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Research Article

A Mini-review on Plants with Potential Anti-hyperlipidemic Properties of Northeast India

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Abstract

Hyperlipidaemia is considered as one of the major risk factors contributing to the development coronary heart diseases. This is a medical condition where abnormally high levels of plasma lipids including triglycerides, cholesterol, cholesterol esters, and phospholipids are found in the blood. Anti-hyperlipidemic drugs such as statins and fibrates are extensively used in the treatment of elevated plasma lipids. But these drugs are cursed with side effects. In the last few years, there has been a rapid growth in the use of medicinal plant and gaining popularity on both developing and developed countries as it possesses minimal side effects. Medicinal plants carry various bioactive secondary metabolites and these metabolites are responsible for showing different properties useful for medicinal purposes. Northeast India is great treasure of plant resources and most of the resources are yet to be explored. This mini-review tries to describe few plant species of NE India having potential anti-hyperlipidemic property.

Keywords: Hyperlipidemia, anti-hyperlipidemic drugs, Lipids, Medicinal plants, Secondary metabolites.

INTRODUCTION

Hyperlipidemia is an abnormal condition accompanied by high levels of one or more of the plasma lipids largely cholesterol and triglycerides in blood. This elevation of plasma lipids is one of the major risk factors associated with cardiovascular diseases. This medical condition is also called hypercholesterolemia/hyperlipoproteinemia (Amit et al., 2011). Lipids do not dissolve in water but are carried in the blood plasma by associating non polar lipid (triacylglycerol and cholesteryl esters) with amphipathic lipids (phospholipids and cholesterol) and proteins to make water-miscible lipoproteins (Murray et al., 2014). Lipoprotein was discovered in 19th century. The high density lipoprotein (HDL) was first isolated from horse serum in 1929 and the low density lipoprotein (LDL) in 1950 (Olson, 1998). Elevated low density lipoprotein (LDL) during hyperlipidemia is an indicator of atherosclerosis, where arteries get hardened due to deposition of cholesterol in the artery wall which causes narrowing of arteries. Atherosclerosis is mainly caused by hypercholesterolemia and hypertriglyceridemia which is strongly related to ischemic heart disease (IHD) (Brouwers et al., 2012). Atherosclerosis and atherosclerosis associated disorders are accelerated by the presence of hyperlipidemia (Shattat, 2014). Hyperlipidemia also induces oxidative stress resulting in production of free oxygen radicals which may lead to oxidative modification of low-density lipoproteins which is a reason in the progression of atherosclerosis and associated cardiovascular disease (Mishra et al., 2011).

The world has been facing a rapid transition in health over the past few decades and hyperlipidemic cases are rising at an alarming rate globally. Cardiovascular diseases (CVD) remain the leading cause of mortality globally, including in India and the United States. Researcher projected that about more than three-quarter death will occur in worldwide due to non-communicable diseases by the year 2030.; CVD will be sole cause for more deaths in low-income countries than infectious diseases (including tuberculosis, HIV/AIDS and malaria), maternal and perinatal conditions, and nutritional disorders combined (Beaglehole & Bonita, 2008). The occurrence of CVDs in India has elevated over the past few decades due to increase in adverse lifestyles such as alcohol consumption, tobacco use, obesity and a stable age adjusted CVD mortality rate.

Nature is the great treasure of various types plant products. Medicines have the utmost importance in daily life. Nature has been a source of healing agents since thousands of years

and a large number of modern drugs have been isolated from various natural sources. Plants and its products are used as medicine since ancient human civilization. Importance of medicinal plants and their effects have been recognized since early days of scientific research. Human race learned the use of herbal medicine from the empirical experiences of the ancient times. A well-known example of Traditional medicine is Chinese Traditional medicines, is an ancient practice of herbal medicine documented 2000 years ago (Xutian et al., 2009). While digging the history of modern medicine, we find the use of cardiac glycosides in the 18th century for the treatment of cardiovascular diseases and willow bark for the relief of pain and fever like problems (Sen and Samanta, 2014). Use of medicinal plants is a universal practice among the world's traditional medical systems, which develops systems based on holistic healing approach.

According to World Health Organization (WHO, 1977) "*a medicinal plant*" is any plant in which one or more of its organs contains substances that can be used for the therapeutic purposes or which, are precursors for the synthesis of useful drugs. Substances extracted from medicinal plants remain the basis for the production of large scale of commercial medications used for heart disease, liver disease, pain, high blood pressure and other problems. In India the history of health care and diseases were documented in several ancient literatures like '*Rig-Veda*' and '*Atharva-Veda*'. The ancient literature like '*Charak Samhita* and '*Susruta Samhita*' were documented in about 1000 years B.C., where use of medicinal plants and polyherbal formulations was highlighted. Ayurveda *Materia Medica* gives detailed information about 1500 herbs and10,000 formulations which are derived from different traditional systems and folklore practices (Patwardhan & Mashelkar, 2009).

India is well known for its richness in plant diversity. About 40,000 species of plants belonging to various groups have been documented in India. 7500 are known for medicinal uses. Nearly 70% of the population depends on medicinal plants or indigenous systems of medicine to help meet their health care needs (Mukherjee & Wahile, 2006). The use of traditional medicines and medicinal plants in most developing countries as therapeutic agents for the maintenance of good health has been widely observed. According to World Health Organization (WHO), about 80% of the world's populations are dependent on traditional medicines and treatment for their health care needs. North eastern India comprises of hilly forest areas as well as plains. It includes the states of Assam, Arunachal Pradesh, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim, and Tripura lies between 21^{o}34'N to 29^{o}50'N latitude and 87^{o}32'E to 97^{o}52'E longitude (Mao et al., 2009). It is a part of both Himalaya as well as Indo-Burma hotspots in the world supporting about 50% of Indian biodiversity (Mao & Hynniewta, 2000). Medicinal plants are considered as an important bioresource of Northeast India. The region's diverse physiography and prevailing variations in climatic conditions nurtures the diverse species of medicinal plants, many of which are used by various ethnic groups as medicines as well as food. In Northeast India, more than 8500 species of angiosperms with about 505 of Indian flora of both general and ethno-medicinal plants have been recorded (Mao & Hynniewta, 2000).

The Secondary metabolites from the plants have various pharmacological properties such as anti-oxidative, anti-allergic, antibiotic, hypoglycemic and anti-carcinogenic etc. Plant based medicines are always considered to be the safest in healthcare system as synthetic drugs causes many side effects in human health. Hyperlipidemia associated lipid disorders are believed to cause cardiovascular complications. The primary aim in the treatment of hyperlipidemia is to lower the risk of developing cardiovascular disease or the occurrence of ischemic heart disease. Medicinal plant based drugs are now advantageous over synthetic drugs as it has better patient tolerance and local availability. Although many advances in the treatment of diseases have been initiated, the progress towards healthy life and proper treatment with minimal side effects of such diseases is still unmet. Medicinal plants are rich source of chemical compounds which contain various therapeutic agents that serve as key raw material for drug production. Thus, the effect of various medicinal plants available in Northeast India in treating hyperlipidemia has been discussed in this review.

Classification of Lipids

Synthesis of lipids that occurs in the liver and adipose tissue are transported between the various tissues and organs for utilization and storage. The lipids are insoluble in water. For transportation of lipid in the aqueous plasma, they are carried by certain molecules called lipoproteins, which consist of a central core containing cholesterol esters and triglycerides surrounded by free cholesterol, phospholipids, and apolipoproteins, which facilitate lipoprotein formation and functions (Dargel, 1989). The lipids can be classified as Total Cholesterol (TC) and its derivatives such as triglycerides (TAG), Low Density Lipoprotein (LDL), High Density Lipoprotein (HDL), and Very Low Density Lipoprotein (VLDL).

Total Cholesterol

According to guidelines of National Cholesterol Education Program (NCEP), TC concentration below 200 mg/dL is desirable, whereas, concentrations greater than 240 mg/dL are referred to as hyperlipidemic. However, epidemiological evidence suggests that the risk of cardiac events decreases as TC levels fall approximately to 150 mg/dL. Moreover, TC should be less than 180 mg/dL for children (Ginsberg & Goldberg, 2001; Fryar, 2010).

Triglycerides

Triglycerides are carried by VLDL in the blood. The body turns excess amount of calories, alcohol or sugar into triglycerides and stored as fats in the adipose tissue (Smelt, 2010). The triglyceride concentration below 150 mg/dL is regarded as normal, whereas, concentrations of 200-

499 mg/dL are considered to the higher side. Moreover, concentrations of 500 mg/dL or higher are considered noxious for the development and progression of various CVDs (Ginsberg & Goldberg, 2001).

LDL Cholesterol

LDL is often called the "*bad*" cholesterol, which is produced by the liver and transported to different parts of the body like, muscles, tissues, organs and heart (Rohilla et al., 2012). The high LDL indicates elevated level of cholesterol in the blood stream and leads to a buildup of cholesterol in arteries and hence, increases the risk of heart disease. According to NCEP guidelines, lower than 100 mg/dL concentrations of LDL cholesterol are considered optimal, whereas concentrations in the range of 160-189 mg/dL are considered to be high. However, increasing evidence supports that normal human LDL cholesterol concentration can be in the range of 50-70 mg/dL (Ginsberg & Goldberg, 2001). Moreover, it is evident that Lowering LDL cholesterol reduces the risk of CVDs.

HDL Cholesterol

HDL cholesterol is commonly known as the "*good cholesterol*", produced by the liver to carry to cholesterol and different types of lipids from tissues back to liver for degradation (Ridker et al., 2010). High HDL level lowers the risk of CVDs and is considered as a good indicator of healthy heart. The concentrations below 40 mg/dL are considered as major risk factor for heart diseases, whereas, the concentrations of 60 mg/dL or higher is regarded as optimal (Goldstein et al., 1973). However, HDL is often elucidated in the context of TC and LDL concentrations, and hence may be considered as less significant when LDL is low.

VLDL cholesterol

Like LDL, VLDL cholesterol is also produced in the liver and released into the bloodstream to different areas of the body. A combination of cholesterol and triglycerides forms VLDL cholesterol. Moreover, it is considered that VLDL cholesterol can induce the development of medical condition such as atherosclerosis and heart diseases (Griffin et al., 1994).

Chylomicrons

Chylomicrons are the triglyceride rich lipoproteins that are produced in the intestinal enterocytes in response to dietary fat ingestion (Julve et al., 2016). They are considered as major vehicles for the transport of all dietary lipids into the circulation. They transport triacyglycerol from the liver to the extrahepatic tissues. The constituents of chlyomicrons are 85-92% TGs, 612% phospholipids, 1-3% cholesterol, and 1-2% protein.

TYPES OF HYPERLIPIDEMIA

Hyperlipidemia in general can be broadly classified into:

Primary hyperlipidemia: Due to a genetic defect, primary hyperlipidemia is also considered as familial. It can be monogenic involving a single gene defect or polygenic, i.e., with multiple gene defects. Primary hyperlipidemia can be classified according to Fredrickson's classification where the abnormal lipoprotein patterns are summarized (Tripathi, 2013).

Secondary hyperlipidemia: Secondary or acquired causes of hyperlipidemia are associated with different types of disorders such as diabetes, chronic alcoholism, hypothyroidism, nephritic syndrome, chronic kidney diseases and with use of drugs like beta blockers, corticosteroids and oral contraceptives (Stone, 1994). Secondary causes can culminate in an atherogenic lipoprotein profile with heightened risk for cardiovascular diseases and risk for acute pancreatitis.

Treatment:

Two types of therapy are involved in the treatment (Amit et al., 2011).

1. Non-pharmacological therapy.
2. Pharmacological therapy

Non pharmacological therapy

Reducing elevated cholesterol is an essential public health challenge. There is considerable evidence from randomized controlled trials that some foods components as well as low fat food can significantly reduce cholesterol. The objectives of non-pharmacological therapy, commonly called dietary therapy is to decrease the intake of total fat, saturated fats, and cholesterol that will help to maintain or achieve a desirable body weight.

1. Reduced saturated fat intake to 7% of daily calories.
2. Reduces total fat intake to 25-35% of daily calories.
3. Dietary cholesterol intake lowered to less than 200 mg per day.
4. Intake soluble fiber to 20 -30g a day, which is found in beans, oats, peas and fruits.
5. Plant stanols or sterols should be included in daily diet. The substances found in nuts, vegetable oil, corn, rice and pulses are essential and should be taken 2-3g daily. Omega-3 fatty acids found in fish may reduce triglycerides (Amit et al., 2011).

Pharmacological approach

National Cholesterol Education Program Adult Treatment Panel III (NCEPATP III) guidelines also suggests that many patients will require drug therapy to attain low density lipoprotein cholestererol (LDL-C) (Lipsy, 2003). LDL is considered as the major atherogenic lipoprotein. Reduction of this lipoprotein is believed to reduce atherosclerosis as well as cardiovascular adverse effects. Drug therapy along with lifestyle changes is important in the treatment of hyperlipidemia.

MEDICINAL PLANTS OF NORTH EAST INDIA USED IN HYPERLIPIDEMIA

As Northeast India is rich in biodiversity, different types of plant resources are found abundantly in this region. From geographic point of view most of the regions of Northeast India is covered by hilly areas, and these hill tracks are inhabited by different tribes. These tribes have incredible indigenous knowledge on those plant resources used in various traditional medicine systems for treating different ailments. Some of the medicinal plants used by North-eastern people for the treatment of hyperlipidemia are described in literature are as follows:

Acorus calamus

Acorus calamus is a perennial plant that belongs to family Acoraceae. It is widely distributed in temperate and sub-temperate regions of the world and is native to India, Japan, China, Southeast Asia and Sulawesi (Khwairakpam et al., 2018). It is locally known as 'boch' in Assamese. The plant is well known for its medicinal and therapeutic values due to presence of different phytochemicals from anatomical parts of *A. calamus* such as glycosides, lignins, mucilage, flavones, xanthone, and saponins are reported in traditional medicine system (Khwairakpam et al., 2018).

The anti-hyperlipidemic effect of *Acorus calamus* (rhizomes) extract was investigated. Administration of 50 % ethanolic extract at a dose of 100 mg/kg and 200 mg/kg as well as saponins (10 mg/kg) in male albino rats for 45 days showed significant decrease in serum cholesterol and triglycerides, but higher efficacy was reported at 200 mg/kg. However, saponins caused the increase of HDL-C levels higher than the two doses (Parab & Mengi, 2002).

AMARANTHUS SPINOSUS, AMARANTHUS CAUDATUS, AND AMARANTHUS VIRIDIS

Amaranthus spinous, commonly known as Kantabhaji in hindi is an herbaceous plant, native to tropical America. It is found in tropical and sub-tropical regions of India, locally known as Khuduna su or Khutra in Assam (Swargiary et al., 2020). This plant is used as diuretic, anti-diabetic, analgesic, anti-pyretic, and is also used in treatment of bronchitis and piles (Girija et al., 2011). *Amaranthus caudatus*, along with *Amaranthus viridis*, are also found in a wide stretch of Northeast India.

Grija et al., (2011) investigated the anti-cholesterolemic and anti-diabetic activity of the methanol extract, prepared from the leaves of *Amaranthus spimosus*, *Amaranthus caudatus*, and *Amaranthus viridis*. The extract was evaluated by using normal and streptozotocin (STZ) induced diabetic rats at a dose of 200 mg/kg and 400 mg/kg daily for 21 days. Blood glucose levels, body weight along with lipid profile were assessed in the experimental animals.

Table 1 Lipid profile observation of rats after 21 days treatment at 400 mg/kg and 200 mg/kg of methanol extract of *A. spinosus, A. viridis* and *A. caudatus.*

The above investigated results showed significant anti-hyperlipidemic activity and provides ethnopharmacological evidence for its traditional claims.

Asparagus racemosus

Asparagus racemosus is an important medicinal plant that belongs to the family Liliaceae. It is commonly known as 'Satavari' and is grown in the tropical and sub-tropical regions such as India, Australia, Asia, and Africa. In Assam, *A. racemosus* is locally known as 'Satomul'. It is widely used in traditional medicine preparation as it known to treat various conditions such as tumors, hepatopathy, dyspepsia, infectious disease, and ulcer. Few reports are available regarding hepatoprotective, immunomodulatory, and anti-inflammatory activities (Alok *et al*., 2013). Bhosale *et al*., (2012) evaluated the lipid lowering activity of *Asparagus racemosus* in hyperlipidemic rats. Rats were fed with dried powder of *A. racemosus* at 5 gm% and 10 gm% doses level resulted in significant reduction in plasma cholesterol, LDL, oxidative stress, and significant increase in HDL in hyperlipidemic condition.

Aegle marmelos

Aegle marmelos commonly known as 'Bael' is an indigenous medicinal plant used by the people of the Indian subcontinent for over 5000 years (Baliga et al., 2011). Locally known as known as 'Bel' in Assamese, it is preferred for its medicinal values and occupies a distinct position in traditional medical systems. Sinha & ghosh (2015) evaluated the anti- hyperlipidemic effect of *Aegle marmelos* (leaves) and *Terminalia arjuna* (bark) in high cholesterol induced hyperlipidemic rats. Oral administration of both the extracts showed significant anti-hyperlipidemic effect by reducing the serum cholesterol and triglycerides level.

Porchelvan & Venkatakrishnamurali (2014) investigated the effect of *Aegle marmelos* leaf extracts and whole leaf powder chronic oral treatment for 90 days in male Wistar

Table 1. Lipid profile observation of rats after 21 days.

LIPID PROFILE	*A. spinosus*		*A. viridis*		*A. caudatus*	
	200 mg/kg	400 mg/kg	200 mg/kg	400 mg/kg	200 mg/kg	400 mg/kg
CHL ↓	15.5%	23.7%	18.6%	28.7%	22.4%	25.7%
TG ↓	31.8%	33.3%	27.3%	39.4%	28.9%	32.6%
LDL ↓	39.7%	45.3%	36.7%	51.3%	28.7%	31.7%
VLDL ↓	34.3%	42.3%	31.2%	39.8%	36.5%	41.7%
HDL ↑	15.3%	20.9%	10.2%	18.3%	7.14%	3.57%

rats. The experiment showed a significant decrease in serum cholesterol, TG, VLDL and LDL. However, a marked increase in HDL is also reported.

Baccaurea ramiflora

Baccaurea ramiflora, commonly known as 'Burmese grape' is a slow growing tree that belongs to the Euphorbiaceae family. This slow growing tree is distributed in the Southeast Asian region and in India, China, Nepal, Myanmar, Thailand and the Andaman Islands (Nesa et al., 2018). It is locally known as 'Leteku' in Assam and is also found growing wild in the other states of Northeast India.

The anti-hyperlipidemic effect of ethanolic extract of *B. ramiflora* (seeds) in high fats induced Wistar albino rats was evaluated. A range of doses, including 150, 250 and 500 mg/kg (body weight) were orally administered. Significant reduction in serum TC, TG and LDL-C levels were reported and the dose 500 mg/kg of ethanolic extract of *B. ramiflora* (seed) is considered to be the effective one. Thus, this indicates the hypolipidemic activity of the seed extract against dietary induced hyperlipidemia (Alam et al., 2019).

Bacopa monniera

Bacopa monniera is a small perennial herb native to the wetlands of India, particular in northeastern regions. It is commonly known as 'Brahmi' in Ayurvedic medicine and is extensively used in India for enhancing memory. Pharmacological studies of several extracts reported the presence of anti-fungal, anti-allergic, anti-oxidant, analgesic and anti-gastric ulcer activities (Komali et al., 2020). Administration of ethanolic extract of *Bacopa monniera* (whole plant powder) significantly decreased the serum levels of TC, TG, VLDL and LDL but significantly increased the level of HDL in high cholesterol diet induced hypercholesterolemic rats (Kamesh & Sumathi, 2012).

Caraca papaya

Caraca papaya is well known for its nutritional and medicinal value. It belongs to family Caricaceae. It is native to the southern parts of America and is also found in Southeast Asia, India, Bangladesh. It is naturalized and also cultivated in various parts of Northeast India and locally known as 'Amita' in Assam. It is also considered as a potent candidate for dengue treatment (Charan et al., 2016). The anti-hyperlipidemic activity of aqueous extract of *C. papaya* seed in albino Wistar rats fed with high fat diet for 5 weeks was evaluated. Rats treated with doses of 200 mg/kg/day and 300 mg/kg/day showed significant reduction in TC, TG, and LDL. However, a decent increase in HDL was reported. These results suggest the hypolipidemic activity of *C. papaya* seeds extract (Nwangwa & Ekhoye, 2013).

Cassia fistula

Cassia fistula, commonly known as 'Indian Laburnum' has been widely used in traditional medical system for myriads of ailments. It is known as 'Sonaru' in Assam and is naturalized and cultivated in different parts of Northeast India. Cassia fistula manifested significant anti-microbial, anti-periodic, antiinflammatory and anti-ulcer activities and showed properties that support folklore claims (Bhalodia & Shukla, 2011).

The anti-hyperlipidemic effect of *Cassia fistula* (bark) was investigated by the administration of high fat diet in Wistar rats for 21 days. Rats orally administered with methanolic and ethyl acetate extracts of *C. fistula* showed significant reduction in serum TC, TG, LDL, VLDL and increased the HDL level (Raj et al., 2015)

Abid et al., (2016) evaluated the hypliopidemic effect of ethanolic extract of *Cassia fistula* (fruit) in hyperlipidemic mice. Oral administration of the extract (100, 300 and 500 mg/kg) body weight in dietary induced hyperlipidemic mice prevented the serum lipid level to increase.

Centella asiatica

Centella asiatica is a perennial plant belonging to the family Apiaceae and is native to Asia. In traditional medical system, *C. asiatica* is considered as an important medicinal herb in Northeast India. Locally known as 'Manimuni' in Assam. It is placed among various medicinal herbs possessing various pharmacological properties such as anti-bacterial, anti-diabetic, anti-inflammatory, anti-hyperlipidemic, anti-ulcer and hepatoprotective properties (Narvariya et al., 2018).

Narvariya et al., (2018) evaluated the anti-hyperlipidemic and anti-diabetic activity of *Centella asiatica* (leaves) in diabetic rats. Administration of different extracts such as ether, dichloromethane, methanolic, and aqueous was evaluated. Among all the extracts, dichloromethane showed significant decrease in VLDL, LDL, TC and TG. A decent increase in HDL level along with significant reduction in blood glucose level was also reported. This result suggests the hypolipidemic activity of *C. asiatica* (leaves).

Chlorophytum borivilianum

Chlorophytum borivilianum, commonly known as '*Safed musli*' is an important medicinal herb in the traditional medical system of India. It belongs to family Liliaceae. Safed musli is endogenous medicinal herb in India and distributed widely in eastern part of India (Assam, Eastern Ghats, Eastern Himalayas, Andhra Pradesh and Bihar) (Haque et al., 2011). It is rich in alkaloids, vitamins, minerals, proteins, carbohydrates, steroids, saponins and polysaccharides. The plant is used as traditional medical system as it possesses aphrodisiac, immunomodulatory, anthelmintic, anti-oxidant, anti-ulcer, anti-stress, antimicrobial, anti-diabetic and anti-mutagenic activity (Singh et al., 2012)

Visavadiya & Narasimhacharya (2007) investigated the efficacy of *Chlorophytum borivilianum* (roots) modulating hypercholesteraemic conditions in male albino rats. Administration of *C. borivilianum* at 0.75 and 1.75/gm/rat/day to hypercholesteraemic rats of different groups

for 4 weeks significantly decreased plasma total lipid content (-18% and -25%), triglycerides (-15% and -20%), total cholesterol (-16% and -27%), LDL-C (-22% and -36%), and VLDL-C (-15%and -20%). On the other hand, there is significant increase in HDL-C (+21 and +34%) compared to the hypercholesteraemic group which is not treated with root powder of *C. borivilianum*. In this regard, saponins of *C. borivilianum* could be responsible for plasma lipid lowering effect. This result indicates the hypolipidemic activity of *Chlorophytum borivilianum*.

Clitoria ternatea

Clitoria ternatea, commonly known as '*Aparajita*' in Assam is a deep-rooted plant that belongs to the family Fabaceae. Different extracts of *C. ternatea* showed pharmacological activities such as hypolipidemic, anti-oxidant, anti-inflmmatory, anticancer, analgesic, antimicrobial and anti-diabetic activities (Al-snafi, 2016)

The anti-hyperlipidemic effect of *Clitoria ternatea* was investigated in hyperlipidemic rats. The poloxamer 407 and diet induced hyperlipidemia models were considered for the experiment. Oral administration of the hydroalcoholic extract of *C. ternetea* (roots and seeds) showed significant reduction in serum TC, TG, VLDL and LDL. Treatment with the extract also normalized the atherogenic index and the HDL/LDL ratio in diet induced hyperlipidemic rats (Solanki & Jain, 2010).

Curcuma longa

Curcuma longa is a perennial herb that belongs to the family Zingiberaceae. It is native to the Indian subcontinent, commonly known as turmeric. The rhizome of turmeric is used extensively in foods as well as in traditional medical systems. It is locally known as '*Halodhi*' in Assam.

Jogdand & Padhye (2019) evaluated and compared the anti-hyperlipidemic effect of *Cucuma longa* with atorvastatin in albino rats. Oral administration of the ethanolic extract of *C. longa* to obese rats for 8 weeks showed significant reduction in serum TC and serum TG. Thus, indicating the hypolipidemic activity of turmeric.

Cynodon dactylon

Cynodon dactylon (Bermuda grass) is a warm season, perennial grass that grows in almost all soil types. It is distributed all over the world, and is widely naturalized in warm temperate and tropical regions. *Cynodon dactylon* is commonly known as 'Dubori bon' in Assam and is evenly found in North-east India. Phytochemical analysis showed the presence of flavanoids, alkaloids, glycosides, terpenoides, triterpenoids steroids, saponins, tannins, resins, phytosterols, reducing sugars, carbohydrates, proteins, volatile oils and fixed oils (Al-Snafi, 2016). *C. dactylon* has been long used as medicinal plant in traditional medical system. This plant is traditionally used to treat various ailments such as diarrhea, dysentery, convulsions, epilepsy, headache, tumors, urogenital disorders, warts and wounds. The various extracts of the plant possesses anti-oxidant, immunomodulatory, anti-diabetic, anti-cancer, anti-diuretic and anti-inflammatory activities (Ashokkumar et al., 2013).

The anti-hyperlipidemic activity of whole plant extract in ethanol of *Cynodon dactylon* was investigated in Wistar albino rats fed with high cholesterol diet to induce hyperlipidemia. Rats were treated with 400 mg/kg body weight of *Cynodon dactylon* extract. The effects of *C. dactylon* extract the plant on the lipid profile were investigated by measuring the plasma concentration of TC, TG, LDL-C, HDL-C, and VLDL-C. Administration of *C. dactylon* showed a significant decrease in the serum TG, TC, LDL-C and VLDL-C as compared to cholesterol fed control rats. These results suggest the anti-hyperlipidemic effects of *C. dactylon* extract in hypercholesterolemic rats (Kaup et al., 2011).

Eclipta prostrata

Eclipta prostrata commonly known as false daisy belongs to the family of Astareceae. It is native to Asia and widely distributed in tropical, subtropical, and temperate regions around the world. It is locally known as '*Keharaj*' in Assam. Tribal practitioners as well as traditional medical systems consider the plant to exhibit many medicinal properties and use it for the treatment of hemorrhagic diseases, coronary heart disease, respiratory disorder, hair loss, and liver disease etc (Feng et al., 2019). Kumari et al., (2006) investigated the anti-hyperlipidemic activity of *Eclipta prostata* (whole plant) in male albino rats for 30 days. The plant extract when evaluated for anti-hyperlipidemic potential showed significant lipid lowering activity in a dose dependant manner when administered in the rats. A dose of 150 mg/kg body weight is considered to be more effective.

Emblica officinalis

Emblica officinalis commonly known as 'Amla' is one the important medicinal herbs described to possess multiple therapeutic properties. It is locally known as 'Amlakhi' in Assam and belongs to the family Euphorbiaceae. The extract or plant is considered to be beneficial against various ailments such as neurological disorders, inflammation, hypertension, parasitic disorders and other infectious disorders (Variya et al., 2016).

Bhatt et al., (2012) investigated the hypolipidemic efficacy of *Emblica officinalis* (Amla) in comparison with HMG-CoA reductase inhibitor simvastatin in sixty type II hyperlipidemic patients. 40 of the patients were treated with *E. officinalis* capsule at a dose of 500 mg for 42 days whereas 20 of them were given simvastatin capsule (20 mg). Treatment with *E. officinalis* showed significant decrease on TC, TG, LDL, VLDL and a decent increase in HDL was also reported. Both treatments showed significant results. However, this favorable effect was more marked in patients treated with *E. officinalis.*

Glycyrrhiza glabra

Glycyrrhiza glabra, commonly known as licorice, herbaceous plant native to Europe and Asia. In Assam it is locally known as '*Jesthimadhu*' and is also found in other parts Northeast India. This plant is traditionally used as medicine as it possesses antibacterial, antiviral, anti-allergic, anti-diabetic, hepatoprotective, and anti-carcinogenic activities (Pastorino et al., 2018).

Shamim et al., (2016) conducted an experiment on rats to evaluate the effect of ethanolic extract of *Glycyrrhiza glabra* against high fat and stretozotocin induced diabetic and hyperlipidemia. The diabetic rats that were fed with high fat diet (D-HFD) showed an increase in serum cholesterol and LDL-C whereas the group pre-treated with extract of *Glycyrrhiza glabra* showed a significant decrease in biochemical parameters like Total cholesterol (TC), Triglyceride (TG), High-density lipoprotein (HDL). A significant elevation in High density lipoprotein (HDL), which plays an inhibitory role in the pathogenesis of atherosclerosis is also seen (Boden and Pearson, 2000).

Hibiscus cannabinus

Hibiscus cannabinus (Kenaf) is a perennial herb. It is native to tropical and subtropical Africa and Asia. It is grown as a medicinal and ornamental plant throughout India. *H. cannabinus* seed oil consists of relatively high amount of monounsaturated and polyunsaturated fatty acids (PUFAs) and is claimed to have cholesterol lowering activity (Nyam et al., 2009). It is locally known as '*Meseka tenga'* in Assamese (Barua et al., 2007*)*.

The anti-hyperlipidemic effect of kenaf seed oil, microencapsulated kenaf seed oil, kenaf seed extract, and defatted kenaf seed meal were evaluated in male Sprague dawley rats for 32 days. Kenaf seed extract showed significant cholesterol lowering properties due to marked decrease in serum TG and TC. Hence kenaf seed extract can be used as a natural product to replace synthetic hypolipidemic drugs (Kai et al., 2015).

Hibiscus sabdariffa

Hibiscus sabdariffa is native to the tropical and subtropical regions of the world. In India, it is widely naturalized and also cultivated by the tribals in the villages of Assam, Meghalaya, West Bengal, Orissa and Madhya Pradesh. It is locally known as 'Tenga mora' in Assamese.

Various studies have shown the anti-hyperlipidemic activity of *H. sabdariffa* extract (HSE) suggesting its potency as an anti-obesity agent. There are evidences from animal models and human trials that *H. sabdariffa* extract has hypolipidemic activity. Hirunpanich et al., (2006) investigated the hypolipidemic and antioxidant effects of aqueous extract of *H. sabdariffa* (dried calyx) in hypercholesterolemic rats. Rats administered with doses of 500 mg/kg and 1000 mg/kg along with high cholesterol diet for 6 weeks showed significant reduction in serum TG. However, no significant change in HDL level was reported. Anti-hyperlipidemic effect has been studied only in flowers and calyces of *H. sabdariffa* (Gosain et al., 2010). Since calyces are not found throughout the year, hence to meet the demand of it, leaves can serve as the better raw material for herbal industry. However more studies are required to claim the hypolipidemic effect of *H. sabdariffa* (leaves).

Ipomoea aquatica

Ipomoea aquatica (Water spinach) is a semi-aquatic tropical plant that belongs to family Convolvulaceae. It is a tradition and potent medicinal plant and is useful against fever, jaundice, bronchitis, liver disease and in management of nervous and general debility of female in Assam (Manvar & Desai, 2013).

The antihyperlipidemic activity of methanolic extract of *Ipomoea aquatica* and the mechanism by which the extract modulated the lipid profile in hyperlipidemic rats was investigated. Rats were treated with doses of 200 mg/kg and 400 mg/kg of methanol leaf extract of *Ipomoea aquatica* for 30 days. Blood analysis of the rats with both dosages of *I. aquatica* extract showed significant lowering of plasma concentration of total cholesterol, total lipid, free fatty acid, phospholipid, and triglycerides. These results suggest that methanolic extract of *I. aquatica* has potential anti-hyperlipidemic activity which provide pharmacological evidence for folklore claims (Sivaraman & Muralidaran, 2010)

Morus alba

Morus alba (mulberry) is extensively used as fodder and traditional medicine. It is considered as the primary food of silkworms for centuries. It belongs to the family Moraceae, locally known as '*Nuni*' in Assamese. Different anatomical parts such as leaves, root bark, and fruits containing flavonoids as main constituents, possesses various pharmacological properties including antihyperlipidemic, anti-oxidant, anti-obesity, anti-inflammatory, anti-atherosclerotic and hepatoprotective activities (Chan et al., 2016).

Chen et al., (2007) investigated the anti-hyperlipidemic effect of flavonoids from *M. alba* leaves in triton WR-1339 induced hyperlipidemic mice. This experiment showed that the alterations in serum lipid induced by WR-1339 can be resisted by flavonoids extracted from mulberry leaves. Significant reduction in TC and TG indicated the presence of hypolipidemic activity.

Nelumbo nucifera

Nelumbo nucifera, commonly known as sacred lotus is a perennial aquatic plant. It is widely used food crop and medicine in tropical and sub-tropical Asia. It belongs to family Nelumbonaceae. It is also evenly scattered in various parts of Northeast India and locally known as '*Padum*' in

Assam. Many pharmacological analysis of *N. nucifera* have proven its anti- inflammatory, hypoglycemic, antioxidant, anti-viral, anti-cancer, hepatoprotective, and antidiarrheal activities (Mehta et al., 2013).

Subasini et al., (2014) investigated the anti-hyperlipidemic effect of hydroalcoholic extract of *Nelumbo nucifera* flower in Poloxamer 407 induced hyperlipidemia in male Wistar rats. A potent antihyperlipidemic effect of the *N. nucifera* extract was obtained by a significant reduction in the serum cholesterol, LDL, VLDL, along with marked increase in HDL. The antihyperlipidemic effect of the *N. nucifera* plant extract may be due to the presence of tannins, flavonoids, alkaloids, vitamin E, and vitamin C.

Sphaeranthus indicus

Sphaeranthus indicus is from the aroma family Asteraceae. It is commonly known as '*Kamadarus*' in Assamese (Ramachandran, 2013). Pandey & Dubey (2009) investigated the anti-hyperlipidemic activity of alcoholic extract of *Sphaeranthus indicus* L. flower head in atherogenic induced hyperlipidemia. Rats were treated with dose of 500 mg/kg alcogolic extract of *S. indicus* for 8 days. There was significant reduction in body weight, TC, LDL, VLDL after oral administration of the *S. indicus* extract. On the other hand, marked increase in the serum HDL was obtained. This investigation indicates the effective suppression of atherogenic diet induced hyperlipidemia in rats by the *S. indicus* extract as it exhibits anti-hyperlipidemic activity.

Terminalia arjuna Roxb.

Terminalia arjuna (Roxb.) is one of the most important medicinal plant in Ayurveda which belongs to the family Combretace. It is native to India and Sri Lanka. Locally known as 'Arjun' in Assam. Shaila et al., (1997) investigated the hypolipidemic effect of *Terminalia arjuna* (bark powder) in male albino rabbits fed with high fat diet. Oral administration showed significant lipid lowering activity and can be considered as potential candidate for the treatment of hyperlipidemia.

Anti-hyperlipidemic and anti-oxidant acitivity of different fractions of *Terminalia arjuna* (Roxb) bark in PX-407 induced hyperlipidemia was evaluated. Rats were treated with the three fractions of diethyl ether, ethyl acetate, and ethanol at two doses levels of 150 mg/kg and 350 mg/kg body weight. The hypolipidemic activity of *T. arjuna* fractions were reported as Ethanol > diethyl ether > ethyl acetate. Hence, ethanolic fraction of *T. arjuna* exhibits the potential of being anti-hyperlipidemic than other fractions (Subramaniam et al., 2011).

Withania somnifera

Withania somnifera, commnonly known as '*Ashwagandha*' is an important medicinal plant that has been used in Ayurvedic and traditional medicine for thousands of years. Many pharmacological studies have been conducted to investigate the pharmacological effects of ashwagandha. Several investigations on this plant have indicated the presence of anti-inflammatory, anti-tumour, anti-stress, antioxidant, immunomodulatory, hemopoietic and rejuvenating properties (Mishra et al., 2000).

Visavadiya & Narasimhacharya (2007) investigated the hypocholesterolemic activity of the root powder of *Withania somnifera* in male albino rats. The hypercholesterolemia induced group fed with root powder at 0.75 and 1.75/gm/rat/day showed a significant decrease in total lipids (-40.54%; -50.69%), cholesterol (-41.58%; -53.01%), and triglycerides (-31.25%; 44.85%) in plasma. On the other hand, increase in plasma HDL-cholesterol levels, HMG-CoA reductase activity and bile content of liver were seen in these animals indicates anti-hyperlipidemic activity.

DISCUSSION

Hyperlipidemia is one of the serious health issues across the globe and affecting a significantly higher proportion of population worldwide. Moreover, it is a major risk factor for cardiovascular heart disease. Due to adverse side effect of synthetic medicines plant derived medicines are most preferred for treating various diseases. Therefore, treating hyperlipidemia with plant derived compounds which are attainable and requires moderate laborious pharmaceutical synthesis are very necessary at present time.

This study revealed 25 plant species found in Northeast India having anti-hyperlipidemic property. Various anatomical parts (leaves, flowers, roots, barks, and whole plant) were useful for the treatment. Different bioactive compounds present in these plants are responsible for anti-hyperlipidemic activity. This mini-review only describes only few of these precious plant species of Northeast India having anti-hyperlipidemic activity. Detailed study on these plant resources of NE India and characterization of the bioactive compounds present in them can open door of pharmaceutical compony and we will get better life saving medicines in future.

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