

## Review

## Chemical composition, antimicrobial and antioxidant properties of seed oil plants of North-East India: A review

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### ABSTRACT

Apart from being used as food, seed oils have also been used traditionally as medicinal products by several communities. However, the full medicinal potential of many seed oil plants is yet to be properly reviewed, particularly for their antimicrobial and antioxidant properties. North-East India has rich resources of seed oil plants. The availability of detailed information on these plants is quite limited. This review aims to explore and evaluate these seed oil plants of the North-East India with particular emphasis on their antimicrobial and antioxidant activities as well as chemical compositions. A comprehensive literature search on seed oil plants of this region has been performed. Seed oil yielding plants of this region can be categorized into two categories: plants that are used traditionally as sources of edible or medicinal oils and plants that are used for purposes other than as sources of oils. Many seed oil plants of this region have been reported to possess antimicrobial and antioxidant properties, and to produce various types of compounds. This review also highlights the importance of these plants in contributing to the local as well as the national economy of India.

**Keywords** antioxidant, antimicrobial, seed oil, chemical composition, North-East India, epidemiological study

### INTRODUCTION

The beneficial uses of seed oil plants have been known since time immemorial. Apart from their uses as food items, oils extracted from seeds are also used for different purposes ranging from medicinal to biofuels. Their chemical compositions, physical and chemical properties generally determine their applications for different purposes.

Many microbial diseases worldwide have become a serious threat to human health because of the emergence of drug-resistant or multi-drug resistant (MDR) microbial strains (Tabassum et al., 2013). Emergence of resistance to the existing drugs (Rio s and Recio, 2005) led the scientists to search for the new alternatives including seed oil producing plants and their oil (Aktar et al., 2014), which are known for their antimicrobial properties. Several *in vitro* studies have been published confirming the effect of seed oils and their major compounds on pathogenic microbes (Burt, 2004). However, there are only limited data available on the antifungal activity of these seed oils against fungal pathogens.

Determination of antioxidant properties of seed oils is also

significant in view of maintaining food quality and preventing many physiological problems such as oxidative stress related complications, liver cirrhosis, and cancer. Food deterioration may occur due to the presence of oxidation-prone ingredients in food items (Shukla et al., 1997). One of the current approaches to prevent this oxidative degradation is addition of natural antioxidants in food items. It is also believed that natural antioxidants can stabilize or deactivate the free-radicals. In living cells, free-radicals may incorporate highly reactive oxygen and attack healthy cells through a range of biochemical reactions (Aluyor and Ori-Jesu, 2008). These free-radical initiated reactions may subsequently lead to cancer initiation and accelerated ageing process. Plant seed oils are reported to possess antioxidant properties that can prevent oxidative stress. The antioxidant property of seed oil is generally attributed to the presence of triglycerides and various natural antioxidant components in them. Formerly, very little or no attention was given to seed oil producing plants as a source of antioxidants (Schmidt et al., 2005). However, in recent years, renewed focus on seed oils as sources of novel antimicrobial and antioxidant compounds has been observed (Jarret et al., 2011).

The region of North-East India is endowed with two biodiversity hotspots of Indo-Burma and Eastern Himalayas. This region consists of eight states of India-Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. Many oil-rich seed bearing plants grow in this region in wild or in cultivated conditions. People residing in this region are using these plants for wide-ranging purposes including consumption as food items and also for medicinal

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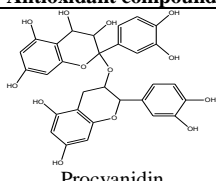
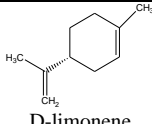
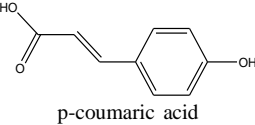
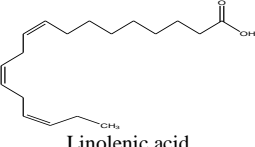
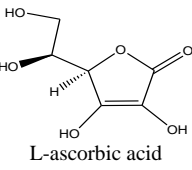
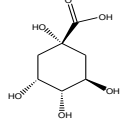
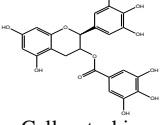
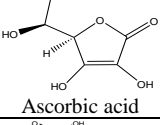
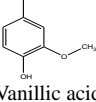
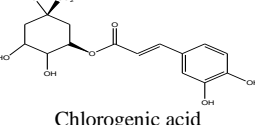
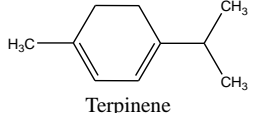
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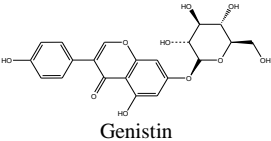
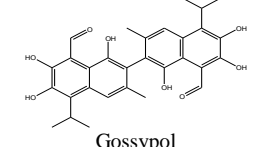
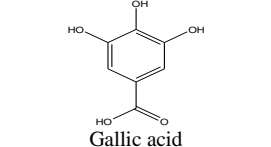
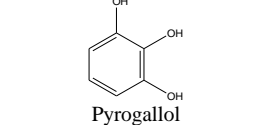
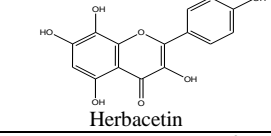
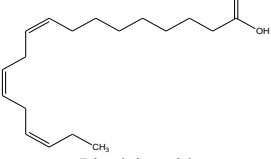
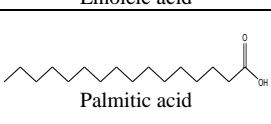
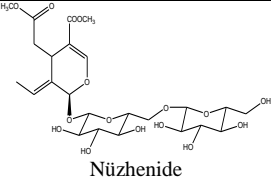
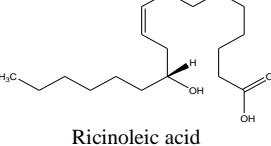
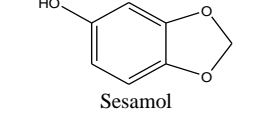
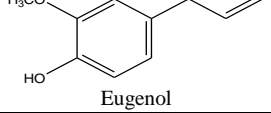
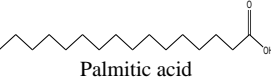
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**Table 1.** List of plants with oil yielding seeds traditionally used in North-east India with their antioxidant compound (1)

Name of plant	Local name	Location	Types of uses	Main chemicals	Antioxidant compound	References
<i>Abelmoschus esculentus</i> (L.) Moench.	Lady's finger (ENG) Bhendi (ASM), Bhelandri (MNI)	Assam, Manipur, and Nagaland	Food, food supplement	Oleic acid, linoleic acid, palmitic acid, and palmitoleic acid	 Procyanidin	Jarret et al., 2011; Robert et al., 2011
<i>Isomeles indica</i> (L.) Kuntze	Bon til (ASM), Thoiding Angouba (MNI), Uneimias(KHS)	Assam and Manipur	Medicinal	D-Limonene, D- $\alpha$ -thujone, and 1-8, cineole	 D-limonene	Islam, 2009
<i>Arachis hypogaea</i> L.	Leibak Hawai (MNI) Mungphali (HIN)	Assam, Manipur	Food	<i>p</i> -Hydroxybenzoic, <i>p</i> -coumaric, syringic ferulic, and caffeic acids	 <i>p</i> -coumaric acid	Bennioin, 1995; Hoppe et al., 1997; Murakami et al., 1984; Schmidt and Pokorný, 2005
<i>Brassica juncea</i> (L.) Czern.	Kadugu, Rai (HIN), Indian mustard (ENG)	Assam	Cosmetics	Oleic and linolenic acids	 Linolenic acid	Amarowicz et al., 1996; Amarowicz et al., 2000; Fukuda et al., 1986a, b; Saikia et al., 2006
<i>Brassica rapa</i> L.	Hanggam (MNI)	Assam, Manipur	Food, biofuel	Sinapine, esters of phenolic acids	 L-ascorbic acid	Amarowicz et al., 2000; Chopra et al., 2002; Dahanukar and Thatte, 1989; Fukuda et al., 1986; Gopalakrishnamn et al., 2003; Schmidt and Pokorný, 2005
<i>Capsella bursa-pastoris</i> (L.) Medik.	Shepherds purse (ENG)	Assam, Manipur	Medicinal	Quinic acid, palmitic acid, and $\beta$ -sitosterol	 Quinic acid	Dutta and Sarma, 2011; Grosso et al., 2011; Finley et al., 2011
<i>Carthamus tinctorius</i> L.	Kusum (BEN), Kusumlei (MAN)	Assam, Manipur	Food supplement, medicinal	Hydroxybenzoic, <i>p</i> -coumaric, and cinnamic acids	 Galocatechin	Armao et al., 2001; Nzaramba et al., 2009; Valko et al., 2007
<i>Cocos nucifera</i> L.	Naariyaal (HIN), Yubi (MNI)	Manipur, Tripura	Food, medicinal	Lauric, oleic, and stearic acids	 Ascorbic acid	Bennioin, 1995; Oliveira et al., 2009; Schmutterer, 2003; Saikia et al., 2006
<i>Croton tiglium</i> L.	Croton (ENG)	Assam	Fish Poison	Phorbol	 Vanillic acid	Kaushik and Agnihotri, 2000
<i>Diploknema butyracea</i> (Roxb.) H.J.Lam	Chiuri (NEP)	Arunachal Pradesh, Sikkim, Tripura	Food	Palmitic and oleic acids	 Chlorogenic acid	Applewhite, 1978; Kankha et al., 2010; Majumder et al., 1998
<i>Dysphania ambrosioides</i> (L.) Mosyakin & Clemants	Tersing Pambi (MNI)	Arunachal Pradesh, Manipur	Medicinal	Limonene, <i>p</i> -cymene, and terpinene	 Terpinene	Chopra et al., 2002; Islam, 2009; Sowemimo et al., 2007

**Table 1.** List of plants with oil yielding seeds traditionally used in North-east India with their antioxidant compound (2)

<i>Glycine max</i> L.	Nung Hawaii (MNI)	Assam, Arunachal Pradesh, Manipur	Medicinal	Syringic, vanillic, ferulic, salicylic, <i>p</i> -coumaric acids, and esters of caffeic and sinapic acids	 Genistin	Hoppe et al., 1997; Howell, 1996; Wang et al., 2002
<i>Gossypium arboreum</i> L.	Lasing (MNI), Cotton (ENG)	Assam, Mizoram, Manipur, Nagaland	Medicinal	Sinapic, ferulic, <i>p</i> -hydroxybenzoic acids, quercetin, and rutin	 Gossypol	Deorani and Fennema, 1985; Hron et al., 1999; Kazeem et al., 2013
<i>Helianthus annuus</i> L.	Numitlei (MNI)	Manipur, Meghalaya	Food	Chlorogenic, caffeic, <i>p</i> -hydroxybenzoic, <i>p</i> -coumaric, and cinnamic acids	 Gallic acid	Ingale and Shrivastava, 2011; Leung et al., 1981
<i>Juglans regia</i> L.	Walnut (ENG), Heijuga (MNI)	Sikkim	Food, medicinal	$\beta$ -Tocopherol, $\gamma$ -tocopherol, and $\delta$ -tocopherol	 Pyrogallol	Clara et al., 2000; Joanna et al., 2003; Li et al., 2007; Ozcan, 2009
<i>Linum usitatissimum</i> L.	Alsi (HIN), flax (ENG)	Arunachal Pradesh, Mizoram	Food supplement, medicinal	Omega-3, sinapic, <i>p</i> -hydroxybenzoic, coumaric, ferulic acids, and lignans	 Herbacetin	Amarowicz et al., 1994
<i>Madhuca longifolia</i> (J.König ex L.) J.F.Macbr.	Mahua (BEN)	All states of North-east India	Biofuel, medicinal	Oleic, linoleic, palmitic, and stearic acids	 Linoleic acid	Marikkar et al., 2010
<i>Mesua ferrea</i> L.	Nag champa (HIN)	All states of North-east India	Industrial	Palmitic, oleic, and stearic acids	 Palmitic acid	Choudhury et al., 1998; Sayeed et al., 2004; Sowemimo et al., 2007
<i>Olea europaea</i> L.	Olive (ENG)	Manipur, Arunachal Pradesh	Food, medicinal	Hydroxytyrosol, Secoiridoids, and oleuropein	 Nüzhenide	Paiva-Martins et al., 2011
<i>Ricinus communis</i> L.	Kege (MNI), Endebelai (BOD)	Manipur, Assam	Fuel	glycerides of ricinoleic acid	 Ricinoleic acid	Amarowicz et al., 1994
<i>Sesamum indicum</i> L.	Thoiding (MNI)	Assam, Manipur, Tripura.	Food	Lignans, and coumaric, ferulic, vanillic and sinapic acids	 Sesamol	Fukuda et al., 1986a, b; Schmidt and Pokorný, 2005
<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry	Laung (MNI)	Meghalaya, Mizoram,	Food, medicinal	Eugenol, butylated Hydroxytoluene, and butylated hydroxyanisole	 Eugenol	Aluyor and Ori-Jesu, 2008; Jarret et al., 2011; Seongwei et al., 2009
<i>Tetranthera angustifolia</i> (Blume) Nees	Black samson (ENG)	Arunachal Pradesh	Medicinal	Palmitic and stearic acids	 Palmitic acid	Aluyor and Ori-Jesu, 2008; Shukla et al., 1997

ASM – Assamese; BEN- Bengali; BOD – Bodo; ENG – English; HIN – Hindi; KHA – Khashi; MNI – Manipuri; NEP – Nepali; MIS – Mishmi.

applications. Enumeration of traditionally used seed oils in this region may help in highlighting the associated biochemical properties. Moreover, exploring those plants, which are not traditionally used by the people, could open up a new vista for production of seed oils having antioxidant properties. To the best of our knowledge, there is no up-to-date review published on the seed-oil plants of North-East India focusing particularly on their antimicrobial and antioxidant potential as well as their chemical compositions. Therefore, this mini review aims to review and document traditionally used and unused seed oil plants of North-East India and also to look into their chemical compositions with special emphasis on antimicrobial and antioxidant properties.

## METHODS

A shortlist of the seed oil yielding plants from the region of North-East India has been prepared from published literature, both from printed and electronic resources. Scientific names reported in the form of synonyms were standardized by cross checking with the Plant List ([www.theplantlist.org](http://www.theplantlist.org)). A comprehensive survey of literature was performed using the electronic databases, viz., PubMed (<http://pubmed.ncbi.nlm.nih.gov>), Science Direct ([www.sciencedirect.com](http://www.sciencedirect.com)) and Google Scholar (<http://scholar.google.com>) as well as various printed sources. Only experimentally verified chemicals were considered and their antioxidant properties were compared with records from PubChem (<http://pubchem.ncbi.nlm.nih.gov>) and ChEMBL (<https://www.ebi.ac.uk/chembl>) databases.

## RESULTS

Seed oil yielding plants reported from North-East India have been categorized into (i) seed oils traditionally used by the ethnic communities for their oils, and (ii) seed oils not traditionally used by the ethnic communities, but used for other plant parts.

### Seed oil plants traditionally used in North-East India

A total of 26 seed-bearing plants from North-East India have been reported for their traditional and commercial uses in this region (Table 1). Vegetable oils, predominantly seed oils, are generally procured from seeds, nuts or fruits by means of traditional processing techniques, such as the net variety system, the steam distillation, hydrodistillation technique and so on.

### Seed oils not traditionally used in North-East India

There are further 38 seed oil yielding plants that grow in North-East India, but their oils are not traditionally used by the indigenous people (Table 2). In certain cases, other plant parts are used by the people of the region. Scientific extraction and utilization of oil from these could enrich the seed oil resources of the region.

Among these plants, *Nigella sativa* seed oil, popularly called as 'Black seed oil' (Islam et al., 2009), is composed mainly of oleic, palmitic, and stearic acids, phytosterol, stigmaterol, and stearic acid. Neem plant (*Azadirachta indica*), generally found in various parts of the North-East India, is not used for its oil, but for other purposes. The seed oil of this plant has been studied extensively for the presence of triterpenoids and especially azadirachtin (Copping, 1995). Other bioactive compounds present in this oil include campesterol,  $\alpha$ -sitosterol, and stigmaterol. Canola oil is another distinctive variety of

rapeseed oil, which contains erucic acid, can be used as edible oil for use in salad dressing and other allied purposes.

### Usage categories of seed oils in North-East India

Seed oil producing plants reported from North-East India are used for wide-ranging purposes including uses as edible oils, various industrial items and as an alternative source of energy. Traditional uses of seed oil plants can be categorized into biofuel, cosmetics, fish poison, medicinal, food, food supplement and industrial uses. Most of the uses of the seed oil are for medicinal purposes, followed by use as food. Main consumption pattern of these seed oil plants have been highlighted in the following sections.

#### Edible oils

Consumption as edible oils is one of the most important and popular uses of plant-seed oil. The commonly used plant seeds oils from North-East India include mustard, sunflower, safflower, and coconut oil. Mustard oil is cultivated from different species of the mustard family (Brassicaceae), such as *Brassica juncea*, *Brassica nigra*, *Brassica rapa*, etc.

Sunflower oil is a mixture of monounsaturated and polyunsaturated fatty acids extracted from sunflower. Although not used by the people of North-East India in the past, the plant is now cultivated in many parts of this region for seed oil.

Another important seed oil bearing plant is Safflower, which produces two types of oil - one containing high monounsaturated fatty acids (oleic acid) and the other having high polyunsaturated fatty acids (linoleic acid). Oil containing monounsaturated fatty acids is mainly used for edible purposes, while the linoleic acid rich oil is used for painting and industrial purposes. Coconut oil is also used for edible purposes in this region.

Rice bran oil is the bi-product of milling and it is emerging as important edible oil in this region. Although it was not used in the past, nowadays its popularity has increased considerably because of its health benefits.

#### Food supplements

The food supplements are generally the substances that give full source of carbohydrate and protein, and provide resistance against microbial attack and improve the immune system. Only three species of seed oil yielding plants in North-East India (*Abelmoschus esculentus*, *Carthamus tinctorius*, and *Linum usitatissimum*) are used as food supplements. *Abelmoschus esculentus*, because of its oil and protein content, is recognized as a source of nutritional supplement. Due to the presence of unsaturated fatty acids such as linoleic acid, this oil is good for human consumption (Adelakun et al., 2009).

However, there are many other plants available in North-East India, which can be used as food supplements. For example, evening primrose seeds, which are generally used for the extraction of oil, are crucial for dietetic purposes (Tabassum and Singha, 2013). Extracted meal is rich in phenolics. Soybean or peanut grits, flours, pastes are regularly used in many other parts of the world as food stabilizers. In certain cases, walnuts, poppy seeds, which are rich in edible oil, are occasionally consumed as food ingredients, flavourings, salad-dressing and addictive.

#### Medicinal

In North-East India, 15 different plant seed oils are used as medicinal materials. Rapeseed oil obtained from *Brassica rapa* is used as laxative. In the traditional medicine, this oil is used as antiscorbutic, embrocation, and to treat muscular rheumatism, stiff neck, dengue, fever, bronchitis, etc (Tenore, 2011).

**Table 2.** List of NorthEast Plants with oil yielding seeds which are not traditionally used (1)

Name of oil	Name of plant	Local name	Location	Important constituents	Uses	References
Pomegranate seed oil	<i>Punica granatum</i> L.	Kaphoi (MNI)	Northern India	Myristic and margaroleic acids	Medicinal	FAO ,2009 Schubert et al., 1999
Rice bran oil	<i>Oryza sativa</i> L.	Rice (ENG), Chawaal (HIN)	Assam, Brahmaputra valley	Oryzanol, and palmitic, oleic and linoleic acids, and tocopherols	Food	Craker, 2004
Neem seed oil	<i>Azadirachta indica</i> A.Juss.	Nim (BEN), Vembu (TAM)	Assam, Eastern Himalayas, Manipur	Linoleic, hexa decanoic, and $\alpha$ -linolenic acid	Biopesticide	Islam, 2007; Schmutterer, 1995
Tobacco seed oil	<i>Nicotiana tabacum</i> L.	Tobacco (ENG) Tupakka(TAM)	Andrapradesh, Karnataka, West Bengal,	Glyceride, phospholipids, sterols, tocopherols	Biofuel	Frega et al., 1991; Usta, 2005; Zlatanov and Angelova, 2007
Rubber seed oil	<i>Hevea brasiliensis</i> (Willd. ex A. Juss.) Müll. Arg	Rubber (ENG)	Assam, Madras	Oleic, linoleic linolenic, and glutamic acids	Fuel	Eka et al., 2007; Ramadhas et al., 2005
	<i>Calophyllum inophyllum</i> L.	Nagchampa (BEN)	Maharashtra	Coumarins	Fuel, anti-HIV	Dutta and Sarma, 2011; Spino et al., 1998; Sowemimo et al., 2007
	<i>Thevetia peruviana</i> (Pers.)	Captain cook tree(ENG), yellow leander(ENG), lucky nut (ENG)	Eastern foothills of the Himalaya	Linoelaidic, linoleic, and $\alpha$ -linolenic acids	Fuel, biopesticides	Deka and Basumatry, 2011; FAO, 2006; Grosso et al., 2011; Kareru et al., 2010
Hemp oil	<i>Cannabis sativa</i> L.	Hemp,marijuana (ENG), dagga (AFR)	Gujrat, Karnataka	Linoleic, linolenic, stearidonic, eicosaenoic acids, $\beta$ -sitosterol, and cannabinoids	Medicinal, biopesticides, fuel	Al-Khalifa et al., 2007; Lampi et al., 1997; Tambe et al., 1996
Corn oil	<i>Zea mays</i> L.	Corn (ENG), bhutta (BEN)	Jammu and Kashmir, Gujrat, Bihar, West Bengal	Campesterol, campestanol, sitosterol, stigmasterol, and sitostanol	Food, fuel	Johnson and Lusas 1983; Juyoung et al., 2010.
Bitter gourd oil	<i>Momordica charantia</i> L.	Bitter gourd or bitter melon (ENG), karela (BEN)	Assam, West Bengal	Apiole, <i>trans</i> -Nerolidol, and $\beta$ -bisabolol	Antidiabetic, Medicinal	Anjum et al., 2013; Braca et al., 2008; Craker, 2004; Simionatto et al., 2005
Pumpkin seed oil	<i>Cucurbita pepo</i> L.	Pumpkin (ENG), kumra (BEN)	Assam, West Bengal	Linoleic, linoleinic, and palmitic acids	Prevents prostate cancer, purifies blood	Ardabili et al., 2011; Elmatbaea, 2006
Atermelon seed oil	<i>Citrullus vulgaris</i> Schrad. ex Eckl. and Zeyh.	Tarmuj (BEN), tarbuj (HIN), kalinda (TAM)	Assam, Gujrat, Rajasthan	Linoleic and stearic acids	Cooking, frying, food supplement	Mabaleha, 2007; Milovanović and Jovanović, 2005
Black seed oil	<i>Nigella sativa</i> L.	Black seed (ENG), kalonji (GUJ), black cummin (ENG), kala jeera (BEN)	Gujrat, South India	Oleic, palmitic, stearic acids, and phytosterol	Medicinal	Jeet et al., 2007
Amaranth oil	<i>Amaranthus cruentus</i> L.	Bari (ASM), rajgira (HIN), Chaulai (BEN)	Bihar, Uttarpradesh	Linoleic and linolenic acids, and lysine	Medicinal, regeneration of brain cells	He et al., 2003
Apricot oil	<i>Prunus armeniaca</i> L.	Chuli (LAD) Khubani (URD)	Himalayan Ladakh in the Jammu and Kashmir	Aarachidic, eicosenoic, linoleic, stearic, and palmitoleic acids	Medicinal, food supplement	Dwivedi and Ram, 2006
Ben oil	<i>Moringa oleifera</i> Lam.	Horseradish tree (ENG), ben oil tree (ENG), drumstick tree (ENG)	Tamil nadu, Kerala	Behenic and oleic acids	Cosmetics	Burkill, 1996.
Borneo tallow nut oil	<i>Shorea robusta</i> Gaertn. f.	Sal (BEN), Salwa (HIN), Guggilu (MAR), rala (MAR)	Assam, Karnataka, Mysore	Arachidic, Oleic, linoleic, palmitic, and stearic acids	Cosmetics, woodings, flavouring agent	Bakkali et al., 2008
Cocklebur oil	<i>Xanthium strumarium</i> L.	Cocklebur (ENG), broad bur (ENG), burdock datura (ENG)	Gujrat, karnataka	Monoterpernes, sesquiterpenes	Medicinal	Pandey and Rather 2012; Scherer and Godoy, 2009

**Table 2.** List of NorthEast Plants with oil yielding seeds which are not traditionally used (2)

Coriander seed oil	<i>Coriandrum sativum</i> L.	Cilantro (ENG), dhania (BEN), Phadigom (MAN)	Assam, Meghalaya	Petro selenic acid	Food and food supplement	Mabaleha et al., 2007
Kenaf seed oil	<i>Hibiscus cannabinus</i> L.	Shougri (MAN), Ambaadi (MAR), Mesta (BEN)	Assam, Manipur	Linoleic, $\alpha$ -linolenic, and oleic acids	Biofuel, cosmetics, vegetable oil	Hopkins et al., 1959; Mishra et al., 1992; Mohamed et al., 1995
Papaya seed oil	<i>Carica papaya</i> L.	Papita (HIN), pepe (BEN), papaya (ENG)	Assam, West Bengal	Free fatty acid, crude fibre,	Food and nutritional value	Afolabi et al., 2011; Fokou et al., 2009
Perilla seed oil	<i>Perilla frutescens</i> (L.) Britton	Perilla (ENG)	Gangtok, the Himalayas	Apigenin, chrysoeriol, luteolin, and rosmarinic and caffeic acids	Medicinal	Kwon et al., 2002
Poppyseed oil	<i>Papaver somniferum</i> L.	Poppy seed (ENG), posto (BEN)	Assam	$\gamma$ -Tocopherol, campesterol, stigmasterol and sitosterol	Medicinal	Huda et al., 2001; Le, 2009
Taramira oil	<i>Eruca sativa</i> Mill.	Tara mira (HIN), rocket salad (ENG)	Haryana, Madhya Pradesh, Punjab, Rajasthan	Erucic, palmitic, and linolenic acids	Medicinal	Miyazawa et al., 2002; Lazzeri et al., 2004
Tea seed oil	<i>Camellia sinensis</i> (L.) Kuntze	Tsubaki (ASM) Tea (ENG) Cha, chai (HIN), Thayilai (TAM)	Assam, Darjeeling	Palimitoyl oleoyl glycerol	Medicinal, cosmetic industry	Pholen and Pohtee, 2011
Tigernut oil	<i>Cyperus esculentus</i> L.	Chufa sedge (ENG), nut grass (ENG), yellow nutsedge (ENG), tigernut sedge (ENG)	Florida	Linoleinic, palmitic, myristic, and estearic acid	Medicinal and cosmetics	Abano and Amoah, 2011; Arafat et al., 2009
Tomato seed oil	<i>Lycopersicon esculentum</i> (L.) Karsten	Tomato (ENG)	Meghalaya, Sikkim	Palmitic acid	Medicinal	Canella and Castriotta, 1980
Pongamia oil	<i>Pongamia pinnata</i> (L.) (Pierre).	Honge (KAN), Karanja (HIN)	Himalayan ranges	Arachidic, behenic, eicosenoic, linolenic, lignoceric, oleic palmitic and stearic acids	Biofuel	Scott et al., 2008
Vernonia oil	<i>Vernonia anthelmintica</i> (L.) Willd	Ironweed (ENG)	Uttar Pradesh	Arachidic, behenic, eicosenoic, and vernolic acids	Industrial use	Edgar et al., 2002
Pine nut oil	<i>Pinus kesya</i> . Rai Dellenia	Pine seed or cedar nut (ENG)	Meghalaya, Sikkim, Uttarakhand	Palmitic, pinolenic, and stearic acids	Medicinal use	Lee et al., 2004
Carrot seed oil	<i>Daucus carota</i> L.	Carrot (ENG), gajar (BEN)	Assam, Meghalaya	Aromadendrene, Farnesene levomenol, vitamin A aldehyde, isolimonene	Medicinal	Bulow and König, 2000
Chaulmoogr oil	<i>Hydnocarpus kurzii</i> (King) Warb.	Nirati (ASM), Chaulmugra (HIN)	Arunachal Pradesh, Manipur, Tubaraka	Isogadolic acid	Medicinal	Gunstone, 2002
Cuphea oil	<i>Cuphea carthagenensis</i> [Jacq.] Macbr.	Cuphea (ENG), cigar plant (ENG)	Central Asia	Capric acid	Industrial, biofuel	Winthrop and Terry, 2006
Mango oil	<i>Mangifera indica</i> L.	Aam (BEN), mango (ENG)	Assam, Barak valley, West Bengal	Arachidic, linoleic, oleic, palmitic, and stearic acids	Medicinal, food industry	Mahale and Goswami, 2011
Rose hip seed oil	<i>Rosa moschata</i> J. Herrm.	Lemon Myrtle, Lemon Scented Myrtle, Lemon Ironwood (ENG)	Karnataka, Sikkim	Linoleic acid	Cosmetics industry, medicinal	Moris, 2006
Beech nut oil	<i>Fagus sylvatica</i> L.	Copper beech, Purple beech (ENG)	Europe, North America	Linoleic, oleic, and palmitic acids	Edible oil, Medicinal	Gunstone, 2002
Cashew oil	<i>Anacardium occidentale</i> L.	Kaju (BEN, HIN)	Karnataka, Malabar coast, Kerala, Tamilnadu	Triglycerides, tocopherols, and linoleic acid	Foods and food supplement	Aremu, 2006; Eromosele and Paschal, 2002
Almond oil	<i>Prunus mygdalus</i> Batsch.	Almond (ENG)	Malabar coast	Linoleic and palmitic acids	Food and cosmetics industries	Jenkins et al., 2002; Mandalari et al., 2010

**Table 2.** List of NorthEast Plants with oil yielding seeds which are not traditionally used (3)

Grape seed oil	<i>Vitis vinifera</i> L.	Aangoor (BEN), Grape (ENG)	Jammu and Kashmir, uttarakhand	Linoleic, oleic, and palmitic acids	Cosmetics industry	Decorde et al., 2009; Nash, 2004
Argemone Oil	<i>Argemone mexicana</i> L.	Mexican poppy (ENG), Mexican prickly poppy (ENG), Flowering thistle (ENG)	Assam, Manipur, Tripura	Columbamine, dehydrocorydalmine, jatrorrhizine and oxyberberine	Medicinal	Willcox, 2007

AFR – African; ASM – Assamese; BEN- Bengali; ENG – English; HIN – Hindi; KAN – Kannada; MAR = Marathi; MNI – Manipuri; TAM – Tamil; URD – Urdu; LAD – Ladhaki.

*Cocos nucifera* is used in various parts of this region for treating cholera and as a nutritional supplement (Deorani and Shama, 2007). In other parts of the world, it is also used as an aphrodisiac, diuretic, and to treat loss of hair and debilitating diseases, fever and urinary disorders (Chopra et al., 1996). *Croton tiglium* is recognized as fish poison in North-East India as well as in other parts of India (Amarowicz et al., 2000). However, jayphala oil obtained from this plant is used as a purgative, irritant, cathartic and in snake-bites in other parts of India (Chopra et al., 1996).

*Trachyspermum ammi* is found in North-East India, but not traditionally used. However, ajwain oil obtained from this plant is used for the treatment of abdominal pain, bronchial problem, diarrhoea, dyspepsia, and hemorrhoids (Jeet et al., 2007). Likewise, *Ocimum americanum*, *Syn Ocimum canum* (tulsi) is a ubiquitous plant in North-East India, (Burt, 2007), particularly in Assam and Manipur, but tulsi oil is not used widely in this region. However, its usage has been reported in other parts of India for its anti-stress, antioxidant, immunomodulatory and anti-radiation properties. This oil appears to have the potential for prevention and treatment of cancer (Burt, 2007).

Methi seed oil, obtained from *Trigonella foenumgracecum*, is used as carminative, tonic, aphrodisiac, dysentery and to treat smallpox (Parekh and Chanda, 2008). Medicinal properties of the plant seed oils are generally attributed to the presence of various constituents of polyphenols, carotenoids, tocopherols, tocotrienols, ascorbic acid, and thiols.

### Biofuel

There are some instances of using plant seed oils as biofuel by the traditional people in the North-East India (Yuan-Chuen and Huang, 2008). Oils extracted from mustard seeds, coconut and castor are used for religious and ritual purposes (Tenore et al, 2011). Whilst large scale extraction of seed oils for their uses as biofuel is still in its infancy, seed oil plants are slowly emerging as an important sources of biofuel and starting to pave the way towards new sources of non-renewable energy. To meet the ever-increasing demands for energy, attempts have been made to produce biodiesel from variety of plants, mainly non-edible plants found in North-East India. *Calophyllum inophyllum*, *Hevea brasiliensis*, *Jatropha curcas*, *Madhuca indica*, and *Pongamia pinnata* are just a few examples (Gogoi et al., 2011).

### Cosmetics

A variety of plant seed oils have been providing the essential ingredients for various cosmetics since time immemorial. In spite of the presence of many plants in North-East India, traditional use of seed oil for cosmetics is rather rare. However,

oil from *Brassica juncea* is mixed with the extracts of *Cynodon dactylon* and *Curcuma longa* to produce skin care products and cosmetics in some parts of Assam (Saikia et al., 2006). Considering the abundance of seed oil plants in this region, one might foresee an emerging trend in using these seed oil producing plants as a source of essential components of cosmetics in industrial scale. Seed oils from grape, papaya and mulberry may also be considered for use in cosmetic industries

### Industrial uses

There are no reported traditional industrial applications of seed oils in the region. Despite that, seed oil growing in this region, can be utilized for industrial purposes, from painting to lubricant industries. *Camellia* sp., growing abundantly in Assam, has its future in oil industry (Kaplowitz and Tsukamoto, 1996). Vegetable oils obtained from soybean and castor, can be used as transformer coolant oils (Schmidt and Pokorný, 2005). Palm oil can be used in isolation as a fluxing dip in the tin plating in steel industries, while olive oil can be used as a yarn lubricant (Kaplowitz and Tsukamoto, 1996).

### Chemical properties and characteristics of seed oils

Chemical characteristics of seed oils generally depend on the fatty acid composition. Presence of other compounds provide unique characteristics of seed oil. Mustard oil is characterized by the pungent odor owing to the presence of allyl isothiocyanate, which serves as defence against herbivores. This compound is stored inside the compartment of the plant cells in the form of glucosinolate (Ratzka et al., 2002). Mustard oil contains generally high amount of monounsaturated fatty acids, such as erucic acid and oleic acid, and lower amounts of polyunsaturated fatty acids comprising omega-3  $\alpha$ -linolenic acid and omega-6 linoleic acid. This oil also contains a little amount of saturated fats, sinapines and esters of phenolic acids (Schmidt and Pokorný, 2005).

Main components of sunflower oil are linoleic, oleic, palmitic, and stearic acids (Gunstone, 2011). Sunflower oil can be categorized by the amount of oleic acid present, high oleic acid sunflower oil (containing more than 70% of the total fatty acids) and mild oleic acid sunflower oil (containing less than 70% of the total fatty acids). Other important components are chlorogenic, caffeic, p-hydroxybenzoic, p-coumaric and cinnamic acids (Amarowicz et al., 2000). In other parts of the world, sunflower oil is used in manufacturing solid sunflower butter. Nowadays people prefer refined product of this oil for edible purposes. Though linolenic acid and linoleic acids are important for human nutrition, they may cause oxidative instability in the oil (Wang, 2002).

Coconut oil exists as solid in room temperature because of its relatively high proportion of saturated fatty acids (92%) particularly lauric acid (Adelakun et al., 2009). Important fatty acid generally includes capric acid, caprylic acid, lauric acid, linoleic acid, myristic acid, oleic acid, palmitic acid, and stearic acid (Chowdhury et al., 2007). Palm, olive, cottonseed, peanut, and sunflower oils are classed as oleic-linoleic acid oils contain high proportion of unsaturated fatty acids, such as

**Table 3.** Smoke points of some plant seed oils used in North-east India

Oil	Smoke Point (°C)
Mustard oil	254
Sunflower oil	227
Safflower oil	107
Coconut oil	177
Rice bran oil	254

**Table 4.** Fatty acid constituents of some major seed oil found in North-east India

Name of oil	Oleic acid	Palmitic acid	Linolenic acid	Stearic acid	Linoleic acid	Omega-3-fatty acids	Omega-6-fatty acids	Trans-Nerolidol	Petro-selenic acid	Erucic acid	Lauric acid	Myristic acid	Palmitoleic acid	Arachidic acid
Mustard oil	+	+	+	+	+	+	-	-	-	+	+	-	+	-
Sunflower oil	+	+	+	+	+	-	-	-	-	-	+	+	+	-
Jatropha oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coconut oil	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Groundnut oil	+	+	-	+	+	-	-	-	-	-	-	+	+	+
Sesame oil	+	+	+	-	+	-	-	-	-	-	-	-	-	-
Flaxseed oil	-	-	+	-	-	+	-	-	-	-	-	-	-	-
Rice bran oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corn oil	-	-	+	-	+	-	-	-	-	-	-	-	-	-
Safflower oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bittergourd oil	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Tomato seed oil	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Soybean oil	-	+	+	+	+	-	-	-	-	-	-	+	-	-
Cotton seed oil	-	+	-	+	-	-	-	-	-	-	-	+	+	-

the monounsaturated oleic acid and the polyunsaturated linoleic acid (Dunn, 2005). Other oils are categorized as the erucic acid oils, which are similar to oleic linoleic acid oils except their unsaturated fatty acid. Rapeseed and mustard seed oils are important oils of this class.

A brief summary of various compositions of fatty acids in the seed oils is given in Table 4. Castor oil (a hydroxy-acid oil), another important oil of this class contains glycerides of ricinoleic acid. Melting point of the specific chemical ingredient plays an important role in maintaining the particular bioactivity expression among the seed oil plants. Mustard oil, proved to be more effective than corn oil, because of the presence of omega-3-polyunsaturated fatty acid in it and also experimentally found effective in preventing color tumor in animals (Dwivedi and Ram, 2003).

Rice bran oil has high content of free fatty acids, wax, and unsaponifiable matter (Shin and Kang, 2001). Its beneficial effects in the health improvement are due to the presence of compounds such as oryzanol, tocotrienols and squalene (Kochhar, 2002). Rice bran oil has high stability in their structure, probably due to the combined effect of oryzanol, phytoosterols, squalene, tocopherols, and tocotrienols (Kochhar, 2002).

#### Antimicrobial properties of the seed oil plants of North-East India

A fair amount of data on the antimicrobial activity of many seed oil producing plants of North-East India is available (Avancini et al., 2000). The phenolic component of the seed oil plants are generally known for their antimicrobial activity. The possible mechanisms of action of natural compounds present in these seed oil plant involves disintegration of cytoplasmic membrane of the bacterial cell, destabilization of the proton motive force (PMF), electron flow, active transport, and coagulation of the cell content (Burt, 2004). The structure of these seed oil compounds disintegrates the external membrane of Gram-negative bacteria, releasing lipopolysaccharides (LPS), and increasing the permeability of the cytoplasmic membrane

to ATP. Analysis in the antimicrobial activity of black pepper, clove, garlic, ginger, and green chilli on the human pathogenic bacteria viz. *Bacillus subtilis*, *Enterobacter aerogenes*, *E. coli*, *P. aeruginosa*, *S. aureus*, *S. epidermidis*, *S. typhi*, and *Shigella flexneri* revealed that, aqueous garlic extract was sensitive against all the bacterial pathogens. Many plants are reported to possess not only the antimicrobial activity but also the resistance modifying ability (Shrestha and Tiwari, 2009).

The terpene content of the oil plays crucial role in the antifungal activity. These seed oil plants exhibit cytotoxic and phototoxic activity leading to fungicidal or fungistatic property (Rios and Recio, 2005). Similarly, inhibitory effect of clove extracts have been studied by Sakagami and Kajimura (2000) on the production of verotoxin by *E. coli*. However, in that study, couple of other plants were also found active against both Gram-positive and Gram-negative bacterial strains.

Mycotoxins mediated diseases, chronic, subchronic, and acute can be treated by seed oils, but their effectiveness depends on the frequency and route of administration and dose of the oils. The other factors include the age, sex the time, and the climatic condition of the plants producing the fixed oils (Table 4).

#### Cytotoxicity

Studies on *C. albicans* revealed that the seed oil of *F. capillaries* not only could inhibit the fungal growth but also could initiate morphological transformations thereby provoking depolarization of the mitochondria with the reduction of the membrane potential affecting  $Ca^{2+}$  cycle (Tenore et al., 2011). As a result, the proton pump and the ATP pool was affected and the cell death occurred by apoptosis or necrosis. In the yeast cell, the ergosterol constitutes the most abundant sterol which is responsible for maintaining the cell function and integrity (Rodriguez et al., 1985). The component of the oil of *F. capillaries* could act on the sterol biosynthesis pathway thereby inhibiting the cell growth by inhibiting the ergosterol biosynthetic enzyme, lanosterol 14 $\alpha$ -demethylase. Thus, seed

**Table 5.** Antimicrobial Activity of the Seed Oil Plants of Northeast India (1)

Name of plant	Biological activity	Mode of action	Therapeutic use	Causative organism	Reference
<i>Abelmoschus esculentus</i> (L.) Moench.	Antibacterial activity	Inhibition of the membrane transport system	Diarrhoea	<i>Bacillus subtilis</i> <i>Staphylococcus aureus</i> <i>Pseudomonas fluorescens</i>	Carvalho et al., 2012
	Antipyloric activity		Gastritis, Pepticulcer diseases	<i>Helicobacter pylori</i>	Olorunnipa et al., 2013
<i>Anisomeles indica</i> (L.) Kuntze	Anti HIVactivity	Cytotoxic effect to the host cell	AIDS	HIV	Baranwal et al., 2012
	Anti bacterial activity		Gastric, peptic cancer	<i>Helicobacter pylori</i>	Wang, 2002. Shobolev, 2012
<i>Arachis hypogaea</i> L.	Antibacterial activity	Increases the apoptotic pathways	Food poisoning	<i>S. aureus</i> <i>S. epidermidis</i> <i>S. subflava</i>	Parekh and Chanda, 2008
<i>Brassica juncea</i> (L.) Czern.	Antibacterial activity	Cell Lysis	Food poisoning, Indigestion	<i>V. parahaemolyticus</i>	Yuan and Huang, 2005
	Antifungal activity	Inhibition of the tube formation	Candidiasis, Aspergillosis Sleeping sickness	<i>Aspergillus niger</i> , <i>A. flavus</i> , <i>Trichoderma viride</i> , <i>Candida albicans</i>	
<i>Brassica rapa</i> L.	Antibacterial activity	Modification In the membrane transport system	Dysentery, Dyspepsia,	Gram-positive bacteria <i>Staphylococcus aureus</i> <i>L. monocytogenes</i> <i>Enterococcus faecalis</i>	Tenore et al., 2011
	Antifungal activity	Inhibition in the germ tube formation	Food poisoning	Gram-negative bacteria <i>P. aeruginosa</i> <i>Klebsiella pneumoniae</i>	
			Aspergillosis	Moulds <i>Aspergillus flavus</i>	
			Botrytris	<i>Botrytis cinerea</i> <i>C. herbarum</i>	
<i>Capsella bursa-pastoris</i> (L.) Medik.		Inhibitor of the virulence factor	Oral infection, Dental caries	<i>S. mutans</i> <i>S. sanguis</i> <i>A. viscosus</i>	Soleimanpour et al., 2013.
	Antibacterial activity	Cell wall Lysis	Food poisoning constipation	<i>E. faecalis</i>	Raad et al., 2013.
<i>Carthamus tinctorius</i> L.	Antibacterial activity	Cellwall Lysis Inhibit the proton pump probably	Duodenal and peptic ulcers	<i>Helicobacter pylori</i>	Moghaddam, 2011
<i>Cocos nucifera</i> L.	Antibacterial activity	Cell wall Lysis	Stomach infection, Bowel syndrome	<i>S. aureus</i>	Bankar, 2011 Silva, 2013
<i>Croton tiglium</i> L.	Antibacterial activity	Rapture of the cell membrane	Cough, Skin disease, tooth ache, Paralysis, diarrhoea, dysentery	<i>Mycobacterium smegmatis</i> , <i>Staphylococcus aureus</i> , <i>Bacillus subtilis</i>	Upadhyay et al., 2010.
	Antifungal activity	Inhibition of spore formation	Candidiasis	<i>Candida albicans</i>	
<i>Diploknema butyracea</i> (Roxb.) H.J.Lam	Antibacterial activity.	Cell wall Lysis of the bacterial cell	Diarrhoea, dysentery	<i>Staphylococcus aureus</i> , <i>Bacillus subtilis</i>	Thapa et al., 2013
<i>Dysphania ambrosioides</i> (L.) Mosyakin and Clemants	Antibacterial activity	Inhibition in the protein synthesis	Dysentery Bowel syndrome	<i>B. subtilis</i> <i>Staphylococcus aureus</i>	Ávila-Blanco et al., 2014, Boutkhila et al., 2009

**Table 5.** Antimicrobial Activity of the Seed Oil Plants of Northeast India (2)

<i>Gaultheria fragrantissima</i> Wall.	Antifungal activity	Mycelial growth Inhibition leakage of the specific ion, Inhibition of the Carbohydrate metabolism	Food borne diseases Food spoiling Food poisoning	<i>Fusarium solani</i>	Shrestha and Tiwari, 2009
<i>Glycine max</i> L.	Antibacterial activity	Cell lysis	Digestional infection	<i>Bacillus subtilis</i> <i>Pseudomonas aeruginosa</i>	Ponnusha et al., 2011
<i>Gossypium arboreum</i> L.	Antibacterial activity	Modification in the membrane transport	Pneumonia Cough, fever	<i>Staphylococcus aureus</i> <i>Paeruginosa</i> <i>Klebsiella pneumoniae</i>	Saidu and Abdullahi, 2011
<i>Helianthus annuus</i> L.	Antifungal activity Antibacterial activity	Mycelial growth inhibition Cell wall rupture	Aspergilliosis Food poisoning Dyspepsia dysentery	<i>Aspergillus niger</i> , <i>Aspergillus flavus</i> , <i>E.coli</i> <i>Streptobacillus sp.</i>	Rajakannuet al., 2013; Sankaranarayanan et al., 2008
<i>Impatiens amplexicaulis</i> Edgew.	Antibacterial activity	Alteration in the membrane transport system	Peptic ulcer Gastritis dyspepsia	<i>Helicobacter pylori</i>	Qayum et al., 2012
<i>Juglans regia</i> L.	Antibacterial activity Antifungal activity	Cell wall Lysis, Stoppage of the replication process Inhibition of spore formation	Food borne diseases, Eye infection, Skin infection	Gram positive <i>Bacillus cereus</i> <i>B. subtilis</i> , <i>Staphylococcus aureus</i>  Gram negative <i>P. aeruginosa</i> <i>Escherichia coli</i> <i>Klebsiella pneumoniae</i>  <i>Candida albicans</i> <i>C. neoformans</i>	Oliveira et al., 2008; Pereira et al., 2007
<i>Lindera neesiana</i> (Wall. ex Nees) Kurz	Antibacterial activity	Inhibition of the protein synthesis	Diarrhoea	<i>B. subtilis</i> , <i>Staphylococcus aureus</i>	Luitel et al., 2014
<i>Linum usitatissimum</i> L.	Antipyretic activity Antibacterial activity	Disruption of cell membrane Modification in the proton pump	Typhoid Food poisoning Desentery	<i>Salmonella typhi</i>  Gram positive <i>Staphylococcus aureus</i> <i>Bacillus subtilis</i>	Kaithwas and Mazumder, 2013  Kalaivani and Jegadeesan, 2013
<i>Madhuca longifolia</i> (J.König ex L.) J.F.Macbr.	Antifungal activity	Cell wall Lysis Inhibition of membrane bound enzyme	Cough Skin infection Aflatoxicosis	Gram negative <i>Escherichia coli</i> <i>P. aeruginosa</i>  Fungi <i>Aspergillus oryzae</i> <i>Aspergillus niger</i>	Sarma et al., 2013
<i>Mesua ferrea</i> L.	Antibacterial activity	Inhibition of membrane permeability	cough,diarrohea, dysentery, dental caries, anemia, fever, piles	<i>Lactobacillus arabinosus</i>  <i>Staphylococcus Aureus</i> <i>Shigella spp.</i>	Chahar et al., 2013; Tambekar et al., 2010  The et al., 2013
<i>Olea europaea</i> L.	Antibacterial activity Antifungal activity	Cell wall Lysis Reduced mycelia growth	Dysentery Ringworm Superficial mycosis	<i>Enterococcus feacalis</i> <i>Bacillus cereus</i>  <i>Alternaria alternaria</i> <i>Aspergillus fumigates</i> <i>Cladosporium herbarum</i>	Fiaza et al., 2011  Pereira et al., 2007
<i>Ricinus communis</i> L.	Antibacterial activity Antifungal activity	Inhibition of cell wall synthesis Attack on fibroblast and endothelial cells	Food borne disease Aflatoxicosis Aspergilliosis	<i>Bacillus subtilis</i>  <i>Aspergillus fumigatus</i> <i>Aspergillus flavus</i>	Naz et al., 2012

**Table 6.** Antioxidant components in seed-oil bearing plants of North-east India

	Probable Mechanism	Seed oil	References
Flavonoids	Chelation with metal ions, scavenging or quenching free-radicals or inhibition of enzymatic systems responsible for free-radical generation	<i>Helianthus annuus</i> L.	Fukuda et al., 1986a, b; Leung et al., 1981
Lignans	Scavenging hydroxyl radicals	<i>Sesamum indicum</i> L.	Schmidt and Pokorný, 2005.
Cinnamic acid derivatives	Scavenging free radicals	<i>Carthamus tinctorius</i> L.	Asgarpanah and Kazemivash, 2013; Valko et al., 2007
Tannins	Act as primary antioxidant by donating hydrogen atom or electrons; also as secondary antioxidants. They chelate metal ions like Fe (II) and interfere with one of the reaction steps in the Fenton reaction thus retarding oxidation	<i>Glycine max</i> L.	Amarowicz et al., 1996; Hoppe et al., 1997; Wang, 2002
Coumarins	Radical scavenging effect	<i>Helianthus annuus</i> L.	Leung et al., 1981
		<i>Arachis hypogaea</i> L.	Chang et al., 2006
		<i>Carthamus tinctorius</i> L.	Asgarpanah and Kazemivash, 2013; Valko et al., 2007
Tocopherols	Free radical scavengers	<i>Juglans regia</i> L.	Joana et al., 2003; Li et al., 2007
Polyfunctional organic acids	React with transition metals forming complexes, thus preventing catalytic effect of the metals in the oxidation reaction	<i>Ricinus communis</i> L.	Amarowicz et al., 1994
		<i>Linum usitatissimum</i> L.	Amarowicz et al., 1994
		<i>Brassica rapa</i> L.	Cartea et al., 2010; Miyazawa et al., 2002; Schmidt and Pokorný, 2005

inhibiting the cell growth by inhibiting the ergosterol biosynthetic enzyme, lanosterol 14 $\alpha$ -demethylase. Thus, seed fixed oil proved to be potent antifungal agents treating candidiasis, cryptococcosis, and ringworm diseases and is effective against superficial infection too.

#### Phototoxicity

Light induced activation of photosensitive components of seed oil produces conjugated cytotoxic adducts of DNA (Averback et al., 1990). The process resulted cell lysis and leakage of many integral proteins of target cell (Bakkali et al., 2004). Microbial population like *Aspergillus niger*, *Aspergillus flavus*, *Fusarium* spp. can be inhibited by blocking synthesis of intracellular and extracellular enzymes synthesis. Application of *Croton campestris* seed oil in fungal cell resulted parietal thickness and plasma membrane disruption (Raad et al., 2013). *Aspergillus flavus* show ultra-structure deterioration characterized by leakage of various vital ions (Shankaranarayan et al., 2008). Fungal growth inhibition is also associated with nonfunctional fungal hyphae after treatment with *Sesamum indicum* L. seed oil (Anilakumar et al., 2010)

#### Antioxidant properties of oil yielding plants from North-east India

Antioxidants protect the biological systems against the potentially harmful effects of several biochemical reactions causing excessive oxidation (Arnao et al., 2001), thereby preventing oxidative stress. Oxidative stress is often results in cancer, atherosclerosis, cardiovascular disorder and many other (Valko et al., 2007). Antioxidant activity is attributed by the changes in the metabolizing key enzymes and thereby controlling the unnecessary quick ageing process in the living systems (Finley et al., 2011; Nzaramba et al., 2009). Living cells possess antioxidant defense system mainly comprising of glutathione, ascorbic acid, vitamin E, superoxide dismutase, and glutathione peroxidase to protect themselves against harmful oxidative stress (Kaplowitz and Tsukamoto, 1996).

Oxidative reactions lead to formation of free-radicals. The most common compounds which are attacked by oxidation are unsaturated fats, which generally turn rancid as a consequence. These reactions are often enhanced with ferrus or copper ions. Degradation due to oxidative reactions can cause adverse effects on all biomolecules. The oils like okra seed oil, ground nut oil, linseed oil, olive oil, and sesame oil (Tables 1 and 2), which are native to North-East India, possess antioxidant activity. These oils are capable of preventing oxidative stress by detoxifying various harmful chemical agents entering the human body. Antioxidants present in the seed oils include mainly tocopherols, flavonoids, carotenoids, and bioactive plant phenols (Table 5) (Dimitrios, 2006; Shukla et al., 1997). Oil producing seeds contain various types of phenolic compounds, such as flavonoids, lignans, lignins, phenolic acids, and tannins. Flavonoids can exert their antioxidant activity via a series of mechanisms, e.g., by chelating metal ions, by scavenging or quenching free-radicals or by inhibiting enzymatic systems responsible for free-radical generation (Dias et al., 2005; Islam, 2009). Flavonoids are the most widely present polyphenolic compounds in many oil seeds (Saikia et al., 2006).

Lignans are dimeric phenyl propanoids and often possess one or more phenol (Ar-OH) functionality. These compounds are considered to be protective against colon, breast, and prostate cancers (Kocchar, 2002). Tocopherols are another important antioxidant present in seed oils.  $\alpha$ -Tocopherol exhibits vitamin E activity and prevents oxidation of lipids. The antioxidant activity of tocopherol is based on the tocopherol-tocopheryl quinone redox system (Shukla et al., 1997). Tocopherol acts as free radical scavenger and thus can be used in the preservation of animal products. Sunflower oil contains high  $\gamma$ -tocopherol making this plant resistant to autoxidation (Arnao et al., 2001). The flax plant *Linum usitatissimum* possesses various tocopherols and carotenoids and some sterols, thus making its oil high in antioxidants. Rapeseed oil and soyabean oil contain high percentage of tocopherols

**Table 7.** Application of various seed-oil Plants of North east India (1)

Name of the Plant	Bioactivity of the plant	Diseases treated	Mode of action of the plant	Reference
<i>Abelmoschus esculentus</i> L. Moench	Anticancer	Intestinal cancer	Cancer is prevented by its ability to bind bile acids	Yogesh et al., 2011
	Antidiabetic activity	Diabetes mellitus	It stabilizes blood sugar by regulating the rate at which sugar is absorbed from the intestinal tract	Sabitha et al., 2011
<i>Anisomeles indica</i> (L.) Kuntze	Anti-inflammatory activity	Bacterial inflammation	inhibit DNA replication of pathogen by inhibiting NO, TNF- $\alpha$ without affecting cell viability	Baranwal et al., 2012
	Antimicrobial activity	Gastric cancer, Malignancy	Inhibition of NF-B activation, as well as IL-8 secretion, in <i>H. pylori</i> might be a useful strategy for the management of chronic gastritis	Rao et al., 2012
		Food poisoning	The seed oil kills the pathogen by interfering with the formation of hyphae	Kundu et al., 2013
<i>Arachis hypogaea</i> L.	Antifungal activity	Conjunctives, Eye injuries Cataract	Oil works by disrupting the cell wall of the fungal hypae	Sobolev et al., 2011
	Anti-inflammatory and Anticancer activity	Scarring of chorioretina Corneal cancer	inhibits NF-kB signaling in treatment of cancer and inflammatory diseases	Kochert et al., 1996
<i>Brassica juncea</i> (L.) Czern	Antidiabetic activity	Diabetes mellitus, Obesity	It involves processes controlling both glucose metabolism and depressive states by decreasing the effects of monoamine levels on the brain	Anand et al., 2009
	Antifungal activity	Oral candidiasis, Dermatophytosis, Nail and skin spoilage	It containing broad antifungal spectrum thereby controlling various fungal diseases	Thakur et al., 2014
	Anticancer activity	Breast Cancer	inhibiting tumor formation in breast	Thakur et al., 2014
<i>Brassica rapa</i> L.	Antioxidant, anticancer, and Anti-inflammatory activities	HIV Cancer	Glucosinolates, component of <i>Brassica rapa</i> L., rapidly hydrolysed yielding glucose and instable aglycons and then break-down to isothiocyanates, having free radical scavenging, anticancer and anti-inflammatory properties	Jafarian-Dehkordi et al., 2013; Cartea et al., 2011; Tawfiq et al., 1995; Tannin-Spitz., 2007
<i>Capsella bursa-pastoris</i> (L.) Medik.	Antioxidant activity	Oxidative stress related various disorder	They can prevent the formation of deleterious radicals, like peroxy nitrite,	Bekker et al., 2002
	Antimicrobial activity	Tinea capitis, Tinea pedis, Tinea corporis, Oxycomycosis	phenolic components of the oil affects the cell wall and membrane permeability of the pathogen,	Goun et al., 2002; Grosso et al., 2011

**Table 7.** Application of various seed-oil Plants of North east India (2)

	Anticoagulant effects	Thrombosis, Bleeding, Thrombopenia	Anticoagulant activity is accomplished by inhibition of platelet aggregation and prolong prothrombin time	Hiramatsu et al., 2009; Yue et al., 2013
<i>Carthamus tinctorius</i> L.	Cardiovascular function	Ischemia	This seed oil can provide protection to H9c2 cardiomyocytes against ischemia by up-regulating HO-1 expression through the PI3K/Akt/Nrf2 signaling pathway	Asgarpanah et al., 2013; Jun et al., 2009; Yue et al., 2013.
	Hepatoprotective activity	Hepatic fibrosis	attenuate oxidative stress mediated injury	Yue et al., 2013; Zang et al., 2011
	Antioxidant activity	Cell apoptosis, Oxidative stress mediated diseases	reducing cell proliferation and suppressing extracellular matrix (ECM) synthesis in the living system	Wang et al., 2013
<i>Cocos nucifera</i> L.	Antineoplastic activities	Cancer	Inhibition of the proliferation of neoplastic cells	Figueira et al., 2013
	Antitumor activity	Malignancy, Myeloid Leukemia	Termination of proliferation of K562 cells, responsible for the occurrence of Myeloid Leukemia	Figueira et al., 2013
	Leishmanicide potential	Leishmaniasis	Termination of cell division	Figueira et al., 2013; Singla, 2012
<i>Croton tiglium</i> L.	Antitumor activity	Melanoma	Induces apoptosis	Nath et al., 2013; Yumnancha et al., 2014
	Antioxidant activity	Parkinson's diseases, Alzheimer's diseases	Modify the activity of one or more protein kinase involved in cell cycle control	Nath et al., 2013
<i>Dysphania ambrosioides</i> (L.) Mosyakin & Clemants	Amoebicidal activity	Amebiasis	Attacks the protozoan parasite cell wall and induces the release of the intracellular constituents thereby affecting permeability	Ávila-Blanco et al., 2014
	Anticancer activity	Colon cancer Cervical cancer and hepatocarcinoma	It works by inhibiting the cell proliferation and cell division by arresting cell cycle	Barros et al., 2013
<i>Gaultheria fragrantissima</i> Wall.	Anti-inflammatory activities	Edema, Acute Pain	Inhibiting the production of pro-inflammatory cytokines responsible for inflammation	Liu et al., 2013; Padmavathy et al., 2014
	Analgesic activities	Rheumatoid Arthritis, Joint pain, Constricting Chest Pain, Transient Ischemic Attack	It is done through significantly inhibiting murine peritoneal capillary permeability	Liu et al., 2013
<i>Glycine max</i> L.	Immunity booster	Immunity deficiency diseases	The omega -3-fatty acid reacts with the immune cell nurturing them producing enhancement in immunity	Mujić et al., 2011
<i>Gossypium arboreum</i> L.	Antioxidant activity	Alzheimer's diseases	Direct interaction of the extracts and the hydrogen peroxide rather than the extracts alter the cell membranes, limiting the damage induced by the hydrogen peroxide	Annan et al., 2008

**Table 7.** Application of various seed-oil Plants of North east India (3)

<i>Helianthus annuus</i> L.	Anticancer activity	Skin cancer	the oil forms a protective layer on your skin and acts as a shield against the harmful UV rays of the sun	Dwivedi and Sharma, 2014
	Anti-ageing activity	Premature aging	the oil helps to protect the elastin and collagen content in our skin	
<i>Juglans regia</i> L.	Antiproliferative activity	Cancer	cell growth inhibition	Carvalho et al., 2010
	Antioxidant activity	Oxidative stress mediated diseases	inhibiting the production of free radicals	Pereira et al., 2007
<i>Linum usitatissimum</i> L.	Anti-inflammatory activity	Arachidonic acid-induced inflammation	The oil inhibits both cyclooxygenase and lipoxygenase pathways of arachidonate metabolism by blocking estrogen receptors	Kaithwas et al., 2011
	Anticancer activity	Breast cancer		Kaithwas et al., 2011
	Antiulcer	Ulceration	oil exhibit significant inhibitory effect on gastric secretion/total acidity	Kaithwas and Mazumder., 2010
	Anti-neuropathy condition	Carpal tunnel syndrome	This oil has a noteworthy recovery rate in this complication, Further mechanism is still unrevealed	Hasempur et al., 2014
<i>Mesua ferrea</i> L.	Antifungal activities	nosocomial infections, tooth decay and dental caries, eye infections	Inhibition of the hyphal protein synthesis	Chahar et al., 2013
<i>Ricinus communis</i> L.	Antiasthmatic activity	Asthma, Bronchitis, hypersensitivity	It significantly decreases milk induced leukocytosis and eosinophilia and protect degranulations of mast cells	Rana et al., 2012
	Cytotoxic activity	Cancer	Ricin, bioactive molecule in the oil targets the cell leaking its vital content out of the cell membrane	
<i>Sesamum indicum</i> L.	Anti-hyperlipidemic effects	Cardiovascular and cerebrovascular diseases	downregulating the activity of lipogenic enzymes	Asgary et al., 2013
	Hepatoprotective activity	Jaundice, Hepatitis A, Liver sclerosis	circulating concentrations of endothelial function biomarkers	
<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry	Anti-infective activity	Food poisoning, Botulism	Inhibits cell wall synthesis of the pathogen.	Kamatou et al., 2012
	Analgesic activity	Rheumatoid Arthritis, Joint pain, Constricting Chest Pain	The oil activates the transient receptor potential vanilloid 1 (TRPV1) receptors which are involved in the transmission and modulation of pain channels in the peripheral nervous system	
	Anticancer activity	Cancer	It induces growth inhibition and apoptosis	

that render antioxidant activities. Coconut oil contains low amount of tocol (tocopherols and tocotrienols) (Valko et al., 2007).

Sterols are steroidal alcohols present in the oil which serve as an important antioxidant. Rapeseed oil contains sterol in free form as well as in esterified form (Raad et al., 2013; Kareru et al., 2010). A group of derivatives of hydroxytyrosol is present in olive and castor oils (Horn et al., 1999). Carotenoids have also been reported to possess high antioxidant activity, especially in the exposure to the light. Phenols present in the seed oils contribute to the antioxidant properties. Common phenolic antioxidants include butylated hydroxyanisole (BHA),

butylated hydroxytoluene (BHT), propyl gallate (PG) and tertiary butyl hydroquinone (TBHQ) (Dutta and Sharma, 2011; Leung et al., 1999). Lipophilic antioxidants are more active in emulsions, while polar antioxidants are more active in bulk fats and oils.

Characteristics of edible oils can be compared through the smoke point because it reflects the molecular structure of the oil (Hunt, 1953). The smoke point of a fat or oil is the point of the temperature at which the lipid begins to disintegrate into fatty acids and glycerol to produce bluish smoke (Table 3). It marks the point from where flavour and nutrition degradation begins, and thus is an important consideration for characteri-

zing the quality of edible oils. Oils having high smoke point are used for deep frying. Antioxidants can have influence on the features of smoke points of oils. It has been observed that the smoke point of soybean oil and lard was increased BHA, BHT or TBHQ and removing cholesterol (Yen et al., 1997). Various biofunction and probable mechanism of action of other notable seed oil plants are summarized in table 7 given below.

## CONCLUSION

Seed oil yielding plants may provide an avenue for developing a new set of drugs for controlling wide range of ailments associated with oxidative stress, as well as several types of contagious and pathogenic diseases. The northeastern states of India, being one of the largest repositories of the plant kingdom, offers various seed oil yielding plants, which could be explored further for their antioxidant activity and antimicrobial properties. Seed oils can be used to increase the self-life of the industrial food products. Thus antioxidant property present in the seed oils can be explored for wide range of applications ranging from preservation of food products to prevention of the oxidative stress related diseases, e.g. cancers and cardiovascular disorders. The antimicrobial property of the seed oil producing plants and various bioactive compounds isolated from them may lead to the discovery of new antimicrobial compounds to fight against MDR microbial strains and various forms of infections in general.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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