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ANTIOXIDANT PROPERTIES
AND HEALTH BENEFITS OF
HORTICULTURAL CROPS

ANTIOXIDANT PROPERTIES AND HEALTH BENEFITS OF HORTICULTURAL CROPS

Part 2: Antioxidant Properties and Health Benefits of Vegetables & Flowers

Dr. Arghya Mani

Dr. Nityamanjari Mishra

Dr. Nirmal Kumar Meena

Dr. Subhrajyoti Chatterjee



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Dr. P.N. Jagdev, Ph.D.

Professor & Ex-Dean of
Research and Extension
Education



Department of Plant Breeding & Genetics,
Odisha University of Agriculture &
Technology, Bhubaneswar,
Odisha -751003

FOREWORD

Fruits and vegetables are reported to have health-improving benefits, hence known as protective foods and they contain different kinds of antioxidants. Some fruits and vegetables like citrus fruits (orange, grapefruit, lime, lemon), grapes, pomegranates, apples, dates, green and yellow vegetables, cabbage, strawberries, carrots, dark leafy greens, and banana are widely known to be rich in natural antioxidant contents.

An antioxidant can be defined as a substance which significantly delays or prevents oxidation of oxidizable substrate when present at low concentration. Antioxidants are broadly divided into two groups namely natural enzymatic antioxidants and non-enzymatic antioxidants. Superoxide dismutase, catalases are natural enzymatic antioxidants and located mostly in peroxisomes. Fruits and vegetables are very good source of natural antioxidants like carotenoids, vitamins, phenolic compounds, flavonoids, dietary glutathione and endogenous metabolites which act as free radical scavengers, singlet and triplet oxygen quenchers, enzyme inhibitors, peroxide decomposers and synergists. Antioxidants exert both additive and synergistic effects in reducing the risk of oxidative damages to cells. Hence, consuming fruits and vegetables can be the most easy and healthy way of reducing the risk of many chronic diseases like cardiovascular, ocular and neurological diseases, strokes, cancer, diabetes, hypertension and blood-related diseases.

The compilation of nutritional and antioxidant properties of various fruits and vegetable crops in the book entitled “**Antioxidant Properties and Health Benefits of Horticultural Crops**” is highly informative and useful for the researchers, teachers, students and extension personnel to take up further scientific research and development. This book would enlighten the readers about the healing power of nature to attract them more towards the plant grown foods rather than choosing the processed food. I am glad and appreciate the endeavours of all the Authors and Editors for bringing and this book encompassing with all these aspects.

Date: 28 January, 2022

Bhubaneswar

(P.N. Jagdev)

Preface

Antioxidants are known to significantly delay or prevent oxidation of oxidizable substrate when present at low concentration as compared to that of an oxidizable substrate. Fruits and vegetables are very natural source of natural antioxidants which consist of many different desirable components. These antioxidants are carotenoids, vitamins, phenolic compounds, flavonoids, dietary glutathione and endogenous metabolites. Carotenoids are found mainly in yellow, orange and red fruits and vegetables. Large amounts of α - and β -carotene are found in carrots, pumpkins, mangoes and peaches; the greatest amounts of lycopene are accumulated in tomatoes, while green leafy vegetables are a good source of lutein and zeaxanthin. Polyphenolic compounds, which include flavonoids, phenolic acids, lignans and stilbenes, are found in many fruits, vegetables, coffee, tea, herbs and spices and chlorophylls found in leafy green vegetables. This book provides in-depth information about the antioxidant properties of different fruits and vegetables including inflorescence, flowers and flower buds (broccoli, cauliflower, cabbage), bulb, stem and stalk (onion, celery, asparagus, celery), leafy vegetables, fruit and seed (peppers, squash, tomato, eggplant, green beans), roots and tubers (red beet, carrots, radish), and fruits, such as citrus (orange, lemon, grapefruit), berries (blackberry, strawberry, lingonberry, bayberry, blueberry), melons (pumpkin, watermelon), and many more. Each chapter, contributed by experts in the field of Horticulture, also discussed the factors that influencing antioxidant content, such as genotype, environmental variation and agronomic conditions. This also contains detailed information on nutritional and anti-nutritional compositions of fruits and vegetables, antioxidant properties of a range of fruits and vegetables. Fruits and vegetables provide an abundant and cheap source of fibre, antioxidants, several vitamins and minerals and thus increasingly recognized as essential component for food and nutritional security. This book discusses the nutritional properties, antioxidant potential and health benefits of fruits and vegetables in human health. Nutritional composition and antioxidant

properties of fruits and vegetables provides an overview of the nutritional and anti-nutritional composition, antioxidant potential, and health benefits of a wide range of commonly consumed fruits and vegetables. The book presents a comprehensive overview on a variety of topics, including fruits, such as Mango, banana, citrus (orange, lemon, grapefruit), berries (blackberry, strawberry, lingonberry, bayberry, blueberry) and vegetables such as melons (pumpkin, watermelon), flower buds (broccoli, cauliflower, cabbage), bulb, stem and stalk (onion, celery, asparagus, celery), leaves (watercress, lettuce, spinach), fruit and seed (peppers, squash, tomato, eggplant, green beans), roots and tubers (red beet, carrots, radish), and many more Underutilized crops. A diet based on the consumption of fresh fruits and vegetable has been associated with health protection and longevity, due to their nutraceutical value. Additionally, fruits and vegetables supply dietary fiber, and fiber intake is linked to lower incidence of cardiovascular disease and obesity. Fruits and vegetables also supply vitamins and minerals to the diet and are sources of phytochemicals that function as antioxidants, phytoestrogens, and anti-inflammatory agents and through other protective mechanisms. Differences among fruits and vegetables in nutrient composition are detailed. The antioxidant compounds such as vitamin C (ascorbic acid), vitamin E (tocopherol), carotenoids, flavonoids as well as phenolic acids, indeed, able to neutralize reactive oxygen species (ROS) and, for this reason, are worldwide recognized as beneficial for preventing human diseases among which cancer and cardiovascular pathologies. Each chapter, contributed by an international level expert in the field also discusses the factors influencing antioxidant content such as genotype, environmental variation and agronomic conditions. Keeping all these in mind the manuscript "Antioxidant Properties and Health Benefits of Horticultural Crops – Part 1 & Part 2" has been prepared as a reference for all concerned with details and elaborative antioxidant properties and health benefits of different vegetables. Humble effort has been made to ensure that the information collected from various sources such as individuals, institutions, organizations, reviews and research publications are accurate. However, we have put our best efforts in preparing this book but if any error or whatsoever has been skipped out, we will welcome the suggestions of the readers by core from our heart in making the book further more informative. We hope that this book will be extremely useful for the students, teachers, researchers and various institutions.

Editors

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Antioxidant Properties and Health Benefits of Moringa/Drum Stick

**M. Viswanath^{1*} Chetanchidambar N Mangalore² Anindita Roy³
Subhrajyoti Chatterjee⁴ B. V. K. Bhagavan⁵ K. Ravindra Kumar⁶ M. Girija
Rani⁷**

^{1,3&4} *Department of Horticulture, Centurion University of Technology and Management, R. Sitapur-761211, Odisha, India.*

² *PhD Scholar, Dept. of Fruit Science, College of Horticulture, Dr. Y. S. R. Horticultural University, Andhra Pradesh.*

⁵ *Principal Scientist & Head (Horticulture), Dr. Y.S.R.H.U, HRS, Ambajipeta, East Godavari, Andhra Pradesh.*

⁶ *Scientist (Horticulture), Dr. Y.S.R.H.U, HRS, Kovvur, West Godavari, Andhra Pradesh.*

⁷ *Senior Scientist & Head (Plant Breeding), ANGRAU, ARS, Machilipatnam, Andhra Pradesh.*

ABSTRACT

Moringa oleifera, often known as the “horseradish tree” or “drumstick tree,” is a beneficial tree native to India that provides a plethora of advantages. Over the last few decades, numerous research papers on *Moringa*’s nutritional and therapeutic qualities have been published in various national and international scientific publications. According to several sources, the *Moringa* tree has lately gained popularity in Ethiopia owing to its many applications. *Moringa oleifera* is known as the “Miracle Tree” since all of its components are useful for nutritional and medicinal purposes. *Moringa* is a highly useful food crop (it is extremely nutritious, grows quickly, and is drought

resistant), but it also has many other uses in impoverished nations, such as being able to be used for crafts (thanks to its tree status) and purifying water. The *Moringa* tree can also help with soil and water conservation and climate change mitigation. This research gives a quick summary of the *Moringa oleifera* tree's multifunctional uses and implications for climate change mitigation. Minerals, vitamins, and other important compounds abound in the leaves. The leaves' extracts are used to treat malnutrition and to supplement breast milk in nursing mothers. It has antioxidant, anticancer, anti-inflammatory, anti-diabetic, and antibacterial properties. A natural coagulant, *Moringa oleifera* seed, is widely utilised in water treatment. This study's scientific endeavour sheds light on the usage of *Moringa* as a diabetic and cancer treatment, as well as the fortification of *Moringain* commercial goods. The goal of this chapter is (a) To go through the therapeutic and nutritional characteristics of this plant. (b) Make recommendations for future policy, research, market, and development initiatives. (c) To consider the implications for mitigating climate change

Key Words: *Moringa oleifera*, Nutrition, Medicine, Tree, *Moringa* leaves, *Moringa* seeds

INTRODUCTION

India is one of the world's fastest growing economies. India now boasts the world's greatest cattle population. To satisfy the current and future demands of the human population, some new methods must be developed to meet input requirements and also to boost the production capacity of indigenous and crossbred cattle, as well as other classes of livestock for production, reproduction, and by-products.

Moringa oleifera (MO) is a plant native to India that thrives in tropical and subtropical climates across the world. It's also known as a 'drumstick tree' or a 'horseradish tree.' *Moringa* is commonly planted across the world because it can tolerate both severe drought and moderate cold. Every component of the tree is appropriate for nutritional or commercial uses due to its high nutritional contents. Minerals, vitamins, and other essential phytochemicals abound in the leaves. The leaves' extracts are used to treat malnutrition and to supplement breast milk in nursing mothers. It has antioxidant, anticancer, anti-inflammatory, anti-diabetic, and antibacterial properties. *Moringa oleifera* is a natural coagulant, oleifera seed, is widely utilized in water treatment. Minerals and critical amino acids are also abundant in *Moringa oleifera*. *Moringa* can be used in pig and rabbit reproduction as well. *Moringa* is regarded as one of the world's most beneficial trees. Its importance as animal feed is supported by its higher nutritional quality and high biomass output, especially during the dry season.

The understanding of *Moringa oleifera*'s taxonomy, distribution, many uses, nutritional value, socioeconomic relevance, morphological and genetic diversity, domestication, propagation, and management is very important. We were proposed

and debated for enhanced valorization in order to address knowledge shortages, research and development possibilities. *Moringa oleifera* supplies the majority of the nutrients necessary for all types of animals, including chicken and fish, and *Moringa* leaves are used as tea powder, a green vegetable, and other things in humans. The use of *Moringa* across disciplines for its medicinal value and deals with cultivation, nutrition, commercial and prominent pharmacological properties of this “Miracle Tree”.

History:

Each component of the *Moringa* tree (fruits, seeds, leaves, flowers, bark, and roots) is linked to at least one, if not all, of the above benefits. *Moringa oleifera* is one of the most widely utilized plants on the planet. All parts of the plant have been used for various purposes in the past, although leaves are the most often utilized all over the world (Moyo *et al.*, 2012). Fodder shortage and poor quality of available fodder are thought to be the primary limitations limiting farm animal output. The available feed, especially during the dry season when natural grasses are mature, is fibrous and insufficient, with low nutritional value due to low crude protein content (Moyo *et al.*, 2012). *Moringa* spp. are all native to Asia, from whence they have spread to many parts of the world, with a focus on warm nations like Malaysia and other tropical areas (Udikala *et al.*, 2017). This tree can withstand temperatures ranging from 19 to 28 degrees Celsius, has a height of 5 to 10 meters, and may be grown across the plains. *Moringa* leaves are utilized as a medication because they are thought to contain numerous phytochemicals, making them useful for both prevention and treatment (Udikala *et al.*, 2017).

Plant scientists, nutritionists, and farmers are focusing their research on a variety of underused crops and trees. *Moringa oleifera* is one of the numerous plant and tree varieties that has been neglected for several years, but is now being researched for its quick growth, greater nutritional characteristics, and use as a cattle feed crop (Nouman *et al.*, 2012). *Moringa* may be cultivated in locations where other crops are difficult to produce. It may also be produced as a crop on arid regions with little water supply and high temperatures (Nouman *et al.*, 2013; Wasif *et al.*, 2014).

Taxonomy and Botanical Description:

Drumstick species belongs to family *Moringaceae* of order *Capparales* of subclass *Dilleniidae* of class *Magnoliopsida* of division *Magnoliophyta* of superdivision *Spermatophyta* of superkingdom *Tracheobionta* of kingdom *Plantae*.

Morphology and physical characteristics: *Moringa* are a slender softwood tree that branches freely and can be extremely fast growing. Although it can reach 3 heights in excess of 10 m (33 f) and a diameter of 20-40 cm at chest height, it is generally considered a small- to medium-size tree (Radovich, 2009).

Stem: The stem is normally straight but occasionally is poorly formed. The tree grows with a short, straight stem that reaches a height of 1.5-2 m before it begins branching but can reach up to 3.0 m (Foidl *et al.*, 2001).

Branch: The extended branches grow in a disorganized manner and the canopy is umbrella shaped.

Leaves: Tripinnate compound leaves are feathery with green to dark green elliptical leaflets 1-2 cm (0.4-0.8 in) long. The tree is often mistaken for a legume because of its leaves. The alternate, twice or thrice pinnate leaves grow mostly at the branch tips. They are 20-70 cm long, grayish-downy when young, long petiole with 8-10 pairs of pinnae each bearing two pairs of opposite, elliptic or obovate leaflets and one at the apex, 1-2 cm long (Morton, 1991).

Flowers: Conspicuous, lightly fragrant flowers are borne on inflorescences 10-25 cm (4-10 in) long, and are generally white to cream colored, 2.5 cm in diameter, borne in sprays, with 5 at the top of the flower, although they can be tinged with pink in some varieties. The flowers, which are pleasantly fragrant and 2.5 cm wide are produced profusely in axillary, drooping panicles 10-25 cm long (Sachan *et al.*, 2010). They are white or cream colored and yellow-dotted at the base. The five-reflexed sepals are linear-lanceolate. The five petals are slender-spatulate. They surround the five stamens and five staminodes and are reflexed except for the lowest.

Fruits: The fruits are trilobed capsules, and are frequently referred to as pods. Immature pods are green and, in some varieties, have some reddish color. Pods are pendulous, brown, triangular, splitting lengthwise into 3 parts when dry, 30-120 cm long, 1.8 cm wide, containing about 20 seeds embedded in the pith, pod tapering at both ends, 9-ribbed. Fruits production in March and April in Sri Lanka (Burkill, 1966).

Seeds: The seeds are round with a brownish semi-permeable seed hull, with 3 papery wings. Seed hulls are generally brown to black, but can be white if kernels are of low viability. Viable seeds germinate within 2 weeks. The hull itself has three white wings that run from top to bottom at 120° intervals. Each tree can produce between 15,000 and 25,000 seeds/year. The average weight per seed is 0.3 g and the kernel to hull ratio is 75:25 (Makkar and Becker, 1997).

Anthesis is said to start as early as 4.30 a.m. and last until 6.30 a.m., with a peak around 5.30 a.m. According to a study from the Horticultural College and Research Institute in Periyakulam, anthesis timing was between 5 and 9 a.m., with temperatures between 27.3 and 29.30°C and RH between 68 and 78 percent (Fahey, 2005). Anther dehiscence is said to happen between 4 and 6.30 a.m. The anther of the longest stamen is the first to dehisce, followed by stamens in order of filament length. The anthers are greenish yellow when fully mature, but fade to a pale colour after dehiscence (Fuglie, 2003). Each anther contains approximately 7,400 pollens, each measuring 5-4 microns in diameter. Honey bees cross pollinate the stigma a day

before flower opening and on the day of flower opening (Amaglo, 2006). At anther dehiscence, pollen viability is at 72%. Natural pollination yields only 11-15 percent fertile pollen, whereas artificial pollination yields 100% fertile pollen. $2n=28$ is the number of the chromosome (Yisehak *et al.*, 2011; Ashfaq *et al.*, 2012).

Due to its heteromorphic nature, the plant is heavily cross pollinated and entomophilous, with bees serving as pollinators. Emasculation takes place in the evening of the preceding day. Pollination is usually done the next morning, before 11 a.m. The presence of self or foreign pollen on the stigmatic surface of the female flower should be verified before pollination (Koul and Chase, 2015). Flowers are packed before being opened to prevent infection. Pollen is gathered from the bloom, or the blossom is utilized to pollinate other flowers. Pollen must be collected in order to pollinate later. Pollen can be gathered in huge quantities for pollination on a big scale or for later pollination. Pollen accumulates in the keel petal of *Moringa* and may be pushed out and transported to the stigma. Pollen can be securely kept for a few days in a dry place for subsequent use (Demeulenaere, 2001; Palada and Chang, 2003).

Moringa flowering occurs from January through April, with a peak in February. The blooms are white with uneven petals and a little odour. Flower anthesis takes place in the morning (6 a.m. to 12 a.m.), followed by pollen dehiscence and nectar secretion. The burst anthers contain a cluster of pollen grains that turns glossy over time, suggesting secretion, and Papilionidae, Pieridae, and beetles pay the flower a visit (Jiru *et al.*, 2006; ECHO, 2009; Melesse *et al.*, 2011).

NUTRITIONAL BENEFITS:

Because of its multifunctional nutritional applications and ability to heal a wide range of illnesses, *Moringa oleifera* is known as the "Miracle Tree." The nutrients are conserved in every area of the plant. Minerals such as calcium, potassium, zinc, magnesium, iron, and copper are abundant in the leaves of *Moringa oleifera*. Because the leaves are low in calories, they can be included in an obese person's diet. The leaves are very high in protein and minerals (Daba, 2016), and contain all necessary amino acids. Pods are abundant in fiber and protein, and are used to treat digestive issues and colon cancer (Gandhi, 2018). Vitamin A, vitamin B, beta-carotene, pyridoxine, nicotinic acid, vitamin C, vitamin D, and vitamin E are all rich in *Moringa oleifera*.

Moringa oleifera also includes anti-cancer substances including glucosinolates, isothio cyanates, glycoside compounds, and glycerol-1-9-octadecanoate, as well as important phytochemicals like tannin, sterols, terpenoids, flavonoids, saponins, anthraquinones, alkaloids, and reducing sugar. In *Moringa* leaves, oligosaccharides and oxalate have been identified as anti-nutrient factors (Anthanont *et al.*, 2016). After 4 and 3 months of storage, dried leaves (*Moringa oleifera*) contained 87.5 percent and 50% of carotene, respectively, and could therefore be processed for practical use (Anwar *et al.*, 2005; Anwar *et al.*, 2007).

Moringa leaves are high in fiber, fat proteins, and minerals such as calcium, magnesium, potassium, phosphorus, copper, iron, and Sulphur. Vitamins such as beta-carotene (vitamin A), choline (vitamin B), thiamine (vitamin B1), riboflavin, nicotinic acid, and ascorbic acid are present. Arg, His, Lys, Trp, Phe, Thr, Leu, Met, Ile, and Val are among the amino acids found (Barichella *et al.*, 2019). Tannins, sterols, saponins, terpenoids, phenolics, alkaloids, and flavonoids such as quercetin, isoquercetin, kaempfericetin, isothiocyanates, and glycoside compounds are among the phytochemicals found (Bharali *et al.*, 2003).

MO's leaves are high in vitamins and minerals, and they have great antioxidant action, which is attributable to the plant's vitamins and phenolic components including quercetin and kaempferol. The leaves can also be consumed as a vegetable and made into tea, powder, and other medicines. Furthermore, juice taken from fresh leaves can be used to function as a growth inhibitor, increasing crop output by 25-35 percent (Asare *et al.*, 2012). Leaves function as an excellent sink for carbon dioxide absorption and utilization, according to a 2009 Japanese study. The rate of carbon dioxide absorption by *Moringa* trees is 20 times greater than that of ordinary vegetation (Asiedu *et al.*, 2014). *Moringa* is claimed to have 7 times the amount of vitamin C as oranges, 10 times the amount of vitamin A as carrots, 17 times the amount of calcium as milk, 9 times the amount of protein as yoghurt, 15 times the amount of potassium as bananas, and 25 times the amount of iron as spinach (Aslam *et al.*, 2005).

Moringa root bark has the ability to heal stomach ulcers and mucosal diseases. It also lowers the acidity of gastric juice and raises the pH (Ali *et al.*, 2013a). As a result, MO has antiulcer and antisecretory properties and might be exploited as a source for antiulcer medicines in the future (Ali *et al.*, 2013b).

Alkaloids, flavonoids, tannins, triterpenoids, diterpenoids, and cardiac glycosides are all found in MO pod husks. MO pod husks extract has antibacterial activity against Gram positive bacteria including *Staphylococcus epidermidis* and *Enterococcus faecalis*, as well as Gram negative bacteria like *Klebsiella pneumoniae* and *Salmonella typhimurium* (Ali *et al.*, 2014).

Moringa oleifera seed contains a range of phytochemicals, including antioxidants such as vitamin C, β -carotene, α and γ -tocopherol, β -sitosterol, vitamin A, the phenolic compounds quercetin and kaempferol, flavonoids, and anthocyanins, along with a few rare classes of compounds, including alkaloids, glucosinolates, and isothiocyanates (Al-Malki and Rabey, 2015). The mature seed of MO is rich in oil, containing between 22 and 40% crude fat. Examination of the oil composition indicates that the oil has a high proportion of monounsaturated fatty acids, particularly oleic acid (Ali *et al.*, 2019). Some vectors, such as malaria mosquitoes *Anopheles stephensi*, might be prevented with the seed extract. The phytochemicals produced from MO seed extracts are efficient mosquito vector control agents, and the plant extracts might be utilized

in future IPM programmes (Ali *et al.*, 2014; Al-Malki and Rabey, 2015; Ali *et al.*, 2019).

In addition, it contains various other nutrients, including the following essential amino acids (Wasif *et al.*, 2014).

- **Threonine** - a nutrient that helps metabolism and prevent fatty build up in the liver. It also aids digestion.
- **Isoleucine** - good for a healthy brain and helps to give the body natural energy.
- **Leucine** - works hand in hand with isoleucine to increase energy levels.
- **Phenylalanine** - aids communication between the brain's nerve cells and also helps to reduce hunger pangs as well as increasing alertness and improving memory.
- **Tryptophan** - supports your immune system, and its mood boosting ability helps to beat depression and anxiety-associated insomnia. It also reduces the risk of heart attack and lowers bad cholesterol levels.
- **Lysine** - aids the absorption of calcium into the bones, supports antibodies and regulates various hormones as well as inhibiting the growth of virus cells.
- **Methionine** - provides the body with sulphur as well as helping to lower cholesterol. It also supports the liver, kidneys, and helps keep skin, hair and nails healthy.
- **Valine** - helps to keep the mind calm.

In general, the *Moringa oleifera* contains following nutrients (Demeulenaere, 2001; Bharali *et al.*, 2003; Fahey, 2005; Bhat, 2014; Bhargave *et al.*, 2015):

Minerals: Iron (Fe), Copper (Cu), Sodium (Na), Calcium (Ca), Magnesium (Mg), Phosphorus (P), Potassium (K), Sulfur (S), Manganese (Mn), Zinc (Zn) and Selenium (Se).

Vitamins: Vitamin B1 (thiamin), Vitamin E, Vitamin B1, Vitamin B6, Vitamin B7, Vitamin D, Vitamin K, Vitamin B2 (riboflavin), Vitamin B3 (niacin) and Vitamin C.

Amino acids: Aspartic Acid, Glutamic Acid, Serine, Glycine, Threonine, Alanine, Valine, Leucin, Isoleucine, Histidine, Lysine, Arginine, Phenylalanine, Tryptophan, Cystine, Proline, Tyrosine, Methionine, Cysteine, Phenylalanine and Choline.

Fats: Myristic, Palmitic, Palmitoleic, Stearic, Oleic, Linoleic, Linolenic, Arachidic, Eicosenoic, Behenic and Lignoceric.

Sterols: Cholesterol, Brassicasterol, 24-methylenecholesterol, Campesterol, Stigmasterol, Ergostadienol, Clerosterol, Stigmastanol, β -sitosterol, Venasterol, Pentena, 2-Hexenal and Heptenal, 2,4-Heptadienal.

Alcohols: 2-Pentenol, 3,3-Dimethyl-Cyclohexanol and Benzyl alcohol.

Ketones: Methyl heptanone, 2-Hexen-4-olide-2-Acetyl pyrrole and Dihydroactinidolide.

Terpenoids: alpha-Himachalene, (E)-Geranyl acetone and Ti(E)-beta-Ionone.

Acids: Acetic acid, Pentanoic acid, Hexanoic acid, Octadecanoic acid, Hexadecanoic acid, Erythroic acid and Citric acid.

Alkaloids: Moringine, Strophantidin, 4-(α -l-rhamnosyloxy), benzyl isothiocyanate, 4-(4'-O-acetyl- α -l-rhamnosyloxy) and benzyl isothioyanate

Flavonoids: Catechin, (β -d-glucopyranosyl-1), benzyl thiocarboxamide, Epicatechin, 4-O-(α -l-rhamnosyloxy), benzyl glucosinolate, Quercetin, 4-benzylglucosinolate, Kaempferol, Niazimicin, 4-(α -l-rhamnosyloxy), benzyl acetonitrile (niazirin), O-ethyl-4-(α -l-rhamnosyloxy) and benzyl carmate.

Phenolic: Gallic acid, Glycerol-1-1-(9-octadecanoate), p-Coumaric acid, 3-O-(6'-O-oleoyl- β -d-glucopyranosyl)- β -sitosterol, Ferulic acid, β -sitosterol-3-O- β -d-glucopyranoside, Caffeic acid, 3-Hydroxy-4-(α -l-rhamnopyranosyloxy), benzyl glucosinolate, Protocatechuic acid, 4-(2/3/4'-O-acetyl- α -l-rhamnopyranosyloxy), benzyl glucosinolate, Cinnamic acid, Glucosinalbin, Ellagic acid, Glucoraphanin and Glucoiberin.

ANTIOXIDANT PROPERTIES:

Moringa species have a high phenolic content, which contributes to their strong antioxidant activity. Phenolic chemicals serve as antioxidants by stabilizing radicals generated in cells by giving or receiving electrons. ROM (Reactive Oxygen Molecules) such as O_2^- , H_2O_2 , and OH are constantly produced inside the human body as a result of exposure to a variety of exogenous substances in our environment and/or a variety of endogenous metabolic processes involving redox enzymes and bioenergetic electron transfer (Chitra and Pillai, 2002). Under normal circumstances, the antioxidants in the body detoxify the ROS produced, and there is a balance between the ROM produced and the antioxidants present. However, due to excessive ROM generation and/or insufficient antioxidant defense, this balance is disrupted, favouring an increase in ROM levels that leads to oxidative stress (Kohen and Gati, 2000).

Antioxidants, particularly polyphenols, are the major plant chemicals capable of reducing oxidative damage in tissues by indirect cell promotion or free radical scavenging (Ali *et al.*, 2014; Al-Malki and Rabey, 2015). Because of its high polyphenol content, the leaves of the *Moringa oleifera* tree have been shown to exhibit antioxidant action (Yisehak *et al.*, 2011; Verma *et al.*, 2009). *Moringa oleifera* extracts from both old and young leaves have high antioxidant activity against free radicals, protect key biomolecules from oxidative damage, and provide considerable protection from oxidative damage (Yisehak *et al.*, 2011; Ashfaq *et al.*, 2012).

LEAVES

DPPH (1,1-di-phenyl-2-picrylhydrazyl) inhibition was greater in a water extract of *Moringa stenopetala* leaves (40g/mL) than in a comparable extract of *Moringa oleifera* leaves (215g/mL). In a DPPH test, rutin has significant antioxidant activity (5g/mL). According to an HPLC investigation, *Moringa stenopetala* contains more rutin than *Moringa oleifera*, making it a more powerful antioxidant (Habtemariam and Varghese, 2015). The DPPH inhibition of a methanol fraction of *Moringa peregrina* leaves (17.07g/mL) was equivalent to that of ascorbic acid (13.68g/mL) (Al-Owaisi *et al.*, 2014). The hexane fraction of *Moringa peregrina* leaves did not contain any phenolic compounds, according to HPLC findings.

Superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH) levels were all raised by the extract. In Sprague-Dawley rats, pre-treatment with the *Moringa oleifera* leaf hydroethanolic extract reduced lipid peroxidation levels and normalized antioxidant enzyme levels, preventing hepatotoxicity caused by paracetamol (Uma *et al.*, 2010). *Moringa oleifera* leaf extract decreased DNA breakage in KB cells while also boosting antioxidant enzymes and reducing lipid peroxidation, according to research (Sreelatha and Padma, 2011).

Isoquercetin, astragalín, and crypto-chlorogenic acid were found in a *Moringa oleifera* leaf extract. In HEK-293 cells, the plant's leaf extract, in combination with the chemicals, decreased reactive oxygen species produced by H₂O₂ (Vongsak *et al.*, 2015). Isoquercetin, which enhanced the mRNA expression levels of CAT, heme oxygenase 1, and SOD, was shown to have the greatest antioxidant activity.

Aqueous *Moringa oleifera* extracts from seed, fruit, and leaf were tested for their ability to inhibit DNA oxidative damage as well as their antioxidant capabilities. The findings indicated that these extracts had a substantial potential for preventing DNA damage, as well as inhibiting trolox synergistically in an effective sequence of leaf > fruit > seed (Singh, 2009).

FLOWERS

The phytochemical content of *Moringa* blossoms was profiled using modern analytical techniques. Chromatography by Gas GCMS analysis of a methanol extract of flowers found 26 chemicals, the most prominent of which are ethyl oleate, quinic acid, and cis -9- hexadecenal, all of which have anticancer, anti-inflammatory, and antioxidant effects (Inbathamizh and Padmini, 2012). Flower volatile components were discovered using simultaneous distillation-extraction and capillary gas chromatography/mass spectrometry. Seventy-four molecules, the main constituents of which are (E)-nerolidol (13.33%), α -terpineol (7.8%), and benzyl isothiocyanate (6.4 %) (Pino, 2013).

Quinic acid, 4-p coumarylquinic acid, Quercetin 3-O-acetyl glucoside, Kaempferol-3-O acetyl hexoside, Octadecenoic acid, Heneicosanoic acid, and Behenic (docosanoic) acid are among the probable chemicals identified by HPLC- DAD-ESI MS/MS analysis of hydroethanolic crude flower extracts (Tan *et al.*, 2015). A proteinaceous Trypsin inhibitor, or MoFTI, was found in aqueous floral preparations (Moura *et al.*, 2011). On the other hand, crude flower extracts have been tested in a variety of pharmacognostical investigations, with a number of encouraging results.

The DPPH technique was chosen for quantitative measurement of antioxidant activity because it was simple, secure, quick, and sensitive. In addition, only a tiny sample was needed (Amorati and Valgimigli, 2015). At a wavelength of 515 nm, the antioxidant activity of the sample was measured. The presence of the antioxidant in the sample caused the DPPH solution in methanol to discolour, changing its colour from purple to light yellow (Liu *et al.*, 2019).

SEEDS

Tannin, phenolic chemicals, and flavonoids are abundant in *Moringa oleifera* aqueous pod (fruit) extract (750 mg/kg). This plant's polyphenolic components may have a role in its ethano-medical use. As a result, it can be concluded that *Moringa oleifera* extracts had substantial antioxidant activity and that the presence of kaempferol in *Moringa oleifera* leaves demonstrated antioxidant activity (Bajpai *et al.*, 2005; Sharma and Singh, 2010).

Moringa oleifera seed oil fractions were tested for rancidity prevention against fresh sunflower oil using a UV accelerated technique at 50 C and showed better antioxidant capabilities. When the antioxidant activity of *Moringa oleifera* seed oil fraction was compared to that of α -tocopherol and BHT (common synthetic antioxidant agents) using the same method on the same sunflower oil, the *Moringa oleifera* seed oil fraction showed higher antioxidant activity than the two known agents (Lalas and Tsaknis, 2002). Maiyo *et al.* (2016) identified two antioxidant-active compounds from *Moringa oleifera* seeds: quercetin- 3-O-glucoside (18) had considerable antioxidant activity, while 4-(β -D-glucopyranosyl-1->4- α -L-rhamnopyranosyloxy) benzylisothiocyanate had moderate activity. The total phenolic components in the water extract of *Moringa oleifera* seed kernel were greater (90.970.134 mg/g gallic acid equivalent) than in the other two extracts (methanol and acetone).

Plant flavonoids have been shown to have potent antioxidant properties (Vinson *et al.*, 1995). The total flavonoids in the water extract of *Moringa oleifera* seed kernel (221.76 \pm 0.221 mg/g of quercetin equivalent) were likewise greater than in the other two extracts. It might be because there are many distinct types of polyphenolic chemicals, including flavonoids, present. Among the three extracts, the methanol extract had the highest total tannin concentration (97.10 \pm 0.153 mg GAE/g of dry extract). The presence of flavonoids and other phenolic components in the water

extract resulted in substantial DPPH radical scavenging activity ($EC_{50} = 36.89 \pm 0.154$ g/mL). The presence of phenolic substances with hydroxyl groups linked to the aromatic ring structures may account for the water extract's high activity in quenching the ABTS radical (Vinson *et al.*, 1998).

The presence of flavonoids and other phenolics as phytochemicals may explain the strong free radical inhibition value of *Moringa oleifera* seed kernel water extract. The presence of reductones, which have been demonstrated to exert antioxidant activity by breaking the free radical chain by donating a hydrogen atom, is typically related with the presence of reducing characteristics (Duh *et al.*, 1999).

ROOTS

This is the first report of antioxidant polyphenols in the plant's root and stem bark, as well as their antioxidant radical scavenging ability. Different types of procyanidins were found in the stem and root bark extracts compared to the leaf extract, indicating that the polyphenol content of the leaf and other sections differed significantly (Siddhuraju and Becker, 2003). However, all sections of the plant studied had high antioxidant and radical scavenging activity, with root bark extracts having the highest antioxidant potential and leaves having the highest radical scavenging potential.

Procyanidins, found in the stem and root barks, are recognized to have an important role in the antioxidant qualities of a variety of foods. These compounds are effective scavengers of reactive oxygen and nitrogen species due to their hydrogen-donating properties and proclivity for nitration. Proanthocyanidins have been found to have 20 times the antioxidant power of vitamin E and 50 times the antioxidant power of vitamin C in scientific studies. Furthermore, new data suggests that these chemicals might interact with redox-sensitive cell signaling pathways (Spencer, 2003).

HEALTH BENEFITS AND MEDICINAL USE OF *Moringa oleifera*

HEALTH BENEFITS

Moringa oleifera contains bioactive chemicals that have been linked to illness prevention and therapy, including antimicrobial (Williams, 2013), anti-inflammatory (Bhattacharya *et al.*, 2018), anticancer, antidiabetic, antioxidant, hepatoprotective, and cardioprotective effects (Koul and Chase, 2021; Kumar *et al.*, 2016; Saini *et al.*, 2016). These applications may also include primary and secondary metabolites. Proteins, polysaccharides, and lipids are primary metabolites that are engaged in physiological activities. Polysaccharides and fibres are the major chemicals that have been shown to have beneficial impacts on chronic illnesses like cancer, cardiovascular disease, diabetes, and obesity. Secondary metabolites, on the other hand, are tiny molecules such phenolic compounds, halogenated chemicals, sterols, terpenes, and short peptides. The majority of the phytochemicals found in *Moringa oleifera* have potential in disease prevention and therapy.

The anti-inflammatory impact is attributed to flavonoids, alkaloids, tannins, and glycosides, with quercetin seeming to block NF-KB activation, resulting in an anti-inflammatory effect (Das *et al.*, 2013). Other compounds with an anti-inflammatory effect include kaempferol derivatives, flavonol glycosides (Manguro and Lemmen, 2007; De-Melo *et al.*, 2009), aurantiamide acetate, 1,3-dibenzylurea (Arora *et al.*, 2013; Sashidhara *et al.*, 2009), diterpenes, α - and β -amyryn (Zhao and Zhang, 2013), benzaldehyde 4-O- β -glucoside (Manguro and Lemmen, 2007; De-Melo *et al.*, 2009), β -sitosterol (Fejér, *et al.*, 2019), rutin (Panda *et al.*, 2013), and glucosinolate, mainly attributed to the glycosylate isothiocyanate, 4-(α -L-rhamnopyranosyloxy) benzyl ITC, resulting from myrosinase (Galuppo, *et al.*, 2013). *Moringa oleifera* suppresses inflammatory enzymes and proteins in the body, and *Moringa oleifera* leaf concentrate can dramatically decrease inflammation in cells (Chaudhary and Chaurasia, 2017).

The antibacterial and antifungal properties of *Moringa oleifera* extracts have been linked to phenolic compounds (Tsfay *et al.*, 2017), with the leaves containing the most of these chemicals. Due to low pH levels and the presence of pterigospermin (Anwar *et al.*, 2007; Martín *et al.*, 2013), *Moringa oleifera* plants help to the control of the growth of unwanted bacteria when incorporated in meals (Jayawardana *et al.*, 2015). *Moringa oleifera* roots are said to be high in antimicrobial compounds and have antibacterial effects. The bark extract has antifungal properties, while the juice from the bark and stem possesses antibacterial properties against *Staphylococcus aureus* (Chaudhary and Chaurasia, 2017; Oluduro *et al.*, 2010; Khor *et al.*, 2018).

Several substances, including glycosylated isothiocyanate, benzyl carbamate niazimycin, and β -sitosterol, have been found to have anticarcinogenic effects against lung, breast, skin, esophageal, and pancreatic cancer in several studies. The plant's leaves and seeds contain significant quantities of these chemicals (Thapa *et al.*, 2019). Ascorbic acid, present in *Moringa Oleifera*, has an anti-diabetic impact by aiding insulin secretion, and myricetin, another component contained in *Moringa Oleifera*, has the same effect (Saralaya *et al.*, 2010; Govardhan *et al.*, 2013). Antioxidants are well-known for their ability to scavenge free radicals, which cause oxidative stress, cell damage, and inflammation (Ferreira *et al.*, 2008). Flavonoids, polyphenols, and ascorbic acid are antioxidants found in *Moringa oleifera* leaves, flowers, and seeds (Farooq *et al.*, 2012). Polyphenols are abundant in the plant, according to studies, giving it a strong antioxidant capability. Folic, gallic, and ellagic acids, β -sitosterol, myricetin, niacimicin A and B, α -tocopherols, δ -tocopherol, γ -tocopherol, vanillin, kaempferol, quercetin, carotene (-)-catechin, astragaloside, and isoquercetin (Ndong *et al.*, 2007; Cheenpracha *et al.*, 2010; Fahey, 2005).

Because of the high quantities of polyphenols in its leaves and blossoms, *Moringa oleifera* plays an essential function in protecting the liver against damage, oxidation, and toxicity (Sultana and Anwar, 2008). *Moringa oleifera* oil can also help to restore normal liver enzyme levels, decreasing oxidative stress and boosting liver

protein content. The *Moringa oleifera* plant's blooms and roots contain a chemical called quercetin, which has been shown to protect the liver (Galuppo *et al.*, 2014). α -sitosterol, quercetin and some of its glycosides, rutin (Panda *et al.*, 2013; Mahajan and Mehta, 2011; Vongsak *et al.*, 2013), and flavonoids, which also inhibit lipid oxidation (Oluduro *et al.*, 2010), are other plant chemicals with this action. The glycosides (Jayawardana *et al.*, 2015) and N- α -L-rhamnopyranosyl vincosamide (Panda *et al.*, 2013) in *Moringa oleifera* leaves and seeds have been shown to help decrease blood pressure. The activity of β -sitosterol in *Moringa oleifera* leaf extract has also been demonstrated to dramatically lower cholesterol levels (Khor *et al.*, 2018).

MEDICINAL USE

The *Moringa* tree has anticancer, circulatory stimulant, antiepileptic, antipyretic, antiulcer, anti-inflammatory, antispasmodic, antihypertensive, diuretic, antioxidant, anti-diabetic, cholesterol lowering, antibacterial, hepatoprotective, and antifungal properties.

Leaves: The leaves of the *Moringa* plant are the most often utilised component of the plant. Hyperglycemia, asthma, flu, heartburn, dyslipidemia, malaria, syphilis, diarrhoea, pneumonia, scurvy, headaches, bronchitis, skin disorders, and eye and ear infections are all treated using *Moringa* leaves. Reduces blood pressure and cholesterol levels, as well as acting as an anticancer agent (Rockwood *et al.*, 2013; Mbikay, 2012; Fuglie, 2005; Ijarotimi *et al.*, 2013; Choudhary *et al.*, 2013; Jung, 2014). Antioxidant, antibacterial, anti-atherosclerotic and anti-diabetic agents, neuroprotectant.

Seeds: According to several studies, *Moringa* seed powder may be used to clean polluted water in a simple and rapid manner. *Moringa* seeds can be used to treat conditions such as Crohn's disease, hyperthyroidism, rheumatism, antiherpes-simplex virus arthritis, cramps, epilepsy, gout, and sexually transmitted illnesses. They can also function as antibacterial and anti-inflammatory agents (Rockwood *et al.*, 2013; Thurber and Fahey, 2010; Kasolo *et al.*, 2010; Nair and Varalakshmi, 2011; Sotalangka *et al.*, 2013).

Root: Root bark has anti-ulcer, anti-inflammatory, and cardiovascular stimulating properties. agent (Choudhary *et al.*, 2013; Monera and Maponga, 2012; Adeyemi and Elebiyo 2014).

Flower: *Moringa* blossoms have been proven to be anti-arthritic, and hypocholesterolemic agents can help with urinary and cold issues, according to several studies (Fuglie, 2005; Sotalangka *et al.*, 2013).

Pods: *Moringa* pods are used to cure liver, spleen, and spleen disorders, as well as joint discomfort. (Rockwood *et al.*, 2013; Kasolo *et al.*, 2010).

PROPERTIES:

Anti-convulsant property:

On Swiss albino mice, experiments were undertaken to determine the effects of *Moringa concanensis* leaf ethanol extract on the maximum electroshock seizure test and the pentylene tetrazole-induced convulsion test (Joy *et al.*, 2013). *Moringa concanensis* reduced mortality in both studies as compared to the control group, which had deaths. The extract may inhibit calcium channels, sodium channels, or NMDA receptors, or it may have GABA agonist action, according to the research.

Anti-cancer property:

The main pathway for the anticancer activity of *Moringa* species is by inhibiting proliferation through apoptosis. *Moringa* species have been shown to suppress malignant cell lines. Methanol crude extracts of *Moringa concanensis* root bark suppressed the growth of hepatocellular carcinoma (Hep-G2) cells via regulating caspase 9 and caspase 3 and lowering the mitochondrial membrane potential of the cells through intrinsic mechanisms (Vijayarajan and Pandian, 2016). The caspase 9 activity was regulated by (4'-O-acetyl- β -L-rhamnopyranosyloxy) benzyl isothiocyanate and niazimicin (Tiloke *et al.*, 2013). Gismondi *et al.* (2013) found that *Moringa oleifera* leaf extract inhibited the growth of B16F10 melanoma cells while also killing about 22% of them.

In a dosage and time-dependent manner, an ethanol extract of *Moringa stenopetala* leaves and seeds decreased Hep-G2 activity and enhanced LDH leakage (Mekonnen *et al.*, 2005). The anticancer activity of 4-(β -D-glucopyranosyl-1 \rightarrow 4- α -rhamnopyranosyloxy)-benzylisothiocyanate was superior to quercetin-3-O-glucoside against Caco-2 and Hep-G2 cells (Maiyo *et al.*, 2016). The presence of eugenol in *Moringa oleifera* bark reduced E2F1/survivin activity, while the presence of D-allose in *Moringa oleifera* leaves inhibited MDA-MB-231 and HCT-8 cancer cells in the G1 phase (Al-Asmari *et al.*, 2015).

By balancing xenobiotic metabolism between Phase I and Phase II, a hydro alcoholic extract of *Moringa oleifera* showed antitumorigenic action (Bharali *et al.*, 2003). In Phase I, the extract enhanced Cyt P450 and Cyt b5 activity while boosting glutathione S-transferase, glutathione reductase, and glutathione peroxidase activity while decreasing GSH levels, which are responsible for Phase II. The extract may potentially function as a "blocking agent" in decreasing xenobiotic substrates for Phase II, according to the research. Furthermore, the extract boosted CAT levels while lowering mouse skin papilloma formation and lipid peroxidation.

Anti-microbial property:

Moringa species have been studied for their antibacterial properties in a variety of ways. Because of their strong antibacterial activity, *Moringa* species have been widely

utilised as water purifiers and antiseptics for water treatment. Waterborne pathogens were inhibited by hexane and methanol seed extracts of both *Moringa oleifera* and *Moringa stenopetala*, notably *Salmonella typhi*, *Vibrio cholerae*, and *Escherichia coli* (Walter *et al.*, 2011). Inhibition was better in most extracts at lower doses.

Elgamily *et al.* (2016) tested dental antibacterial and antifungal activities of ethyl acetate, acetone, and ethanol extracts of *Moringa oleifera* seeds, roots, leaves, and a combination. *Streptococcus aureus* and *Streptococcus mutans* were inhibited by all of the extracts, with the ethanol extract and leaf extract exhibiting the most inhibition. None of the extracts, on the other hand, inhibited *Candida albicans*. Another study found that larger doses of *Moringa oleifera* seeds were required to stop *Candida albicans* from growing (Saadabi and Abu Zaid, 2011).

Moringa oleifera ethanolic leaf extract was used to create mouthwash and toothpaste (Elgamily *et al.*, 2016). As a consequence, the toothpaste inhibited *Streptococcus aureus*, *Streptococcus mutans*, and *Candida albicans*, whereas the mouthwash was just antimicrobial. The dermatophytes *Trichophyton mentagrophytes*, *Microsporum canis*, *Trichophyton rubrum*, and *Epidermophyton floccosum* were also inhibited by ethanol extracts of *Moringa oleifera* seeds and leaves (Chuang *et al.*, 2007). *Moringa oleifera* leaf extracts in hexane, ethyl acetate, methanol, and chloroform were also evaluated against *Serratia marcescens*, a diarrhea-causing bacterium (Rahman *et al.*, 2010).

Aqueous and ethanolic extracts of *Moringa oleifera* leaves inhibited *Staphylococcus aureus*, *Vibrio parahaemolyticus*, *Enterococcus faecalis*, and *Aeromonas caviae*, according to Peixoto *et al.* (2011). The extracts, on the other hand, were shown to be ineffective against *Escherichia coli*, *Salmonella enteritidis*, and *Pseudomonas aeruginosa*. Throughout the investigation, it was discovered that the extract inhibited gram-positive bacteria more than gram-negative bacteria.

In healthy volunteers, Torondel *et al.* (2014) investigated the efficacy of dry and wet *Moringa oleifera* leaf powder as a hand-washing product. Only the highest dose of *Moringa oleifera*, 4 g, demonstrated levels of suppression of *Escherichia coli* equivalent to a non-medicated liquid soap, according to the findings. This activity was not linked to the mechanical friction created during washing hands, according to the study. The presence of saponin in the extract, which has surfactant characteristics, may explain why aqueous preparations of *Moringa oleifera* leaf powder demonstrated greater microbial inhibition than dry preparations, according to the research.

Anti-trypanosomal property

Moringa stenopetala, a member of the *Moringa* genus, has anti-trypanosomal action. The infective stages of *Trypanosoma brucei* were suppressed by *Moringa stenopetala* leaf acetone extract and root ethanol extract (Mekonnen, 2002). Against *Trypanosoma congolense*, a methanol extract of *Moringa stenopetala* provided 100

percent survival (Kifleyohannes *et al.*, 2014). PCV, a means of managing anaemia, was also reduced.

Because it inhibited the parasite at particular enzymes and permanently inhibited trypanothione reductase, the chemical was said to have the potential to become a high-quality anti-trypanosomal medication. With ED₅₀ values of 10 and 9.2µg/mL, respectively, an acetone extract of *M. stenopetala* leaves and an ethanol extract of *M. stenopetala* root wood suppressed *Trypanosoma brucei* trypomastigotes (Mekonnen *et al.*, 1999).

Anti-leishmanial Properties:

High quantities of *Moringa stenopetala* extract, 600 to 1,500g/mL, altered the morphology of *Leishmania donovani* promastigotes and resulted in the loss of their flagella in 40–95 percent of them, according to Mekonnen and Gessesse (1998). In mice, a plant root extract suppressed *Leishmanial aethiopica* (Bekele *et al.*, 2013). The parasite's promastigotes and amastigotes stages were suppressed by 1,3-dilinoleoyl-2-olein and 1,3-dioleoyl-2-linolein from the roots. Inhibition of the promastigotes stage by 1,3-Dilinoleoyl-2-olein was equivalent to that of miltefosine, a positive control.

Anti-viral Properties:

In mice, the extract suppressed both phosphonoacetate-resistant and kinase-deficient HSV-1 strains. The extract decreased the mortality of infected mice by extending their mean survival time and delayed the formation of skin lesions at a dosage of 750 mg/kg. In mice infected with HSV-1, an aqueous extract of *Moringa oleifera* leaves stimulated cellular immunity by lowering viral concentration and preventing the formation of herpetic skin lesions (Kurokawa *et al.*, 2016). Soltan and Zaki (2009) found that *Moringa peregrina* seed oil has antiviral properties against HSV.

Anti-HBV action was found in a buffer extract of *Moringa oleifera* fruits, and a hydroalcoholic extract of the plant's leaves decreased HBV ccdNA levels in HepG2 cells (Waiyaput *et al.*, 2012). According to a survey, *Moringa oleifera* was used as a complement to antiretroviral therapy for HIV infection, but no additional study on the plant's efficacy as an antiviral agent has been done (Monera and Maponga, 2010).

Antihyperglycemic, Antihyperlipidemic, and Hypocholesterolemic properties:

Ethanol and aqueous extracts of *M. peregrina* aerial parts have antihyperglycemic action, decreasing blood glucose levels in streptozotocin diabetic rats (El-Alfy *et al.*, 2011). For three and a half hours after delivery, the hexane fraction of an ethanol extract of the plant decreased blood glucose levels by 64–77.4%. This effect was attributed to

the presence of the antihyperglycemic chemicals lupeol acetate and -sitosterol in the fraction, according to the research. Maltase, sucrase, pancreatic cholesterol esterase, and other enzymes linked to hyperglycemia and hyperlipidemia have been found to be inhibited by *M. stenopetala* leaf hydroalcoholic extract (Toma *et al.*, 2014).

The effects of *Moringa oleifera* leaf hydroethanolic extract on advanced glycation end products were investigated by Sangkitikomol *et al.* (2014). PPAR α 1, PPAR-g, and HMG-CoAR, all of which are involved in maintaining lipid homeostasis, had their mRNA expression decreased throughout the research. In HepG2 cells, dosages of 2.5–10 mg/mL of the extract reduced the development of AGE. In addition to decreasing monosaccharides, *Moringa oleifera* aqueous leaf extract reduced thiol oxidation and protein carbonyl content, which prevented the development of both nonfluorescent and fluorescent advanced glycation end products (Nunthanawanich *et al.*, 2016).

Normal rabbits and hypercholesterolemic rabbits treated with *Moringa oleifera* had varied reactions to HDL levels. Mehta *et al.*, 2003 and Nunthanawanich *et al.*, 2016 found that *Moringa oleifera* lowered HDL levels in normal rabbits but raised HDL levels in hypercholesterolemic rabbits. In hypercholesterolemic rabbits, the lipid profiles of the aorta, heart, and liver were decreased.

Conclusions

The *Moringa oleifera* tree is a wonder tree with immense medical and culinary potential that has yet to be completely realized. All components of the *Moringa oleifera* tree are claimed to offer beneficial properties for humans. This chapter attempted to examine the multifunctional uses of *Moringa oleifera* as well as make recommendations for future climate change mitigation. *Moringa oleifera* is a multifunctional tree that is rapidly growing and highly suited to growing in harsh climate circumstances, according to several studies, which makes it impossible to overlook in today's struggle against climate change. *Moringa* has a direct impact on agriculture, nutrition, health, water, the environment, biodiversity, and sanitation, according to several research.

According to the most recent study, *Moringa oleifera* is one of the medicines that can help to minimize the prevalence of waterborne illness, which is one of the leading causes of mortality in poor nations. As a result, *Moringa oleifera* seeds have the ability to attract and cling to bacteria and viruses present in polluted and turbid water. The *Moringa* tree's ability to mitigate the negative impacts of climate change is encouraging. According to a Japanese study, the rate of carbon dioxide (CO₂) absorption by the *Moringa* tree is twenty times (20x) greater than that of ordinary vegetation. The *Moringa* tree has enormous promise for not just storing carbon but also improving the livelihoods of many smallholder farmers. As a result, planting this tree in various locations around the country will help to reduce the effects of climate change.

Moringa oleifera is known as a “miracle tree” since it serves several purposes for humans and is thus referred to as a low-cost natural gift. Market development methods, strong policies, and research were necessary in order to uncover and exploit the full potential of this miraculous tree. *Moringa* is a great crop for sustainable food production that flourishes as the environment changes, thanks to its many applications and flexibility. *Moringa oleifera* may be used as a food supplement, medication, nutrition, water treatment, livestock feed, vegetable, oil, foliar spray, green manure, natural fertilizer, cosmetic, fodder and care items, as well as to save soil and water and reduce greenhouse gas emissions. *Moringa* should be encouraged for increased intake in order to enhance nutrition and therapeutic properties, as well as to help combat climate change.

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THE EDITORS



Dr. Arghya Mani is working as Assistant Director of Horticulture, Government of West Bengal. He has completed B.Sc. Horticulture and M.Sc. Pomology and Post-Harvest Technology in the year 2015 and 2017 respectively. He has completed his Ph.D. degree from the Department of Post-Harvest Technology, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, India. He has qualified ICAR-NET in Fruit Science and Vegetable Science. He has attended 12 national & international conferences/seminars/symposium, 5 workshops, 3 training programs. He has industrial training exposure in "Overseas Agro-product Pvt. Ltd". He has organized several training programmes and webinars. He has 1 year experience as Assistant Professor in Horticulture where he served Sage University, Indore and Lovely Professional University, Punjab. As 1st author he published several books, 30+ popular articles, 20+ research papers, 15+ book chapters, 10+ review papers published at Scopus, WOS and NAAS indexed journals. He has successfully represented NGOs to disseminate knowledge related to horticulture technology and food processing at farmer's level. He has attended several webinars and online courses. He has organized and coordinated some seminars and webinars as well. He is editor in reputed journals like "Dysona - Applied Science Journal", "Dysona - Life Science Journal", "RADS Journal of Biological Research & Applied Sciences" and "e-Planet journal". He is reviewer of "Journal of Agricultural and bio-chemical Sciences", "International Journal of Agricultural Sciences", "International Journal of Agricultural Marketing". He is advisory board member of "Cambridge Scholar Publishing". He got awarded with "Certificate of Merit" for his academic excellence during his bachelor degree. Beside that he has been awarded with "Best Oral presentation" four times in different events. He has also been awarded "Young Professional Award" twice in different seminars. He got awarded "Young Scientist Award" by SIRI society as well. He got honoured with "Outstanding Horticulturist Award" by 'Green Agri Professional Society'. He was felicitated with "Gold Medal" for 'Best Master Degree Thesis' during 6th convocation of Uttar Banga Krishi Viswavidyalaya. At present, he is doing research on diverse aspects related to minor and underutilized fruits. He is actively involved in research to ensure doubling of farmers' income by innovative processing technology. He is serving the farming community as ADH under the Department of FPI & Horticulture, Government of West Bengal



Dr. Nityamanjari Mishra (DOB: 15/08/1986) is presently working as Junior Scientist (Horticulture) in Regional Research and Technology Transfer Station, Odisha University of Agriculture and Technology, Keonjhar, Odisha. She has completed her MSc (Horticulture) and Ph.D. in vegetable Science from OUAT, Bhubaneswar, Odisha during the year 2009 and 2014 respectively. She has published about more than 40 research papers in different National Journals and International Journals, 30 numbers of popular articles in regional journals and Scientific magazines, 5 booklets in regional language (Odiya) and eleven book chapters and two books till date. She has attended many National and International seminars/symposiums and delivered 25 numbers of oral and poster presentations and got many best poster and oral presentation award. She is member in many scientific societies. She has also acted as associated editor in E-Planet (A multi-disciplinary International Journal of Ecology, Environment, Agriculture and Allied Sciences) and a reviewer in International Journal of Agriculture Sciences and Editor in Chief in Agriculture and food:e-Newsletter. She has got the best young Scientist award for the year 2016 from International Journal of Tropical Agriculture at New Delhi on 26th June 2016, Honorable Jury Mention Young Scientist Award in 6th Academic Brilliance award ceremony-2018 on 28th January 2018 at Noida, New Delhi and Young Researcher of the year award in International Education award conference 2020 from Kites and Krafts production.



Dr. Nirmal Kumar Meena is working as Assistant Professor (Fruit Science) and Principal Investigator in All India Coordinated Research Project on Arid Zone Fruits at Agriculture University, Kota (India). He did his MSc and Ph. D from ICAR- Indian Agricultural Research Institute, New Delhi. He is actively involved in research on arid fruits, teaching and guiding of PG students. He has published 25 research papers in reputed international journals having IF 4 and more. He has edited three books and published 15 book chapters and more than 50 articles in different reputed magazines. He has been awarded with Prof. P. B. Patil Memorial Award -2020 by NGT. He has

recipient of Young Scientist Award, Young Achiever Award and Best Poster Award by many societies. He is active life member of AuSHS, Australia, ASHS, USA, IAHS, India, ISAH, India and SCI, London. He is active reviewer of Journal of the Science of Food and Agriculture, Scientia Horticulturae, Post harvest Biology and Technology, Journal of Food Science and Technology, Int. Journal of Fruit Science, JHBT and many others. He is also member in editorial board of International Journal of AgriWorld, India, Archives of Agri and Env'tl Sciences, India, Int. J. of Phytology, India and J of Modern Agri and Biotech, China. His areas of specialization are arid fruit cultivation, post harvest technology, shelf life and quality in horticultural produce.



Dr. Subhrajyoti Chatterjee is presently working as an Assistant Professor in the Department of Horticulture, M S Swaminathan School of Agriculture (MSSSoA), Centurion University of Technology and Management (CUTM, ICAR accredited), Gajapati, Odisha. He has completed his B.Sc. (Horticulture) from Bidhan Chandra Krishi Viswavidyalaya (BCKV) in 2015, M.Sc. (Horticulture) in Vegetable Science from Dr. Yashwant Singh Parmar University of Horticulture and Forestry (Dr YSPUHF), Solan, Himachal Pradesh in 2017 and Ph.D. from Bidhan Chandra Krishi Viswavidyalaya (BCKV) in 2022. He qualified 'ICAR-AIEEA (PG)' in the discipline of 'Horticulture' in 2015 and pursued his Master's study with ICAR-NTS (National Talent Scholarship). He was also the recipient of prestigious 'University Research Scholarship (URS)' from Government of West Bengal during his Ph.D. in BCKV. He also qualified 'ICAR AICE-JRF/SRF (Ph.D.)' in 2017 in the discipline of 'Horticulture', 'NET-2017' and 'NET-2021' (National Eligibility Test) conducted by ICAR-ASRB (Indian Council of Agricultural Research-Agricultural Scientists Recruitment Board) in the discipline of Olericulture/ Vegetable Science. He has published more than 15 research papers in several nationally and internationally reputed journals. He also authored 8 book chapters and 7 short communications in several books and magazines. He is also having 7 vernacular language (Bengali) short communications and 2 newspaper articles in his name. He has also attended 5 national and international seminars/ conferences and 21 webinars. He is associated with nationally reputed magazine 'Agriculture & Food: e-Newsletter' as an 'Subject Specialist Editor'. Dr. Chatterjee was felicitated with 'Gold Medal' for being all India topper in short term course namely 'Green Revolution Global Certification Programme: An Initiative by International Center for Culture & Education' to educate, inspire and act against climate change. (Supported by United

Nations: Framework Convention on Climate Change) in 2019. He also received 'Young Scientist Award' in "11th International Scientist Awards on Engineering, Science and Medicine" from "VDGOOD" Organization in the year 2020. His specialized area of research is conventional breeding for yield and disease resistance in Leguminous and Brassica vegetable crops. Presently, he is actively associated in teaching, research and extension activities in MSSSoA, CUTM.