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"MIRACLE MORINGA: UNVEILING THE NUTRITIONAL, MEDICINAL, AND ENVIRONMENTAL MARVELS OF MORINGA OLEIFERA"

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Abstract: The purpose of this review article is to shed light on the exceptional adaptability and health-promoting qualities of Moringa oleifera, a plant that is highly valued for both its medicinal and nutritional worth. This document, which covers a wide range of topics, summarises the various uses of moringa in agriculture, medical, nutrition, and environmental sustainability. The review digs into the rich composition of important vitamins, minerals, antioxidants, and amino acids found in moringa, highlighting its nutritional powerhouse status and placing it as an invaluable source of nourishment—especially in areas where malnutrition is a problem. Furthermore, because of its exceptional resilience and flexibility, which allow it to flourish in challenging conditions and provide answers for food security, it is a godsend for sustainable agriculture. This review clarifies the possible therapeutic effects of moringa in the field of health and medicine by looking at its anti-inflammatory, antibacterial, and antioxidative qualities, which show promise in treating a range of illnesses. Its relevance as a natural cure is further shown by its participation in traditional medicine systems worldwide and ongoing scientific investigation. This study offers a thorough resource for researchers, practitioners, and policymakers looking to fully utilise Moringa oleifera for environmental sustainability, global health, and nutrition by compiling and evaluating a wide range of studies and uses. Moringa oleifera, commonly referred to as the drumstick tree or the miracle tree, has garnered increasing attention in recent years for its diverse range of nutritional, medicinal, and environmental benefits. This review article aims to provide a comprehensive overview of the various facets of Moringa oleifera, encompassing its nutritional content, medicinal properties, sustainable agricultural practices, and potential applications in addressing global health challenges.

Keywords: Moringa olefiera, versatile, nutritional, medicinal potency, phytochemistry

1. Introduction

The "drumstick" or "HORSERADISH" tree, Moringa oleifera L. (Moringa pterygosperma G.), is indigenous to Northwest India, the region that produces the most of it. It is also found in South Africa, Northeast Africa, Madagascar, Tropical Asia, Southwest Asia, and Latin America. It works well as a malnutrition treatment. M. oleifera is the most well-known species in the Moringa family, which includes 13 other species: M. arborea, M. rivae, M. ruspoliana, M. drouhardii, M. hildebrandtii, M. concanensis, M. borziana, M. longituba, M. pygmaea, M. ovalifolia, M. peregrina, and M. stenopetala[1,2]. "Reduce by half the proportion of children that are malnourished (MDG)" is one of the first MDGs, or measures towards eradicating extreme poverty and hunger, in the framework of the global vision. Malnutrition is a different phrase from hunger, which is often used to describe food shortage. Lack of

wholesome food that is insufficient to maintain healthy growth and development is referred to as malnutrition. Out of the 7.6 billion people on the planet, 815 million people did not have enough food to survive in November 2017, according to a report from the World Hunger Project (Know Your World, The World Hunger Project). Furthermore, as time goes on, the boundaries of food security are threatened by the exponential expansion in population[3,4]. Malneuritio can be effectively treated with moringa. Because its leaves, pods, and seeds contain a range of vital compounds, moringa is high in nutrients. Moringa is believed to have seven times the amount of vitamin C as oranges, ten times the amount of vitamin A as carrots, seventeen times the amount of calcium as milk, nine times the amount of protein as yoghurt, fifteen times the amount of potassium as bananas, and twenty-five times the amount of iron as spinach. Moringa is a sustainable treatment for malnutrition since it is simple to grow. Children in nations like Senegal and Benin are given moringa treatments[5].

1.1.Phytopharmaceutical Formulations

Researchers have always been interested in plant extracts since they can be used to make a variety of therapeutic goods. Typically, this procedure entails the creation of pharmaceuticals that are distinguished by two attributes. Researchers have always been interested in plant extracts because they can produce a stable product and increase patient compliance, two benefits of using them in pharmaceuticals. The benefit of extracts from the Moringa plant is that, at the quantities and volumes often used for medicinal efficacy, they seem to be extremely safe. In the field of research, M. oleifera has gained widespread acceptance, and scientists have developed a variety of formulations using a variety of techniques. The many phytoformulations made using M. oleifera[6].

Plant part used	**Natre of extract**	**Formula**	**Method of pre-production and polymers /excipients used**	**Applicatio n**	**Inferance**
Leave	Ethyl acetate	Polyherba l formulatio n	Suspending method (carboxy methyl cellulose)	Anti-ulcer	The potent anti-ulcer activity was observed in polyherbal formulations.
Leaves	Aqueous/methan olic	Polyherba l ointments	Water in oil mixing (wool fat, hard paraffin, cetostearyl alcohol, PEG4000,	Edema	• The methanolic extract had a more anti-inflammatory effect than the aqueous extract. • Apart from potent anti-inflammatory activity, the

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			PEG400, sorbitol mono-oleate, liquid paraffin, white beeswax, span 60, tween 60)		-miscible base ointment showed good drug diffusion.
Seed	Oil	Micro-dispersion	Vortexing (Span 80, tween 80)	Anti-inflammatory	• Showed higher permeation rather than pure oil. • Tween 80 enhances the permeation
Leaves	Ethanolic	Lozenges	Wet granulation (Polyvinyl-pyrrolidone, magnesium stearate, menthol, vanillin)	Anti-microbial activity	• Flavoring agents gave better acceptance for the consumer than formulation with no addition of flavoring agent. • Due to limited solubility of quercetin in aq. phase, only 40–50% of quercetin is released.
Seed	Oil	Nano-micelle	Microemulsion method (Tween 80, Ethanol)	Mitochondrial cancer cell Apoptosis	• Targetability increases when seed oil is formulated in nano-micelle. • Nanomicelles kill 50% colon cancerous Caco-2 cells compared to seed oil which kills only 40% of cancer cells.
Leaves + fruits (Embelia	Hydro-alcoholic	Thermo-reversible in-situ nasal gel	Cold method (poly (ethylene glycol)	Allergic rhinitis	• On increasing PF127 concentration, the viscosity of

ribes)			(PEG400), Pluronic F127, xanthum gum, carbopol 934), hydroxypropyl methylcellulose (HPMC K4M).		in-situ gel increases. • PF127 exhibited less mucoadhesion as compared to HPMC/carbopol/xanthan gum. • Plant in situ gel was formulated to overcome low bioavailability and first-pass metabolism.
Leaves	Aqueous, ethanolic	Film dressing	Solvent casting method (Alginate, pectin)	Wound healing	• Aq. leaf extracts showed effective results in cell proliferation and migration properties. • Optimal physicochemical properties were exhibited by the extract.
Leaves	Ethanolic	Effervescent tablets	Wet granulation (70% ethanol, lactose, citric acid, tartaric acid, sodium bicarbonate, aspartame, PEG600)	Anti-anemia	• The effervescent times of all formulations were less than 2 min, and thus all lie within the range mentioned in the pharmacopoeia standard.

1.2.Dietary supplement of Moringa oleifera

US20090098230A1: Nutraceutical formulations made from the leaves, fruits, or seeds of the Moringa species plant are the subject of the current invention. The goal of this invention is to create a nutraceutical composition that is rich in beta-sitosterol, kaempferol, quercetin, and zeatin from the leaves, fruits, and seeds of the Moringa plant without having any of the negative side effects that come with using synthetic ingredients. This is useful since these natural substances are thought to function as a trigger for a speedy and full metabolism in humans when combined in an effective proportion and offer several health benefits.

Additionally, it's thought that the current invention provides vital omega oils and amino acids, some of which come almost solely from the seed cake.

US20060222682A1: Nutraceutical formulations made from plants belonging to the Moringa species are the subject of the current invention. Specifically, the compositions of the invention as described herein supply in a unique way the naturally occurring chemicals from the leaves, seeds, and fruits of the Moringa plant, such as important fatty acid compounds, kaempferol, quercetin, zeatin, and beta-sitosterol..

Yudianti, Muh. Hasyim et al: Young moringa seed flour is more commonly obtained for its iron and calcium content. Dried moringa seed flour has a higher protein content.

Ivana Matic et al: The ability of exogenous plant-derived microRNAs to fine-tune mammalian gene expression and the ability of plant-derived polyphenols to control endogenous mammalian microRNA levels has led to the discovery of a novel genetic regulation mechanism. A burgeoning field of study, this cross-kingdom control holds great promise for the development of functional foods and nutraceutical chemicals derived from medicinal plants. M. oleifera, one of the most widely used plants on the African continent with exceptional nutritional value and medicinal capabilities, has recently had its microRNA sequenced and then examined in order to identify the cross-kingdom interaction on its microRNAs. The nutraceuticals industry is focusing on moringa due to its potential cross-kingdom regulation, medical and nutritional benefits, and bioactive chemical composition[9].

Shad Mahfuz et al: Research indicates that M. oleifera may be successfully employed as a natural growth promoter and an immune-stimulating ingredient in the hens' diet. Even though M. oleifera was included in the experimental meals of the chickens, several researchers suggested more research on the effects of M. oleifera dosages on healthy hens and maximum performance. Thus, the upcoming research should be carried out correctly in order to investigate the applications of M. oleifera in response to a doses and pathogen challenge. In this work, we propose that M. oleifera be used as an substitute for antibiotics in hens, enabling it to be utilised as a successful tactic for organic meat and laying of eggs.

Adewumi T et al: The M. oleifera plant is a true marvel that has a wealth of untapped culinary application possibilities. It was reviewed how M. Oleifera leaf powder, M. Oleifera seed powder, and M. Oleifera flower powder are used in a variety of food applications, including ogi (maize gruel), amala (stiff dough), bread, cookies, yoghurt, cheese, and soup preparation. In order to support their conclusions, many of the studies that are summarised in this paper require additional research. For example, it has been found that M. Oleifera leaf powder reduces the tendency for retrogradation in stiff dough made from plantain flour, as seen by the low set back viscosity values[10].

1.3.Phytochemistry of Moringa oleifera

Moringa oleifera is abundant in compounds that contain rhamnose, a simple sugar, as well as glucosinolates and isothiocyanates, a rather uncommon class of chemicals. It has been reported that two alkaloids, moringine and moringinine, are present in the stem bark. From

the stem of M. oleifera, vanillin, β-sitosterol [14], β-sitostenone, 4-hydroxymellin, and octacosanoic acid have been extracted. L-arabinose, L-galactose, L-glucuronic acid, L-rhamnose, L-mannose, and L-xylose have all been found to be present in the purified, whole-gum exudate from M. oleifera. Mild acid hydrolysis of the entire gum produced a homogenous, degraded gum polysaccharide that included L-galactose, L-glucuronic acid, and L-mannose. Nine amino acids, sucrose, D-glucose, wax, quercetin, kaempferat, and traces of alkaloids are all present in flowers; the ash is high in calcium and potassium[11,12,13].

L.O. Manguro & P. Lemmen et al : Five flavonol glycosides, identified as kaempferide 3-O-(2",3"-diacetylglucoside), kaempferide 3-O-(2"-Ogalloylrhamnoside), and kaempferide 3-O-(2"-O-galloylrutinoside), were isolated and reported by L.O. Manguro & P. Lemmen in 2007.Beta-glucosyl-(1 → 2), kaempferol 3-O-[7-O-alpha-rhamnoside]-[alpha-rhamnosyl-(1 ` 6)]-alpha-rhamnoside and kaempferol 3-O-[alpha-rhamnosyl-(1 → 2)]-beta-glucoside-7-OAlpha-rhamnosyl-(1 →4)]When benzoic acid and betaglucoside-7-O-alpha-rhamnoside are combined, 4-Benzoic acid, O-beta-glucoside 4-(1 → 2)-O-alpha-rhamnosyl-Benzaldehyde with beta-glucoside 4-O-beta-glucoside has been identified in the methanolic extract of leaves of Moringa oleifera. The same extract also included recognised chemicals, including quercetin 3-O-beta-glucoside, rutin, syringic acid, gallic acid, and kaempferol 3-O-alpha-rhamnoside. By comparing their structures with information from known substances and employing spectroscopic techniques, their structures were identified[14].

S.K. Roy et al: extracted a water-soluble polysaccharide from the Moringa oleifera pod aqueous extract. D-galactose, 6-O-Me-D-galactose, Dgalacturonic acid, l-arabinose, and l-rhamnose are present in the polysaccharide in a molar ratio of 1:1:1:1 [23]. The seeds and seed oil from the n-hexane extract contained a variety of sterols, tocopherols, and fatty acids, according to F. Anwar & U. Rashid's 2007 research. Of all the sterols, stigmasterol has the highest percentage (18.8%), whereas α-tocopherol was the most abundant (140.5 mg/kg) of the tocopherols[15].

K.V. Sashidhara et al: Aurantiamide acetate 4 and 1, 3-dibenzyl urea 5 were extracted and characterised from the roots of Moringa oleifera. From this genus, both of these chemicals were isolated for the first time [28]. A.O. Ogunbinu et al. (2009) used hydrodistillation to extract the essential oil of Moringa oleifera, which was then analysed by GC and GC-MS to isolate monoterpenoid chemicals (81.8%). Alpha-phellandrene makes up the largest portion of the oil (25.2%), followed by p-cymene (24.9%)[16].

R.E. Renitta et al: examined using GC-MS a variety of phytochemicals found in the ethanolic extract of Moringa oleifera's leaves, seeds, and flowers. There are fifteen components in the leaves. The main constituents included 2-hexanone, 3-cyclohexyliden-4-ethyl - E2-Dodecenylacetate, 2-oleic safflower oil, hexadecanoic acid, ethyl palmitate, palmitic acid ethyl ester, 2, 6-Dimethyl-1, 7-octadiene-3-ol, 4-Hexadecen-6-yne, and safflower oil. The three main substances found in the seeds were 9-Octadecenoic acid, veridiflorol, and robidin E. Major chemicals from the flowers were found to be 9-Octadecen-1-ol, cis-9-Octadecen-1-ol, Oleol, Satol, Ocenol, Sipo, Decanoic acid, and Dodecanal[17].

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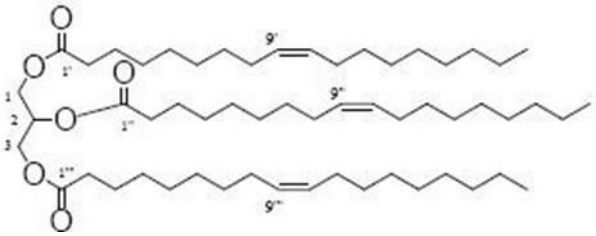
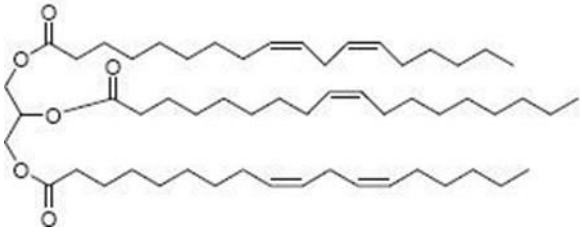
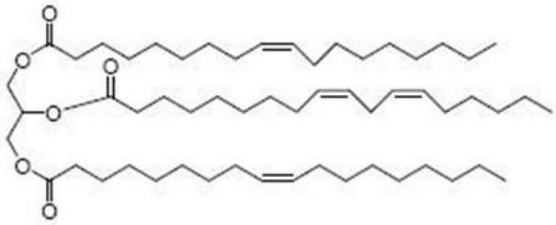
D. Yammuenart et al: From the ethylene chloride extract of Moringa oleifera, seven compounds were isolated: β-sitosterol-3-O-β-D-glucopyranoside, β-sitosterol, linoleic sitosteroate, linoleic acid, 1,2,3-triolein, a mixture of 1,3-dilinoleoyl-2-olein, 1,3-dioleoyl-2-linolein, and 1,2,3-trilinolein, as well as isothiocyanatomethylbenzene[18].



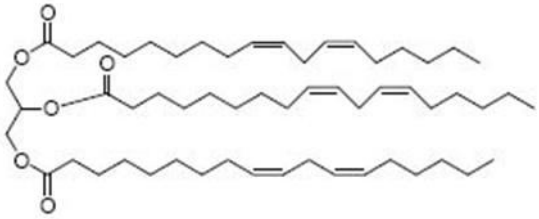
1, 2, 3 – triolein



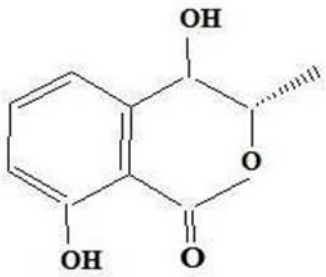
1,3 – dilinoleoyl-2-olein



1, 3-dioleoyl-2-linolein



1, 2, 3-trilinolein



4-hydroxy mullein

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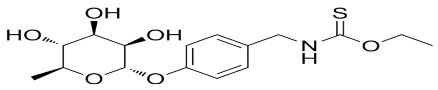
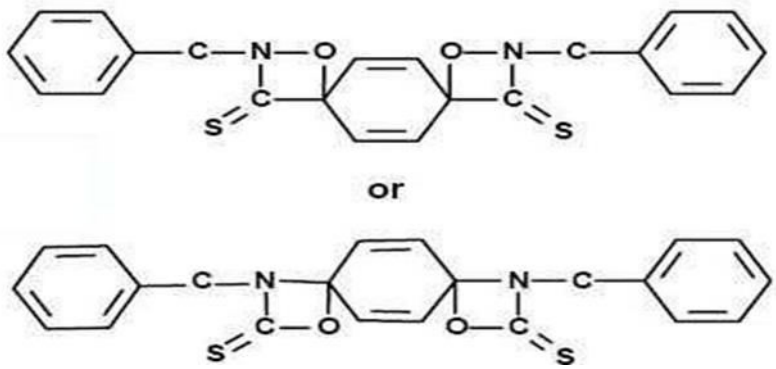
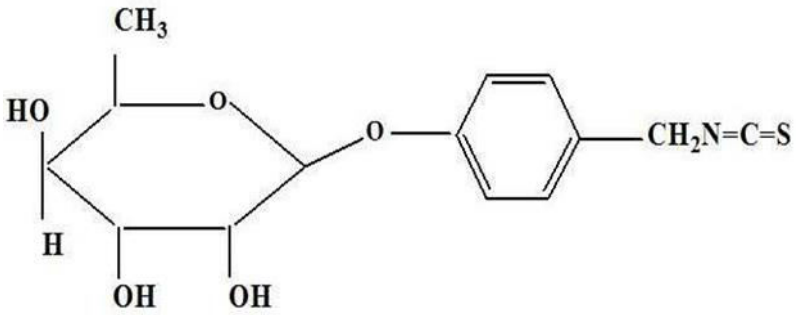


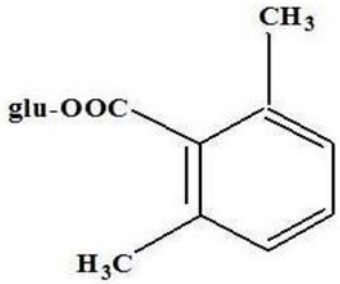
Niazimicin



Pterygospermin



4-(α-L-rhamnosyloxy) benzyl isothiocyanate



Moringyne

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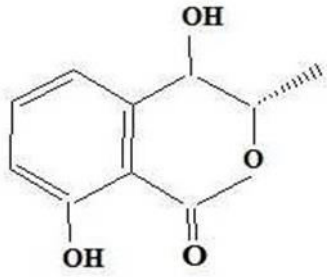
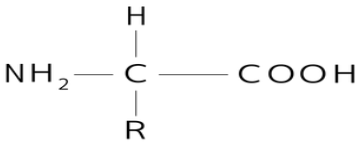
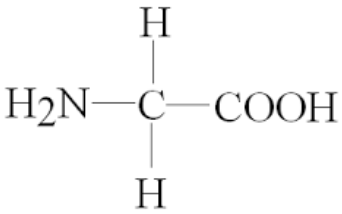


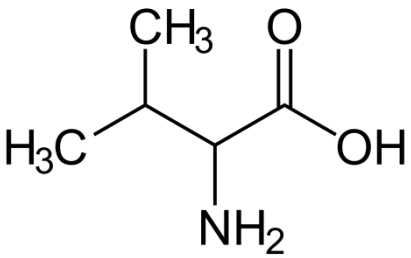
4-hydroxy mullein



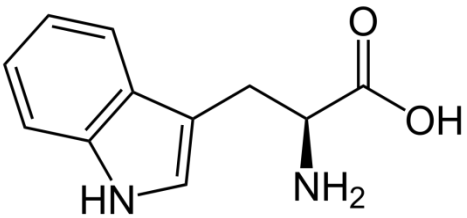
Alanine



glycine



Valine



Tryptophan

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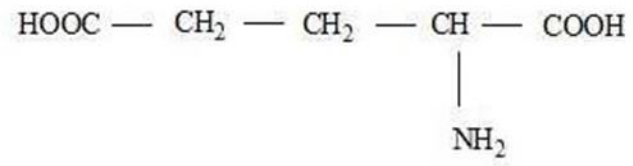
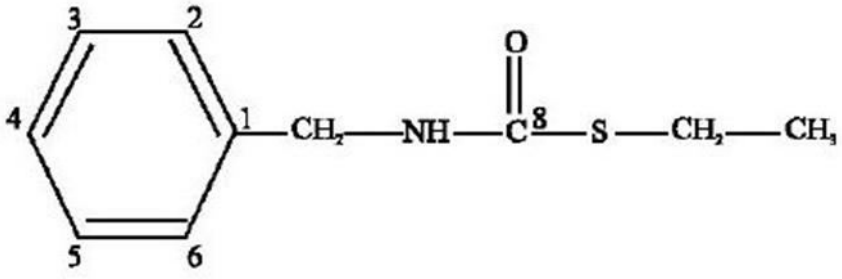
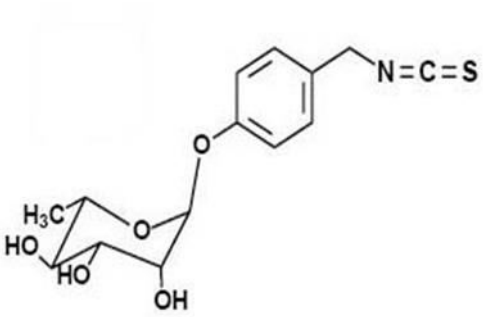


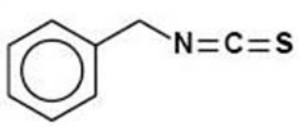
Glutamic acid



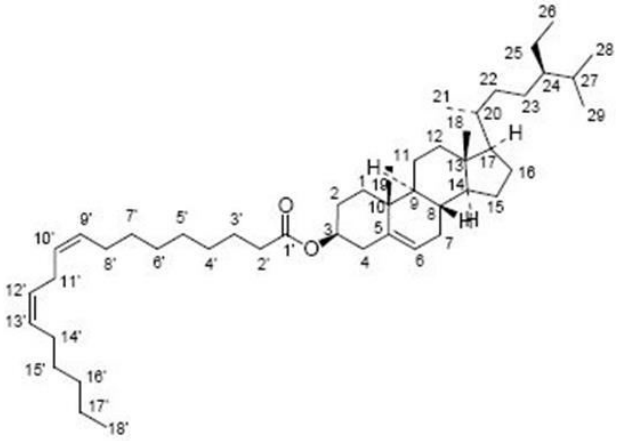
Aglycone of Deoxy-Niazimicine (N-benzyl, S-ethyl thioformate)



4-(α-L-rhamnopyranosyloxy) benzyl isothiocyanate



Benzyl isothiocyanate



Linoleic sitosteroate

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1.4.Pharmacological Actions of Moringa oleifera

1.4.1. Anticancer activity

Kinjal Bhadresha et al: The objective of the investigation was to assess the M. oleifera leaf extracts' in vitro anticancer properties. In a dose-dependent way, the M. oleifera leaf extracts markedly reduced the growth of the human cancer cell line A549. According to morphological investigations, the extract from moringa leaves induced apoptosis as seen by nuclear fragmentation, chromatin condensation, blebbing, and shrinking of the cells. The expression profiles of Bax and Bcl-2 were shown to be aberrant under different treatment settings, as revealed by quantitative RT-PCR studies. According to this study, M. oleifera leaves may be able to improve human health, inhibit the formation of cancer cells, and produce novel food ingredients. According to in vitro research, the phytochemicals found in M. oleifera leaves can be used as the main drugs to treat cancer[19].

Kang Zi Khor et al: With differing degrees of efficacy, researchers have examined extracts from different sections of the moringa tree both in vitro and in vivo on a variety of cancer types. The current status of research on M. oleifera's anticancer capabilities is examined in this review[20].

L Berkovich et al: All examined pancreatic cell lines were unable to proliferate in response to the leaf extract of Moringa oleifera. After all cells were exposed to ≥0.75 mg/ml of the extract, this effect was substantial. When Panc-1 cells were exposed to Moringa leaf extract, they showed a decrease in the production of p65, p-IkBα, and IkBα proteins in crude cell extracts and an increase in the sub-G1 cell population of the cell cycle. Finally, the cytotoxic impact of cisplatin on Panc-1 cells was synergistically amplified by Moringa Oleifera leaf extract[21].

Niveen Madi et al: Find a plant extract that inhibits the growth of cancer cells in cell lines. In A549 cancer cells, MO extract causes apoptosis and alters mitochondrial viability in a way that is dependent on ROS[22].

Charlette Tiloke et al: Using a malignant oesophagus cell line (SNO), we examined the antiproliferative impact of MO crude aqueous leaf extract (MOE). To assess cytotoxicity, SNO cells were subjected to a variety of MOE dilutions (MTT assay). The TBARS assay was used to assess oxidative stress. To evaluate DNA damage, the comet test was employed. Next, using flow cytometry to measure phosphatidylserine (PS) externalisation, luminometry to measure adenosine triphosphate (ATP) levels, and caspase-3/7 and caspase-9 activities,Cancer is just one of the many ailments for which it has been utilised. Investigated MO crude aqueous leaf extract's (MOE) antiproliferative effects using a malignant oesophagus cell line (SNO). SNO cells were exposed to various MOE dilutions in order to evaluate cytotoxicity (MTT assay). To evaluate oxidative stress, the TBARS assay was employed. The comet test was used to assess DNA damage. Next, phosphatidylserine (PS) externalisation was measured by flow cytometry, ATP levels were determined by luminometry, and caspase-3/7 and caspase-9 activities were assessed[23].

A Hermawan et al: This study looked at the cytotoxic effects of Moringa oleifera (EMO) ethanolic extract both alone and in combination with doxorubicin on HeLa cancer cells. Using the MTT assay, cell viability tests for the combination, doxorubicin, and EMO treatments were performed. Ethidium bromide-acridine orange double staining was used to perform the test for apoptosis. In HeLa cells, EMO had a cytotoxic impact with an IC50 greater than 250 µg/mL. When doxorubicin was used alone at 100 and 200 nM, its cytotoxic effect was reduced; however, MO (5, 50, and 250 µg/mL) enhanced it. The combination exhibiting the highest cytotoxic action was 250 µg/mL EMO and 250 nM doxorubicin. A single 250 µg/mL EMO treatment demonstrated a negligible induction of apoptosis; but, when combined with 250 µg/mL EMO, doxorubicin's apoptosis induction was enhanced in comparison to doxorubicin's single 250 µM treatment. It may be possible to develop moringa oleifera as a co-chemotherapeutic agent to treat cervical cancer[24].

1.4.2. Antidiabetic activity

Abdulrahman L. Al-Malki et al: Two low dosages of Moringa seed powder (50 and 100 mg/kg body weight, in the diet) were tested for their antidiabetic effects in male rats with diabetes induced by streptozotocin (STZ). Four groups consisting of forty rats were created. In comparison to the negative control group, the diabetic positive control group (STZ treated) exhibited lower antioxidant enzyme, higher IL-6, and higher lipid peroxide in the blood and kidney tissue homogenate. Diabetes in G2 rats also resulted in elevated levels of glycosylated haemoglobin, fasting blood sugar, and immunoglobulins (IgA, IgG). Additionally, albumin was reduced but α-amylase and liver enzymes were unaffected. Moreover, elevated potassium and sodium levels in G2 and renal functions were indicative of diabetic nephropathy. Additionally, glucosuria and elevated levels of potassium, sodium, creatinine, uric acid, and albumin were shown by urine examination. Comparing the tissues from the negative control group, the kidney and pancreas likewise displayed pathological change. When the diabetic rats were given 50 or 100 mg of powdered Moringa seeds/kg body weight in G3 and G4, respectively, the levels of all these parameters were improved and approached the negative control values. Additionally, the kidney and pancreas histologies were restored to normal in comparison to the diabetic positive control group[25].

Hanan Dawood Yassa et al: In order to treat streptozotocin-induced diabetic albino rats, the current study evaluated the potential antioxidant and antidiabetic effects of an aqueous extract of M. oleifera leaves. Aqueous extract of M. oleifera leaves was evaluated for its antidiabetic properties using histomorphometric, ultrastructural, and biochemical methods. Monitoring of fasting plasma glucose (FPG) and morphometric analyses of collagen fibres (using Mallory's trichrome stain) and β-cells of Langerhans' islets were carried out. By evaluating the reduced glutathione and lipid peroxidation product, malondialdehyde, in pancreatic tissue, the antioxidant properties of M. oleifera leaves were ascertained. When compared to control levels, M. oleifera therapy dramatically improved the altered FPG (from 380% to 145%), reduced glutathione (from 22% to 73%), and malondialdehyde (from 385% to 186%) [26].

Irfan Degirmenci et al: In this work, diabetic (type 2) rats induced with streptozotocin (STZ) were used to observe the effects of acarbose and Rumex patientia on the morphological

alteration of pancreatic B cells. Periodically, blood glucose levels were monitored during the experimentation period, Blood glucose levels were monitored over the trial period, and at the conclusion, cardiac blood was used to measure the HbA1c level. An electron microscope was used to analyse pancreatic tissues. Acarbose and Rumex patientia reduced the HbA1c and glucose levels that were elevated by STZ. Morphological analysis revealed that the B cells of STZ-induced diabetic rats exhibited swelling and vacuolization of the mitochondria, together with dilatation of the endoplasmic reticulum. Furthermore, the STZ-induced diabetes group showed a reduction in B cell secretory granules. There were no discernible pathological alterations in the STZ + acarbose group. A little enlargement in the B cells was noted in a few mitochondria in the STZ + Rumex patientia group[27].

Sai mangala divi et al : In this study, insulin-resistant (IR) and type 1 diabetic rat models were used to assess the effects of an aqueous extract of Moringa oleifera leaves on body weight, insulin, plasma glucose, lipid profiles, HOMA, and the oral glucose tolerance test. The current study set out to assess the impact of an aqueous extract of Moringa Oleifera leaves on lipid profiles, insulin, body weight, plasma glucose, HOMA, and the oral glucose tolerance test in rat models of type 1 diabetes and insulin resistance. Streptozotocin injections intraperitoneally (55 mg/kg body weight) caused type 1 diabetes and an increased fructose diet to cause insulin resistance. For 60 days, oral intubation was used to deliver the extract at a dose of 200 mg/kg body weight. Rats given fructose showed signs of insulin resistance (IR), as seen by elevated body weight, hyperinsulinemia, hyperglycemia, and HOMA. Rats with diabetes caused by STZ displayed hyperglycemia, hypoinsulinemia, and failure to acquire weight. In STZ, the degree of hyperglycemia was greater[28].

J. Sugunabai et al: The aim of the research was to examine and contrast the anti-diabetic and hypolipidemic properties of Solanum nigrum and Moringa oleifera in individuals with established diabetes and hyperlipidemia. These plants' aqueous extract was evaluated for its hypoglycemic and hypolipidemic properties. It was also examined for the presence of primary and secondary metabolites[29]. Patients between the ages of 35 and 60 were chosen for the investigation. The trial lasted ninety days and only male patients were chosen. During treatment with Moringa oleifera, the levels of glucose, glycosylated haemoglobin, total cholesterol, triglycerides, LDL-cholesterol, and HDL-cholesterol were reduced to 23, 2.5, 40, 18%, and 20%, respectively. On treatment with Solanum nigrum, the levels were reduced to 19, 10, 17, 8%, and increased to 2%.

1.4.3. Antioxidant property

Rocío Peñalver et al: It has been shown that moringa oleifera possesses anti-inflammatory and antioxidant qualities. The mineral bioaccessibility and antioxidant capacity were evaluated because of its abundance in macronutrients and minerals. Aside from that, the mineral content, fatty acid, amino acid, and chemical composition were also assessed. The chemical composition's high protein and low fat content was shown by the analysis that was done. K, S, Ca, and Fe were the elements with the highest concentrations in terms of mineral content; Ca and Fe showed the highest bioaccessibility. High antioxidant capacity was

demonstrated by the values obtained using the FRAP, ABTS, and ORAC methods. This was closely correlated with the higher amount of phenolic compounds[30].

Luana C. B. B. Coelho et al: This study examines the antioxidant activity of ethanolic (E1) and saline (E2) extracts of M. oleifera from the following sources: flowers (a), seeds (b), inflorescence rachis (c), leaf tissue (d), leaf rachis (e), and essential stem tissues (f). Using dot-blots on thin layer chromatography stained with a 0.4 mM 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) solution, the extracts' radical scavenging capacity (RSC) was assessed; spectrophotometric tests were recorded at 515 nm. There were antioxidant components found in every E1 and E2 from a, b, and d. E1d produced the highest RSC; the antioxidants in E2 interacted with DPPH relatively slowly. At least three flavonoids were present in the ethanolic extract of the flowers, inflorescence rachis, fundamental tissue of the stem, and leaf tissue, according to the chromatogram produced by the diphenylborinate2-ethylamine methanolic solution. At least two flavonoids were found in the saline extract extracted from the flower and leaf tissue. In conclusion, antioxidants found in M. oleifera ethanolic and saline extracts support the use of plant tissues as dietary sources[31].

Ismet Ara Jahan et al : This study assesses the antioxidant capacity of Bangladeshi-grown Moringa oleifera Lam. seed kernels. Three different solvents were used to extract the M. oleifera seed kernel: methanol, acetone, and water. Total phenolic, total flavonoid, and total tannin contents were determined in order to assess the phytochemical composition. The study's findings showed that, among the three M. oleifera seed kernel extracts, the water extract had the most free radical scavenging ability. For the water extract, reducing power, total phenolic, and total flavonoid levels were also found to be significant. Based on all of the study's findings, it can be said that of the three extracts (methanol, acetone, and water), the water extract had the strongest antioxidant activity, supporting the use of M. oleifera seed kernel as a naturally occurring antioxidant[32].

Boonyadist Vongsak et al : The best technique for extracting M. oleifera's dried leaves is maceration with 70% ethanol. It encouraged the highest levels of major active components, total flavonoids, total phenolics, and the strongest antioxidant activity in addition to a high yield of crude extract[33].

Wiwit Denny et al : Research has been done on the antioxidant activity of Moringa oleifera. Using methanol, ethyl acetate, dichloromethane, and n-hexane, M. oleifera leaves were extracted. The 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging activity assay and an enhanced 2,2'-azino-bis-[3-ethylbenzothiazoline sulphonate] (ABTS) radical cation decolorization assay were used to assess the antioxidant activity of the extracts in vitro. As a reference, trolox was utilised, with an IC50 of 3.06 µg/mL in the ABTS test and 5.89 µg/mL in the DPPH assay. In both the DPPH and ABTS assays, the methanol extract exhibited the strongest free radical scavenging activity, with IC50 values of 49.30 µg/mL and 11.73 µg/mL, respectively. According to this study, M. oleifera leaves have antioxidants[34].

1.4.4. Antiepileptic activity

Suvarna P. Ingale et al: The anxiolytic and antiepileptic properties of M. oleifera's aqueous extract may be mediated by GABA mimetic activity. These results support the conventional wisdom on the use of M. oleifera in the treatment of anxiety and epilepsy. The identification of the plant's active ingredients may provide a starting point for the creation of medications that would enhance the quality of life for epilepsy sufferers by treating their anxiety instead of their condition[35].

María Eva González-Trujano et al: In mice and rats, extracts of Moringa oleifera (ethanol) and hexane delayed the onset of seizures; this effect was enhanced when hexane extract containing the active metabolite hexadecanoic acid was present. The potency of the EEG, which resulted in a decrease in the spike frequency and amplitude as well as in the length and intensity of the seizures, supported the anticonvulsant effects in the spectral analysis. The hexane extract's effects were similar to those of the antiepileptic medication ethosuximide, which served as the reference. Nonetheless, it appears that the non-polar components play a significant role through the partial involvement of fatty acids, indicating the plant's potential benefits for treating epilepsy[36].

1.4.5. Antimicrobial activity

Doughari et al: The phytochemical analysis's findings showed that common phytoconstituents like tannins, saponins, flavanoids, glycosides, and terpenoids were present. both the extracts from MOL1 and MOL2. Flavanoids, terpenoids, saponins, and tannins have been recognised from the extract of MOS. Phlobatannins, steroid, glycoside, saponin, tannins, and We detected flavonoids in the MOF extract. These ingredients' existence has been claimed to explain how plants exert their antibacterial action[37].

P. Nepolean et al : GC-MS analysis of an ethanolic leaf extract of M. oleifera revealed fifteen main components. The range of the retention time was 11.075 to 12.635. Compounds such as (z)-(CAS), 2-keto dimethyl-1, 7-octadiene-3-ol, 4-hexadecen-6-yne, hexadecanoic acid, ethyl ester (CAS), ethyl palmitate, and palmitic acid ethyl ester have all been found[38]. The retention time range was displayed by the MOL2 extract as 11.083 to 19.783. From the second extract, substances such as 2-hexanone, 3-cyclohexyliden-4-ethyl - E2-Dodecenylacetate, Hi-oleic safflower oil (CAS), and safflower oil have been found. In MOS extract, fifteen components were found with a retention period ranging from 12.667 to 21.375. The main substances discovered included 9-Octadecenoic acid, veridiflorol, and robidin E. The MOF extract displayed a retention time of 9.542 to 12.650. Nine-Octadecen-1-ol, (Z)-(CAS) cis The MOF extract has been shown to contain - 9 - Octadecen -1 - ol, Oleol, Satol, Ocenol, Sipo, Decanoic acid, Dodecanal, etc.

Moyo, Busan et al: Antibacterial activity against Escherichia coli, Enterobacter cloace, Proteus vulgaris, Staphylococcus aureus, and Micrococcus kristinae were demonstrated by the acetone extract of M. oleifera leaves at a dosage of 5 mg/ml. The most vulnerable species was M. kristinae, whose growth was suppressed at 0.5 mg/ml. Conversely, Streptococcus faecalis, Bacillus pumilus, Klebsiela pneumonia, Bacillus cereus, and Pseudomonas

aeruginosa were not inhibited by M. oleifera acetone extract. When applied to E. Coli and M. Kristinae, the acetone extract proved bactericidal[39].

M. Umar Dahot et al: Three fractions were extracted using Sephadex G-25 column chromatography from Moringa oleifera leaves. These fractions were found to have single bands on Polyacrylamide SDS gel electrophoresis. A tiny protein or peptide's antibacterial activity was evaluated against S. aureus, K. pneumoniae, and E. coli Kl. aerogenes. B. subtilis and S. aureus. Strong inhibitory activity was demonstrated by fractions P1, P2, and P3 against S. aureus, E. coli, and B subtilis, although a distinct zone of inhibition was also seen when using peptide 1 against K1. aerogenes. Fraction P2 shown substantial inhibitory zone for Aspergillus niger[40].

Armando Caceres et al: In vitro tests were conducted to examine the antibacterial properties of Moringa oleifera leaves, roots, bark, and seeds against human pathogenic bacteria, yeast, dermatophytes, and helminths. Pseudomonas aeruginosa and Staphylococcus aureus growth is suppressed by fresh leaf juice and aqueous extracts from the seeds, and this activity is inhibited by extraction temperatures above 56°C, as shown by a disk-diffusion method. Against Candida albicans and four other pathogenic Gram-positive and Gram-negative bacteria, no action was shown. Using a dilution approach, no action against six pathogenic dermatophytes could be found. A standardised procedure was developed to investigate how aqueous extracts affected Ascaris lumbricoides eggs[41].

Amer Jamil et al: Assessed the antibacterial activity of Moringa oleifera seeds. The antibacterial activity of Moringa oleifera seed extracts was assessed against strains of bacteria (Escherichia coli, Bacillus subtilis, Staphlocuccus aureus, Fusarium solani, and Rhizopus solani) and fungi (Pasturella multocida, Bacillus subtilis, and Bacillus aureus). In contrast to the fungal strains, the zones of growth suppression shown increased sensitivity to the bacterial strains. The microorganisms that were most sensitive were Bacillus subtilis and Pasturella multocida, according to extracts with minimum inhibitory concentrations (MIC) [42].

1.4.6. Cardiovascular activity

Anwar H. Gilani et al: ethanolic extract of Moringa oleifera (MO) leaves was fractionated using a bioassay-directed method, four pure chemicals were isolated: niazinin A (1), niazinin B (2), niazimicin (3), and niaziminin A + B (4 + 5). In rats under anaesthesia, intravenous injection of one of the compounds (1–10 mg/kg) resulted in bradycardia and hypotension.Acetylcholine (ACh)'s hypotensive and bradycardiac effects were entirely eliminated in the animals when atropine (1 mg/kg) was administered prior to treatment; in contrast, the test chemicals' effects on the cardiovascular system did not change, excluding the possibility that muscarinic receptor activation was involved. Every chemical (50–150 µg/mL) had detrimental inotropic and chronotropic effects in isolated guinea pig atria. At comparable dosages, each drug suppressed ileal contractions caused by histamine or ACh as well as K+-induced contractions in the rabbit aorta. Additionally, all chemicals reduced rat uterine spontaneous contractions in an equal manner. These findings suggest that the compounds' direct depressive activity, which was detected on all isolated preparations tested, is most likely what causes the hypotensive and bradycardiac effects seen in vivo[43].

Jihen Taleb et al: This study aimed to assess the impact of a methanolic extract of Moringa oleifera leaves (MEML) on obesity and heart damage in rats that were induced by a high-fat diet (HFD). For a period of 12 weeks, obese rats were given MEML orally at doses of 200 mg and 400 mg/kg/bw. It has been demonstrated that M. oleifera leaves are nutrient- and mineral-rich. Using LC-ESI-MS analysis, the diversity of phenolic chemicals in MEML was demonstrated. Rats given a prolonged high-fat diet (HFD) experienced a decrease in HDL-C levels and an increase in body weight growth, total cholesterol, and triglycerides. The results showed that in obese rats, the level of the cardiac marker enzyme had significantly increased (). When comparing the high-fat diet group to the control, there was a substantial drop () in the levels of cardiac catalase (CAT), glutathione peroxidase (GPx), and superoxide dismutase (SOD) activities along with an increase () in malondialdehyde (MDA). Particularly in the case of the higher concentration, the MEML treatment restored the normal histological structure of the heart and reduced anomalies in the serum biochemical measures while also balancing the antioxidant status. Leaves from the moringa oleifera plant show promise for treating obesity and its after effects, including heart issues[44].

Mostafa Cheraghi et al: Rats with doxorubicin (Dox)-induced cardiac toxicity were used to assess the cardioprotective effect of N, α-L-rhamnopyranosyl vincosamide (VR), which was extracted from the leaves of the Moringa oleifera plant.This extract also decreased the initially elevated MDA level in cardiac tissue. Following VR treatment, the reduced GSH and SOD levels increased. The assessment of pharmacokinetic characteristics revealed that rats treated with nanogel had considerably higher VR plasma concentrations, as well as Cmax, Kel, t½(a), t½(el), Ka, and AUC. According to the study's findings, virtual reality (VR) may shorten the duration of treatment for cardiovascular diseases (CVD) and help cut dose levels. Our conclusion suggests that isolated VR has cardio-protective qualities and benefits through its ability to scavenge free radicals[45].

Melva Louisa et al : A total of 108 publications on clinical trials and nonclinical investigations of MO in cardiometabolic-related illnesses are included in this review. With its antioxidative and anti-inflammatory properties, moringa oleifera extracts or isolated compounds influence CMD by modifying glucose and lipid metabolism and preserving target organ damage. Numerous research investigations have substantiated the advantageous impact of MO on gut microbiome regulation, which results in the diversity of gut microbiota and lower levels of pathogenic bacteria in the caecum. Numerous molecular actions have been investigated, such as blocking the production of the Nox4 protein, suppressing NF-kB translocation, upregulating the Nrf2/Keap1 pathway, stimulating total antioxidant capacity by lowering PKCζ activation, and several other suggested pathways[46].

B.Y. Aju et al:The goal of the current investigation is to ascertain Moringa oleifera's protective function in diabetic heart tissue. For 60 days, methanolic extract of Moringa oleifera leaves was given orally to diabetic rats at a dose of 300 mg/Kg body weight. Serum glucose, glycated haemoglobin, plasma insulin, and the amounts of hydroperoxides (HP), conjugated dienes (D), glutathione peroxidase (GPx), glutathione-reductase (GRD), reduced glutathione content (GSH), and thiobarbituric acid reactive substances (TBARS) were all measured in relation to the extract. As normal medications, atorvastatin and metformin were

administered. Significant reductions in serum glucose and glycated haemoglobin levels were seen, along with an increase in plasma insulin, reduced glutathione content (GSH), activities of glutathione peroxidase (GPx), glutathione-reductase (GRD), and superoxide dismutase (SOD), catalase (CAT), and GSH. The treated groups showed a significant decrease in serum glucose, glycated haemoglobin, thiobarbituric acid reactive substances (TBARS), hydroperoxides (HP), and conjugated dienes (CD), and a significant increase in plasma insulin, activities of superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), glutathione-reductase (GRD), and reduced glutathione content (GSH). The antioxidant capacity of Moringa oleifera leaf methanolic extract was assessed in this work. These results point to Moringa oleifera's potential protective effect against oxidative stress in the heart of diabetic rats[47].

1.4.7. Another multifaceted utilization

Zofia Nizioł-Łukaszewska et al show that Research has demonstrated that the leaf extract of Moringa oleifera is a significant source of phenolic and flavonoid components. Additionally, it demonstrates potent antioxidant action through the scavenging of free radicals. According to in vitro toxicity studies, the studied extracts, at concentrations of up to 5%, had a favourable impact on cell growth and metabolism and may help lower oxidative stress in cells. It was observed that the tested model formulation of the cosmetic (1% SCS) with the inclusion of various extract types could help to lower skin irritation and increase product safety[48]. Sirivan Athikomkulchai et al proves The cream containing moringa seed oil demonstrated antioxidant activity, increased skin hydration, and decreased skin erythema; however, it had no effect on skin viscoelasticity or melanin concentration. It was safe to use the moringa seed oil cream because it did not cause skin irritation[49]. Farzana Chowdhary et al shows that The investigation's findings imply that topical formulations containing moringa extract can rejuvenate skin and lessen indications of ageing. To fully understand the anti-aging properties and mechanisms of plant ingredients in topical formulations, more research is needed[50]. Fajrul Fhalaq Baso et al show that the leaves of Moringa oleifera L. are recognised for their high protein content and isoflavones, which suppress the activity of tyrosinase. The purpose of the study was to determine whether Moringa leaf extract inhibits tyrosinase and to develop a cream that brightens skin using the extract[51].

2. Conclusion

The powerful plant Moringa oleifera exhibits a wide range of pharmacological properties. Its abundant nutrient composition, which includes antioxidants, vitamins, and minerals, has anti-inflammatory, antibacterial, and anti-diabetic effects. Its medicinal potential is aided by bioactive substances such as quercetin and chlorogenic acid, which also help to reduce blood sugar, fight oxidative stress, and improve wound healing. The heart is additionally supported by the anti-hypertensive and cholesterol-lowering properties of moringa. While further research is needed, Moringa oleifera's wide range of pharmacological properties point to potential uses in the treatment of a number of illnesses, establishing it as a rich natural resource for pharmaceutical research.

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