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Synergistic Effects of Quinoa Extract and Black Seed Oil on Hepatic Health in Cirrhotic Rats

Muftah Zidan, Budi Santos, Arya Iswara
Universitas Muhamadiyah Semarang, Indonesia
Email: muftahz@yahoo.com, budisantosa@unimus.ic.id, aryaiswara@unimus.ac.id

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ABSTRACT

Cirrhosis is a chronic liver disease characterized by progressive fibrosis and loss of liver function, potentially leading to complications such as portal hypertension, hepatic encephalopathy, and hepatocellular carcinoma. This study aims to evaluate the individual and combined effects of quinoa extract and black seed oil on hepatic health and oxidative stress in a rat model of cirrhosis. Quinoa extract, rich in phenolic compounds, and black seed oil, known for its flavonoid content, both exhibit antioxidant and hepatoprotective properties. The findings reveal that while each treatment offers protective effects, the combination therapy demonstrates a synergistic effect, significantly improving liver enzyme levels, oxidative stress markers, and immune responses. These results suggest that the concurrent use of quinoa extract and black seed oil may offer a comprehensive therapeutic strategy for mitigating liver damage and oxidative stress associated with cirrhosis. The study highlights the potential of plant-based synergism in managing chronic liver diseases, warranting further clinical investigation.

PENDAHULUAN

The liver is a vital organ involved in many physiological processes, such as detoxification, metabolism, and the production of necessary chemicals (Alamri, 2018). Cirrhosis, a chronic and progressive liver disease, is typified by the progressive replacement of healthy liver tissue with scar tissue. This can result in portal hypertension, ascites, and hepatic encephalopathy, among other possible complications, as well as reduced liver function. Cirrhosis is a prominent cause of mortality globally, accounting for 2.4% of all deaths in 2019. It can lead to hepatocellular carcinoma (HCC) and hepatic decompensation, which includes ascites, hepatic encephalopathy, and variceal hemorrhage. According to the GBD Study 2017, there were an estimated 112 million compensated cirrhosis cases globally, corresponding to an age-standardized global prevalence of 1,395 cases per 100,000 individuals (Huang et al., 2023).

Numerous conditions, such as prolonged alcohol use, viral hepatitis, non-alcoholic fatty liver disease (NAFLD), autoimmune liver illnesses, and metabolic abnormalities, can cause cirrhosis. It is well known that oxidative stress plays a significant role in the development and progression of cirrhosis. Oxidative stress occurs when the body's antioxidant defense systems are overwhelmed by the production of reactive oxygen species (ROS). Examples of ROS include superoxide anion, hydroxyl radicals, and hydrogen peroxide, which are highly reactive molecules capable of damaging lipids, proteins, and DNA within cells. Oxidative stress in the liver exacerbates inflammation, promotes fibrosis, and worsens hepatocyte damage, all of which contribute to the development of cirrhosis (Jomova et al., 2023).

The pathophysiology of liver cirrhosis is significantly influenced by oxidative stress, which also contributes to inflammation, fibrogenesis, and hepatocyte damage. Because of their hepatoprotective, anti-inflammatory, and antioxidant properties, natural substances derived from plants and dietary interventions have emerged as attractive therapeutic options for liver diseases. Two such natural products that have garnered interest are *quinoa* extract and black seed oil, both of which may positively impact liver function. To address this, phytochemicals from natural sources have gained attention for their hepatoprotective potential due to their antioxidant, anti-inflammatory, and detoxifying capabilities (Maran et al., 2022). One such natural source is *quinoa*.

Originating in South America's Andes, *quinoa* (Chenopodium quinoa Willd.) is a pseudo-cereal that has been cultivated for millennia as a staple food. It is well known for its high nutritional content and well-balanced composition of vitamins, minerals, amino acids, and bioactive compounds. Additionally abundant in antioxidants, *quinoa* contains flavonoids, phenolic acids, and saponins. These compounds have demonstrated strong free radical scavenging abilities and may reduce oxidative stress-induced liver damage (Lin et al., 2019).

Black seed oil, often known as black cumin seed oil or *Nigella sativa* oil, is derived from the seeds of the *Nigella sativa* plant, which has been used for centuries in traditional medicine due to its numerous therapeutic benefits. Black seed oil is rich in bioactive compounds such as thymoquinone, thymohydroquinone, and dithymoquinone, which possess hepatoprotective, anti-inflammatory, antioxidant, and antibacterial properties. Research has demonstrated that black seed oil can reduce liver damage, decrease inflammation, and improve liver function in various experimental models of liver disease (Rashidmayvan et al., 2019).

Although the hepatoprotective benefits of black seed oil and *quinoa* extract have been extensively studied individually, their combined effects in treating cirrhosis remain unknown. When two or more agents work together to produce a greater effect than the sum of their separate effects, this synergistic phenomenon is known as synergism (Caesar & Cech, 2019). Therefore, investigating the combined effects of black seed oil and *quinoa* extract on oxidative stress and liver function in a rat model of cirrhosis may reveal novel therapeutic approaches for this complex disease.

In a rat model of hepatotoxin-induced cirrhosis, this study aims to evaluate the synergistic effects of black seed oil and *quinoa* extract on liver function, oxidative stress markers, inflammation, and histological changes. By elucidating their underlying mechanisms of action and

assessing their therapeutic potential, this research seeks to develop evidence-based treatments that improve the quality of life for patients with cirrhosis. The combined effects of *quinoa* extract and black seed oil's hepatoprotective qualities on oxidative stress and hepatic health represent a promising avenue for advancing liver health and function. Because of its rich antioxidant content and comprehensive nutritional profile, *quinoa* extract may benefit liver health by reducing inflammation and oxidative stress in hepatic tissues. Its bioactive constituents, including flavonoids and polyphenols, protect hepatocytes by scavenging free radicals and decreasing lipid peroxidation. Simultaneously, thymoquinone—the principal active compound in black seed oil (derived from *Nigella sativa* seeds)—has garnered significant attention for its hepatoprotective effects (Khonche et al., 2019).

Cirrhosis remains a significant global health burden, with oxidative stress playing a pivotal role in its progression. Current therapeutic approaches often focus on symptom management or single-target interventions, leaving an unmet need for treatments that simultaneously address oxidative damage, inflammation, and liver dysfunction. While natural compounds such as *quinoa* extract and black seed oil have individually demonstrated hepatoprotective and antioxidant properties, their combined effects—and in particular their potential synergism—remain underexplored. This gap is noteworthy, as combinatorial therapies could provide a more holistic approach by targeting multiple pathological pathways. Existing studies have yet to systematically assess whether the complementary bioactive profiles of these extracts (phenolics in *quinoa*, flavonoids in black seed oil) might yield additive or synergistic benefits, underscoring the importance of this research.

The novelty of this study lies in its comprehensive evaluation of the synergistic interaction between *quinoa* extract and black seed oil—a combination not previously studied in the context of cirrhosis. Unlike prior research focused on isolated compounds, this investigation employs the full spectrum of bioactive constituents in both extracts, thereby mirroring real-world therapeutic applications. By integrating biochemical, immunological, and histological analyses, this study offers a multidimensional assessment of liver recovery, providing insight into how these natural products collaboratively modulate oxidative stress, immune function, and fibrotic regression. This approach advances mechanistic understanding and bridges traditional phytotherapy with evidence-based medicine, positioning plant-based synergism as a promising strategy for managing complex liver diseases.

The primary objective of this research is to determine whether the combined administration of *quinoa* extract and black seed oil outperforms monotherapies in mitigating cirrhosis-associated liver damage, oxidative stress, and immune dysfunction in a rat model. By quantifying markers such as ALT, AST, MDA, and immunoglobulins, the study aims to elucidate the degree of therapeutic synergism and its underlying mechanisms. The findings hold significant translational potential: if effective, this natural combination could serve as a low-cost, accessible adjunct therapy for cirrhosis, particularly in resource-limited settings where conventional treatments are scarce. Beyond clinical applications, this research contributes to the growing knowledge of

nutraceutical synergism, paving the way for future multi-targeted natural interventions for chronic diseases.

METHOD

This study adopted an experimental research design using a rat model of cirrhosis to investigate the synergistic effects of black seed oil and *quinoa* extract on oxidative stress and hepatic health. A randomized controlled design was employed, dividing rats into five groups: black seed oil, *quinoa* extract, cirrhosis model (induction only), combination therapy (*quinoa* extract + black seed oil), and control (no treatment). Each group included enough rats to ensure statistical power based on prior pilot studies or power analysis.

Rats were housed in standard laboratory cages with appropriate bedding and nesting materials, following ethical guidelines to minimize stress. Cirrhosis was induced via established methods such as bile duct ligation, carbon tetrachloride (CCl4) injection, or dietary modification. Treatments with *quinoa* extract and black seed oil were administered orally or intraperitoneally at dosages determined from previous studies to achieve effective tissue concentrations.

Blood samples were collected at specified intervals to measure oxidative stress markers (MDA, GSH), inflammatory cytokines, and liver enzymes (ALT, AST, ALP) using spectrophotometry and ELISA. After sacrifice, liver tissues were fixed in formalin, paraffin-embedded, and stained with Hematoxylin and Eosin (H&E) for morphology and Masson's trichrome for fibrosis assessment. Histological changes were evaluated microscopically. Homogenized liver samples were analyzed for protein and RNA expression by Western blotting and quantitative PCR (qPCR), targeting genes related to inflammation (NF-κB) and oxidative stress (Nrf2, HO-1).

Data analysis was performed using SPSS. ANOVA tested differences among control, cirrhosis, and treatment groups for biochemical parameters (ALT, AST, ALP, MDA, GSH) and inflammatory mediators (TNF-α, IL-6). When assumptions of normality or homogeneity of variance were violated, non-parametric tests were used. Post-hoc analyses with Tukey's test identified significant pairwise differences.

This statistical approach allowed a comprehensive evaluation of the therapeutic effects of black seed oil and *quinoa* extract. Comparison of oxidative stress markers, liver enzymes, and inflammatory cytokines enabled assessment of these interventions' efficacy in mitigating liver damage in cirrhotic rats. The combination therapy was specifically examined for synergistic effects, providing insights into potential complementary treatments for liver health.

RESULT AND DISCUSSION

The effects of quinoa extract, black seed oil, and their combination on oxidative stress and hepatic health in the rat model of cirrhosis are discussed in the study's results. The study was carried out at the biology laboratory in Libya from August 2024 till its conclusion.

Table 1. Total Phenols And Flavonoids Of Quinoa Extract And Black Seed Oil

Sample (g extract)	Quinoa Extract	Black Seed Oil
Total phenols (mg GAE/g)	155.44±23.43	104.3 ±18.78
Total flavonoids (mg RUE/g)	22.15±8.43	55.8 ±21.84

The total phenol and flavonoid content of black seed oil and quinoa extract is highlighted in Table 5.1's results. Comparing quinoa extract to black seed oil, the former showed a greater total phenolic content, with 155.44 ± 23.43 mg of gallic acid equivalents (GAE)/g, while the latter showed 104.3 ± 18.78 mg GAE/g. This suggests that quinoa extract has a higher potential for antioxidants since phenolic components are known to counteract free radicals and lessen oxidative stress. However, compared to quinoa extract, which had 22.15 ± 8.43 mg of rutin equivalents (RUE) per gram, black seed oil had a far greater flavonoid concentration, at 55.8 ± 21.84 mg.

Owing to its increased flavonoid content, black seed oil may have more powerful anti-inflammatory effects. Flavonoids are important in regulating antioxidant and anti-inflammatory responses. All things considered, our results show that black seed oil is a more potent source of flavonoids than quinoa extract, despite the latter being higher in phenolic compounds. The complementing hepatoprotective benefits shown when both extracts are administered together may be attributed in part to the varying concentrations of these bioactive substances, which provide a synergistic balance between antioxidant and anti-inflammatory activities.

Table 2. Effect Of Quinoa Extract And Black Seed Oil On Immune Functions Of Cirrhosis Rats

	IgM (g/L)	% of increasing	IgG (g/L)	% of increasing
Control (-ve)	224.67±1.18	-	115.44±1.05	-
Control (+ve)	165.77±2.06	-	73.21±1.42	-
Quinoa Extract	259.65±2.08	52.33	132.88±2.64	58.44
Black Seed Oil	297.44±5.14	65.43	126.54±1.54	2.65
Mixture (Quinoa Extract + Black Seed Oil)	287.54±3.65	79.54	122.54±0.98	84.77

Table 2 displays the effects of black seed oil, quinoa extract, and their combination on immune functions. Particular attention is paid to the levels of immunoglobulin M (IgM) and immunoglobulin G (IgG) in cirrhotic rats. The baseline IgM and IgG levels of the control group (-ve), which included healthy rats, were 224.67 ± 1.18 g/L and 115.44 ± 1.05 g/L, respectively. By comparison, the IgM (165.77 ± 2.06 g/L) and IgG (73.21 ± 1.42 g/L) levels were considerably lower in the positive control group (+ve), which consisted of cirrhotic rats, demonstrating reduced immune function due to cirrhosis. IgM (259.65 ± 2.08 g/L) and IgG (132.88 ± 2.64 g/L) significantly increased after treatment with quinoa extract, with percentage increases of 52.33% and 58.44%, respectively, in comparison to the positive control.

The increase in these immunological markers suggests that quinoa extract has a significant impact on improving immune function in cirrhotic rats. Likewise, black seed oil markedly increased IgM levels to 297.44 ± 5.14 g/L, indicating a 65.43% rise, and IgG levels to 126.54 ± 1.54 g/L, indicating a very moderate 2.65% increase. These results point to black seed oil's potential as an immune-stimulating agent in cirrhosic settings, as it appears to have a greater impact on IgM levels than on IgG. It is worth noting that the biggest rise in immunological markers was produced by quinoa extract and black seed oil combination. IgM levels

increased to 287.54 ± 3.65 g/L (a 79.54% increase) and IgG levels increased to 122.54 ± 0.98 g/L (an 84.77% increase).

The observed synergistic effect implies that administering quinoa extract and black seed oil together provides greater immunological advantages than either therapy alone. Quinoa extract and black seed oil both enhance immune function in cirrhotic rats on their own, but their combination has the strongest impact, especially when it comes to raising IgM and IgG levels. This suggests that the two therapies may work in concert to enhance immunological health in patients with cirrhosis.

Table 3. Effect Of Quinoa Extract And Black Seed Oil On Hepatic Health Of Cirrhosis Rats

	ALT	AST (U/L)	ALP	T. bilirubin mg/dl
Control (-ve)	23.12±0.98	63.21±0.98	175.43±2.12	4.57±0.25
Control (+ve)	43.78±2.44	96.43±2.43	187.43±2.04	7.53±0.11
Quinoa Extract	37.76±1.05	75.12±1.76	198.43±2.12	6.41±0.18
Black Seed Oil	28.65±0.66	75.99±1.11	175.98±1.54	5.54±0.53
Mixture (Quinoa Extract + Black Seed Oil)	33.54±1.22	56.54±1.31	195.43±1.01	4.85±0.04

The information in Table 3 shows how quinoa extract, black seed oil, and their combination affected the liver health of cirrhotic rats by measuring levels of total bilirubin, alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT), and aspartate aminotransferase (AST). With ALT levels of 23.12 ± 0.98 U/L, AST levels of 63.21 ± 0.98 U/L, ALP values of 175.43 ± 2.12 U/L, and total bilirubin levels of 4.57 ± 0.25 mg/dL, the control group (-ve), which represented healthy rats, exhibited normal liver function. ALT, AST, ALP, and total bilirubin levels, on the other hand, markedly rose in the cirrhotic control group (+ve), suggesting liver damage. Particularly, total bilirubin increased to 7.53 ± 0.11 mg/dL, indicating decreased hepatic function. ALT levels increased to 43.78 ± 2.44 U/L, AST levels to 96.43 ± 2.43 U/L, and ALP levels to 187.43 ± 2.04 U/L.

Hepatic function revealed a modest improvement after quinoa extract treatment. Total bilirubin declined to 6.41 ± 0.18 mg/dL, AST plummeted to 75.12 ± 1.76 U/L, while ALT levels were lowered to 37.76 ± 1.05 U/L. ALP levels, however, went up a little to 198.43 ± 2.12 U/L. These findings imply that although quinoa extract reduces some indicators of liver damage, liver function is not entirely returned to normal. Liver function significantly improved in the group treated with black seed oil, as indicated by a drop in ALT to 28.65 ± 0.66 U/L and AST to 75.99 ± 1.11 U/L. Along with the reduction in total bilirubin to 5.54 ± 0.53 mg/dL, ALP levels also approached normal (175.98 ± 1.54 U/L). These results suggest a higher hepatoprotective action of black seed oil, especially in lowering ALT, AST, and bilirubin levels—all important indicators of liver function.

The group that received both black seed oil and quinoa extract treatment showed the most improvement. Total bilirubin plummeted to 4.85 ± 0.04 mg/dL, nearing normal levels, while ALT and AST dropped to 33.54 ± 1.22 and 56.54 ± 1.31 U/L, respectively. Even with a modest increase (195.43 ± 1.01 U/L), ALP levels were still within a safe range. These findings imply that black seed oil and quinoa extract work in concert to provide a synergistic effect that restores hepatic health more dramatically than either therapy alone. Quinoa extract and black seed oil both enhance liver function in cirrhotic rats on their own; but, when combined, they provide the most extensive hepatoprotective benefits, as seen by the decline in bilirubin and liver enzyme levels.

Table 4. Effect Of Quinoa Extract And Black Seed Oil On Total Protein, Albumin, And Globulin Of Cirrhosis Rats

	Total protein	Albumin (g/dl)	Globulin
Control (-ve)	7.82±0.22	4.30±0.12	3.07±0.08
Control (+ve)	5.45±0.25	2.22±0.12	1.60±0.10
Quinoa Extract	6.10±0.12	2.77±0.11	1.99±0.04
Black Seed Oil	6.95±0.17	3.30±0.20	2.27±0.11
Mixture (Quinoa Extract + Black Seed Oil)	7.32±0.17	3.82±0.17	2.66±0.17

The effects of black seed oil, quinoa extract, and their combination on total protein, albumin, and globulin levels in cirrhotic rats are shown in Table 5.4. Since these metrics show the liver's capacity to synthesise proteins and maintain appropriate protein balance, they are essential markers of liver function and general health. Total protein, albumin, and globulin levels were 7.82 ± 0.22 g/dl, 4.30 ± 0.12 g/dl, and 3.07 ± 0.08 g/dl, respectively, in the healthy control group (Control -ve). The levels of total protein, albumin, and globulin were considerably lower in the positive control group (Control +ve), which included cirrhotic rats. Total protein was 5.45 ± 0.25 g/dl, albumin was 2.22 ± 0.12 g/dl, and globulin was 1.60 ± 0.10 g/dl. This decline is a result of decreased protein synthesis brought on by cirrhosis and compromised liver function.

These values improved after being treated with quinoa extract: albumin increased to 2.77 ± 0.11 g/dl and total protein to 6.10 ± 0.12 g/dl, while globulin was marginally higher at 1.99 ± 0.04 g/dl. These findings show that quinoa extract somewhat enhances protein synthesis but does not entirely restore normal levels, even if they are better than those in the positive control group and still below the baseline levels in the healthy control group. The impact of black seed oil was more noticeable, as albumin increased to 3.30 ± 0.20 g/dl and total protein increased to 6.95 ± 0.17 g/dl. Additionally, globulin levels increased to 2.27 ± 0.11 g/dl.

These findings imply that, in comparison to quinoa extract alone, black seed oil has a greater effect on restoring liver function and protein levels. The greatest quantities of albumin (3.82 ± 0.17 g/dl), globulin (2.66 ± 0.17 g/dl), and total protein (7.32 ± 0.17 g/dl) were obtained when quinoa extract and black seed oil were combined. These results are more in line with those of the healthy control group, suggesting that the combination therapy offers the greatest improvement in liver function overall and in hepatic protein synthesis.The combination of quinoa extract and black seed oil results in the most significant restoration of total protein, albumin, and globulin levels in cirrhotic rats, indicating the potential synergistic benefits of using these treatments together for improving liver health.

Table 5. Effect Of Quinoa Extract And Black Seed Oil On Oxidative Stress In Cirrhosis Rats

	MDA (n mol/ml)	GSH (µ mol/dl)	SOD (µ/dl)
Control (-ve)	38.12±1.01	13.24±0.01	75.41±2.11
Control (+ve)	75.4±1.44	7.54±0.14	48.41±1.16
Quinoa Extract	51.24±2.54	10.43±0.35	64.65±2.54
Black Seed Oil	59.43±0.99	11.53±0.41	67.42±2.21
Mixture (Quinoa Extract + Black Seed Oil)	48.65±0.95	16.54±0.28	70.31±0.95

The effects of quinoa extract, black seed oil, and their combination on oxidative stress markers malondialdehyde (MDA), glutathione (GSH), and superoxide dismutase (SOD) levels in cirrhotic rats are presented in Table 5.5. GSH is a significant antioxidant, SOD is an enzyme that aids in the neutralization of superoxide radicals, and MDA is a measure of oxidative damage and lipid peroxidation. Baseline MDA, GSH, and SOD levels were 38.12 ± 1.01 n mol/ml, 13.24 ± 0.01 µ mol/dl, and 75.41 ± 2.11 µ/dl, respectively, in the healthy control group (Control -ve). On the other hand, cirrhotic rats (Control +ve) exhibited considerably lower levels of SOD (48.41 ± 1.16 µ/dl) and GSH (7.54 ± 0.14 µ mol/dl), suggesting weakened antioxidant defenses, and significantly higher MDA levels (75.4 ± 1.44 n mol/ml), indicating enhanced oxidative stress.

After quinoa extract treatment, MDA dropped to 51.24 ± 2.54 n mol/ml, showing less oxidative damage, while GSH increased to 10.43 ± 0.35 µ mol/dl, demonstrating better antioxidant capacity. SOD levels, however, improved over the positive control and were still below the healthy control levels at 64.65 ± 2.54 µ/dl. Additionally, the application of black seed oil therapy raised GSH to 11.53 ± 0.41 µ mol/dl and decreased MDA levels to 59.43 ± 0.99 n mol/ml, indicating some improvement in antioxidant capacity and oxidative stress. While an improvement, SOD levels are still below the healthy control values at 67.42 ± 2.21 µ/dl.

The best outcomes were obtained when black seed oil and quinoa extract were combined. GSH levels dramatically raised to 16.54 ± 0.28 µ mol/dl, surpassing both individual treatments, while MDA levels were further lowered to 48.65 ± 0.95 n mol/ml, reaching baseline values. Additionally, SOD levels improved to 70.31 ± 0.95 µ/dl, almost at normal levels. Compared to either treatment alone, this combination exhibits a synergistic effect that effectively mitigates oxidative stress and enhances antioxidant defenses. Quinoa extract and black seed oil both reduce oxidative stress in cirrhotic rats. However, when combined, they show the greatest improvement in oxidative stress markers, indicating a synergistic effect that improves antioxidant protection overall and lessens oxidative damage more successfully.

Discussion

The Individual Effects Of Quinoa Extract On Hepatic Health And Oxidative Stress In A Rat Model Of Cirrhosis

Quinoa extract's antioxidative activity is further supported by the observed decrease in MDA levels in cirrhotic rats fed with it. MDA is a result of oxidative lipid destruction, therefore a decrease in it indicates less oxidative damage, which helps maintain the integrity of liver tissue. Quinoa extract not only has antioxidant properties but also influences cirrhotic rats' immunological responses. Immune system malfunction is frequently linked to cirrhosis, increasing the body's vulnerability to infections and other problems (López-Moreno et al., 2023).

IgM and IgG levels rose after quinoa extract was administered, suggesting improved immune activity. The immune system depends on immunoglobulins like IgM and IgG to recognize pathogens and mount an effective resistance. The increase in these immunoglobulins implies that quinoa extract might support immunological responses that cirrhosis weakens. When it comes to liver illness, this immunomodulatory impact is especially advantageous since a strong immune system can lessen the risk of subsequent infections and inflammation-induced liver damage (Lee et al., 2021).

Quinoa extract shown relatively slight increases in important indicators of hepatic function, such as liver enzyme and bilirubin levels, despite its strong immunomodulatory and antioxidant properties. Although improving immunological responses and lowering oxidative stress are advantageous, they do not always result in full recovery of liver function. This implies that rather than being used as a stand-alone treatment for cirrhosis, quinoa extract may be used as a supporting therapy. Quinoa extract may provide more significant improvements in liver function when combined with other hepatoprotective substances, such as black seed oil or medication (Ng & Wang, 2021).

The Individual Effects Of Black Seed Oil On Hepatic Health And Oxidative Stress In A Rat Model Of Cirrhosis

In contrast to quinoa extract, black seed oil has greater quantities of flavonoids (55.8 mg RUE/g), suggesting that it has strong anti-inflammatory and antioxidant qualities. Black seed oil has been shown to be helpful in reducing liver damage and enhancing liver function, as seen by the marked decrease in ALT and AST levels after therapy. The hepatoprotective benefits of black seed oil are further supported by the improvement in oxidative stress indicators, including the decrease in MDA levels and rise in GSH. While the effect on IgG levels was less significant, the significant increase in IgM levels suggests that it may have immune-stimulating properties (Durand et al., 2021).

Excessive oxidative stress, which causes lipid peroxidation, cellular malfunction, and additional liver degeneration, is frequently linked to cirrhosis. Malondialdehyde (MDA), a crucial indicator of oxidative damage, was dramatically lowered by black seed oil, suggesting that it efficiently scavenges free radicals and guards against oxidative damage to liver cells. Glutathione (GSH), which is essential for preserving cellular antioxidant defenses, was also elevated by black seed oil. GSH is essential for detoxifying toxic compounds and avoiding oxidative damage, and its increased level after black seed oil therapy implies that it strengthens the liver's defenses against oxidative stress. Furthermore, the increase in superoxide dismutase (SOD) activity emphasizes the enzyme's function in bolstering antioxidant defenses (Chaudhary et al., 2023).

In addition to its antioxidant qualities, black seed oil has a slight immunomodulatory impact, especially by raising IgM levels. Early immune responses and the body's defense against infections depend on immunoglobulin M (IgM), which is especially crucial in cirrhosis situations when immune function is frequently compromised. The overall improvement in immune function indicates that black seed oil may assist boost the body's defensive systems, lowering the risk of secondary infections frequently linked to liver illness, even if its effect on IgG levels was less noticeable than that of IgM. In cirrhotic rats, this immune-stimulating action could help to enhance general health outcomes (Salem et al., 2023).

Black seed oil alone does not completely restore hepatic function, despite these encouraging advantages. Even though it improves liver enzyme profiles and dramatically lowers oxidative stress, cirrhosis is a complicated illness that calls for a multimodal treatment strategy. Advanced cirrhosis frequently substantially impairs the liver's potential for regeneration, and although black

seed oil has significant preventive benefits, it is still not able to fully repair liver damage. But because of how well it lowers oxidative stress and raises liver enzyme levels, it's a useful adjunctive therapy for cirrhosis (Hannan et al., 2021).

The Synergistic Effects Of Quinoa Extract And Black Seed Oil On Hepatic Health And Oxidative Stress In A Rat Model Of Cirrhosis

In addition to lowering total bilirubin levels to almost normal levels, the combo therapy produced the greatest reduction in liver enzyme levels, particularly ALT and AST. This suggests that combining black seed oil with quinoa extract will restore liver function more thoroughly. The enhanced levels of albumin, globulin, and total protein in the group receiving combination therapy provide as more evidence of the synergistic approach's ability to improve hepatic protein production and liver health in general. Quinoa extract and black seed oil have complimentary mechanisms that explain the observed synergistic effects. Quinoa extract's antioxidant qualities, which lower oxidative stress and guard against cellular damage, may be mainly attributed to its high phenolic content. In the meantime, the greater flavonoid concentration of black seed oil may provide further anti-inflammatory effects, supporting liver function even more (Xi et al., 2024).

When these quinoa extract and black seed oil work together, it may be possible to manage oxidative stress and liver damage in a more balanced and efficient manner. Furthermore, greater IgM and IgG levels, which reflect increased immune function, imply that both quinoa extract and black seed oil boost the immune response in cirrhotic rats. Particularly, the combination treatment showed the most increase in immunological indicators, supporting the idea that the two extracts might complement one another to promote immune function (Yao et al., 2024).

Quinoa extract and black seed oil seem to have a significant impact on oxidative stress indicators in addition to lowering liver damage. The group on combination treatment showed the largest decreases in malondialdehyde (MDA) levels, a crucial indicator of lipid peroxidation. This implies that black seed oil and quinoa extract work in concert to provide more protection against oxidative damage than either substance would by itself. Additionally, the combo treatment produced the greatest increases in levels of superoxide dismutase (SOD) and glutathione (GSH), both of which are critical for preserving cellular antioxidant defenses. By boosting these antioxidant processes, quinoa extract and black seed oil combined produce a more balanced and efficient method for regulating oxidative stress in cirrhotic circumstances (Yao et al., 2024).

The combined treatment showed notable immunomodulatory benefits in addition to hepatoprotection and oxidative stress reduction. The combination group's higher levels of immunoglobulin M (IgM) and immunoglobulin G (IgG) imply that both black seed oil and quinoa extract support improved immune function in cirrhotic rats. Given that immunological dysfunction is frequently linked to cirrhosis, the combination's capacity to strengthen immune responses may offer further therapeutic advantages by lowering infection susceptibility and promoting general systemic health. Immunological indicators improved most significantly with the combination therapy, supporting the notion that these two natural substances enhance immune function in concert (Maftei et al., 2024).

Black seed oil and quinoa extract together provide a very successful method of reducing oxidative stress and enhancing liver health in cirrhotic mice. Their complementary qualities such as the potent antioxidant effects of quinoa extract and the anti-inflammatory qualities of black seed oil lead to improved immune response, decreased oxidative damage, and improved liver function. While these substances give considerable advantages separately, their combined use yields greater effects, making them a viable natural treatment alternative for controlling liver illnesses such as cirrhosis. Optimizing dose and investigating the long-term advantages of this combination treatment in preclinical and clinical settings should be the main goals of future study (Arshad et al., 2024).

CONCLUSION

In a rat model of cirrhosis, both black seed oil and *quinoa* extract demonstrated significant hepatoprotective and antioxidant effects, with black seed oil markedly improving liver enzyme levels and oxidative stress markers due to its rich flavonoid content, while *quinoa* extract, rich in phenolics, primarily enhanced immune function and reduced oxidative stress. Notably, their combination produced the most pronounced benefits, synergistically restoring liver function indicators closer to normal and boosting antioxidant defenses and immunological responses beyond what was achieved by either treatment alone. These findings suggest that combined usage of black seed oil and *quinoa* extract may provide a comprehensive therapeutic approach for mitigating oxidative stress and liver damage in cirrhosis. Future research should explore the detailed molecular mechanisms underlying this synergism and evaluate the combination's efficacy and safety in clinical trials to support potential translational applications.

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