages were taken as single cluster and one sample is collected from a cluster. The information was collected via the administration of semi-structured interviews with the help of ready-made questionnaire. The information collected from informants included informer's bio-data, name of the plant, parts used, traditional formulation processes and mode of administration. A total of 54 traditional healers were interviewed from different villages of Kokrajhar district but only 15 informants were found to have knowledge regarding medicinal plants used for the treatment of diabetes. The medicinal plants mentioned by the herbalist were photograph and collected for identification. Herbarium sheets were prepared and submitted to the Department of Botany, Bodoland University, the identification numbers were collected and the voucher specimen were preserved.

Data analysis

All the statistical calculations, graphs etc. were carried out in Microsoft excel and Origin software. The documented data was analysed by comparing a number of parameters such as number of plant species, families, plant part used, modes of utilization, habit and habitat of the plant species.

Results and discussion

In the present study 54 local healers were interviewed from 54 different villages of 11 CDBs under Kokrajhar district. However, only 15 informants were found to possess ethnomedicinal knowledge regarding the antidiabetic medicinal plants

as well as other common diseases. Out of the 15 informants, 11 were male and 4 were female. The names of the CDBs, Informant's villages and their geographical locations are given below in Table 1. Out of the 15 informants, the highest numbers of informants were recorded from Kokrajhar CDB followed by Dotma and Gossaigaon. Fig. 1 represents the different locations of information collection sites. Regarding literacy, it is found that most of the informants (40%) were having school level education, while 33.3% have college level education, and 20% has no formal education at all (Table 2). Similarly, many such ethnomedicinal survey reports have revealed that traditional knowledge bearers are always illiterate, poor and rural based livelihood[63,64]. Regarding the ethnomedicinal knowledge literate

Table 1 — List of villages where antidiabetic medicinal plants were collected along with the geographical location

Sl no	C.D. Block	List of villages	Geographical location
1.	Chapar- Salkocha	Borghola	26°17'04.23″N 90°18'20.32″E
2.	Dotma	Baoraguri	26°27'07.21″N90°08'36.27″E
3.		Dotma Bazar	26°28'06.81″N 90°09'02.61″E
4.		Narenguri	26°29'19.30″N 90°05'23.74″E
5.	Kachugaon	Karikhar FV	26°32'47.01″N 90°03'35.05″E
6.		Kumtola FV	26°33'06.04″N 90°02'55.13″E
7.	Kokrajhar	Chilaguri	26°28'35.26″N 90°12'04.06″E
8.		Mahendrapur	26°36'09.86″N 90°14'24.07″E
9.		Mawriagaon-II	26°27'04.83″N 90°08'40.14″E
10.		Pakhriguri	26°31'00.58″N 90°14'32.44″E
11.		Sutharpara	26°29'36.69″N 90°20'38.95″E
12.	Gossaigaon	Banglabari	26°39'90.55″N 90°03'27.32″E
13.		Gossaigaon-I	26°42'84.87″N 89°99'98.33″E
14		Singimari-II	26°36'04.09″N 89°99'01.02″E
15	Debitola	Kazigaon Pt.-I	26°19'21.79″N 89°99'46.81″E

*Part (Pt.) means some villages of Debitola CDB comes under Dhubri district and some under Kokrajhar district and the villages that come under Kokrajhar district is written as 'Part'. FV - forest village.

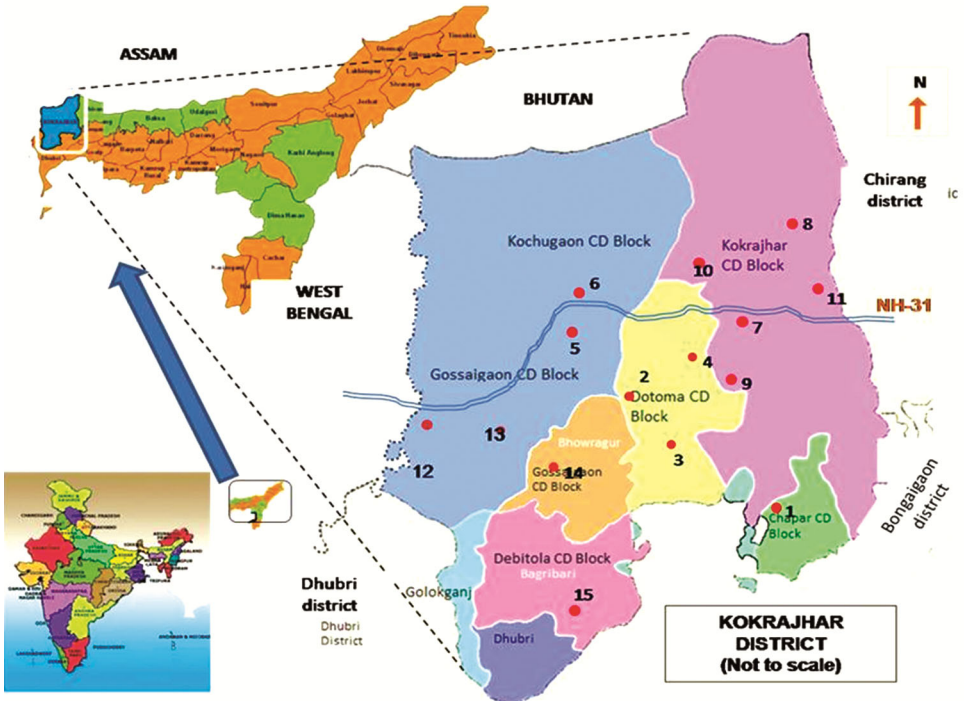

Fig. 1 — Map showing geographical locations of informants of 11 CDB of Kokrajhar district

traditional healers were found to possess move information (4.8 plant citations/informants) than illiterates (2.3 plant citations/informants). All the informants were local healers, who had been practicing traditional medicine system since long times. It has also been found that most of the knowledge about the medicinal plants has been passed onto them by their parents or grandparents or some relatives who had a vast knowledge about the diseases and its cure. The names of the plant species, its local names as well as the traditional formulation methods is shown in Table 3. Our survey revealed that 37 species of medicinal plants belonging to 24 families and 33 genera are found to be used for the treatment of diabetes. Our survey also found that, most of the plants cited by the local healers are locally available,

Table 2 — Demographic characteristics of informants of Kokrajhar district CDBs

Block	School	College	Illiterate
Chapar-Salkhocha	1	-	-
Dotma	2	1	-
Debitola	1	-	1
Gossaigaon	1	1	1
Kokrajhar	1	3	-
Kachugaon	1	-	1
Total	**7**	**5**	**3**

Table 3 — Name of the plants, parts used, traditional formulation and habit of plants

Sl. No.	Scientific Name & Voucher Number	Family	Local Name (Bodo)	Parts Used	Preparation	Habit	References
1.	*Tinospora cordifolia* (Willd.) Meirs [BUBH2018024]	Menispermaceae	amar lotha	stem, leaves	decoction	climber	Yes[12-14]
2.	*Phyllanthus emblica* L. [BUBH2018023]	Euphorbiaceae	amla	fruit	raw	tree	Yes[15,16]
3.	*Terminalia arjuna* (Roxb. Ex DC.) Wigt & Arn [BUBH2018066]	Combretaceae	arjun	bark	infusion	tree	Yes[17,18]
4.	*Musa balbisiana* Colla [BUBH2018067]	Musaceae	athia thalir	aerial stem	decoction	shrub	No
5.	*Phlogacanthus tubiflorus* Nees [BUBH2018028]	Acanthaceae	basikhor	flower	decoction	shrub	NO
6.	*Aegle marmelos* (L.) Corrêa [BUBH2018068]	Rutaceae	bell	leaves	decoction	tree	Yes[19-21]
7.	*Terminalia bellirica* (Gaertn.) Roxb. [BUBH2018069]	Combretaceae	bhaora	fruit	raw	tree	Yes[15,22]
8.	*Paspalum fimbriatum* Kunth [BUBH2018070]	Poaceae	dapsa	whole plant	decoction	herb	No
9.	*Syzygium jambos* (L.) Alston [BUBH2018071]	Myrtaceae	godjaam	tender leaves	raw	tree	Yes[23]
10.	*Calotropis gigantea* (L.) R. Br. ex Schult. [BUBH2018072]	Apocynaceae	gogondo	leaves	decoction	shrub	Yes[24,25]
11.	*Rosa alba* L. [BUBH2018073]	Rosaceae	golabgufur	flower	infusion	shrub	No
12.	*Syzygium cumini* (L.) Skeels BUBH2018074]	Myrtaceae	gwswm jamboo	seed	infusion	tree	Yes[26-28]
13.	*Hodgsonia heteroclita* (Roxb.) Hook.f. & Thomson [BUBH2018075]	Cucurbitaceae	hagrani jwgwnar	fruit	decoction	climber	Yes[29]
14.	*Artocarpus heterophyllus* Lam. [BUBH2018076]	Moraceae	khanthal	leaves	infusion	tree	Yes[30-32]
15.	*Ficus racemosa* L. [BUBH2018077]	Moraceae	dumburu	fruit	decoction	tree	No
16.	*Alpinia galanga* (L.) Willd. [BUBH2018078]	Zingiberaceae	jermao	tuber	raw	herb	Yes[33]
17.	*Andrographis paniculata* (Burm.f.) Nees [BUBH2018009]	Acanthaceae	kalmith	leaves	decoction	herb	No
18.	*Oroxylum indicum* (L.) Kurz [BUBH2018012]	Bignoniaceae	Kharong khandai	leaves	decoction	tree	No

(*Contd.*)

Table 3 — Name of the plants, parts used, traditional formulation and habit of plants (*Contd*.)

Sl. No.	Scientific Name & Voucher Number	Family	Local Name (Bodo)	Parts Used	Preparation	Habit	References
19.	*Rauvolfia tetraphylla* L. [BUBH2018013]	Apocynaceae	kharwkha	root	decoction	shrub	No
20.	*Syzygium aromaticum* (L.) Merr. &L.M.Perry [BUBH20180079]	Myrtaceae	long	flower bud	decoction	tree	Yes[34-36]
21.	*Centella asiatica* (L.) Urb. [BUBH2018020]	Apiaceae	manimuni gidir	leaf	decoction	herb	Yes[37-39]
22.	*Hydrocotyle sibthorpioides* Lam. [BUBH2018019]	Apiaceae	manimuni fisa	whole plant	decoction	herb	No
23.	*Trigonella foenum-graecum* L. [BUBH2018080]	Fabaceae	methi	seed	infusion	herb	Yes[40-42]
24.	*Clerodendrum infortunatum* L. [BUBH2018047]	Lamiaceae	mwkhwna	tender leaf	decoction	shrub	No
25.	*Lindernia crustacea* (L.) F. Muell. [BUBH2018048]	Linderniaceae	na bikhi	whole plant	decoction	herb	No
26.	*Azadirachta indica* A. Juss. [BUBH2018051]	Meliaceae	neem	leaf	raw	tree	Yes[43-45]
27.	*Asparagus racemosus* Willd. [BUBH2018063]	Asparagaceae	nilikhor	roots	decoction	climber	Yes[46,47]
28.	*Catharanthus roseus* var. *albus* G. Don [BUBH2018081]	Apocynaceae	parboti	flower, leaves	decoction	herb	Yes[48]
29.	*Bryophyllum pinnatum* (Lam.) Oken [BUBH2018057]	Crassulaceae	path gaja	leaf	infusion	herb	Yes[49]
30.	*Ficus religiosa* L. [BUBH2018082]	Moraceae	phakhri	leaves	decoction	tree	Yes[50-52]
31.	*Nelumbo nucifera* Gaertn. [BUBH2018083]	Nelumbonaceae	podophul	stem	infusion	herb	Yes[53,54]
32.	*Terminalia chebula* Retz. **[BUBH2018062]**	Combretaceae	selekha	fruit	raw	tree	Yes[55-57]
33.	*Nyctanthes arbor-tristis* L. **[BUBH2018084]**	Oleaceae	sewali	flower	decoction	tree	Yes[58]
34.	*Piper longum* L. [BUBH2018085]	Piperaceae	simfri	fruit	raw	climber	Yes[59]
35.	*Alstonia scholaris* (L.) R. Br. **[BUBH2018040]**	Apocynaceae	sithona	bark	infusion	tree	No
36.	*Ocimum tenuiflorum* L. **[BUBH2018045]**	Lamiaceae	tulsi	roots	decoction	herb	No
37.	*Momordica charantia* L. [BUBH2018086]	Cucurbitaceae	udasi	tender leaf, fruit	decoction	climber	Yes[60-62]

some are wild, and some plants had been grown by them for easy availability as well as to conserve the valuable medicinal plants. Furthermore, on being asked about the plant availability, they also added that most of the plants which were available several years ago are now found to be decreased in their numbers. This shows the decrease of valuable medicinal plants.

The most cited plant families was seen to be Apocynaceae (16.6%), followed by Moraceae, Combretaceae and Myrtaceae (12.5%), Cucurbitaceae, Acanthaceae, Apiaceae and Lamiaceae (8.3%). The most highly cited plant life forms are found to be a big tree (40.54%) followed by herbs (29.72%), shrubs (16.21%) and climbers (13.51%). *H. heteroclita* was found to be the most popular plant with 6 numbers of citations followed by *A. paniculata* (5 citations) and *R. tetraphylla* (3 citations). Out of the 37 reported plant species, 26 numbers of plant species have been mentioned once by the informers (Fig. 2). The most common plant part used in the preparation of traditional medicine was found to be leaves (51.35%), followed by fruit (16.21%), flowers (13.50%), roots

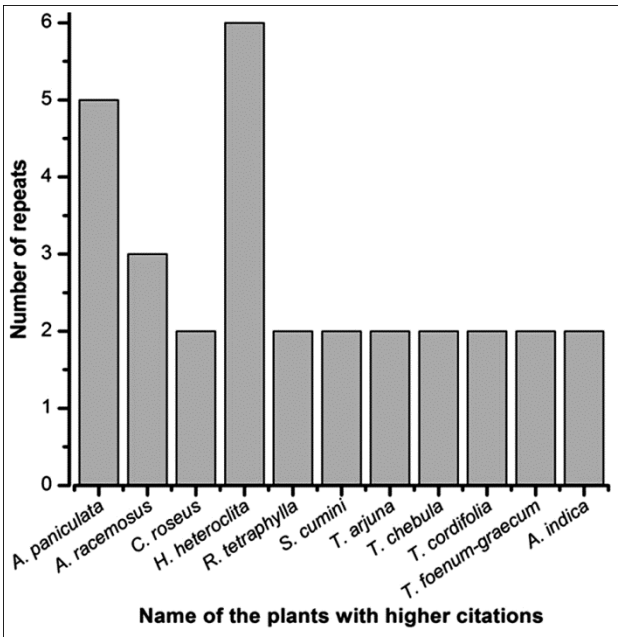

Fig. 2 — List of plants and citations by traditional healers

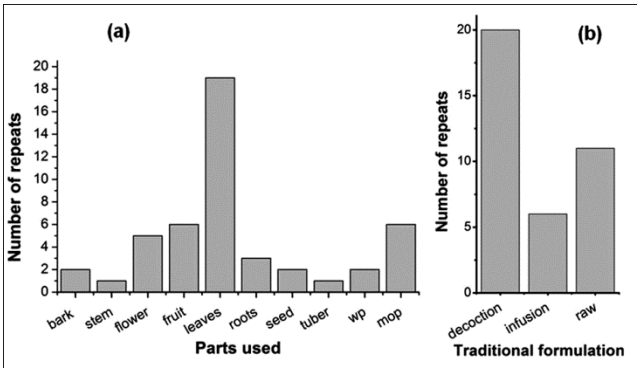

Fig. 3 a) — frequency of plant parts used during preparation of herbal medicines and b) traditional formulations adopted by the traditional healers in the preparation of herbal remedies. mop-more than one part, wp-whole plant

(8.10%), bark (5.40%), seed (5.40%), stem (2.70%) and tuber (2.70%) (Fig. 3a). In two plants, namely *H. sibthorpioides,* and *L. crustacea,* the whole plant was found to be used. Similar to our finding, leaves has been found to be the mostly used parts for preparation of herbal remedies in many other studies[65,66]. It has come into our observation that out of 37 plant species, in 6% of the plants more than one part is used for the preparation of traditional medicine. *Nelumbo nucifera* is the most common plant where leaves, rhizome and stem are used.

Decoction, infusion and raw preparations were found to be the common traditional herbal formulation practices among the traditional healers of Kokrajhar district of Assam. Based on the method of preparation, our survey found that decoction (54.05%) is the mostly used method adopted by the traditional healers. Similar to our study, many ethnomedicinal survey reports also reported decoction being the mostly used method for preparation of herbal medicines[67]. Fig. 3b showed the various ethnomedicine preparations practiced by traditional healers. We have also performed a literature survey for all the plants cited by the traditional healers and found that 62.16% of the plants have one or more literature regarding antidiabetic property. However, 37.83% of the plants and the parts cited by the traditional healers were found to have no scientific literature on antidiabetic property. Similar to our study, an ethnobotanical survey was carried out in Nalbari district of Assam which revealed 35 species of plants belonging to 28 families which are used to cure diabetes and most of them are consumed in the form of raw juice[68]. In another study, Tarak *et al.*[69] surveyed and collected the ethnomedicinal information on antidiabetic medicinal plants of Dhemaji district showing the use of 21 plant species belonging to 20 families to cure diabetes. The traditional healers of Unakoti district of Tripura were also found to use 39 medicinal plant species belonging to 37 genera and 28 families for diabetes treatment[70].

Conclusion

The medicinal plant plays an important role in the treatment of Diabetes among the Bodo community of Kokrajhar district, Assam. Out of total 37 reported plants, 13 plants were found to have no scientific literature regarding the antidiabetic activity. *Andrographis paniculata* and *Rauvolfia tetraphylla*, although popularly used for diabetes cure in Kokrajhar district, there is no report of any experimental validation from India in favor of their antidiabetic activity. However, few literatures are available from outside of India. Most of the plants cited the traditional healers possesses scientific validation about antidiabetic property and therefore, the importance and significance of ethnomedicinal knowledge practiced since time immemorial cannot be ruled out. Traditional healers although do not have any scientific experimental methodology, but they do have some kind of experimentation by which diseases are cured. With the increase in urbanisation and mass deforestation, there is a rapid loss of many important medicinal plants. In addition to it, the blooming modern healthcare facilities have overshadowed the ethnomedicinal practice leading to the deterioration of

traditional knowledge. The present study will be helpful, to protect the ancient and traditional ethnomedicinal knowledge of Bodo community and also to preserve and transfer the knowledge to the next generations for the development of effective herbal remedies in the near future.

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Study of Phytochemical Content and Antioxidant Properties of *Musa Balbisiana* Corm Extract

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Daimari *et al.*: Phytochemical investigation of *Musa balbisiana* corm extract

***Musa balbisiana* colla is an important plant native to India and many other Asian countries. Parts of this plant such as seeds, fruit pulp, inflorescence, pseudo-stem, and corm have been known to possess several medicinal values. In Kokrajhar district of Assam, the decoction of corm part of the plant is traditionally used as antidiabetic medicine. The present study was aimed to investigate the phytochemicals, antioxidants, trace element, and major compounds of the corm part of *Musa balbisiana*. Phenolic and flavonoid contents were estimated following standard protocols. The antioxidant activity of the plant was studied by ferric reducing antioxidant power assay, total antioxidant capacity, 1,1-diphenyl-2-picryl-hydrazyl, and lipid peroxidation scavenging assay. The phytochemical study revealed that the corm extract is rich in protein, carbohydrates, phenolics, and flavonoid content. Antioxidant study revealed strong free radical scavenging property of the crude corm extract of *Musa balbisiana*. The elemental analysis showed highest Zn content (0.2993 ppm) followed by Ni, Cu, and Mn. Pb, Cd, and Cr were not detected in the extract. GC-MS analysis showed difluroisocyanotophosphine to be the major compound of *Musa balbisiana* corm extract**

Key words: Phytochemicals, antioxidants, trace elements, gc-ms, musa balbisiana, kokrajhar

Natural products play an important role in the treatment of various diseases and drug discovery processes. Plants have been used in ethnomedicine system since ancient times to cure many diseases including diabetes[1]. Many therapeutically active plants are known to be used in the preparation of herbal medicine. Plants are rich sources of pharmacologically active substances which can be helpful in designing therapeutically active medicines for treating various ailments. Phytochemical content such as phenols or their oxygen substituted derivatives such as tannins while some may contain nitrogen or sulfur that are biologically active and useful for

the treatment of diseases and preserve well-being in humans and animals[2]. It is estimated that about 70-80% population of tropical countries rely on medicinal plant as the source of medicine, and the tendency to use ethnomedicine is also gradually increasing in other developed countries because of its healthy effects[3]. In many developing countries like India, several plants and its derivatives have been used traditionally for the treatment of many diseases[4,5]. The state of Assam is one of the 29th states of India blessed with rich flora and fauna. With the geographical location 89°50/ E to 96°10/ E and 24°30/ N to 28°10/ N Assam state is one among the richest biodiversity zones of North-East India[6]. Most of the people, especially ethnic tribal groups living in this state perform various traditional health-care practices and rely on traditional medicines as the primary source of healthcare needs. According to World Health Organisation (WHO), the use of traditional herbal medicine has spread not only in the developing countries but also in the industrialized ones, as a complementary way to treat and prevent illness[7]. Natural products could be a potential source of drugs for humans or livestock, and also the products and their analogs can act as intermediates for the synthesis of useful drugs[8]. Plant possesses many phytochemicals with various bioactivities including antioxidant, anti-inflammatory, anticancer, antiviral, antidiabetic, anthelmintic, etc[9-11]. *Musa balbisiana* colla belonging to the family Musaceae is an important monocotyledonous herb having several religious and medicinal values[12]. Among the different varieties of Musa species, *M. balbisiana* is native to India and has been utilized as folk medicine since ancient times[13]. Various parts of this plant are reported to be used for the treatment of diseases including diabetes, diarrhea, scabies, helminthiasis, stomach problem, and inflammation[14]. Several studies have reported the pharmacological properties of different parts of *M. balbisiana*. However, we did not find any literature regarding the corm extract of the plant. Therefore, the present study has been designed to study the phytochemical profile and antioxidant activities of *Musa balbisiana* corm extract. Sample plant was collected from Kokrajhar district of Assam and identified in the department of Botany, Bodoland University. The sample plant was identified as *Musa balbisiana* Colla and the identification number is BUBH2018067.

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The corm parts of *M. balbisiana* were collected from Kokrajhar district of Assam with the help of local people. The plant part was brought to the laboratory and washed with distilled water and dried in hot air oven below 50° and processed for preparation of crude extract. Dried plant parts were ground into powdered form and soaked into 80% methanol. Solution was filtered after 72 hrs of soaking and fresh solvent was added. The process was repeated three times and the filtrate obtained was evaporated in a rotary evaporator. Dry, semi-solid *M. balbisiana* methanolic extract (MBME) obtained was kept at -20º for further use. The process was followed as per the method described in our earlier publication[6].

The protein content of the plant extract was estimated following the Lowry method[15]. The presence of total carbohydrate content in MBME was estimated following the Anthrone method[16]. The total phenolic content (TPC) was estimated using Folin-Ciocalteu reagent[17]. The amount of TPC was calculated from a calibration curve of gallic acid and results were expressed as µg gallic acid equivalent (GAE)/mg plant extract. The total flavonoid content (TFC) was determined following the method of Ordonez *et al.*[18]. TFC was calculated from the standard curve of quercetin, and the values were expressed as µg quercetin equivalent (QE)/mg plant extract.

The total antioxidant capacity (TAC) of MBME was done by phosphomolybdate method using ammonium molybdate[19]. The reaction mixture was incubated at 95° for 30 min and absorbance measured at 695 nm against a blank solution. TAC was expressed as µg ascorbic acid equivalent (AAE)/mg plant extract.

Ferric reducing antioxidant power assay (FRAP) was performed following the method of Iloki-Assanga *et al*[20]. The FRAP activity of MBME was compared with the standard ascorbic acid and values were expressed as µg Fe^{2+} equivalent (FE)/mg plant extract. The 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging activity of MBME was estimated using DPPH as described by Mamta *et al.*[21]. Lipid peroxidation

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inhibitory activity was studied following the modified thiobarbituric acid reactive species (TBARS) assay to measure the lipid peroxide formation using egg yolk homogenates as lipid-rich media[22]. The colouration of the assay mixture was measured at 532 nm. ~~2~~*The 2,2'-Azinobis-(3-ethylbenzothiazoline-6-sulfonate) (ABTS) free radical scavenging activity of MBME was* measured following the method of Re *et al*[23] using gallic acid as the standard reference. Seven elements such as lead (Pb), chromium (Cr), nickel (Ni), cadmium (Cd), copper (Cu), manganese (Mn), and zinc (Zn) were analyzed using Atomic Absorption Spectroscopy (AAS) following the method of Zheljazkov and Nielson with slight modification[24]. Briefly, 1 g of plant powder was digested with concentrated HNO_3 at 90º for 45 min. The temperature is then slowly increased up to 100º and boiled for 6-7 h by the addition of HNO_3 till complete digestion. The process was continued till the solution became colourless and the end volume was maintained at 10 ml. The solution was then diluted to 100 ml of distilled water and then filtered using Whatman filter no. 1. The solution was then analysed for trace elements at AAS, Shimadzu AA-7000. The chemical composition of MBME was determined using the GC-MS system (TQ-8030 Shimadzu Corporation Kyoto, Japan) as described by Kalita *et al.*[12]. All the statistical calculations were carried out in Microsoft excel. IC_{50} (concentration of plant extract at 50% inhibition of activity) values were calculated using SPSS software. Correlation study and figures were drawn using OriginPro software. All the experiments were represented with mean ± standard deviation (SD). Statistical significance was calculated at P≤0.05 level.

Medicinal plants are rich sources of phytochemicals and secondary metabolites. In the present study, phytochemical content of methanolic crude extract of *M. balbisiana* corm was analyzed. Fig. 1 showed the moisture content, crude extract obtained, phenolic, and flavonoid content of MBME. The plant part (corm) was found to contain high moisture content (75.30%) while the crude extract obtained was only 2.35% after three rounds of extraction process. The methanolic extract of corm was found to contain high protein content (79.65±1.22 µg/mg extract) while the carbohydrate content was found to be almost half of the protein (43.9±3.13 µg/mg extract). Statistical analysis showed significant difference (at P≤0.05 level) between the protein and carbohydrate content of *M. balbisiana.* MBME also showed considerable amount of phenolic and flavonoid content. *M. balbisiana*

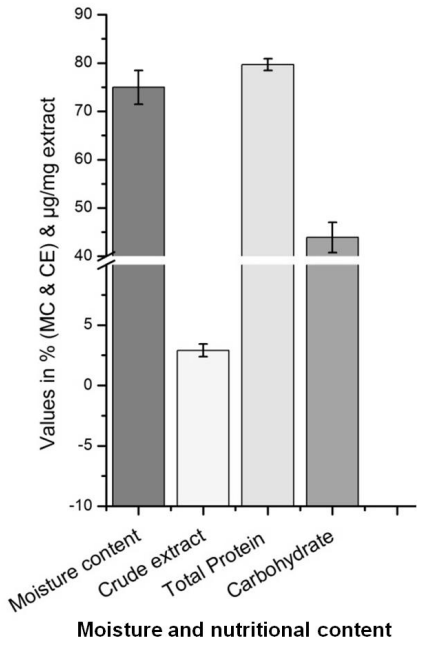

Fig. 1: Moisture content (MC), crude extract (CE) and phytochemical contents of *Musa balbisiana*. MC and CE were represented as percentage (%) of moisture per 100 g plant and % of methanolic extract obtained per 100 g of dry plant powder. Values were represented as mean ± SD.

corm extract showed higher TPC content than TFC. The TPC and TFC were found to be 10.93±1.71 µgGAE/mg and 4.72±0.33 µgQE/mg plant extract, respectively. Similarly, the TAC and FRAP activity was found to be 24.43±2.42 µgAAE/mg extract and 87.69±3.27 µg FeE/mg extract, respectively (fig. 2a). The methanolic crude extract of *M. balbisiana* was found to possess strong free radical scavenging activity. The IC_{50} values for DPPH, ABTS, and TBARS assays were found to be 287±17.45 µg/ml, 102.89±4.16 µg/ml, and 60.11±0.86 µg/ml, respectively. The standard reference chemical showed 3.64±0.365 µg/ml, 1.76±0.05 µg/ml, and 37.65±0.91 µg/ml for DPPH, ABTS, and TBARS antioxidant assays, respectively (fig. 2b). Fig. 3 showed the metallic content of the methanolic crude extract of *M. balbisiana*. A total of seven trace elements were analysed out of which Zn was found to be in highest concentration (0.2993 ppm) followed by Ni (0.03 ppm), Cu (0.0124 ppm), and Mn (0.0121 ppm). On the contrary, three toxic elements, Cd, Pb, and Cr were not detected in the analysis. All the metallic contents were found to be in the permissible limit.

GC-MS analysis identified five compounds from the corm extract of *M. balbisiana*. Table 1 showed the GC-MS parameters of all the five compounds identified from the plant. The five major compounds identified were difluoroisocyanatophosphine (1), 2'-methoxy-2,3',4,4'-tetrabromodiphenyl ether (2), isophthalic

acid, ethyl 6-ethyloct-3-yl ester (3), phthalic acid, 2-(4-chlorophenoxy)ethyl hexylester (4), and pseudodiosgenin diacetate (5). The chromatograms of retention time and m/z intensities are presented in fig. 4a & b. The compound which shows highest peak was identified as Difluoroisocyanatophosphine and has the molecular formula CF_2NOP and molecular weight of 110.987 with the retention time of 5.785 (Table 1).

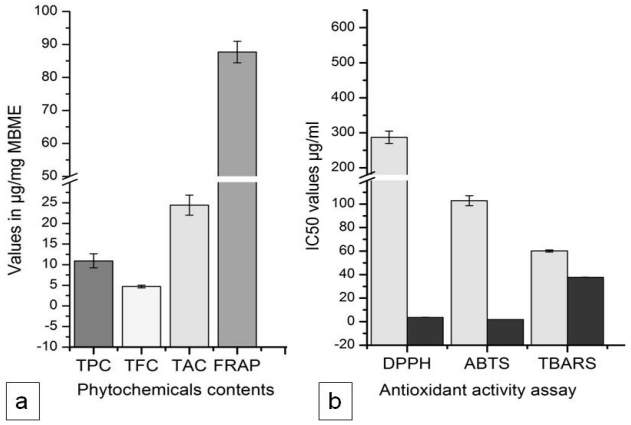

Fig. 2: Phytochemical and antioxidant properties of methanolic extract of *Musa balbisiana*. Values of TPC, TFC, TAC and FRAP were expressed as µg/mg extract and (a) DPPH, ABTS, and TBARS assays were represented in IC_{50}.

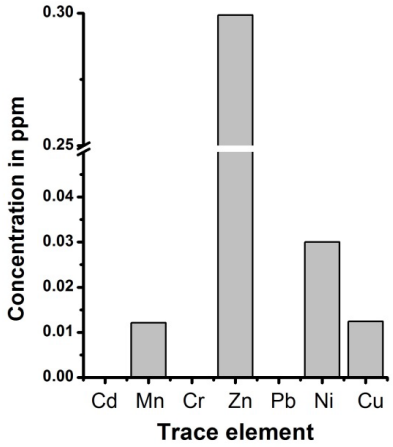

Fig. 3: Composition of trace elements of corm extract of *musa balbisiana*. Cd - cadmium, pb - lead, cr - chromium, zn- zinc, cu - copper, ni - nickel, Mn - manganese

Phytochemical analysis revealed high protein, carbohydrate, phenolic, and flavonoid content in the methanolic corm extract of *M. balbisiana*. Similar to our study, Mahmood reported high content of TPC and less content of TFC in *M. paradisiaca*[25]. The presence of phenolic, flavonoid, and glycosides was also reported in *M. acuminata*[26]. Free radicals are generated continuously in our bodies as a result of several metabolic processes. Our body has an innate capacity to neutralise these free radicals. However, our innate antioxidant capacity to neutralize free radicals is limited to certain concentration and beyond that concentration our body fails to neutralize it. With rich phytochemicals and secondary metabolites, plants act as a source of antioxidant molecules which can increase the antioxidant property of our body[27,28]. Several studies have reported the antioxidant and free radical scavenging properties of several medicinal plants[29,30].

Metallic content plays a vital role in our day to day life. It can be harmful or toxic if it crosses the permissible level. In our analysis, we have found that the toxic heavy metals such as Pb and Cd were below the WHO permissible limits[31]. The study thus suggests that the corm extract do not contain metallic content at the range that is toxic to human consumption. Trace elements are important for several biological activities and human health. Trace elements such as Zn, Cu, Fe, and Mg functions as cofactors for many proteins and enzymes[32,33]. On the other hand, heavy metals like Pb, Cd, Ni, and Cr do not have any beneficial roles but are known to be toxic to the health[34]. GC-MS study of corm extract of *M. balbisiana* showed five major compounds from the plant. All the compounds were reported for the first time from *M. balbisiana* corm extract. We did not find any literature about the pharmacological properties of the identified compounds. Similarly, several ester compounds were reported from the fruit peel extract of Musa species[35]. Recent studies by Yingyuen *et al.*[36] reported the presence of rutin as the major compound in the leaves of *M. balbisiana*. Similarly, Kumari *et al.*[37]

TABLE 1: GC-MS PROFILES OF THE COMPOUNDS IDENTIFIED FROM CORM EXTRACT OF *MUSA BALBISIANA*

Name of the compound	Retention time	m/z	Area (%)	Height (%)	Mol. weight (g/mol)	Mol. Formula
1. Difluoroisocyanatophosphine	5.785	69.25	8.77	24.94	110.987	CF_2NOP
2. 2'-Methoxy-2,3',4,4'-tetrabromodiphenyl ether	9.793	569.00	10.42	20.49	515.8	$C_{13}H_8Br_4O_2$
3. Isophthalic acid, ethyl 6-ethyloct-3-yl ester	15.100	177.00	30.20	21.14	334.4	$C_{20}H_{30}O_4$
4. Phthalic acid, 2-(4-chlorophenoxy)ethyl hexyl ester	20.460	193.00	29.98	16.67	404.9	$C_{22}H_{25}ClO_5$
5. Pseudodiosgenin diacetate	23.588	81.00	20.63	16.76	498.7	$C_{31}H_{46}O_5$

reported seven major phenolic content from the fruit pulp of *M. balbisiana* and also revealed that the extract contains cardioprotective activity.

Medicinal plants own the impression of significant success in the traditional system of disease treatment. This paper sheds a light on the phytochemical profile and antioxidant properties of the plant. Considering the different activities of plants, it therefore, justifies the traditional use of medicinal plants in the treatment of different health disorders. *Musa balbisiana* corm extract showed rich phytochemical and antioxidant properties as well as low toxic elements which are indicative enough for rich medicinal values of the plant. However, proper pharmacological studies and characterisation of bioactive compounds need to be carried out to understand the detailed mode of action.

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Conflict of Interest:

Authors declares no conflict of Interest.

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