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Introduction

Moringa oleifera Lam. (*M. oleifera*), also known as drumstick or horseradish, is a perennial tree that belongs to the Moringaceae family.¹ It is considered to be a medicine food homology plant with great medicinal values and was introduced into Yunnan province, China, in the 1960.² *M. oleifera*, acquainted with "Tree of Wonders", "Tree of Life" and "Diamond of Plants", is widely cultivated for its drought resistance, rapid growth and nutrient-rich properties in African and Asian countries.³ (Fig. 1). *M. oleifera* is a remarkable plant with multiple edible parts, each offering unique biological activities. Its leaves, fruit pods, fruits, seeds, flowers, and roots all contribute to its versatility and potential benefits. And in India and Africa, it is commonly used to treat diabetes, skin diseases, hypoimmunity, arthritis, cancer, and so on.

The safety of *M. oleifera* is closely related to its ingredients, therefore, an increasing number of scholars have focused on the identification of the active compounds for the investigation of its pharmacological effects and potential mechanisms which are crucial in the process of *M. oleifera* application of drugs and food products development. It is of great significance and value to explore the relationship between its ingredients and efficacy, the determination of key ingredients, the selection of different

dosage forms and the toxicity evaluation of *M. oleifera* on the human body. Fortunately, studies on *M. oleifera* have been conducted and numerous new active ingredients were found, leading to the developments of new preparation methods, pharmacological efficacies and toxicological effects of *M. oleifera*. What's more, the underlying molecular mechanism of *M. oleifera* action is also being revealed.⁴

This article summarized the past 10 years of research on the medicinal parts, active ingredients, health benefits and the mechanisms, dosage forms and applications of *M. oleifera*. In addition, we also use UPLC-Q-TOF-MS, network pharmacology and molecular docking to analyse the components and pharmacological mechanisms. This article summarizes and explains the chemical composition and biological activity and mechanisms of action of *M. oleifera*. It predicts trends in the expansion of *M. oleifera* products and formulation design with a focus on innovation and diversification, aiming to provide theoretical support and research ideas for subsequent studies. In this way, this paper provides not only a basic research summary but also a comprehensive future research plan for *M. oleifera*. Furthermore, the challenges and future trends of *M. oleifera* are summarized to provide a research approach for the further development and application.

M. oleifera related article acquisition based on CiteSpace

This study regards the Web of Science Core Collection as a data-collection platform according to data resources required in CiteSpace. The bibliometric search strategy can be described as the following: topics = ("*Moringa oleifera* Lam. OR *Moringa*

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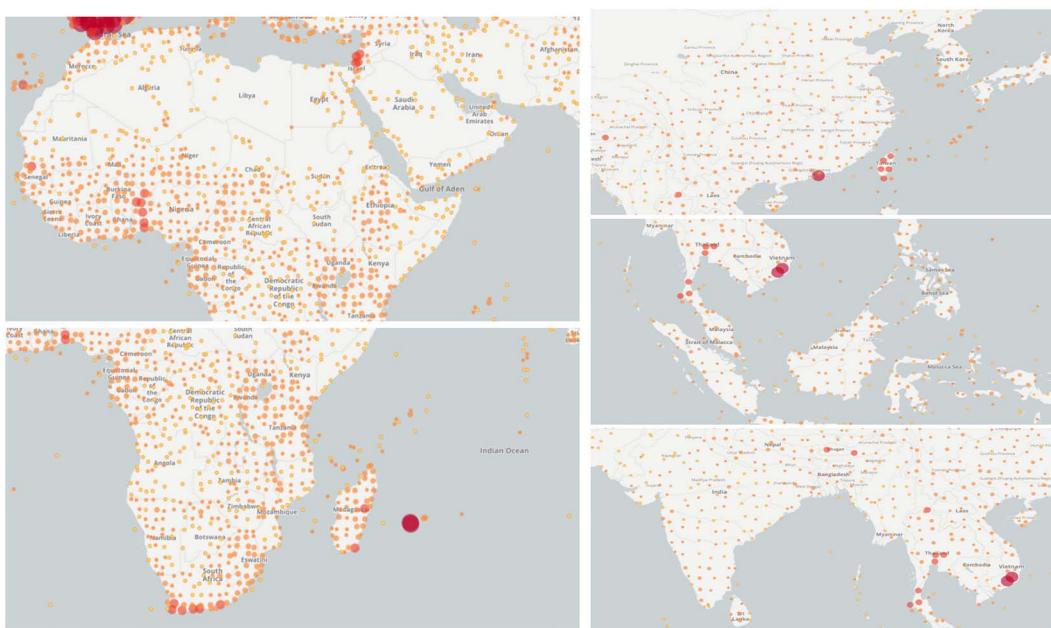


Fig. 1 Key distribution areas of *M. oleifera* worldwide (the dots indicate the presence of *M. oleifera* in this area. Images were obtained from <https://www.gbif.org/>).

oleifera OR Moringa"), time span = 2012–2023, and language = English.⁵ We used the 6.1.R6 version of CiteSpace software to analyse the current hot spots of *M. oleifera*.

We searched 5249 publications related to *M. oleifera*. (Fig. 2A) Bergamasco Rosangela was the most prolific author

with most publications, *i.e.*, with 60 articles (Fig. 2B). The India, Egypt and China were the leading country and the top institution in this field of study, with 725, 372 and 348 articles, respectively (Fig. 2C). There was active cooperation between institutions, countries, and authors. Hot topics focused on

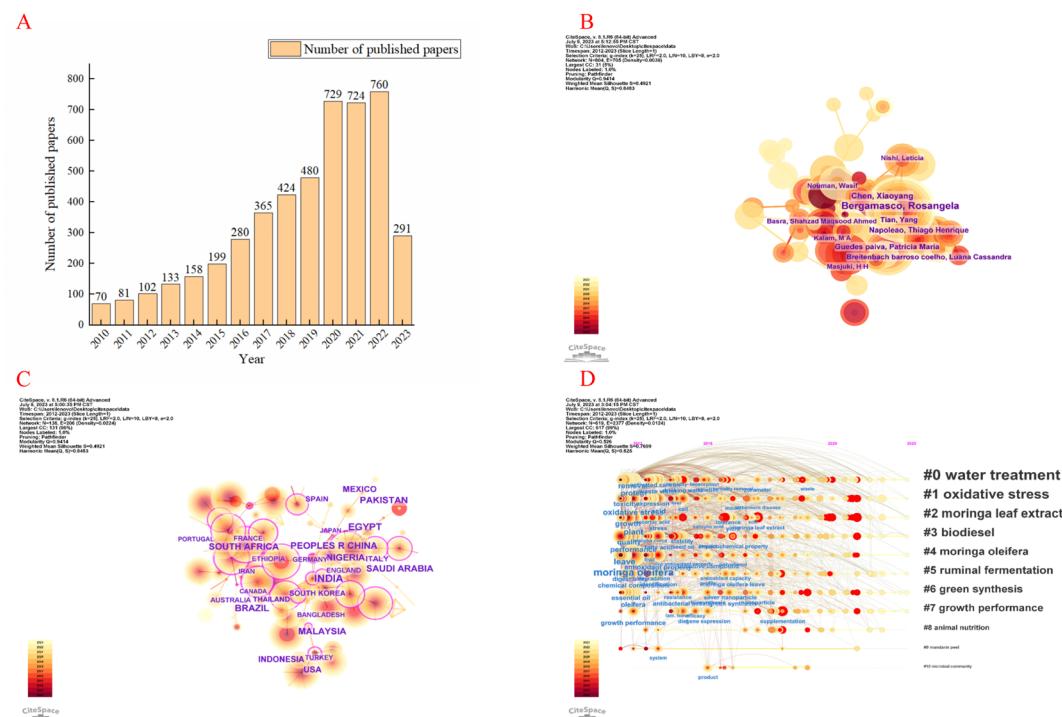


Fig. 2 CiteSpace, the Java application, can be used to generate knowledge-domain visualization. Annual trend chart of publications (A). The network of author and countries in the study area of insomnia and circadian rhythm (B and C). Timeline diagram of keywords in the field of *M. oleifera* (D).

Moringa oleifera leave, *Moringa oleifera* extract, antioxidant activity, and oxidative stress (Fig. 2D).

Medicinal parts of *M. oleifera*

The whole plant of *M. oleifera* including leaf, fruit pod, fruit, seed, flower and root, all have a variety of biological activities, and can even play medicinal roles in preventing and treating diseases.

The leaves of *M. oleifera* are rich in resources and easily harvested which mainly contain active components such as polyphenols, flavonoids, phenylpropanoids, terpenoids, fatty acids, alkanes, sterols, as well as minerals and vitamins.⁶ Among them, polyphenols and flavonoids are the main bioactive constituents, with antioxidant activity and anticancer properties,⁷ antisepsis,⁸ anti-inflammatory,⁹ anti-hypertension, anti-diabetes, anti-spasm, reduce metal toxicity,¹⁰ reduces plasma and liver lipids and affects obesity-related reproductive

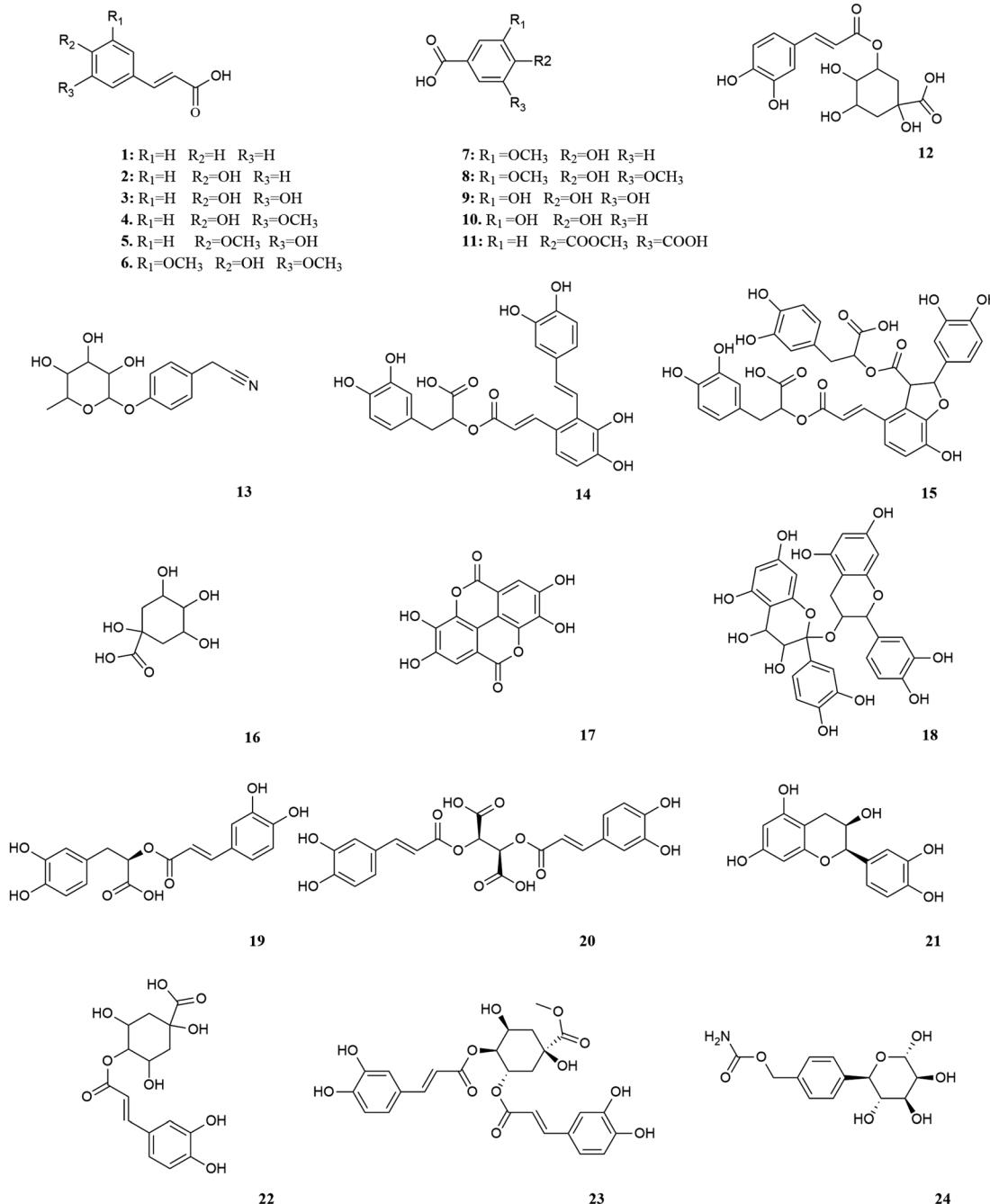


Fig. 3 Polyphenols in *M. oleifera*. [1] Cinnamic acid, [2] *p*-coumaric acid, [3] caffeic acid, [4] ferulic acid, [5] isoferulic acid, [6] sinapic acid, [7] vanillic acid, [8] syringic acid, [9] gallic acid, [10] protocatechuic acid, [11] gentiolic acid, [12] chlorogenic acid, [13] niazirin, [14] salvianolic acid A, [15] salvianolic acid B, [16] quinic acid, [17] ellagic acid, [18] procyanidin, [19] rosmarinic acid, [20] chicoric acid, [21] epicatechin, [22] 4-*O*-caffeoylelquinic acid, [23] 3,4-di-*O*-caffeoylelquinic, [24] 4-methyl-(α-L-rhamnose pyranoxy)-carbamate.



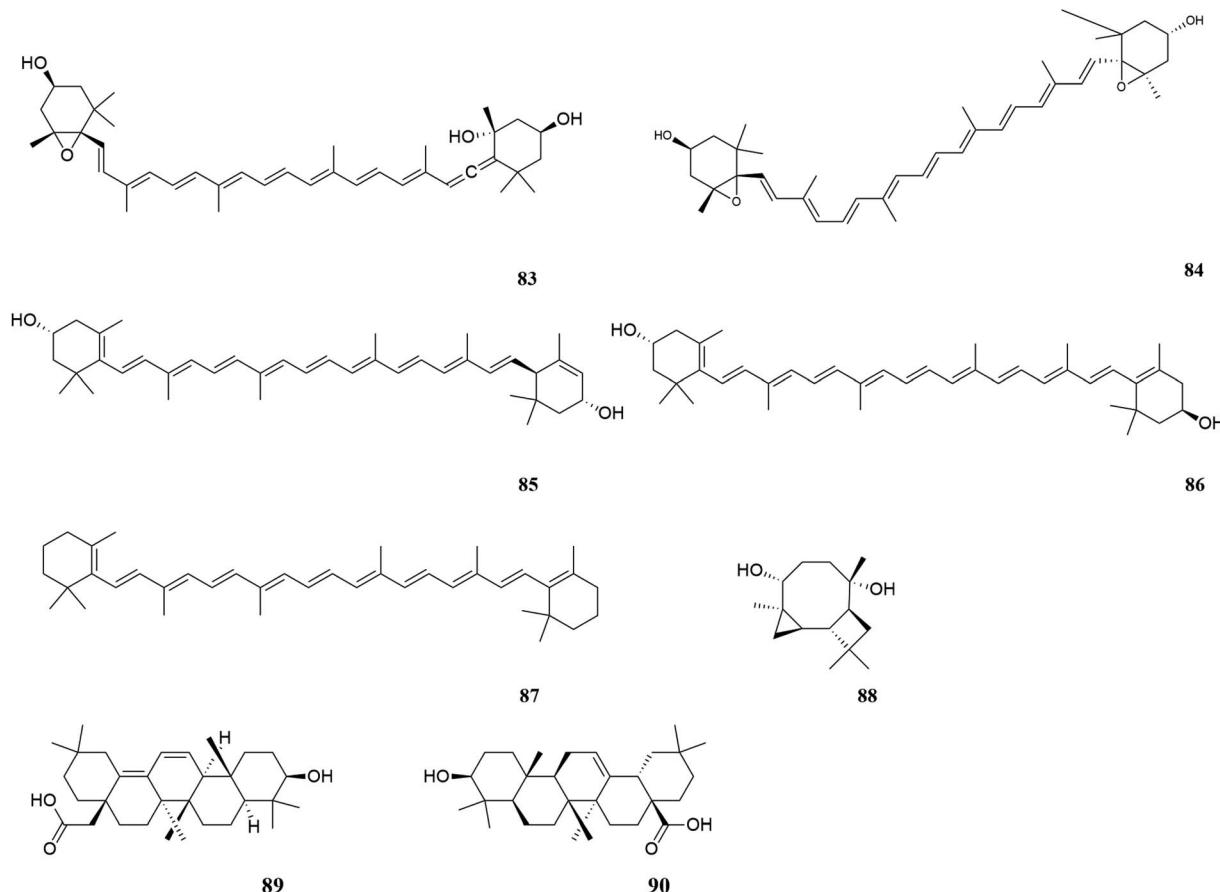


Fig. 7 Terpenoids in *M. oleifera*. [83] Neoxanthin, [84] violaxanthin, [85] lutein, [86] zeaxanthin, [87] β -carotene, [88] tricyclohumuladiol, [89] 3β -hydroxy-oleano-11,13(18)-diene-28-carboxylic acid, [90] oleanolic acid.

to inflammation and consequently to a variety of diseases such as pancreatitis,⁹⁶ periodontitis,⁹⁷ arthritis,⁹⁸ acute kidney injury,⁹⁹ colitis¹⁰⁰ and so on. Previous studies have suggested

that the flavonoids and polyphenols contained in *M. oleifera*, such as rutin and myricetin, are the main active ingredients that exert the antioxidant and anti-inflammatory functions.¹⁰¹ In

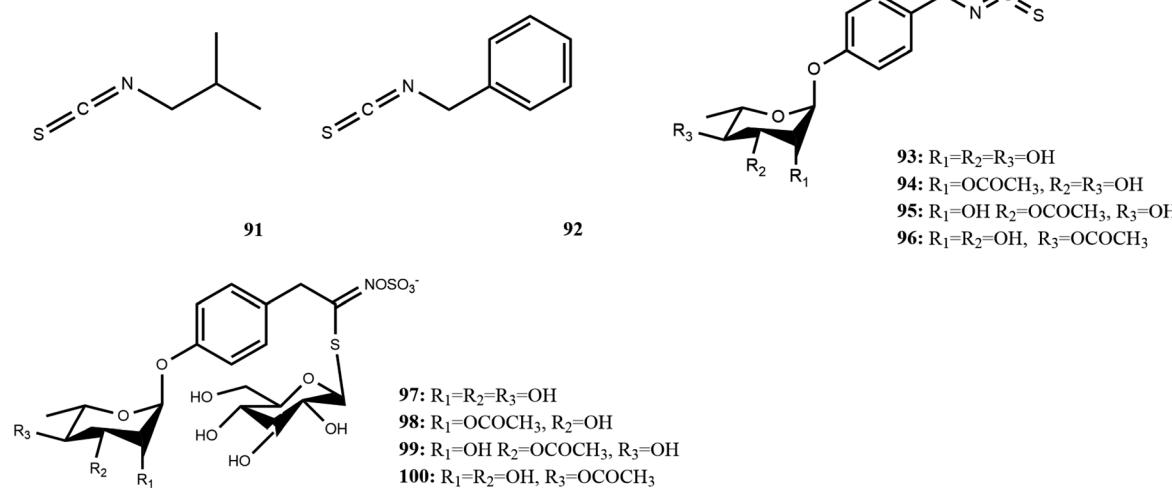


Fig. 8 Glucosinolates and isothiocyanates in *M. oleifera*. [91] isobutyl isothiocyanate, [92] benzyl isothiocyanate, [93] 4-[(α -L-rhamnosyloxy)benzyl] isothiocyanate, [94] 4-[(2-O-acetyl- α -L-rhamnosyloxy)benzyl] isothiocyanate, [95] 4-[(3-O-acetyl- α -L-rhamnosyloxy)benzyl] isothiocyanate, [96] 4-[(4-O-acetyl- α -L-rhamnosyloxy)benzyl] isothiocyanate, [97] 4-[(α -L-rhamnosyloxy)benzyl]glucosinolate, [98] 4-[(2'-O-acetyl- α -L-rhamnosyloxy)benzyl]glucosinolate, [99] 4-[(3'-O-acetyl- α -L-rhamnosyloxy)benzyl]glucosinolate, [100] 4-[(4'-O-acetyl- α -L-rhamnosyloxy)benzyl]glucosinolate.

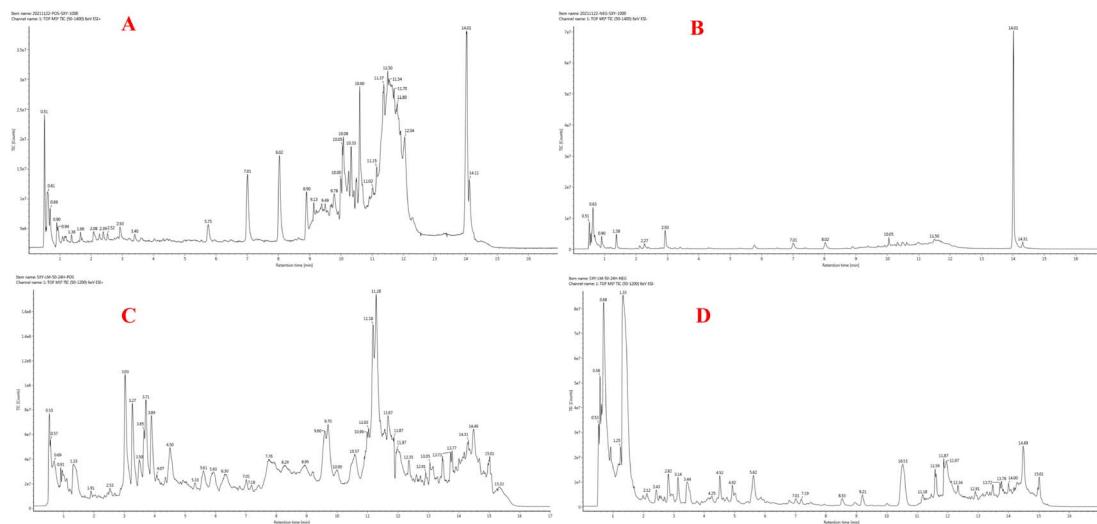


Fig. 9 Chromatographic analysis was performed on a Waters Acuity UPLC system, equipped with a binary pump solvent management system, an online degasser and an autosampler. All separations were carried out on an ACQUITY UPLC™ HSS T3 column ($2.1\text{ mm} \times 100\text{ mm}$, $1.8\text{ }\mu\text{m}$) at $45\text{ }^\circ\text{C}$. The mixture of (A) acetonitrile and (B) 0.1 (v/v) methanoic acid aqueous solution was chosen as the mobile phase using a gradient program: 0–2 min, 5–15% A; 2–8 min, 15–23% A; 8–11 min, 23–100% A; 11–13 min, 100–5% A; and stayed at 5% A for 4 min. The flow rate was 0.4 mL min^{-1} and the injection volume was $2\text{ }\mu\text{L}$. UPLC-Q-TOF-MS chromatogram of MOL in positive ionization mode (A), and in negative ionization mode (B); UPLC-Q-TOF-MS chromatogram of MOS in positive ionization mode (C), and in negative ionization mode (D).

meanwhile, MSE supplementation can reduce body weight, obesity and inflammatory gene expression, improve glucose tolerance, and increase antioxidant gene expression.⁴⁶ Wang *et al.* extracted the polysaccharide component MOS-2-A from *M. oleifera* leaves.¹⁰³ Through experiments, they verified that MOS-2-A could reduce the number of pathogenic bacteria by increasing the number of beneficial bacteria, significantly improve the diversity of intestinal flora in mice, improve the structure of intestinal flora, and help maintain the integrity of intestinal mucosa, promote digestion and promote intestinal health. *M. oleifera* leaves induce the production of acetic acid, propionic acid and n-butyric acid after gastrointestinal digestion and colonic fermentation *in vitro*, resulting in a decrease in pH and promoting the growth of beneficial colonic bacteria.⁴⁰ In addition, more experimental results reveal that *M. oleifera* has the ability to regulate intestinal for the treatment of diseases.

Neuroprotective effect

Herbs therapy is widely used in the treatment of many diseases due to its low toxicity and good curative effect. *M. oleifera* has a variety of functions, including protective effects on the nervous system, due to its rich active ingredients.

M. oleifera is rich in flavonoids and polyphenols, which have neuroprotective effects. Di-(2-ethylhexyl) phthalate (DEHP) at specific concentrations can produce neurotoxic effects after prenatal and postnatal exposure. In rats, prenatal exposure to DEHP can disrupt the development of the central nervous system and reduce brain weight. It was found that *M. oleifera* extract can restore the activity of mitochondrial respiratory chain complex by regulating and reducing the formation of ROS, prevent oxidative injury by regulating Nrf2/HO-1 expression, and inhibit endoplasmic reticulum stress (ER stress)

response to prevent neuron injury and protect neurons SH-SY5Y cells were protected from DEHP-induced apoptosis and maintained mitochondrial membrane permeability and caspase-3 activation, thus realizing the neuroprotective effect of *M. oleifera* extract on DEHP injury. *M. oleifera* seeds are rich in glucosinolates, such as niaziminic (NZ), the main bioactive substance.¹⁰⁴ Abdelsayed *et al.* found that NZ in *M. oleifera* seeds can play a neuroprotective role by affecting oxidative stress marker glutathione (GSH), malondialdehyde (MDA) inflammatory mediators NF- κ B and NO neurotransmitters, dopamine and 5-hydroxytryptamine, and brain fatty acids (FA) levels in AlCl₃-induced dementia rats.¹⁰⁵

Ameliorate metabolic syndrome effect

Metabolic syndrome is a group of clinical syndromes with hypertension, central obesity, diabetes mellitus, hyperlipidemia and abnormal glucose metabolism. In modern times, people's life pressure, irregular work and rest, unreasonable diet structure and other factors lead to the low age of metabolic syndrome diseases, and become one of the main causes of death.¹⁰⁶ And studies have shown that *M. oleifera* can play a significant role in the treatment of these diseases.

Niazirin, a phenol glycoside isolated from *M. oleifera* seeds, could improve insulin resistance, hyperglycemia, hyperlipidemia, and non-alcoholic fatty liver disease. And in-depth investigation showed that niazirin can reduce the accumulation of gluconeogenesis and lipid, improve glycolysis and lipid oxidation by activating the AMP-Activated Protein Kinase (AMPK) pathway. These findings suggest that niazirin could serve as an effective treatment for metabolic syndrome.¹

Additional studies have shown that *M. oleifera* leaf hydrolysate (MOLH), which is rich in phenols and peptides, can



Table 3 (Contd.)

Effect	Disease	Subjects	Model	Dose	Components	Mechanism of action	Functional properties	Ref.
—	—	Murine macrophage cell line RAW 246.7	<i>In vitro</i>	50 $\mu\text{g mL}^{-1}$, 100 $\mu\text{g mL}^{-1}$, 400 $\mu\text{g mL}^{-1}$	<i>M. oleifera</i> leaves protein hydrolysate (MOPH)	Peptides remove DDPH and ABTS radicals and exhibit strong ORAC determination activity. Increase in the number of exposed amino acid residues and promote an increase in scavenging activity; inhibits NO production and acts as an anti-inflammatory	Antioxidant and anti-inflammatory activity	56
Antioxidant and anti-inflammatory effect	Hepatic inflammation	Healthy adult male mice	<i>In vivo</i>	100 mg kg^{-1} , 200 mg kg^{-1} , 400 mg kg^{-1}	<i>M. oleifera</i> leaves extract (MOLE)	Modulated TLR4/NF- κ B pathway, suppressed TLR4 and NF- κ B gene expression and as well as TLR4 and NF- κ B-p65 protein expression. Protects from apoptotic cell death <i>via</i> antioxidative and anti-inflammatory impacts with consequent attenuation of DNA-induced genotoxicity	Protective role against hepatotoxicity	64
Ageing	Wistar albino rats	<i>In vivo</i>		200 mg per kg per body weight	<i>M. oleifera</i> leaves (MOAE)	Reduced lipid peroxidation and lipofuscin pigmentation increased serotonin and antioxidant enzymes	Protective effect on age-related cerebral oxidative stress	65
Stomach and forestomach ulceration	<i>E. coli</i> , <i>P. aeruginosa</i> , <i>S. aureus</i> , Sprague-Dawley male rats	<i>In vivo, in vitro</i>		100–500 $\mu\text{g mL}^{-1}$, 100 mg kg^{-1}	<i>M. oleifera</i> leaves extract	Hydrochloric acid secretion neutralization effect in gastric mucosa, decreased MDA level and increasing antioxidant enzyme activity (CAT, SOD, GPx)	Anti-ulcer effect, protect the gastric ulcer	66
Antitumor effect	Human breast cancer cells	Breast cancer cells, T-47D and MDA-MB-231	<i>In vitro</i>	200 mg per kg body wt	<i>M. oleifera</i> aqueous extract	Reduces oxidative stress-induced DNA damage by improving NF- κ B and TNF- α , restoring lead disturbance, preserving hepatocyte integrity and reducing serum liver enzyme activity	Alleviated lead-induced adverse effects	67
				0.25 $\mu\text{g mL}^{-1}$, 5 $\mu\text{g mL}^{-1}$, 10 $\mu\text{g mL}^{-1}$, 15 $\mu\text{g mL}^{-1}$, 20 $\mu\text{g mL}^{-1}$, 40 $\mu\text{g mL}^{-1}$, 80 $\mu\text{g mL}^{-1}$, 100 $\mu\text{g mL}^{-1}$	<i>M. oleifera</i> leaves methanolic extract (MOME)	Antiproliferative effect on T-47D and MDA-MB-231. The phosphatidylserine exposure on the membrane of the cells confirmed the mitochondria mediated intrinsic apoptosis induction in the MOME treated cells	Contributes to cell cycle arrest and inhibits the proliferation of breast cancer cells	68

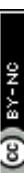


Table 3 (Contd.)

Effect	Disease	Subjects	Model	Dose	Components	Mechanism of action	Functional properties	Ref.
Antitumor effect	MDA-MB-231 cells	MDA-MB-231 cells, Female mice	<i>In vitro, in vivo</i>	A high-fat diet (HFD) supplemented with 0.6% w/w MC	<i>M. oleifera</i> seeds concentrate (MC)	Decreased fasting blood glucose and increased insulin sensitivity in mice after obesity attack. Decreased protein expression of CD31	Protected against high-fat diet- and chemotherapy-induced increases in fasting glucose and improved insulin sensitivity	69
	A549 lung and SNO oesophageal cancer	A549 lung and SNO oesophageal cancer cells	<i>In vitro</i>	1.575–393.83 µg mL ⁻¹	AuNP synthesized from MO aqueous leaf extracts (MLAuNP)	Increased caspase activity in SNO cells and PS externalization, ΔY_m , caspase-9, caspase-3/7 activities, and decreased ATP levels in A549 cells. Increased p53 mRNA and protein levels, SRP20a ($P = 0.428$), Bax, Smac/DIABLO and PARP-1 24 kDa fragment levels and protein levels and activated alternate splicing with caspase-9a splice variant.	No cytotoxic to PBMCs, pro-apoptotic properties were confirmed in A549 and SNO cells	70
	The human pancreatic epithelioid carcinoma	PANC-1 cell, immune deficient athymic CD-1 nude mice	<i>In vivo</i>	0.5, 1.0, and 1.5 mg g ⁻¹ , 200 µL per mouse	<i>M. oleifera</i> aqueous leaves extract	Decreased expression of the pro-apoptotic protein Bcl-2, and downregulated the key component of DNA repair pathways PARP-1 and the NF-κB-related proteins IκB-α, p65-subunit, and COX-2.	Antiproliferative and antiangiogenic effects, decreased pancreatic cancer cell survival and metastatic activity and inhibited tumor growth	71
	Colorectal cancer	CD-1 male (ICR) mice	<i>In vivo</i>	2.5% w/w and 5% w/w	<i>M. oleifera</i> leaves powder	Reduce the activity of harmful faecal enzymes (β-glucosidase, β-glucuronidase, tryptophanase and urease)	Diminish colonic lesions and decrease the activity of fecal harmful enzymes such as β-glucosidase, β-glucuronidase, tryptophanase and urease	72
	Hepatocellular carcinoma	Wistar male rats	<i>In vivo</i>	500 mg kg ⁻¹	<i>M. oleifera</i> leaf ethanol extract (MOLEE)	Reduce Bcl-2 and Bcl-xL and the up-regulation of Bax and caspase 3, and reduced the expression level of β-arrestin-2 mRNA, thus promoting apoptosis signal transduction	Against DEN-induced HCC by exerting antioxidant and apoptotic activities	73



Table 3 (Contd.)

Effect	Disease	Subjects	Model	Dose	Components	Mechanism of action	Functional properties	Ref.
Sarcoma	Sarcoma	Sarcoma 180 cells, Swiss female mice	<i>In vitro, in vivo</i>	24.6–25 µg mL ⁻¹ , 15 M. oleifera flower trypsin inhibitor (MoFTI) or 30 mg kg ⁻¹	Upregulation of pro-apoptotic proteins and the downregulation of anti-apoptotic proteins (e.g., Bcl-2 and Bcl-xL), caspase activation, and cytochrome c release.	Cytotoxic to sarcoma 180 cells, reduce in tumor weight and antiangiogenic effect	74	
Gut protective and regulation of intestinal flora effect	Hymenolepasis nana	Female Swiss albino mice	<i>In vivo</i>	400 mg per kg body weight	<i>M. oleifera</i> leaves extract	Decreased TGF-β, IFN-γ and MMC counts versus increased GC counts, T-helper cell type 2 (Th2) cytokines and IgA level achieve protection against <i>H. nana</i> infections	Anti-inflammatory and induce protection against <i>H. nana</i> infection	75
Adiposity	C57BL/6J male mice	<i>In vivo</i>	Dietary supplementation with 0.34%MIC-1 (0.73%MSE)	<i>M. oleifera</i> seed extract (MSE)	Activate Nr12 and its downstream targets and/or regulation of gut microbiota, MSE activates Nr12 and its downstream targets and/or modulates the gut microbiota. MIC-1 has antibiotic properties, making it an, affecting host metabolism by regulating energy balance, glucose metabolism, lipid metabolism, and inflammation	Reduce body weight, obesity and inflammatory gene expression, improve glucose tolerance, and increase antioxidant gene expression	46	
—	C57BL/6 mice	<i>In vivo</i>	40 mg kg ⁻¹ , 60 mg kg ⁻¹	<i>M. oleifera</i> polysaccharides	Inhibit the expression levels of IL-6 and TNF-α, affecting immune repertoire and change immune state	Regulate the intestinal flora, increase the relative abundance of beneficial bacteria and reduce the relative abundance of harmful bacteria, promoting intestinal health	54	

Table 3 (Contd.)

Effect	Disease	Subjects	Model	Dose	Components	Mechanism of action	Functional properties	Ref.
—	C57BL/7 mice	<i>In vivo</i>		20 mg kg ⁻¹ , 40 mg kg ⁻¹ , 61 mg kg ⁻¹	<i>M. oleifera</i> polysaccharides	Reduced glucose, total cholesterol, and malondialdehyde. Improved superoxide dismutase and catalase in serum. Modulates the microbiological balance of the gut by increasing the abundance of good bacteria and decreasing the abundance of bad bacteria in the gut	Improve serum index, intestinal morphology, caecal microflora in mice and the villi length and crypt depth in both ileum and jejunum; increased the ratio of villi length to crypt depth in jejunum.	52
—	Stool samples from healthy participants	<i>In vitro</i>		The stool suspension was loaded into sterile anaerobic jars containing 50 mg polysaccharide samples	<i>M. oleifera</i> root polysaccharides (MRP)	Improve the intestinal environment by producing short-chain fatty acids by intestinal flora fermentation, and maintain intestinal homeostasis by controlling the composition of intestinal flora	Increased the content of beneficial microflora and decreased the abundance of harmful microflora	76
Neuroprotective effect	Glutamate-induced DNA damage in RGCs	RGCS cells	<i>In vitro</i>	10 µg mL ⁻¹ , 50 µg mL ⁻¹ , 45 µg mL ⁻¹	<i>M. oleifera</i> seeds extract	Increase neuronal cell viability and minimal cellular injury, extend branches in neurons, modulate axonal development, and promote synaptogenesis	Neuroprotective effects	77
Neuroprotective effect	Neurodegenerative	Periodontal tissue cell	<i>In vitro</i>	0.5 µM	Moringin was isolated from <i>M. oleifera</i> seeds	Increased the expression of genes involved in neuron cortical development and in particular in neuron belonging to upper and deep cortical layers, involved in osteogenesis and adipogenesis	Promote and accelerate cortical neuronal differentiation of hPDLCs to improve stem cell therapy for neurological diseases	78
—	PC12 cells	<i>In vitro</i>		0.01 µM, 0.1 µM, 1 µM, 10 µM, 50 µM, and 100 µM	Pyrrrole-2-carbaldehydes from <i>M. oleifera</i> seeds (pyrrolemonines A–G)	Against oxygen-glucose deprivation/reperfusion injury in PC12 cells by regulating NF- κ b and Nrf2 activities, and attenuate PC12 cell damage induced by oxygen glucose deprivation	Pyrrolemonines A, E, and pyrrolemarumine displayed neuroprotective activities, and attenuate PC12 cell damage induced by oxygen glucose deprivation	79
Peripheral nerve injury (PNI)	Adult male albino mice (BALB/c)	<i>In vivo</i>		200 mg per kg body weight	<i>M. oleifera</i> leaves extract	Promoting effects of <i>M. oleifera</i> leaves might be attributed to the flavonoid class	Prove a valuable target for the discovery of effective and affordable intervention against peripheral nerve injuries	80



Table 3 (Contd.)

Effect	Disease	Subjects	Model	Dose	Components	Mechanism of action	Functional properties	Ref.
Aneliorate metabolic syndrome effect	NAFLD	ICR mice, L02 cells	<i>In vivo, in vitro</i>	50 mg kg ⁻¹ , 100 mg kg ⁻¹ , and 200 mg kg ⁻¹ , 0.2, 0.4, 0.6, 0.8, and 1 mM	<i>M. oleifera</i> seed extract containing 1-O-(4-hydroxy-methylphenyl)- α -L-rhamno-pyranoside (GR)	Inhibits lipid accumulation in L1 cells by regulating AMPK/mTOR/SREBP-02 and PPAR α pathways. GR anti-inflammatory can promote PPAR α and AMPK, inhibiting downstream mTOR/SREBP-1, activating lipoprotein lipase and changing gene coding enzyme to induce transcription and participate in lipid and lipoprotein metabolism, improve the release of intracellular reactive oxygen species, reduce the accumulation of oil and TG, and promote lipid metabolism	Decreased serum fat content, inhibited liver injury, and increased antioxidant mechanism	81
Diabetes	Wister male rats	<i>In vivo</i>		500 mg kg ⁻¹ , 250 mg kg ⁻¹ and 500 mg kg ⁻¹	<i>M. oleifera</i> leaves methanolic leave extracts (MO)	Reduced inflammation and oxidative stress, reducing hyperglycemia-related liver damage	Reduced fasting plasma ALAT, ASAT, GGT, increased plasma albumin, and restored the damage hepatocellular architecture	82
Diabetes	Pre-diabetic subjects aged 40 to 70 years who have not used medication to control glycemic	<i>In vivo</i>		1600 mg per day	<i>M. oleifera</i> leaves capsule	TNF- α to be a key factor to identify potential respondents	The beneficial effect on blood glucose control in pre-diabetic patients	83
Aneliorate metabolic syndrome effect	Diabetes and NAFLD	C57BL/6 mice	<i>In vivo</i>	250 mg kg ⁻¹	<i>M. oleifera</i> fermentation extract (FM)	Reduced high fat diet-induced ER stress, oxidative stress, lipid toxicity of quadriceps muscle and proinflammatory cytokine mRNA expression in the liver, epididymal adipose tissue, and quadriceps of HFD-fed mice, glucose intolerance and NAFLD in HFD-induced obesity by reducing ER stress, oxidative stress, and inflammation	Antidiabetic effects and can be an effective dietary supplement for treating hyperglycemia and NAFLD	84



Table 3 (Contd.)

Effect	Disease	Subjects	Model	Dose	Components	Mechanism of action	Functional properties	Ref.
	T2DM	UCD T2DM rats	<i>In vivo</i>	202 mg per kg per day, 94 mg per kg per day	<i>M. oleifera</i> seeds extract	Reduced inflammatory markers (KC/GRO and TNF- α). MS has anti-inflammatory activity by activating Nrf2 pathway	Delayed onset of diabetes in rat models of ucd T2DM	85
Hypertensive	Wistar Kyoto male rats	<i>In vivo</i>		750 mg per day per rat	<i>M. oleifera</i> (MOL) seed powder	Decreased the level of free- isoprostaglandin circulation and the expressions of iNOS and NF- κ B protein were decreased, up-regulated the expressions of p _{2-phox} and p _{47-phox} and SOD2	Vascular antioxidant, anti-inflammatory, and endothelial protective effects in SHR. Combat cardiovascular diseases associated with oxidative stress and inflammation	86
	Reproductive protection	NIH Swiss female and male mice	<i>In vivo</i>	Diet supplemented with 4% MOL, diet supplemented with 8% MOL	<i>M. oleifera</i> leave (MOL) powder	Decreased serum MDA in both male and female mice, reduced the rate of sperm abnormality in male, and the expression of Bax	Affecting reproductive	87
Other	—	NZW rabbits	<i>In vivo</i>	5 g kg ⁻¹ , 10 g kg ⁻¹ and 15 g kg ⁻¹	<i>M. oleifera</i> leaves extract	Attenuate phytoestrogenic pituitary-gonadal axis, and reduced serum gonadotropin (FSH and LH) and oestrogen concentration in does	Female rabbits: reductions in serum FSH, LH, and estrogen concentrations. Male rabbits: increased, FSH and LH, and decreased the serum testosterone concentration. Improved semen volume, sperm count and motility were significantly	88
	—	Sprague Dawley male rats	<i>In vivo</i>	800 mg kg ⁻¹	<i>M. oleifera</i> aqueous extract	Reduces the oxidative stress in a unilateral cryptorchidism induced rats, and attenuate histopathological damages, HSP expression and germ cell apoptosis	Increased apoptotic cells in the undescended testes. Decreased pathological damages, oxidative stress, expression level of HSP70 and apoptosis	20



Table 3 (Contd.)

Effect	Disease	Subjects	Model	Dose	Components	Mechanism of action	Functional properties	Ref.
Other	Promote wound healing	<i>P. aeruginosa</i> , <i>S. aureus</i> , and <i>E. coli</i> , Swiss albino male mice	<i>In vivo</i> , <i>in vitro</i>	100 mg mL ⁻¹ , 10% hydrogel was formulated using 10 g of <i>M. oleifera</i> n-hexane seed extract and 90 g of gel w/w aqueous fraction	<i>M. oleifera</i> seeds extract	Antioxidant, antimicrobial, and wound healing activities. Gram-positive and Gram-negative bactericidal potential	Could be used as potential herbal wound healing agents	89
	Diabetic foot ulcers	Wister male rats	<i>In vivo</i>	0.5%, 1%, and 2% w/w aqueous fraction	<i>M. oleifera</i> leaves extract	Decreased wound size, improved wound contraction, and tissue regeneration, as well as downregulation of inflammatory mediators, such as TNF- α , IL-1 β , IL-6, inducible nitric oxide synthase, and cyclooxygenase-2, and upregulate an angiogenic marker vascular endothelial growth factor in wound tissue	Vicenin-2 active compound may accelerate wound healing in hyperglycemic condition	90
	Bone protection	Early osteoblasts resulting from neonatal rats	<i>In vitro</i>	25 μ g mL ⁻¹ , 50 μ g mL ⁻¹ , 100 μ g mL ⁻¹ , and 150 μ g mL ⁻¹ , 1 g kg ⁻¹	<i>M. oleifera</i> polysaccharides	Reduced apoptosis and intracellular ROS levels in glucocorticoid-induced femoral necrosis. Decreased the expression of TNF- α and IL-6 genes with polysaccharide, and increased the expression of OCN, RUNX2 and COL-1 genes in cartilage tissue, protecting femoral head necrosis	Controlling and regenerating osteoblasts cells, and preventing necrosis of the femoral head	91

regulate AMPK and peroxisome proliferator-activated receptor (PPAR α), down-regulate Mechanistic Target of Rapamycin (mTOR) and sterol regulatory element binding transcription factor 1 (SREBP-1) to achieve liver lipid homeostasis. GR could also reduce serum fat content in high-fat diet mice, inhibit liver injury, and increase antioxidant mechanism, indicating that GR has hypolipidemia and liver protection activities. MOE water extract can drive vasodilation to reduce arterial blood pressure by stimulating endothelium-derived NO, providing a new method for the treatment of hypertension.¹⁰⁸

Other effects

Herbs therapy is widely used in the treatment of many diseases due to its low toxicity and good curative effect. Because the therapy affects reproductive physiology and improves certain infertility problems by acting on the hypothalamic–pituitary–gonadal axis.¹⁰⁹ *M. oleifera* is commonly prescribed by herbalists in Nigeria and other tropical countries to treat male infertility and female reproductive diseases.

Traditional plant medicines have often been used for wound treatment since ancient times. Besides the use of chemical drugs, high prices, side effects and other problems, herbal remedies have attracted attention.¹¹⁰ *M. oleifera* is widely used in wound treatment due to its low side effects and excellent antioxidant and antibacterial activity. In addition to the above functions, *M. oleifera* can also be used for bone protection,⁹¹ promote coagulation¹¹¹ and so on.

Mechanism and components of *M. oleifera* in preventing and treating diseases

M. oleifera has been extensively studied for its pharmacological activity and function, and the mechanism of action of *M. oleifera* should be further elucidated at the molecular level. In this paper, from a network pharmacology perspective, we have explored the potential targets and molecular mechanisms of action of the major components of the *Moringa oleifera* leaves (MOL) against major diseases.

Combined with literature review and pharmacological action review results, cancer,⁷ hypertension,^{112,113} diabetes⁹³ and arthritis¹¹⁴ were selected as potential treatment diseases of MOL. Refer to Table 2 for the results of UPLC-Q-TOF-MS analysis of the chemical composition of the MOL.

Metascape data platform was used to analyse the Gene Ontology (GO) and Kyoto Encyclopedia of Genes and Genomes (KEGG) pathway enrichment of MOL for diabetes, hypertension, arthritis and tumor intersections. The results showed that the main biological processes were icosanoid metabolic process, unsaturated fatty acid metabolic process, fatty acid metabolic process. Molecular functional targets are mainly related to heme binding, tetrapyrrole binding and oxidoreductase activity, acting on paired donors, with incorporation or reduction of molecular oxygen. The main enrichment items of the targets in cellular component are membrane raft, membrane micro-domain and plasma membrane raft.

The enrichment results of KEGG pathway were sorted according to Partition coefficient value ($-\log P$), and the top results were selected to draw a chart ($P < 0.05$)¹¹⁵ (Fig. 11 and S1 to S4†). The results showed that the arthritis pathway was mainly enriched in: chemical carcinogenesis–DNA adducts, drug metabolism–cytochrome P450, linoleic acid metabolism, *et al.* In collagen-induced arthritis of rats, the linoleic acid metabolic pathway was significantly altered before and after treatment with 2-deoxy-D-glucose, suggesting that the linoleic acid metabolic pathway is closely related to the treatment of arthritis and may serve as a potential target.¹¹⁶ And studies showed that the bezoar bile acid in the rheumatoid arthritis (RA) rats' body of the small molecule can affect the metabolic pathways of steroid hormone biosynthesis, which led to a decline in immune function in rats, by taking the Atractylodes DC., and the metabolic pathway to normal levels, which can be speculated that by steroid hormones in the treatment of RA.⁴⁵

Study on the major pathways of hypertension has shown that the haploidy insufficiency of glucocorticoid receptor in rats can cause the disorder of linoleic acid metabolism pathway.⁵⁷ Another study on the mechanism of melatonin-mediated hypotension, at 18 h, melatonin acted on the (cGMP-PKG) signaling pathway involved in NO synthesis, suggesting that the regulation of blood pressure could be achieved through the cGMP-PKG signaling pathway.¹¹⁸

According to KEGG pathway analysis of diabetes, there are drug metabolism–cytochrome P450, linoleic acid metabolism and Neuroactive ligand–receptor interaction, *et al.* Hogan *et al.* used quantitative reverse transcription Quantitative Real-time polymerase chain reaction (QRT-PCR) to identify differentially regulated gene expression of islet amyloid, which is associated with islet physiology and pathology of type II diabetes mellitus, and found that it contains steroidogenic acute regulatory protein (STAR protein), which is part of the synthetic response group of steroid hormone metabolism. It can be inferred that the pathway of steroid hormone metabolism is closely related to diabetes.¹¹⁹ Resveratrol plays a protective role in the treatment of inflammation-induced vascular injury in type II diabetes by regulating NF- κ B signaling pathway, suggesting that this signaling pathway has significant potential for type II diabetes and its complications.¹²⁰

The results of KEGG pathway enrichment analysis suggested that amphiphysin (AMPH1), a protein at the nerve endings, plays an inhibitory role in ovarian cancer. Studies have demonstrated that AMPH1 inhibits the growth of tumor cells by inhibiting the growth of phosphatidylinositol 3 kinase/protein kinase B (PI3K/AKT) signaling pathway in ovarian cancer.¹²¹ Sadegh *et al.* studied the carcinogenic or anti-cancer effects of miRNA in cancer and apoptosis, and speculated that manipulating miRNA expression level might be a potential method to treat cancer.¹²²

Based on the MOL composition-disease target-pathway network, combined with literature records and degree values, the main active components and targets of the MOL for different diseases were screened for molecular docking validation.¹²³ It is generally believed that the lower the conformational stability energy of the ligand and the receptor, the greater the



possibility of interaction, based on the choice of the degree value of the top core target in the corresponding active ingredient for docking as shown in Fig. S5.† The results show that there is a strong interaction between the target and the compound which score between $-10.5 \sim -9.6$ kcal mol $^{-1}$. The core compound of arthritis, diabetes and tumour is rutin. The docking results with the lowest binding energies for the four diseases are shown in Fig. S6† respectively.

Preparation formulations of *M. oleifera*

M. oleifera has numerous functions that are expected to be used to treat human diseases. Therefore, the selection of preparation formulation of *M. oleifera* should not be ignored. *M. oleifera* has been developed into granules, tablets, capsules, external preparation and other different preparation formulations such as nanoparticles. Additionally, the ingredient of *M. oleifera* can also be used as preparation excipients in the development of current drugs.

Tablet and capsules

A tablet is a solid preparation of flake or profile-flake formed after uniform mixing of drug and excipient. Commonly, tablets are known to enhance drug dissolution and bioavailability, and has the advantages of stable quality, accurate dose, easy to take and carry. As for the choice of adhesive during the preparation of *M. oleifera* tablet, researchers carried on a detailed study with different adhesives including corn starch, gelatin and micro-crystalline cellulose (MCC) and the water extract of *M. oleifera* leaves preparation of tablets, the formula were characterized using various parameters, such as the chemical and physical properties (bulk density tap water content, density ratio, Karr index ash value strength (fragility and crushing strength) and release properties (disintegration and dissolution time tests)).^{124,125} The results showed that compared with MCC and corn starch, the tablets with gelatin as binder had the lowest brittleness and disintegration time, and the crushing strength was within the acceptable range (36 kgF). The comprehensive results showed that gelatin was the best adhesive for *M. oleifera* tablets. On the other hand, capsules are composed of an active content with the appropriate auxiliary materials, either in the hollow hard capsule filling or seal in soft capsule material. *M. oleifera* have bitter taste, is not convenient to make direct oral powder, sealed with hard capsule or hollow capsule material, preparation into capsule not only can hide *M. oleifera* bad smell at the same time also can according to different drug purposes to achieve the location of drug release. *M. oleifera* leaves alcohol extract was prepared and standardized hard gelatin capsules (400 mg per capsule), in order to study the anti-obesity effect of *M. oleifera* leaves.¹²⁶ Fifteen female participants aged 45–55 years with a body mass index (BMI) of $29\text{--}34$ kg m $^{-2}$ were selected for the test. The mean BMI total cholesterol (TC) and low-density lipoprotein (LDL) were significantly reduced in obese patients after taking *M. oleifera* capsules for eight weeks ($P < 0.05$). Moreover, *M. oleifera* capsules can also be used as a natural emulsion to increase the volume of breast milk.¹²⁷

New preparation technology

The components of *M. oleifera* have been found to have low solubility bioavailability in drug preparation and poor compliance in common preparations due to their specific smell and taste. To improve the application and promotion of *M. oleifera* preparations, new preparation formulations have been gradually applied in it. Isothiocyanate extracted from *M. oleifera* (MITC) has excellent anti-skin photoaging effect, but its application is limited due to its extremely low water solubility, low bioavailability and easy degradation.¹⁶ Therefore, they prepared amphiphilic hyaluronic acid (HA) conjugated with ceramide (CE) to modify nanoliposomes for MITC (HACE/MITC NPs) delivery. The results showed that the entrapment of MITC in nanoliposomes improves its stability, efficacy, and skin permeation. In addition, *M. oleifera* extract has been found to have mosquito repellent effect and can be used as a safe and cost-effective substitute for *N,N*-diethyl-3-methylbenzamide (DEET). Gelatin nanoparticles coated with *M. oleifera* bioactive extract were used to improve its availability.¹²⁸ Moreover, silver nanoparticles synthesized from *M. oleifera* leaf extract have also been found to have good anti-leishmania activity.¹²⁹ The treated fabric repellency to *Culex pipiens* mosquitoes showed stable 100% repellency for 6 days for all treated fabrics and ranged from 50 to 90% repellency after 12 days. Green synthesis of silver nanoparticles has been shown to have anticancer activity, Althomali *et al.* took *M. oleifera* leaf extract as the reducing agent and stabilizer of synthesize AgNPs, and the synthesized compound showed superior anticancer activity against human cancer cell line HTC116 and SW480 than *M. oleifera* leaf extract.¹³⁰ This result implies that AgNPs synthesized by *M. oleifera* extract could be an ideal strategy to combat colon cancer.

Preparations for external use and others

In order to find a way to prevent 2019-nCoV through personal hygiene, researcher found that various components in *M. oleifera* leaves had antibacterial effects, for example: polyphenols, terpenoids, saponins, and so on.¹³¹ The hand sanitizer is extracted by osmosis, and after processing, it can meet hand sanitizer quality standards and bacteriostatic standards. The hydrogel prepared with hexane extract of *M. oleifera* seeds has significant wound healing activity.⁸⁹ *M. oleifera* seed n-hexane water gel preparation can be used as a skin repair replacement therapy during wound healing. A membrane consisting of normalized water extract of oil tea leaf was then prepared for wound healing, which enhanced the proliferation and migration properties of human dermal fibroblasts and keratinocytes.¹³² Study investigated the potential of *M. oleifera* seed polysaccharide (MOS-PS) and its composite with MOS-PS-AgNPs as an alternative material for wound dressing.²⁴ In addition, oral treatment of a predominantly Leishmania infected mouse model using silver nanoparticles biosynthesized from *M. oleifera* leaf extract (AG-NPs) was found to significantly reduce the mean size of skin lesions of leishmaniasis.¹³³ It was proved that the nanoparticles synthesized from *M. oleifera* leaf extract had good anti-leishmania activity.



Pharmaceutical adjunct

Moringa oleifera is available in various dosage forms and due to its diverse composition, it can serve multiple purposes such as an emetic, a dissolvent, an adhesive, and a drug carrier. *M. oleifera* powder, although only slightly soluble in water, has the capability to expand and form a highly viscous solution, which can be used as an adhesive in the preparation of tablets.¹³⁴ The coagulated protein was extracted from *M. oleifera*, and its interface properties and interaction with sodium dodecyl sulfate (SDS) were studied. The results showed that the protein extracted from *M. oleifera* seeds had significant surfactant behavior and could be used as a surfactant. Therefore, moringa gum powder extracted from *M. oleifera* can also be used as disintegrating agent. On the basis of the research, moringa gum has potential as a binder and sustained-release agent in tablets.¹³⁵ Moreover, *in vitro* drug release studies have evaluated the sensitivity of moringa gum to colonic bacteria and tablets containing it have shown a drug release rate of 90.46%. According to the results, moringa gum could be used as a potential carrier for colonic specific drug delivery.¹³⁶

Future trends

On the one hand, herbal medicine can fully mobilize the human immune system through multi-target and multi-way synergistic effect, and play a radical cure effect. On the other hand, extensive toxicity experiments have proved its safety. Based on this, in recent years, medicinal plants and herbs have gradually become a treatment strategy for a variety of diseases. According to traditional ancient books, *M. oleifera* has multiple functions and plays a key role in curing and preventing diseases. As a medicinal and edible plant, *M. oleifera* has attracted extensive attention from countries around the world. How to study *M. oleifera*, an exotic species, with the help of traditional Chinese medical theory, and explain the pharmacological action and mechanism of its medicinal substance has become an opportunity and challenge for us to face. At the same time, the development of dietary supplements and adjuncts is inextricably linked to the design of prepared formulations, the selection of appropriate preparations, which can improve the stability and safety, in addition, enhance their efficacy. At present, *M. oleifera* only has common dosage forms such as granules, tablets, and capsules. Among the new preparations, only nano preparations have been studied, and the other preparation types are still to be developed. In addition, the development of current preparation types should start from the biopharmaceutical properties of *M. oleifera* itself, such as clarifying the solubility and permeability of relevant medicinal substances. In combination with different dosage forms, such as nano-pharmaceuticals, to improve the safety and stability of the *in vivo* bioavailability of the preparations.

M. oleifera used in health products

Beyond its considerable medicinal properties, *M. oleifera* is also widely utilized in food industry, natural resource preservation

efforts, cosmeceuticals and other health product applications. Studies have demonstrated the nutritional benefits of incorporating *M. oleifera* leaves and buds into food products as a rich source of vitamins, minerals, and protein.¹³⁷ For instance, adding moringa bud powder (MSP) to conventional pasta has been shown to bolster the content of protein, lipid, fiber and minerals, while the content of carbohydrate showed a trend of decline. The addition of MSP also increases the levels of thiamine, riboflavin, gamma-aminobutyric acid, glucosinolate and antioxidant activity in pasta. Based on the sensory scores, the inclusion of MSP is a technical approach that can improve the nutritional value and biological activity of traditional pasta without compromising consumer acceptance.¹³⁸ From the perspective of nutrition, researchers have also developed a cheese product containing *M. oleifera* leaf powder. The aim is to increase the ash, protein, fiber and fat content of the product with the powder, so that cheese can be used as an alternative food in the fight against malnutrition.¹³⁹ *M. oleifera* is also widely used in baked goods. In response to consumer demand for organic food, moringa bread was developed by incorporating natural plant moringa leaves into baking product recipes. Studies have found that moringa bread products are more beneficial to human health because they are higher in nutrients and antioxidant activity than regular bread products, which contain less fiber and bioactive substances.¹⁴⁰ Besides, the addition of *M. oleifera* leaf to biscuits can also increase the iron and protein content of the product, while providing essential amino acids to the human body.¹⁴¹ It is worth noting also *M. oleifera* contains large amounts of flavonoids and phenols, which have good antioxidant activity, so it can be used in the development of cosmeceuticals like body washes and lotions, as it is gentle on skin and helps to reduce irritation. For example, several studies have developed moringa-containing lotions by exploiting the properties of moringa, which can be used externally on the skin and have the properties of natural plant ingredients⁶⁴. In addition to its ingredient properties, the addition of *M. oleifera* has the advantage of reducing skin irritation and improving the safety of the body wash.¹⁴² As well as developing excellent emollient products using *M. oleifera* seed oil. Finally, *M. oleifera*'s biocoagulant capabilities make it a promising tool in natural resource management for water purification purposes. *M. oleifera* seed can remove turbidity and natural organic material to bring surface water up to standard requirements and it has the advantages of low-cost, simple operation, high efficiency and health safety.¹⁴³

Summary

M. oleifera is a kind of plant which can be used both as medicine and food. In this review the medicinal component of *M. oleifera* and the chemical components of each component of *M. oleifera* in combination with their functions was summarized, finding that MOL and MOS are currently the most widely used. It was found that the main components of *M. oleifera* are flavonoids and polyphenols. These bioactive compounds exhibit promising antioxidant, anti-inflammatory, anti-tumor, improve gut microbiota antibacterial, neuroprotective antioxidant,



ameliorate metabolic syndrome and other activities. Based on the pharmacological action and molecular mechanism was used to analyse the mechanism of *M. oleifera*, which may play a key role through PI3K-Akt signaling pathway in treating cancer and other diseases. Finally, the application of *M. oleifera* preparation, products and other format is reviewed. However, there are still some key questions that need to be answered through further studies: firstly, as an edible product, it is important to address the bitterness of *M. oleifera* for better future development. Next, although there have been several studies on the composition and function of *M. oleifera*, a more in-depth study of the unique composition, including structural and pharmacological aspects, is needed. Thirdly, the underlying mechanism of the MOL function is obtained from data calculations and simulation methods. To further confirm their correctness, *in vitro* and *in vivo* experiments should be designed for validation. Fourthly, it is found that research on *M. oleifera* preparation formulations mainly focused on traditional tablets, granules and capsules, etc. The preparation is relatively monotonous, and how to improve *M. oleifera*'s bitter taste needs further research. In addition, the database used in this study is still constantly updated, so further research is needed to clarify the specific mechanism of *M. oleifera* on diseases, so as to better guide the development of functional foods and complementary drugs.

Abbreviations

<i>M. oleifera</i>	<i>Moringa oleifera</i> Lam.	
MOL	<i>Moringa oleifera</i> Lam. leaves	
MOS	<i>Moringa oleifera</i> Lam. seed	
UPLC-Q-	Ultra High Performance Liquid	
TOF-MS	Chromatography-Quadrupole-Time of Flight-Mass Spectrometry	
ROS	Reactive oxygen species	
NHDF	Normal human dermal fibroblasts	
MOS-PS-	Silver nanocomposites with <i>M. oleifera</i> seed polysaccharides	
AGNPs		
IL-6	Interleukin 6	
IL-17A	Interleukin 17A	
IL-4	Interleukin4	
IL-10	Interleukin10	
INOS	Inducible Nitric Oxide Synthase	
IL-1 β	Interleukin1 β	
NQO1	Quinone oxidoreductase 1	
HO-1	Heme oxygenase 1	
CAT	Catalase	
SOD	Superoxide dismutase	
GPX	Glutathione peroxidase	
COX-2	Cyclooxygenase-2	
A549	Human non small cell lung cancer cell	
JAK2	Janus kinase2	
STAT3	Signal Transducer and Activator of Transcription 3	
PCR	Polymerase Chain Reaction	
MSE	<i>M. oleifera</i> seed extract	
cGMP-PKG	cGMP-dependent protein kinase	
MOS-2-a	A polysaccharide separated from <i>M. oleifera</i> leaf	
DEHP	Di-(2-ethylhexyl) phthalate	
Nrf2	Factor erythro2-related factor 2	
ER stress	Endoplasmic reticulum stress	
NZ	Niaziminic	
GSH	Glutathione	
MDA	Malondialdehyde	
NF- κ B	Nuclear factor kappa-B	
FA	Fatty acids	
AMPK	AMP-activated Protein Kinase	
MOLH	<i>M. oleifera</i> leaf hydrolysate	
GR	1-O-(4-Hydroxy-methylphenyl)- α -L-rhamnopyranoside	
PPAR α	Peroxisome proliferator-activated receptor	
mTOR	Mechanistic Target Of Rapamycin	
SREBP-1	Sterol regulatory element binding transcription factor 1	
GO	Gene ontology	
KEGG	Kyoto Encyclopedia of Genes and Genomes	
-log P value	Partition coefficient value	
RA	Rheumatoid arthritis	
QRT-PCR	Quantitative Real-time polymerase chain reaction	
STAR	Steroidogenic acute regulatory protein	
protein		
AMPH1	Amphiphysin	
PI3K/AKT	Phosphatidylinositol 3 kinase/protein kinase B	
MCC	Microcrystalline cellulose	
TC	Total cholesterol	
LDL	Lowdensity lipoprotein	
MITC	Isothiocyanate extracted from <i>M. oleifera</i>	
HA	Hyaluronic acid	
CE	Conjugated with ceramide	
DEET	N,N-Diethyl-3-methylbenzamide	
MOS-PS	<i>M. oleifera</i> seed polysaccharide	
AG-NPs	<i>M. oleifera</i> leaf extract	
SDS	Sodium dodecyl sulfate	
MSP	Moringa bud powder	
DPPH	2,2-Diphenyl-1-picrylhydrazyl	
ABTS	2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)	
LPO	Lactoperoxidase	
AGES	Advanced glycation end-products	
Bax	BCL ₂ -associated X protein	
BCL ₂	B-Cell lymphoma-2	
ACE	Angiotensin I-converting enzyme	
IL-3	Interleukin-3	
STAT5	Signal Transducer and Activator of Transcription 5	
UVB	Ultraviolet radiation b	
MMP-1	Matrix metalloproteinase 1	
MMP-3	Matrix metalloproteinase 3	
MMP-9	Matrix metalloproteinase 9	
TNF- α	Tumor necrosis factors- α	
IAVS	Influenza A viruses	
GSK-3 β	Glycogen synthase kinase-3 β	
antibody		
DDPH	2,2-Diphenyl-1-picrylhydrazyl	
ORAC	Oxygen Radical Absorption Capacity	



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