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Review

Mini-Review: The Detoxification Effects of Black Radish in Metabolically Dysfunctional-Associated Fatty Liver Disease

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Abstract

The prevalence of liver disease is steadily increasing worldwide. Meanwhile, metabolic dysfunction-associated steatotic liver disease (MASLD) has become the most prevalent chronic liver disease globally, characterized by the extensive involvement of multiple organs. Currently, the recommended treatment for MASLD is adopting a healthy lifestyle, which includes regular exercise and a balanced diet that incorporates plenty of vegetables. In this context, black radish is a cruciferous vegetable rich in glucosinolates, which represent the most beneficial active components. Glucosinolates act by preventing the induction of reactive oxygen species (ROS) and factors related to lipid metabolism, such as fibroblast growth factor 21 (FGF21) and nuclear factor erythroid 2-related factor 2 (Nrf2). There are several other components, such as precursors for glutathione (GSH) synthesis, which regulate liver enzymes and lipid peroxidation, as well as flavonoids, which help ameliorate lipid accumulation and possess antioxidant properties. These preventive health effects contribute to lipid metabolism and cellular energy balance, which, in turn, aid in liver detoxification and preventing diseases. This review aims to assess the biological detoxification mechanisms and effects of black radish in MASLD and related chronic diseases.

Keywords: fatty liver; steatohepatitis; *Raphanus sativus*; glucosinolates; flavonoids; polyphenols; anthocyanins; oxidative stress

1. Introduction

Non-alcoholic fatty liver disease (NAFLD) has recently been renamed metabolic dysfunction-associated steatotic liver disease (MASLD), emphasizing the independence of this disease from exclusion criteria. This change recognizes the fact that MASLD can coexist with other chronic liver diseases [1]. Moreover, MASLD provides a more specific term that offers a positive, non-stigmatizing description of the condition, rather than one based on exclusion [2]. MASLD has metabolic dysfunction as its foundation, highlighting the significant impact and reduced heterogeneity this disease has. Key criteria include being overweight or obese, as well as having type 2 diabetes mellitus [3]. There are important risk factors that promote the development of MASLD, such as an increase in waist and/or abdominal circumference, obesity, hyperglycemia, dyslipidemia, and high blood pressure. Steatohepatitis can lead to the development of organic failure, resulting in liver cirrhosis, which requires liver transplant, or could lead to hepatocellular carcinoma due to inappropriate treatment, for example, if pharmacological or non-pharmacological treatments are not carried out [4].

MASLD is becoming a more frequent chronic disease (particularly in the Western world), with a worldwide prevalence of 25%, and is a main cause of cirrhosis and hepatocellular carcinoma. Metabolic alterations in this disease mainly occur in the liver, with other characteristics including alterations in cell and liver function indicators. One-quarter of the global population has been reported to have developed this disease [5]. Moreover, diseases such as obesity (with a prevalence of 82%), dyslipidemia (70%), and hypertension (68%) represent diseases that are most frequently related to fatty liver-associated metabolic syndrome [6]. Approximately 30% of the adult population is considered to have developed MASLD [7].

The human body is constantly exposed to toxins from different sources, such as foods or medicines, and the liver is one of the main organs involved in their detoxification [8]. The liver is an organ in which physiological functions such as the metabolism of macronutrients; production of bile for the absorption of fats; homeostasis of cholesterol, triglycerides, and drugs; and glucose storage (in the form of glycogen) are carried out [9]. It also processes primary metabolites, such as fatty acids, when they are supplied in large quantities or when their proper elimination cannot be carried out, promoting the production of toxic lipid species and inducing stress, injury, and death in liver cells [10].

2. Black Radish

Previous study has shown that consumption of supplements or vegetables naturally promotes functions that have beneficial effects on the liver [8]. Specifically, *Raphanus sativus var. Sativus*, also known as black radish or Spanish black radish, belongs to the Brassicaceae or cruciferous family [8,11] and can be eaten naturally (i.e., as fresh food) or used as a food supplement [12]. This vegetable has European origins, and in Mexico, it is cultivated for medicinal and culinary purposes [13]. Interestingly, it has been demonstrated that black radish facilitates the release of detoxification enzymes, such as quinone reductase, cytochrome P450 (CYP) family, heme oxygenase 1, and glutathione S-transferase α2 [14,15].

2.1 Core Pathways of Principal Mediators

It is important to mention some of the core pathways of certain principal mediators involved in lipids and glucose regulation. The nuclear factor erythroid 2-related factor 2 (Nrf2) is a basic leucine zipper transcription factor that promotes the induction of genes involved in glucose metabolism and lipid oxidation. It has been demonstrated that its activation via *Keap1* gene hypomorphic knockdown (Keap1$^{flox/-}$) markedly suppresses the onset of diabetes; furthermore, liver triglyceride levels are reduced via the activation of Nrf2 signaling in a murine model [16]. This pathway reduces the accumulation of hepatic triglyceride, improves insulin sensitivity, and alleviates fibroblast growth factor 21 (FGF21) resistance [17]; according to this, FGF21 functions as an endocrine agent and is considered an energy metabolic regulator [18].

Cysteine-rich proteins and sulfates are precursors for glutathione (GSH) synthesis, when GSH and catalase activity increased, they conferee protection from oxidative damage reducing lipid peroxidation [19]. Furthermore, it has been described the ability of quercetin to neutralize free radicals such as superoxide anions, nitric oxide, and peroxynitrites apparently due to its chemical structure, which in turn also increase endogenous antioxidant levels and prevent cell death by inhibiting several enzymes such as xanthine, lipoxygenase, and nicotinamide adenine dinucleotide phosphate (NADPH) oxidase [20]. Xanthine oxidase is an iron–molybdenum flavoprotein that plays a crucial role in catabolism, while lipoxygenase belongs to a large monomeric protein family that comprises iron cofactor-containing dioxygenases that catalyze the oxidation of lipids, producing leukotrienes and lipoxins as a result [21]. Finally, NADPH oxidase has an important role in several inflammatory diseases; for instance, quercetin can modulate NADPH oxidase activity in a macrophage-cell model via heme oxygenase-1 induction [22].

2.2 Glucosinolates

Glucosinolates are sulfur-containing phytochemicals abundant in cruciferous vegetables, and their biological effects are mainly attributed to their metabolites. Glucosinolates are found in different types of plant families; the family richest in them is *Brassica*, which includes black radish and other vegetables such as cabbage, brussels sprouts, broccoli, cauliflower, collards, kale, and kohlrabi [23]. The chemical properties of glucosinolates' metabolites determine their biological activity and, thus, their effects on human health [14]. They are composed mainly of sulfate and thioglucose, which are precursors of isothiocyanates, to which they are hydrolyzed by myrosinase [24]. Their metabolism is characterized into phases: Phase I consists of their biotransformation, from which free radicals and reactive oxygen species are generated; in phase II, the free radicals and reactive oxygen species generated in phase I are deactivated. Phase II is known as the detoxification phase and has anticancer, antibacterial, anti-inflammatory, and antioxidant characteristics [8].

The two principal glucosinolates in black radish are glucoraphasatin and glucoraphanin:

Glucoraphasatin accounts for >65% of the glucosinolate content in Spanish black radish. Its isothiocyanate metabolite, 4-methylthio-3-butenyl isothiocyanate (MIBITC), induces phase II detoxification enzymes such as quinone reductase, which catalyzes electron transfer to prevent the formation of reactive oxygen species (ROS) and protect hepatocytes from oxidative injury [15,25]. Raphasatin, another metabolite of glucoraphasatin, also stimulates quinone reductase activity, supporting antioxidant defense; however, this metabolite is unstable in an aqueous environment [14].

Glucoraphanin, a sulforaphane precursor, has demonstrated metabolic benefits in murine models of obesity. Sulforaphane is capable of activates Nrf2 signaling, which has been explained before. On the other hand, sulforaphane is a hydrolysate of glucosinolates found in large quantities in cruciferous vegetables [14] capable of regulating lipid metabolism by deactivating c-Jun N-terminal kinase and glucose metabolism and alleviating FGF21 resistance in an obese mouse model [26]. Indeed, FGF21 has been related to the improvement of hepatic steatosis [18]. Moreover, sulforaphane has been shown to confer bactericidal properties, mainly against *Helicobacter pylori* and *Staphyloccocus aureus*; consequently, these properties exert a beneficial effect on diabetes [27].

Sinigrin and gluconapin are two other glucosinolate extracts from *Brassica juncea* that have demonstrated hepatoprotective effects in a murine model of MASLD, including the inhibition of lipid accumulation and a reduction in the activities of inflammatory molecules, such as tumor necrosis factor-alpha (TNFα) and nuclear factor-kappa B (NFκB). These effects were confirmed in a cell line model and involved the activation of adenosine monophosphate (AMP)-activated protein kinase [28].

Mechanistic relevance: By enhancing phase II detoxification, promoting antioxidant gene expression, and modulating lipid/glucose pathways, black radish glucosinolates provide a strong molecular basis for their hepatoprotective role in MASLD.

Cysteine Sulfates

Black radish contains high concentrations of sulfates and cysteine-rich proteins. It was observed that a methanol extract of *Raphanus sativus* root reduced the levels of thiobarbituric acid substances, as well as serum glutamate oxaloacetate transaminase (SGOT) and serum glutamate aspartate transaminase (SGPT): Enzymes that are specific indicators of liver cell injury. Therefore, this extract can reduce damage induced by paracetamol and return serum SGOT and SGPT to normal levels, which may translate to liver recovery [19]. Furthermore, an *in vitro* study has demonstrated that radish seeds contain two homologous 5 kD cysteine-rich proteins designated *Raphanus sativus*-antifungal protein 1 (RsAFP1) and RsAFP2, which exhibit potent antifungal activity; they are important components of the defense system of radish seeds [29,30]. This evidence needs to be applied to studies in animal and human models.

2.3 Flavonoids

Flavonoids are abundant phytochemicals in black radish, with quercetin being one of the most studied components. Quercetin exerts antioxidant, anti-inflammatory, and antifibrotic effects relevant to MASLD. For example, in an *in vitro* steatosis model, flavonoids have been demonstrated to ameliorate lipid accumulation and mitigate the enhancement of de novo lipid synthesis [31]. Quercetin is an interesting plant pigment and a flavonoid which is well known for its antioxidant properties [20] as described before.

In MASLD murine and cell models, quercetin has been demonstrated to regulate liver lipid metabolites through the glycerophospholipid metabolic pathway, thereby improving liver lipid accumulation and injury, as well as inhibiting ferroptosis through the p38 mitogen-activated protein kinases (MAPK)/extracellular signal-regulated kinase (ERK) signaling pathway and alleviating the progression of MASLD [32]. Furthermore, it has been found that quercetin, either alone or in combination with phosphodiesterase inhibitors, improves liver biochemical markers, such as TNFα and interleukin-β and inflammation, as well as Nrf2 and hypoxia-inducible factor 1-alpha—antioxidant and hypoxic parameters, respectively—in a liver fibrosis murine model [33].

Moreover, another benefit of fermented black radish is its inhibition of transforming growth factor beta-1 and the collagen type I alpha 1 chain, which are involved in liver fibrosis mitigation [34]. This appears to explain quercetin's antiproliferative function [35].

Clinical relevance: Quercetin supplementation, either alone or in combination with phosphodiesterase inhibitors, has been shown to improve biochemical markers of fibrosis, and inflammation, highlighting its therapeutic potential for MASLD.

Anthocyanins

Anthocyanins, a subclass of flavonoids, provide additional metabolic benefits. They regulate carbohydrate metabolism, increase adiponectin and leptin secretion, and protect pancreatic β-cells from oxidative damage [12].

A key metabolite, protocatechuic acid, reduces lipid accumulation in hepatocytes by inhibiting the cluster of differentiation 36 (CD36) palmitoylation, apparently by lowering zinc finger Asp-His-His-Cys (DHHC)-type palmitoyltransferase 5 palmitoylation [36]. Palmitoylation is a reversible post-translational lipid modification of proteins, catalyzed by the zinc finger DHHC domain-containing (ZDHHC) family of palmitoyltransferases; its dysregulation has been implicated in metabolic disorders [37,38], which could impact MASLD inhibition. Importantly, a study indicated that anthocyanins account for 31.7% of flavonoid intake in reducing the risk of MASLD [39].

2.4 Polyphenols

Polyphenols are secondary plant metabolites widely recognized for their antioxidant and hepatoprotective properties. In black radish and related plants, polyphenols contribute to liver detoxification by donating hydrogen atoms, chelating metal ions, and neutralizing free radicals [11,40].

A previous study evaluated an extracted polyphenolic fraction (EPF) from bergamot (*citrus bergamia Risso* and *poiteau*) and administered it in a murine MASLD model. While no effect on body weight was observed, a significant decrease was evident in circulating leptin, insulin, lipid levels, and proinflammatory cytokine and chemokine levels in a Western diet murine model [41]. It is important to mention that leptin is considered an anorexigenic hormone and an important mediator of energy homeostasis; serum leptin levels are directly proportional to adipose tissue [42]. Thus, EPF is capable of restoring leptin levels and improving glucose and lipid metabolism.

Another product of the *Rutaceae* family, named after *citrus lumia Risso*, plays an important role in reducing the risk of metabolic diseases due to its polyphenol content. In an experimental study, a concentrated extract of citrus lumia, principally enriched with eriocitrin and hesperidin (rutinosidic flavanones), was administered to co-cultures of hepatic cell lines (HepG2/LX2), where a decrease in intracellular lipid content was observed [43]. Furthermore, curcumin, a principal active compound in turmeric and a plant-derived polyphenol, has substantial therapeutic potential; however, its low bioavailability and rapid metabolic degradation have limited its use [44].

Mechanistic relevance: Polyphenols exert hepatoprotection by regulating adipokine signaling, reducing oxidative stress, and downregulating inflammatory pathways.

Collectively, these actions support black radish as a dietary adjunct in MASLD management.

3. Metabolic Effects of Black Radish

Obesity represents the main risk factor for developing various diseases that affect different organs, such as the heart, pancreas, and liver. In this scenario, a diet rich in cholesterol can lead to fatty liver complications, such as steatohepatitis, liver fibrosis, cirrhosis, and, ultimately, liver cancer [6,45,46]. The hepatoprotective effects and reduction in lipid levels following the ingestion of black radish juice have been studied in a mouse model of hyperlipidemia, demonstrating its antioxidant properties [47]. In this context, a Korean group has carried out a murine study with pretreated fermented black radish, demonstrating that its hepatoprotective factor decreases the deposition of cholesterol and triglycerides in hepatocytes and liver inflammation through the regulation of adipogenic transcription factors and genes related to lipid metabolism. These include CCATT/enhancer binding protein α (C/EBPα), sterol regulatory element-binding protein 1c (SREBP 1c), and peroxisome proliferator-activated receptor gamma (PPARγ). Furthermore, a decrease in fibrosis was also observed, since activation of Kupffer cells, infiltration of inflammatory cells, and collagen liver-tissue proliferation decreased significantly; moreover, profibrogenic expression genes such as alpha-smooth muscle actin (*SMA*), Transforming Growth Factor Beta 1 (*TGFB1*), and collagen type 1 alpha1 chain (*Col1A1*) were dramatically downregulated [34].

A study conducted by Evans *et al*. [8] aimed to investigate the effects of black radish on liver function in a human model by measuring acetaminophen metabolites after administrating a 1000 mg dose both before and after 28 days of supplementation with black radish (370 mg). It was shown that dietary supplementation with black radish promoted detoxification, reduced estradiol in the blood, and helped the liver profile to reach normal ranges more rapidly, thus promoting liver cell protection [8].

Moreover, there is evidence that black radish also has a beneficial effect on diabetes mellitus, as it reduces glucose absorption. The above evidence demonstrates that this antioxidant activity reduces oxidative stress and lipid peroxidation. It has been observed that various parts of black radish have different effects on glucose. For example, black radish seeds reduce insulin resistance and glucose absorption; meanwhile, its leaves decrease the intestinal absorption of glucose, and leaf juice has strong antioxidant behavior, protecting against oxidative activities and preventing H_2O_2-induced hemolysis by more than 50% in red blood cells of a murine model [48,49].

It is well known that a high-cholesterol diet can lead to the formation of gallstones, as cholesterol is their main component. In a murine study, it was speculated that glucoraphasatin would reduce serum levels of cholesterol and triglycerides [50]. According to this assumption, in another murine model, after gallstones were induced with a lithogenic diet, the efficacy of black radish root juice was evaluated. The eradication of gallstones was observed alongside decreases in triglycerides, cholesterol, and high-density protein levels in the groups that received concentrated black radish root juice at a concentration of 1:10, in comparison with the group that received root juice at a ratio of 1:100, urodeoxycholic acid (0.05%), or no treatment [51]. Elevated cholesterol levels are an important factor affecting abdominal inflammation and poor food intake, consequently decreasing intestinal absorption. There are other risk factors related to the formation of gallstones and the development of fatty liver disease, including an increase in body mass index in patients with obesity and patients losing weight too quickly because of low-calorie diets or bariatric surgery [52].

Importantly, the consumption of fast food, meat, refined sugars, and carbohydrates may also lead to the formation of gallstones. The carbohydrate sucrose has been related to a higher sediment concentration, thus promoting the formation of gallstones; this event can be attributed to a reduction in hepatic fatty acid oxidation, which leads to the incomplete activation of leptin's signal transduction pathway, specifically through the fatty acid catabolism regulators AMPK and the nuclear receptor peroxisome proliferator-activated receptor alpha (PPARα) [53]. Furthermore, excessive consumption of fructose can lead to several gastrointestinal complications, which can affect functions related to the liver [54].

Black radish has long been used as a homeopathic medicine for indigestion and abdominal inflammation, as well as stimulating bile juice production, thus improving digestion [47]. In mouse models, black radish favorably impacts the kidneys as it prevents the formation of stones and possesses diuretic properties [51]. In Mexican states, such as Guerrero and Oaxaca, this plant is well known for the treatment of urolithiasis, as well as a wide variety of urinary disorders [13]. Moreover, previous findings have indicated that this tuber has antifungal functions due to its rich cysteine content [13]. In the context of traditional medicine, its ethanolic and aqueous extracts have been shown to have antibiotic properties [55].

4. Therapeutic Characteristics of Black Radish

The pharmacological treatment of liver disease recommended by clinical practice guidelines includes vitamin E and pioglitazone. As black radish seems to have powerful antioxidant effects, it has the potential to ameliorate liver disease, as supported by experimental evidence [56]. According to an epidemiological study, there is a close association between an unhealthy lifestyle and fatty liver; indeed, weight loss can lead to the reversal of fatty liver disease, as well as a decrease in insulin resistance, when combined

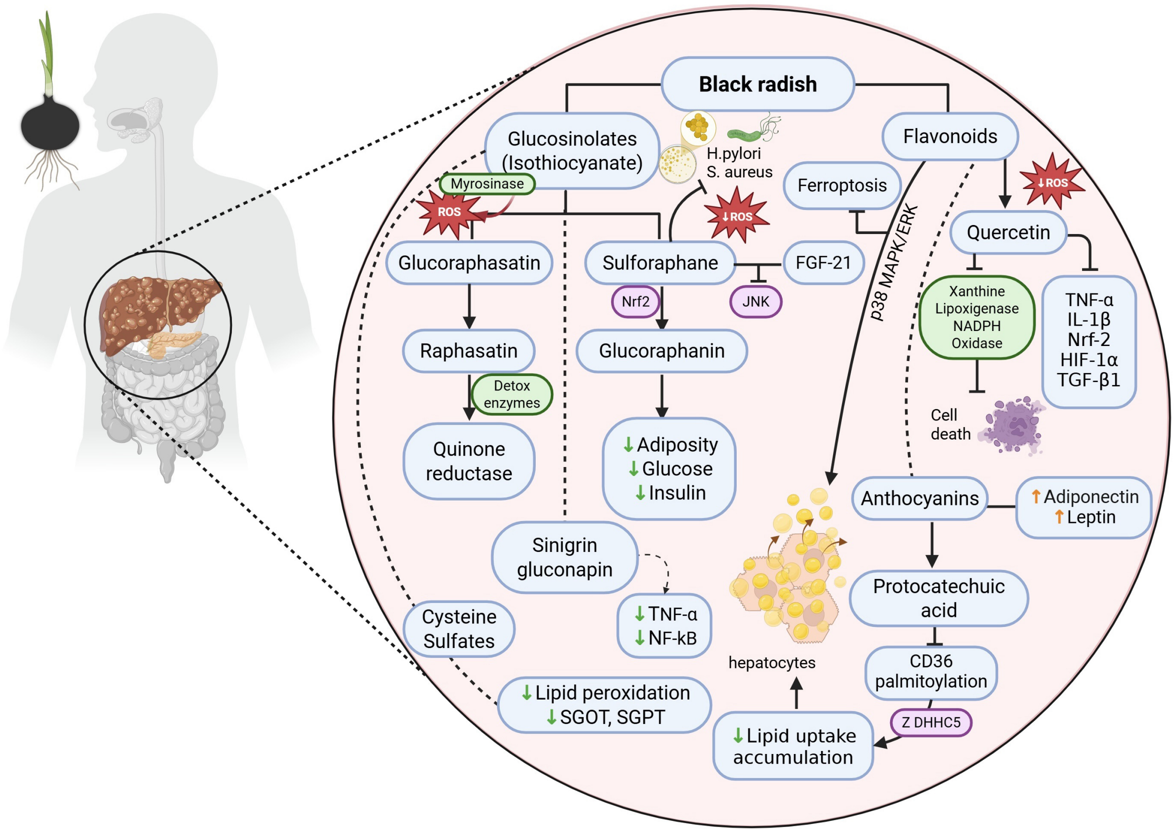


Fig. 1. Molecular mechanisms of the hepato-metabolic effects of black radish (*Raphanus sativus* L. var. *niger*) in MASLD. Glucosinolates (glucoraphasatin, sulforaphane, and sinigrin) are metabolized into active isothiocyanates (raphasatin and glucoraphanin), which upregulate detoxification enzymes (e.g., quinone reductase) and regulate pathways such as Nrf2 and c-Jun N-terminal kinase (JNK), thereby decreasing lipid peroxidation, the serum levels of hepatic transaminases such as glutamic oxaloacetic transaminase (SGOT) and serum glutamic pyruvic transaminase (SGPT), and proinflammatory cytokines (TNF-α, NF-κB). On the other hand, flavonoids (quercetin) inhibit oxidative enzymes such as xanthine and lipoxygenase as well as cell death by reducing inflammation and ferroptosis through the p38 mitogen-activated protein kinases (MAPK)/extracellular signalregulated kinase (ERK) pathway. Finally, anthocyanins, through metabolite protocatechuic acid, modulate CD36 palmitoylation, reducing hepatic lipid uptake and promoting the secretion of adiponectin and leptin. Additionally, the antimicrobial effects against *H. pylori* and *S. aureus*, along with FGF-21 induction, reinforce the metabolic protective role of black radish. Collectively, these compounds contribute to reduced hepatic lipid accumulation, systemic inflammation, and insulin resistance. ↑ Upregulated/↓ Downregulated. MASLD, metabolic dysfunction-associated steatotic liver disease; ROS, reactive oxygen species; FGF-21, fibroblast growth factor 21; Nrf2, nuclear factor erythroid 2-related factor 2; TNFα, tumor necrosis factor-alpha; NFκB, nuclear factor-kappa B; IL-1β, interleukin-1 beta; HIF-1α, hypoxia-inducible factor-1; TGF-β1, transforming growth factor beta-1; DHHC5, Asp-His-His-Cys-5; CD36, cluster of differentiation 36. The figure was created using BioRender (https://www.biorender.com/).

with personalized aerobic exercise. Successful treatment is reflected in the patient's clinical condition by a reduced risk of progressive disease; however, there is currently no specific medication for this disease [57].

At present, non-pharmacological treatment does not lead to entirely favorable results for the control of MASLD [2]. Treatment with medicinal plants is accessible for patients living in developing countries, and traditional medicine has become the first option in such regions for ethical, practical, and economical treatments as opposed to conventional treatments, such as surgery, which are sophisticated and expensive [58].

In this regard, Mexico represents a country that has a great variety of medicinal plant species (4500 species). As a result, 90% of the population employs medicinal plants to treat different diseases, representing a very frequent practice among this population. However, it is still necessary to continue research on liver damage and mechanisms that impact the liver, as well as the effectiveness and safety of these plants and their active components when consumed [56,58].

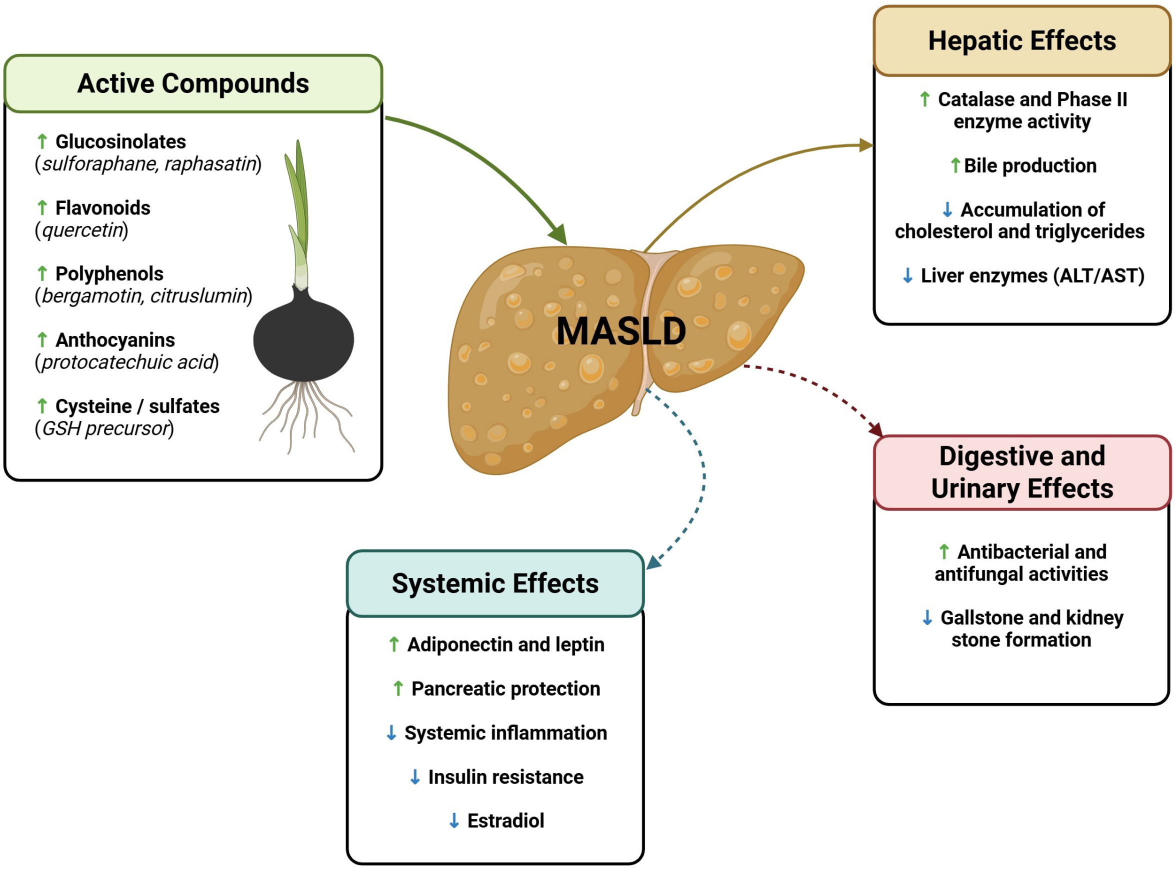


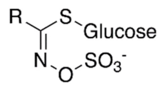
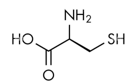
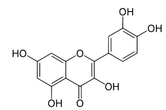
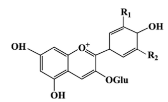
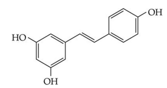
Fig. 2. Hepatic, digestive, and systemic effects of black radish (*Raphanus sativus* L. var. *niger*) in MASLD pathophysiology. Key phytochemicals—including glucosinolates, flavonoids, polyphenols, anthocyanins, and sulfur-containing compounds—exert multiple beneficial effects on hepatic and metabolic functions. In the liver, black radish increases catalase and phase II detoxification enzyme activity, promotes bile production, and reduces cholesterol and triglyceride accumulation. In the digestive and urinary systems, its antibacterial, antifungal, and antilithiasic effects support its overall detoxifying profile. Systemically, it increases adiponectin and leptin levels, protects pancreatic function, and reduces inflammation, insulin resistance, and estradiol levels. ↑ Increase/↓ Decrease. GSH, glutathione; ALT: alanine aminotransferase; AST: aspartate aminotransferase. The figure was created using BioRender (https://www.biorender.com/).

5. Discussion

Liver disease is becoming increasingly important due to the growing number of people worldwide who suffer from it and the increasing prevalence of sedentary lifestyles and diets rich in high-carbohydrate foods. The recently renamed MASLD encompasses diseases that can coexist with other chronic liver diseases. At present, it is known that patients who suffer from insulin resistance and type 2 diabetes mellitus are more likely to be diagnosed with this disease. While a healthy lifestyle—including a balanced diet and regular exercise—is a major part of treatment and disease prevention, it has not been possible, to date, to propose a global treatment that mitigates all the complications of metabolic disease. This scenario has led to the search for alternative adjuvant solutions.

Black radish has been used for many years to treat certain discomforts and diseases, such as digestive problems and prevent gallstones and kidney stones, due to its ability to reduce blood levels of cholesterol and triglycerides. Even though the exact mechanisms associated with the metabolites present in black radish are unclear, there is evidence that the juice of black radish roots can eradicate gallstones. In current medical practice, one of the chemicals used to disintegrate bile stones is ursodeoxycholic acid; however, research has indicated that black radish root has a more powerful effect. In addition, it seems that black radish confers a liver-protective effect due to the presence of one of its main compounds—namely, glucosinolates—in addition to having multiple antioxidant functions. However, interestingly, there are other components such as anthocyanins, which at least partly account for the reduction in liver disease risk through their detoxifying abilities. Indeed, it seems that various parts of black radish have different effects on specific metabolic pathways (Table 1, Ref. [8,11,12,14,15,17–19,21,24–44,59,60]). Therefore, specific extracts of bioactive compounds from plants

Table 1. Principal characteristics of active compounds in black radish.

Family compound	Metabolites	Principal chemical compounds	Biological effects	Systemic effects	Structure	References
Glucosinolates	Isothiocyanates: ·Glucoraphasatin *Raphastin* ·Glucoraphanin *Sulforaphane* ·Sinigrin ·Gluconapin	Sulfate Thioglucose (0.3–560 mg/kg)	↑ Phase II detoxification enzymes ↑ Quinone reductase activity ↑ Nrf2, AMP- protein kinase ↓ Blood glucose and insulin c-Jun N-terminal kinase, TNFα, NFκB, and FGF21 resistance	Cancer prevention Hepatoprotective effects Lipid and glucose metabolism regulation Antioxidant and bactericidal properties		[8,14,15,17–19,21,24]
Cysteine/Sulfates	GSH precursor	Sulfates and Cysteine-rich proteins (10 mg/kg)	↓ SGOT, SGPT ↑ GSH and catalase activity	↓ Lipid peroxidation Liver recovery		[25–27]
Flavonoids	Quercetin	Phenolic structures Aglycones, Glycosides, and Methylated derivatives (0.0015–150 mg/kg)	↑ Nrf2, HIF-1α ↓ Free radicals and NADPH oxidase ↓ Hepatic lipid accumulation ↓ Ferroptosis ↓ Inflammation and enzymes	Hepatoprotection Antifibrotic activity ↓ TGF-β1 ↓ Oxidative stress and cell death		[28–35]
Anthocyanins	Protocatechuic acid	Aglycones (20–320 mg/kg)	↑ Adiponectin and leptin ↓ Lipid uptake and accumulation in hepatocytes ↓ CD36 palmitoylation	Prevention of T2DM Carbohydrate regulation Hepatic and pancreatic protective effects ↓ MASLD risk		[12,36–39,59,60]
Polyphenols	Bergamotin Citrus lumia Curcumin	Broad categories such as Glycosides, Aglycones (25 µg–100 mg/mL)	↓ Serum and intracellular lipids ↓ Proinflammatory cytokines and Free radicals ↓ Leptin and insulin levels	Liver detoxification Metabolic regulation Improved glucose and lipid metabolism Antioxidant properties		[11,40–44]

↑ Increase/↓ Decrease. NADPH, nicotinamide adenine dinucleotide phosphate; T2DM, type 2 diabetes mellitus; AMP, adenosine monophosphate.

Table 2. Clinical and experimental studies of black radish's effects.

Author/Year	Country	Population	Black Radish Compound	Study Design/Method	Outcomes/Observation
Evans *et al*., 2014 [8]	London	n = 20 healthy men	Spanish black radish	Pre-acetaminophen administration (1 g) Spanish Black Radish (370 mg/wk) 3wk	↑ Liver detoxification ↑ Hepatic cell protection (Phase I and II enzymes)
Jeon *et al*., 2020 [11]	Korea	Cell line RAW264.7	Black radish extract	[25/50/100 and 200 µg/mL] (6–24 hrs)	↓ Proinflammatory and stress mediators ↓ JAK2 and STAT3 pathway
Hanlon *et al*., 2007 [15]	USA	Hepatocellular carcinoma cell line	SBR MIBITC	SBR dry (0.3–3.0 mg) MIBITC [10 µM]	↑ Phase II detoxification enzymes CYP450, QR, HO-1, TrxR
Nagata *et al*., 2017 [17]	Japan	High-fat-diet Nrf2-KO murine model	Glucoraphanin	135 mg/gr [0.31 mmol/g] 14 wk	↑ Weight loss and obesity ↑ Improved insulin sensitivity and glucose tolerance ↓ Hepatic steatosis
Tian *et al*., 2021 [26]	China	Obese mouse model	Sulforaphane	10 mg/kg body weight 8 wk	Regulation of glucose and lipid metabolism ↓ Oxidative stress and insulin resistance
Sheu *et al*., 2023 [28]	Taiwan	High-fat-diet rat model and HepG2 cell line	WBJ BGE Sinigrin (97.3%) Gluconapin (2.67%)	Murine: WBJ (0.5–2.0%) 8 wk Cell: BGE (2–6 mg/mL) 24 hrs [50 µM glucosinolates]	Promote fatty acid β-oxidation ↓ Body weight ↓ Lipid synthesis ↓ Proinflammatory factors (TNFα, NFκB)
Chaturvedi and Machacha, 2007 [19]	Africa	Murine albino rat model	RSME	80 and 120 mg/kg Paracetamol (100 mg/kg) 30 days	↓ TBARS, SGOT, SGPT ↓ Lipid peroxidation ↑ GSH and catalase activity
Ma *et al*., 2025 [31]	EUA-China	Steatosis model HepG2 cells	Flavonoids	Naringenin, Morin and Silibinin [10 µM] Topiramate [44 µM] 72 hrs	↑ De novo synthesis of saturated fatty acids ↓ Lipid accumulation
Chen *et al*., 2025 [32]	China	MASLD murine and HepG2 cell line models	Quercetin	Murine model: [35/70/140 mg/kg] 28 days Cell model: [5–80 µM] 48 hrs	↑ Liver lipid metabolite-regulation ↓ Liver injury and ferroptosis
Nasr *et al*., 2025 [33]	Egypt	Fibrosis murine model	Quercetin	50 mg/kg/day Sild 50 mg/kg/day PTX 20 mg/kg/day 4 wk	↑ Antioxidant (Nrf2) ↓ Anti-inflammatory (TNFα, NFκB) ↓ Hypoxic signal pathway (HIF-1α)

Table 2. Continued.

Author/Year	Country	Population	Black Radish Compound	Study Design/Method	Outcomes/Observation
Asghari *et al*., 2015 [35]	Iran	Pulmonary fibrosis rat model	*Raphanus sativus L.* var niger extract	75–150 mg/kg 3 wk	↓ TGFb1 ↓ Severity of histological lesions
Cardamone *et al*., 2024 [41]	Italy	MASLD murine model	Polyphenolic fraction of bergamot	50 mg/kg/day 14 wk	Improve leptin, insulin and lipid metabolism ↓ Proinflammatory cytokines
Musolino *et al*., 2025 [43]	Italy	Hepatic cell lines (HepG2/LX2)	Citrus Lumia Risso extract (polyphenols)	25/50/100 mg/mL 48 hrs	↓ Intracellular lipid content
Kocsis *et al*., 2002 [47]	Hungary	Male Wistar rats	Black radish root juice [1:10]	150 mL/kg 9 days	↑ Diuretic properties ↓ Lipid levels and kidney stones Improved liver enzyme values
Ahn *et al*., 2019 [34]	Korea	NAFLD murine models Adipocyte cell line (3T3L1)	Fermented black radish Silymarin (100 mg/kg)	Murine: 50/100/200 and 400 mg/kg (2 wk) Cells: 0.7–1.0% (6 d)	Hepatoprotective effect ↓ Deposition of cholesterol and triglycerides in hepatocytes ↓ Lipids, liver inflammation, and fibrosis
Castro-Torres *et al*., 2012 [51]	Mexico	Mouse model with lithogenic diet	Black radish juice Ursodeoxycholic acid 0.5%	1:100, 1:10 [0.1 mL/10 g] juice	↓ Gallstones, triglycerides, cholesterol, and high-density lipoproteins

↑ Increase/↓ Decrease. JAK2, janus kinase 2; STAT3, signal transducer and activator of transcription 3; SBR, Spanish black radish; MIBITC, isothiocyanate metabolite of glucoraphasatin; QR, quinone reductase; HO-1, heme oxygenase-1; TrxR, thioredoxin reductase 1; Nrf2-KO, nuclear factor erythroid 2-related factor 2-knock out; WBJ, whole plants of *Brassica juncea*; BGE, extract of *Brassica juncea*; RSME, raphanus sativus root; TBARS, thiobarbituric acid reactive substances; Sild, sildenafil; PTX, pentoxifylline; NAFLD, non-alcoholic fatty liver disease.

could have beneficial effects on lipid metabolism and cellular energy balance, providing potential key strategies for biology and clinical applications (Fig. 1).

Although research has shown the beneficial effects of black radish, optimal concentrations and dose–response relationships have yet to be established. Determining these factors could help define a therapeutic dose that is effective without being harmful. Additionally, many of the above-mentioned studies mentioned do not consider the female gender in their methodologies. Given that women are four times more likely than men to develop gallstones, inter-gender comparisons are an important aspect to address. Moreover, the methods of administering black radish and other drugs varied among the study groups. The detoxifying properties of black radish suggest that similar effects could potentially be observed with other drug treatments, underscoring the need for further research into the beneficial detoxifying effects of black radish in different contexts (Table 2, Ref. [8,11,15,17,19,26,28,31–35,41,43,47,51]).

However, several limitations of the current evidence must be acknowledged. Most studies were conducted in preclinical settings, either *in vitro* or using animal models, which may not accurately reflect the complexities of MASLD in humans. Clinical trials are scarce, often involve small sample sizes, and exhibit heterogeneity in the types of black radish and preparations used (fresh root, fermented extracts, or isolated metabolites), as well as in the doses and methods of administration. These methodological inconsistencies restrict the comparability of results and the establishment of standardized therapeutic protocols. Additionally, outcome measures differ across studies, making it challenging to determine consistent clinical endpoints.

Overall, these constraints emphasize the need for well-designed, large-scale clinical studies to confirm efficacy, define optimal dosing, and ensure safety across diverse patient populations. Importantly, some findings remain inconsistent across studies, particularly regarding lipid metabolism outcomes and antifibrotic activity. These discrepancies underscore the importance of replication, the harmonization of study protocols, and a critical comparison of experimental designs to better establish the clinical potential of black radish in MASLD.

6. Conclusion

MASLD is the most common chronic liver disease worldwide, affecting more than 30% of the global population. At present, its treatment includes healthy lifestyle modifications, such as exercise and diet. Black radish possesses certain components—such as glucosinolates, anthocyanins, flavonoids, and polyphenols—which exert anti-inflammatory and antioxidant biological activities (Fig. 2). As such, this vegetable could be promising as an adjuvant treatment for liver detoxification and the prevention of disease.

Author Contributions

SAT: design concept, acquisition of information, and writing of the first draft manuscript; PSCF: figure elaboration and edition, review and correction of final manuscript version. MU: conceptualization, funding acquisition and critical revision; VJBB: guidance in the design and conceptualization, supervision, critical revision, writing—review & editing. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

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