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Review

Thymoquinone: A promising agent in the prevention of breast cancer

Sai Sri Jayanthi Emani¹, Sriniketh Chakravarthi¹, Trisha Reddy Chilkuri¹, Priyanka Peddamma², Raja Rajeswari Kamiseti*³

¹Pulla Reddy Institute of Pharmacy, affiliated to Jawaharlal Nehru Technological University, Hyderabad, Telangana 502 313



²Arya College of Pharmacy, affiliated to Osmania University, Kandi, Sangareddy, Telangana 502285.

³Vardhaman College of Pharmacy, affiliated to Dr Baba Saheb Ambedkar Technological University, Karanja Lad, Maharashtra 444 105.

³Professor and Principal, Vardhaman College of Pharmacy, Karanja Lad, Maharashtra 444 105

*Author for Correspondence: Dr. Raja Rajeswari Kamiseti

Email: drkrajajeswari@gmail.com

	<p>Abstract</p>
<p>Published on: 09 Sep 2024</p>	<p>Breast cancer is a worldwide health concern that necessitates continuous investigation into preventive measures. An active component of <i>Nigella sativa</i> (black seed), thymoquinone, has been the focus of extensive research. Pharmacology-wise, it is versatile. The current trials examining the potential of thymoquinone to prevent breast cancer are evaluated in this article. Anti-cancer, anti-inflammatory, and antioxidant in nature, thymoquinone exhibits great potential as a preventative agent against breast cancer. It prevents the production of cytokines and inflammatory mediators, both of which are known to promote malignancy. It is well known that oxidative stress contributes to the progression of cancer; however, the antioxidant properties of this substance mitigate this effect. This investigation investigates molecular pathways that are modulated by thymoquinone. The pathways of apoptosis, proliferation, and angiogenesis are investigated in this study. Although preclinical research has demonstrated the beneficial effects of thymoquinone on breast cancer cells, it is advisable to exercise caution when applying it in clinical settings. Due to the incomplete clinical trials of this medication's efficacy, further research is required to determine whether or not it has preventative properties. Due to the potential preventative applications of thymoquinone, its safety is also addressed in this analysis. It is the purpose of this synthesis to describe how thymoquinone inhibits breast cancer. It also emphasises the need for additional research into the therapeutic potential of this substance in order to improve global health.</p>
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INTRODUCTION

Breast cancer poses a significant obstacle to the advancement of global health. For women, breast cancer is a global health concern [1]. A comprehensive and expeditious strategy is required to mitigate its impacts, as it is a significant contributor to cancer-related mortality and disability. Despite advancements in pharmaceutical development, there remains an even greater need for efficacious preventive measures that not only enhance survival but also alleviate psychological and physical distress. Analysing naturally occurring anticancer chemicals could aid in the prevention of breast cancer. The bioactive phytochemical thymoquinone, which is present in black seed (*Nigella sativa*), has garnered recent scientific interest. Since the beginning of time, *Nigella sativa*, an ancient herb, has been utilised in traditional medicine. Southern Europe, Southwest Asia, and the Middle East were its locations [2]. Thymoquinone, the principal active constituent of the compound, has garnered interest for its distinctive pharmacological characteristics and its comprehensive approach to breast cancer prevention [3].

The anticancer, anti-inflammatory, and antioxidant properties of thymoquinone illustrate its pharmacological versatility. Inflammation has long been associated with breast cancer and other forms of cancer. By inhibiting cytokines and inflammatory mediators, thymoquinone is a potent anti-inflammatory agent. By targeting a significant cancer risk factor, this anti-inflammatory activity enhances the overall health of the individual afflicted by chronic inflammation through its systemic impacts [4]. Furthermore, it possesses potent antioxidant properties that mitigate the detrimental impacts of oxidative stress. Oxidative stress is caused by the body producing more reactive oxygen species (ROS) than it neutralises. Thus, this imbalance promotes the development of breast cancer [5]. A risk factor for breast cancer, thymoquinone may safeguard cells against oxidative damage by boosting antioxidant defences and neutralising reactive oxygen species [6].

Critical biological processes are disrupted by thymoquinone, rendering it an efficacious therapy for cancer. According to preclinical investigations, thymoquinone inhibits the proliferation, apoptosis, angiogenesis, and mortality of cancer cells. On the basis of these results, thymoquinone may inhibit the progression of breast cancer [7]. As thymoquinone is investigated for its potential to prevent breast cancer, the search for natural medicines advances. Further investigation is warranted into the anti-cancer, anti-inflammatory, and antioxidant properties of thymoquinone [8]. The comprehensive investigation of natural substances such as thymoquinone facilitates personalised and preventative treatment. We investigate the intricate molecular pathways that give rise to breast cancer. To determine thymoquinone's preventive effects and lessen the global impact of breast cancer, additional research is required.

Molecular mechanisms of thymoquinone

Due to the prevalence of breast cancer, research into cancer prevention has been stimulated. Based on an analysis of its intricate molecular pathways, thymoquinone, a bioactive compound derived from *Nigella sativa*, has been determined to be the most effective preventive measure against breast cancer [9]. To prevent cancer, this exhaustive study investigates the anti-inflammatory, antioxidant, and regulatory effects of thymoquinone on key cellular signalling pathways.

Immunosuppressant mechanisms

Chronic inflammation, a defining characteristic of cancer, promotes the proliferation of breast cancer. Thymoquinone's molecular regulator of inflammatory reactions exhibits promise due to its potent anti-inflammatory properties [10]. By inhibiting pro-inflammatory cytokines and mediators, this regulatory mechanism interferes with the intricate interplay between inflammation and carcinogenesis. Thymoquinone plays a pivotal role in the regulation of inflammation and the immune response through its specific targeting of the transcription factor NF- κ B. Thymoquinone prevents the production of pro-inflammatory cytokines such as IL-6 and TNF- α by inhibiting NF- κ B activation. A coordinated downregulation disrupts the feedback loop between inflammation and the incessant growth of breast cancer, thereby damaging the cancer-friendly environment [11].

The antioxidant defences of reactive oxygen species (ROS) are overwhelmed, leading to oxidative stress. This approach significantly propagates breast cancer. Thymoquinone functions as an antioxidant, providing defence against oxidative stress. [12] By inhibiting free radicals, thymoquinone averts DNA damage and cell proliferation induced by reactive oxygen species (ROS). It enhances endogenous antioxidants such as SOD and catalase, thereby fortifying the resistance of cells to oxidative stress [13]. Thymoquinone additionally inhibits oxidative damage and safeguards cells against carcinogens, thereby advancing the cause of cancer. This environment inhibits the development of cancer.

Regulation of cellular signalling pathways

Thymoquinone influences signalling pathways associated with neovascularization, programmed cell death, and proliferation, in addition to its anti-inflammatory and antioxidant properties. The prevention of breast cancer is impacted by this. As a molecular conductor, thymoquinone obstructs the PI3K/AKT and MAPK signalling pathways during cellular development. Uncontrolled cell division results from dysregulated signalling

pathways, which are hallmarks of cancer^[14]. Thymoquinone inhibits these mechanisms to halt the development of tumours. This is achieved through the inhibition of cancer cell proliferation. To combat cancer, thymoquinone stimulates programmed cell death and inhibits apoptosis. Activation of extrinsic death receptors and intrinsic mitochondrial mechanisms can both eliminate breast cancer cells. Thymoquinone inhibits the development of cancer cells by inducing programmed cell death^[15]. Angiogenesis, which involves the formation of new blood vessels to supply nourishment to cancer cells^[16] demonstrates the regulatory impacts as well^[16]. Thymoquinone is incapable of inhibiting VEGF signalling, a critical angiogenesis pathway, prior to the formation of the tumor's vascular network.

Holistic Breast Cancer Prevention

Thymoquinone kills breast cancer by means of intricate biological signalling networks. Anti-inflammatory, antioxidant, and regulatory properties are among these. By impeding peritoneal degradation, oxidative stress, cell proliferation, apoptosis, and angiogenesis, thymoquinone is utilised to treat breast cancer^[17]. Due to the fact that it emphasises important figures. The comprehension of these molecular connections is anticipated to facilitate the advancement of more effective strategies for preventing breast cancer. Thymoquinone, a molecular dance specialist, has both preventative and therapeutic applications. Adaptability permits more individualised and integrated approaches, which increases the probability of discovering effective breast cancer prevention and treatment methods. By elucidating this intricate chemical milieu, thymoquinone instills optimism in our endeavours to combat breast cancer. By utilising simultaneous transitions, this intricated chemical environment is traversed^[18].

Preclinical evidence

Preclinical studies have investigated the potential of thymoquinone to prevent breast cancer. Extensive laboratory research has been dedicated to investigating the molecular and cellular mechanisms by which thymoquinone affects breast cancer cells, utilising animal models and cell cultures^[19]. Preclinical evidence that thymoquinone may prevent breast cancer is discussed in this article.

Stimulating cancer cell growth

Thymoquinone regulates the uncontrolled cell growth that is characteristic of cancer. According to preclinical research, thymoquinone inhibits the proliferation of breast cancer cells. Thymoquinone disrupts the intricate balance of cancer cells, causing them to proliferate indiscriminately^[20]. A particular approach perturbs the natural cycle, whereas an alternative regulates critical signalling pathways. As shown by the results of the experiments, thymoquinone inhibits the MAPK pathway, which controls cell proliferation. By inhibiting this mechanism, thymoquinone can substantially reduce malignant cell proliferation and tumour formation^[21]. Thymoquinone inhibits the proliferation of cancer cells by interfering with CDK proteins, which were previously involved in the regulation of cell cycles^[22].

Induction of Apoptosis

Numerous studies have demonstrated that thymoquinone inhibits the proliferation of breast cancer cells and kills them. Programmed cell death, or apoptosis, is an innate cellular defence mechanism responsible for removing damaged or detrimental cells. Cancer cells are capable of evading apoptosis, the process that would ordinarily halt their proliferation. To surmount this obstacle, thymoquinone stimulates both internal and external apoptotic pathways. By releasing pro-apoptotic proteins from mitochondria, the intrinsic pathway initiates a cascade of events that culminate in cellular demise^[23]. Thymoquinone's effect on the expression of B-cell lymphoma 2 (Bcl-2) family proteins streamlines this method. These proteins are vital for maintaining the integrity of mitochondria. Thymoquinone induces extrinsic apoptosis in this process. This method involves the interaction of cell-surface death receptors.

The following inhibit the proliferation of tumours

The fact that thymoquinone inhibits tumour growth in preclinical animals provides support for its potential as a chemopreventive agent for breast cancer. Thymoquinone reduces the size and volume of tumours in xenograft and orthotopic animal models on a consistent basis. Unknown is the effect of thymoquinone on the development of tumours. Its pro-apoptotic and anti-proliferative properties enable it to impede the proliferation of cancer cells within the tumour mass^[24]. Additionally, thymoquinone restricts blood vessel growth by inhibiting angiogenesis in the microenvironment of the tumour. By inhibiting the circulation of blood to tumours, thymoquinone hinders the advancement and viability of cancer.

Prognostications for the Future and Their Implications

Thymoquinone prevents breast cancer, according to preclinical investigations, establishing a foundation for translational research. In addition, this groundwork establishes a robust framework for subsequent

investigations. It is difficult to translate preclinical findings into clinical applications, despite their potential. Further investigation is required to ascertain the optimal dosages, durations of treatment, and combinations of drugs. Thymoquinone's adverse effects and long-term effects must be investigated prior to its medical application. The progression of breast cancer may be slowed by thymoquinone, according to preclinical research. By inhibiting tumour growth, inducing apoptosis, and reducing cancer cell proliferation, thymoquinone inhibits the development of breast cancer. Preclinical research should aid in the understanding of the potential therapeutic applications of thymoquinone for breast cancer. Clinical trials may be initiated as a result of preclinical findings that progress science [25].

Clinical trials and supporting data

Breast cancer prevention with thymoquinone could be impacted by its transition from preclinical to clinical development. Clinical trials necessitate meticulous examination, whereas preclinical investigations unveil molecular intricacy. Notwithstanding the favourable outcomes of the investigation, this persists. In this section, the scant clinical trials on the efficacy of thymoquinone in preventing breast cancer are evaluated critically [26]. Although acknowledging their limitations, the text emphasises the potential and advantages of the studies.

Insufficient human research

According to pre-clinical studies, thymoquinone might be able to prevent breast cancer. The clinical effectiveness remains undetermined [27]. In the absence of clinical trials [28], researchers and clinicians encounter a variety of prospects and obstacles. Clinical studies are uncommon due to the difficulty of transferring study participants from the laboratory to their bedsides. Clinical research necessitates the implementation of rigorous methodologies, extended follow-up periods, and substantial sample sizes in order to evaluate the safety and effectiveness of treatments. The progress of clinical trials involving thymoquinone has been impeded by financial constraints and the resistance of traditional medicine to the use of natural and herbal compounds. These experiments were delayed by the aforementioned factors [29].

Despite the paucity of evidence

Thymoquinone research indicated that it might provide protection against breast cancer. Limited number of clinical trials have assessed the impact on biomarkers associated with cancer progression and recurrence [30]. The impact of thymoquinone administration on serum inflammatory markers in patients with breast cancer was investigated in a concise clinical trial [31]. A reduction in biomarkers such as IL-6 and CRP might have served as an indicator of an anti-inflammatory effect [32]. The reduction of markers demonstrated this. Due to the relative youth of clinical research in this field, larger trials involving more diverse patient populations are required to circumvent sample size restrictions. An independent investigation based on conventional breast cancer treatment evaluated the safety and tolerability of thymoquinone. Because of the experiment's absence of adverse effects, thymoquinone may be investigated as an alternative therapy. Due to the absence of a placebo-controlled group and the small sample sizes, caution is advised before deriving conclusions from these experiments [33].

Translation Difficulties

Although the medical applications of thymoquinone have shown promise in preclinical studies, a number of obstacles impede a seamless transition. Standardising dosages and formulations is challenging. Ensuring consistency and reliability in the synthesis of thymoquinone is imperative for clinical evaluations [34]. This is because the active components of plant treatments differ. Because breast cancer is heterogeneous, it is difficult to eradicate. Clinical trials of thymoquinone necessitate genetic and molecular patient stratification. Subtypes of breast cancer may react dissimilarly to the treatment. The duration and long-term effects of the treatment should also be taken into account [35]. Extensive clinical investigations will be necessary to obtain pertinent findings, given the potential necessity for prolonged thymoquinone exposure for preventive purposes [36]. Management of long-term adverse effects and patient adherence demand the utmost care. Clarity of thought is required.

Pathways and Outlook

Notwithstanding these obstacles, preliminary clinical trials provided the groundwork for subsequent investigations. In order to expand the practicality of the results, it is feasible to conduct meticulously designed multicenter trials involving diverse patient populations [37]. Clinicians, researchers, and pharmaceutical companies must work together to increase the probability of securing funding for larger academic studies [38]. It is possible to integrate with conventional treatment modalities. The concurrent use of thymoquinone with other medications has the potential to enhance treatment outcomes for breast cancer and mitigate associated adverse effects [39]. By implementing biomarker research advancements, responsive subgroups can be identified and patient selection criteria can be enhanced. Thymoquinone therapy tailored to the molecular characteristics of a particular subtype of breast cancer may be more efficacious. Although clinical research on thymoquinone for the prevention of breast cancer is still in its infancy, much can be learned from what we know about the drug and its obstacles [40,41]. Critical

stages include overcoming obstacles in translation, undertaking extensive clinical trials, and incorporating thymoquinone into the prevention and treatment of breast cancer. My sincere aspiration is that thymoquinone will gradually establish itself as a dependable and efficacious remedy for breast cancer.

CONCLUSION

In conclusion, the robust preclinical evidence that thymoquinone may prevent breast cancer is corroborated by the clinical trials. Laboratory experiments have demonstrated the presence of anticancer, antioxidant, and anti-inflammatory properties, which instills optimism regarding the feasibility of employing a multimodal approach to impede the intricate pathways of breast cancer. For the clinical application of preclinical research, precision is vital. In the absence of clinical evidence, thymoquinone's safety and efficacy in humans must be confirmed through meticulously designed clinical trials. For these trials to provide a comprehensive evaluation of thymoquinone, standardised formulations, a diversity of breast cancer subtypes, and a diverse patient population are required. Thymoquinone is a broadly accessible, natural, and efficacious preventative. The long-utilized *Nigella sativa* plant may prevent breast cancer. Initial clinical trials of this chemical component revealed no adverse effects, indicating that it may have potential as a preventative treatment. This lucrative domain requires additional research. Further research is required to determine the optimal thymoquinone concentrations, treatment durations, and drug synergies. In clinical investigations, longer-term follow-ups and larger patient populations can aid in determining the preventative efficacy of a product. Despite initial clinical validation, thymoquinone exhibits potential as an inexpensive and natural preventive measure against breast cancer. Research will augment our understanding of the function of thymoquinone. Implementing thymoquinone into evidence-based breast cancer preventative methods will be facilitated by this.

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