

Effect of *Chlorophytum borivilianum* on erectile dysfunction

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Abstract

Chlorophytum borivilianum, which is commonly referred to as Safed Musli, is a medicinal plant that is extensively acknowledged within the framework of traditional Ayurvedic medicine for its potential to promote male reproductive health, vitality, and overall vigor. As a member of the Vajikaran Rasayana category, Safed Musli provides considerable therapeutic advantages, which encompass its aphrodisiac characteristics, effects analogous to testosterone, and its capacity as an antioxidant. This review scrutinizes the mechanisms that underpin the influence of Safed Musli on critical reproductive parameters, including sperm quality, testosterone synthesis, libido, and sexual performance. The steroidal saponins present in the herb mimic the action of testosterone, thereby facilitating spermatogenesis and maintaining hormonal equilibrium, whereas its antioxidant properties mitigate oxidative stress, thereby safeguarding sperm DNA and enhancing motility. Comparative analyses with other Vajikaran Rasayana herbs, such as *Asparagus racemosus* (Shatavari) and *Curculigo orchoides* (Kali Musli), underscore the superior androgenic properties of Safed Musli, especially in relation to augmenting testosterone levels and improving sperm characteristics. Although Shatavari contributes to reproductive health by promoting hormonal balance and enhancing vitality, Kali Musli exhibits pronounced aphrodisiac properties, particularly in the enhancement of libido and erectile function. The multifaceted role of Safed Musli in addressing male infertility, hormonal dysregulation, and sexual dysfunction emphasizes its significance within both traditional and contemporary therapeutic paradigms. Subsequent research endeavors should concentrate on elucidating its bioactive constituents, optimizing dosage protocols, and conducting extensive clinical trials to validate its efficacy and safety.

Keywords: *Chlorophytum borivilianum*; Safed Musli; Vajikaran Rasayana; Aphrodisiac

1. Introduction

Chlorophytum borivilianum, commonly known as *Safed Musli*, is a medicinal herb native to India. It belongs to the family Asparagaceae and is widely recognized in traditional Ayurvedic medicine for its various health benefits.[1] The plant is characterized by its slender, green leaves and small white flowers. Its roots are the most utilized part, known for their therapeutic properties, especially in improving sexual health, energy levels, and overall vitality.[2] The herb has been used for centuries to treat various ailments, such as fatigue, sexual dysfunction, and general debility. It is classified as an adaptogen, meaning it helps the body resist physical, chemical, and biological stressors. The roots of *Safed Musli* are rich in saponins, alkaloids, and other bioactive compounds that contribute to its medicinal properties, making it a popular choice in natural remedies aimed at enhancing male health and treating erectile dysfunction.[3] Studies have shown that *Chlorophytum borivilianum* has potential aphrodisiac effects, which may help address erectile dysfunction (ED) by boosting testosterone levels, improving blood circulation, and enhancing libido. The herb's natural composition promotes hormonal balance and supports the body's ability to recover from stress, both of which are important factors in sexual health.[4]

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1.1. Botanical Description

Chlorophytum borivilianum, commonly known as Safed Musli, is a perennial herb that typically grows to a height of 30-60 cm. It has a distinctive appearance, characterized by its narrow, linear, and long leaves that are green in colour.[5] The plant's roots are fleshy, fibrous, and often tuberous, which are the part of the plant used for medicinal purposes. The roots have a white to pale yellow colour and possess a mild odour.[6] The leaves of Safed Musli are long, linear, and narrow, growing in a rosette-like arrangement from the base of the plant. They can grow up to 30 cm in length and have parallel venation typical of plants in the Asparagaceae family.[7] The flowers are small, white, and arranged in clusters. They are typically inconspicuous and bloom during the flowering season, usually in the summer months. The flowers grow from a short, branched inflorescence.[8] The roots of *Chlorophytum borivilianum* are the most valued part of the plant. They are tuberous, fleshy, and contain a range of bioactive compounds, such as saponins, alkaloids, and glycosides, which contribute to the plant's medicinal properties. The roots are often harvested, dried, and processed into powders or extracts for therapeutic use.[9]

1.2. Distribution

Chlorophytum borivilianum is primarily native to India and is found in the tropical and subtropical regions of the country. The plant thrives in dry, sandy, and well-drained soils, often growing in regions with a warm, temperate climate.[10] *Safed Musli* is mainly found in the western and central parts of India, including the states of Maharashtra, Madhya Pradesh, Gujarat, and Rajasthan. It can also be found in other parts of India, particularly in areas with low to moderate rainfall.[11] It is typically found in dry forests, grasslands, and other areas with poor or sandy soil conditions. It tends to grow in the wild but is also cultivated in several regions due to its increasing demand for its medicinal and commercial value.[12] While the plant is native to India, *Chlorophytum borivilianum* is also cultivated in other parts of Asia and Africa, as well as in some parts of the world where tropical conditions exist, though its most significant distribution remains in India.[13]

1.3. Traditional Uses of *Chlorophytum borivilianum* in Ayurvedic Medicine

Chlorophytum borivilianum, commonly known as *Safed Musli*, has been a cornerstone in traditional Ayurvedic medicine for centuries due to its numerous health benefits. In Ayurveda, it is considered a potent tonic and adaptogen, offering a wide range of therapeutic properties aimed at improving overall vitality, stamina, and sexual health. Below are some of its traditional uses in Ayurvedic medicine.

Table 1 Traditional Uses and Preparations of *Chlorophytum borivilianum* (Safed Musli)

Traditional Uses	Details	References
Aphrodisiac and Sexual Health	Used to enhance sexual performance, libido, and treat sexual dysfunction (e.g., erectile dysfunction, premature ejaculation). Stimulates the reproductive system and balances hormones.	[14][15]
For Men	Increases sperm count, improves semen quality, enhances sexual desire, boosts testosterone levels, and improves genital blood circulation.	[16][17]
For Women	Regulates hormonal balance, improves reproductive function, and addresses low libido and infertility.	[15][18]
Energy and Vitality	Acts as a powerful tonic to combat fatigue, weakness, and debility; improves endurance and vitality.	[19]
Adaptogenic Properties	Helps the body resist physical and emotional stress by supporting adrenal glands and maintaining hormonal balance.	[20]
Reproductive Health and Fertility	Promotes hormone regulation and improves the quality of eggs and sperm.	[21][22]
For Men	Enhances sperm production and quality, stimulates testes, increases semen volume, and improves sperm motility.	[16][23]
For Women	Regulates menstrual cycles, treats amenorrhea, and enhances ovarian function to improve fertility.	[18][21]
General Health and Immune System Support	Improves overall health, prevents illness, and supports natural healing processes.	[23]

Anti-inflammatory and Antioxidant	Protects the body from free radical damage, reduces inflammation, and supports natural defenses.	[24][25]
Boosting Immunity	Enhances resistance to infections and illnesses.	[26]
Digestive Health	Promotes digestive health, alleviates constipation and indigestion, soothes the digestive tract, and reduces bloating and gas.	[27]
Skin and Hair Health	Reduces wrinkles, improves skin tone, promotes hair growth, and nourishes and moisturizes skin.	[28]
Muscle Strength and Joint Health	Strengthens muscles, supports joint health, improves flexibility, and eases pain caused by arthritis or weakness.	[29]
Detoxification and Blood Purification	Purifies the blood, cleanses toxins, and supports kidney and liver detoxification.	[30]
Traditional Preparations	Forms	References
Powder	Dried root ground into powder, mixed with milk or water.	[31]
Decoction	Roots boiled in water to extract medicinal properties.	[32]
Capsules or Tablets	Modern form for easier consumption.	[33]

2. Phytochemical Composition of *Chlorophytum borivilianum* (Safed Musli)

Chlorophytum borivilianum (Safed Musli) is renowned for its rich phytochemical profile, which contributes to its wide range of medicinal properties. The roots of the plant, which are primarily used for therapeutic purposes, contain a variety of bioactive compounds. These phytochemicals are responsible for the herb's aphrodisiac, adaptogenic, anti-inflammatory, antioxidant, and immune-boosting effects.

2.1. Saponins and Sapogenins in *Chlorophytum borivilianum* (Safed Musli)

Saponins are a class of bioactive compounds found in *Chlorophytum borivilianum* (Safed Musli), which are glycosides with a sugar moiety attached to an aglycone or sapogenin. These compounds have various pharmacological effects, including enhancing sexual health, supporting immune function, reducing inflammation, and improving energy levels. Saponins are primarily responsible for the herb's therapeutic effects, such as aphrodisiac properties, immune system modulation, antioxidant and anti-inflammatory effects, cholesterol reduction, and anticancer effects.[34] Sapogenins, the non-sugar part of saponins, play a crucial role in their biological activities and contribute to their health benefits. Steroidal sapogenins, similar to hormones like testosterone and estrogen, contribute to the herb's ability to improve sexual health, fertility, and energy levels. They also influence hormone balance, regulate estrogen and progesterone levels, and protect cells from oxidative damage. Sapogenins also have health benefits, such as muscle building and strength, anti-fatigue, and adaptogenic effects. Further research is needed to fully understand their role in cancer prevention.[35]

Table 2 Bioactive Compounds in *Chlorophytum borivilianum* and Their Medicinal Effects.

Bioactive Compound	Key Effects	Medicinal Effects	References
Alkaloids	Anti-inflammatory, Analgesic, Sexual Health	Reduces inflammation, provides pain relief, boosts libido, enhances sexual performance	[36], [37]
Flavonoids	Antioxidant, Anti-inflammatory, Cardiovascular Health	Neutralizes free radicals, reduces inflammation, improves blood circulation, supports heart health	[38], [39]
Triterpenoids	Anti-inflammatory, Antioxidant, Antimicrobial	Reduces inflammation and oxidative stress, protects against infections	[40], [41]
Glycosides	Circulatory Health, Detoxification	Improves blood flow, supports detoxification processes	[42], [43]

Steroids	Sexual Health, Fertility, Muscle Strength	Boosts testosterone, improves sperm quality, enhances muscle growth and endurance	[44], [45]
Tannins	Digestive Health, Wound Healing, Antioxidant Properties	Treats gastrointestinal issues, supports wound healing, reduces oxidative stress	[46], [47]
Essential Oils	Antimicrobial, Anti-inflammatory, Adaptogenic	Fights infections, reduces inflammation, supports stress adaptation	[48], [49]
Carbohydrates and Proteins	Energy, Stamina, Muscle Repair	Provides energy, promotes muscle growth, supports recovery	[50], [51]
Vitamins and Minerals	Immune Support, Bone and Cardiovascular Health, Oxygen Transport	Boosts immunity, supports bone and heart health, improves energy levels	[52], [53]

2.2. Effects of *Chlorophytum borivilianum* (Safed Musli) on Erectile Function

Chlorophytum borivilianum (Safed Musli) has long been used in traditional medicine as a potent aphrodisiac and a remedy for improving sexual health, particularly in enhancing erectile function. Several bioactive compounds in the herb, such as saponins, sapogenins, alkaloids, and steroidal compounds, contribute to its positive effects on erectile function. These compounds work synergistically to address the underlying physiological and hormonal factors that affect male sexual health.

Table 3 Effects of *Chlorophytum borivilianum* on Erectile Function.

Effect	Mechanism	Impact on Erectile Function	References
Enhancement of Testosterone Levels	Sapogenins in Safed Musli mimic testosterone and stimulate its secretion.	Improves libido, sexual stamina, and overall sexual health by increasing testosterone levels.	[54], [55]
Improved Blood Circulation	Saponins promote vasodilation, improving blood flow to the penile area.	Enhances erectile function by improving blood circulation to the penis, leading to stronger erections.	[56]
Reduction of Oxidative Stress	Antioxidants neutralize free radicals, reducing oxidative damage to blood vessels and nerves.	Protects penile tissues from oxidative damage, improving erectile function and preventing age-related erectile dysfunction.	[57]
Improvement in Sperm Quality	Steroidal saponins and bioactive compounds improve sperm production, motility, and count by boosting testosterone levels.	Enhances sperm health, leading to improved hormonal balance, sexual confidence, and reduced performance anxiety.	[58]
Anti-Inflammatory and Adaptogenic Properties	Flavonoids and triterpenoids reduce inflammation; saponins help the body adapt to stress.	Reduces performance anxiety and inflammation, supporting overall sexual health by balancing cortisol levels.	[59]
Increased Sexual Stamina	Carbohydrates, proteins, and steroidal compounds provide energy and improve physical endurance.	Enhances sexual performance by improving stamina, leading to longer-lasting sexual activity and reduced premature ejaculation.	[60]
Mood and Stress Reduction	Alkaloids and saponins have mild sedative and mood-enhancing effects, reducing anxiety and stress.	Helps prevent psychological erectile dysfunction (ED) by reducing stress and improving sexual confidence.	[61]
Improved Overall Vitality and Health	Bioactive compounds nourish the body, improving energy, vitality, and overall health.	Supports erectile function by reducing fatigue, improving overall physical strength and health, leading to enhanced sexual vitality.	[62]

2.3. Penile Erection Index (PEI)

The Penile Erection Index (PEI) is a clinical measure used to assess erectile function, often as part of studies or evaluations of erectile dysfunction (ED).[63] It is a composite index that combines multiple factors related to erectile function, including the frequency, quality, and duration of erections, to give an overall assessment of sexual health.[64] The PEI is generally used in clinical research and practice to gauge the effectiveness of treatments for erectile dysfunction.[65] This measures how often an individual experiences an erection, which can be an indicator of underlying physiological or psychological health. For example, reduced frequency can point to issues like low testosterone or poor blood flow, both of which are important in the context of erectile dysfunction.[66] This evaluates the firmness and rigidity of the erection. An erection that is not firm enough to engage in sexual intercourse or maintain throughout the activity may indicate underlying problems such as vascular issues, hormonal imbalances, or psychological factors like anxiety or stress.[67] This component measures how long an erection lasts once it occurs. A decrease in duration could suggest problems such as inadequate blood flow, nerve damage, or the presence of underlying health conditions like diabetes or hypertension, which can affect erectile function.[68] Some versions of the PEI also take into account the individual's satisfaction with the quality of their erections, which can be influenced by both physiological and psychological factors. The Penile Erection Index is used to assess the severity of erectile dysfunction (ED) and track progress over time in response to treatments. It helps doctors understand the underlying causes of ED, which could be physical, psychological, or a combination of both. [69] The effectiveness of treatment interventions, including lifestyle changes, medications, or herbal remedies like *Chlorophytum borivilianum* (Safed Musli).[70] Whether there are comorbid conditions (e.g., cardiovascular disease, diabetes, or hormonal imbalances) affecting erectile function.[71] The PEI is useful for determining the severity of ED in patients and identifying areas for improvement.[72] When used during clinical trials or in response to specific treatments for ED, the PEI can be used to measure how effective a given treatment is.[73] The PEI can also reveal how psychological factors, such as stress or anxiety, might affect erectile function.[74]

2.4. Nitric Oxide (NO) Release and Vasodilation in Erectile Function

Nitric oxide (NO) is a crucial molecule in the body that regulates vascular tone, blood flow, and erectile function. It triggers vasodilation, a process essential for the physiological mechanism behind penile erections. Understanding how NO works and its relationship with vasodilation can help explain how certain treatments, including herbs like *Chlorophytum borivilianum* (Safed Musli), may improve erectile function.[75] During sexual arousal, signals from the nervous system or external stimuli cause the release of NO from the endothelial cells lining blood vessels in the penis.[76] NO activates an enzyme called guanylate cyclase, which increases the levels of cyclic GMP (cGMP) inside smooth muscle cells.[77] This promotes smooth muscle relaxation, leading to vasodilation (widening of blood vessels). As the blood vessels dilate, more blood flows into the erectile tissues of the penis, leading to an erection.[78] Penile vasodilation (dilation of blood vessels) increases blood flow into the erectile tissues, resulting in an erection. At the same time, the veins draining blood from the penis constrict to trap blood within the erectile tissues, helping to maintain the erection.[79] In the context of erectile dysfunction (ED), inadequate NO production or impaired NO signaling can lead to poor vasodilation, resulting in insufficient blood flow to the penis. This is one of the main causes of ED in many individuals.[80] Several factors can influence the production and release of nitric oxide, including diet, exercise, health conditions, and herbal remedies. Certain foods, particularly those rich in nitrates, are known to boost NO production, promoting vasodilation and improving circulation. Physical activity has been shown to increase NO production by improving endothelial function, supporting better blood flow and erectile function. Chronic conditions like hypertension, diabetes, and obesity can impair NO production by damaging the endothelial cells, leading to reduced vasodilation and contributing to erectile dysfunction.[81] Herbal remedies, such as *Chlorophytum borivilianum* (Safed Musli), may influence nitric oxide production and enhance erectile function through their bioactive compounds, particularly saponins and alkaloids. Saponins are known to have vasodilatory effects and may help enhance nitric oxide production. Some compounds in Safed Musli may also stimulate endothelial cells to release more NO, improving blood flow and circulation, which may contribute to better erectile function.[82] Inhibiting phosphodiesterase type 5 (PDE5), an enzyme that breaks down cyclic GMP (cGMP), can enhance NO-induced vasodilation by maintaining elevated cGMP levels. Medications like sildenafil (Viagra) are PDE5 inhibitors, and some herbal remedies may have similar effects in promoting NO release and improving erectile function. Combining lifestyle changes, medications, and natural supplements may help maximize nitric oxide production, improve vasodilation, and enhance overall erectile function.[83]

2.5. Impact of *Chlorophytum borivilianum* (Safed Musli) on Reproductive Parameters

Chlorophytum borivilianum (commonly known as Safed Musli) is traditionally used in Ayurvedic medicine as an aphrodisiac and a general tonic for enhancing reproductive health. Its effects on reproductive parameters, including sperm quality, testosterone levels, and fertility, have been the subject of various studies. This plant contains a wide

range of bioactive compounds such as saponins, alkaloids, sterols, and peptides, which contribute to its positive effects on male reproductive health.

Table 4 Benefits of *Chlorophytum borivilianum* on Male Reproductive Health.

Benefit	Description	Mechanism/Impact	Reference
Improvement in Sperm Quality	Enhances sperm count, motility, and morphology, crucial for male fertility.	Increased sperm count due to testosterone boosting, enhanced sperm motility through antioxidant effects, and improved morphology for better fertilization potential.	[84]
Testosterone Boosting Effects	Increases testosterone levels, benefiting sperm production, libido, and sexual health.	Steroidal saponins mimic testosterone, stimulating the production of androgens to support reproductive health.	[85]
Antioxidant Properties & Oxidative Stress Reduction	Reduces oxidative stress, preventing sperm DNA and membrane damage, improving sperm viability.	Neutralizes free radicals to protect sperm and reproductive tissues, improving sperm motility, function, and overall quality.	[86]
Adaptogenic Properties and Stress Reduction	Reduces stress, maintaining optimal hormonal balance for fertility.	Balances cortisol and stress hormones, maintaining testosterone levels and promoting healthy sperm production.	[87]
Increased Libido & Sexual Function	Enhances sexual desire and energy, improving the chances of conception.	Boosts libido via testosterone increases, improved energy, and overall well-being, contributing to better sexual health and frequent intercourse.	[88]
Effects on Semen Volume & Quality	May increase semen volume, supporting fertility potential.	Supports semen production by enhancing testosterone and sperm quality, thus increasing semen volume during ejaculation.	[89]
Potential Benefits for Erectile Function	Improves erectile function, supporting sexual performance.	Boosts blood flow via nitric oxide production, improving erectile function and contributing to more frequent, effective sexual intercourse.	[90]
Fertility Enhancement	Enhances fertility by improving sperm quality, testosterone levels, and sexual function.	Positive effects on sperm count, motility, morphology, testosterone levels, and sexual health make Safed Musli an option for improving male fertility.	[91]

2.6. Sperm Count and Quality: Impact of *Chlorophytum borivilianum* (Safed Musli)

Chlorophytum borivilianum (Safed Musli) has been shown to positively influence sperm count and quality, making it an important herb for improving male fertility. Numerous studies have reported that *Safed Musli* helps increase sperm count in infertile men. It is believed that the steroidal saponins found in *Safed Musli* may act similarly to testosterone, stimulating spermatogenesis (the process of sperm production). The increase in testosterone levels helps in the optimal functioning of the male reproductive system, thus improving sperm count.[92] The bioactive compounds in *Safed Musli*, particularly saponins and alkaloids, may support the hypothalamic-pituitary-gonadal axis, which regulates the production of hormones like testosterone. Higher testosterone levels promote spermatogenesis in the testes, leading to an increase in sperm count.[93] *Safed Musli* has been found to improve sperm motility, which is crucial for fertility as sperm need to be able to swim effectively to reach and fertilize the egg. The antioxidant properties of *Safed Musli* help reduce oxidative stress, which is a major factor contributing to reduced sperm motility. By neutralizing free radicals, it protects sperm cells from damage, improving their movement.[94] *Safed Musli* may also help improve sperm morphology, or the shape and structure of sperm. Abnormal sperm morphology can impair the sperm's ability to fertilize an egg. The improved antioxidant status from *Safed Musli* contributes to better sperm quality, ensuring that sperm have the proper shape to fertilize the egg.[95] Oxidative stress can cause DNA damage in sperm cells, reducing motility, morphology, and overall quality. The antioxidant compounds in *Safed Musli*, such as flavonoids, saponins, and phenolic compounds, help protect sperm from oxidative damage, ensuring better sperm health.[96]

2.7. Seminal Fructose Content and Its Significance

Seminal fructose is an important component of seminal fluid and plays a critical role in providing energy for sperm motility. Fructose is primarily produced by the seminal vesicles and serves as a major energy source for sperm cells during ejaculation.[97] Fructose is essential for sperm motility because it provides the necessary fuel for sperm to swim effectively toward the egg. It is especially crucial during prolonged sperm activity, such as when sperm travel through the female reproductive tract to fertilize an egg.[98] Low seminal fructose content can be an indicator of dysfunction in the seminal vesicles or prostate, both of which are critical for producing seminal fluid. Seminal fructose content is often measured in fertility assessments to evaluate the function of these organs.[9] Although there is limited direct research on *Safed Musli's* effect on seminal fructose, the herb's positive influence on male reproductive health suggests it may have an indirect impact on seminal fluid composition, including fructose content.[100] As *Safed Musli* is known to support testosterone production, which is essential for the functioning of the male reproductive organs, it may help maintain the health of the seminal vesicles and prostate. This could support the normal production of seminal fluid, including fructose.[101] By improving sperm motility and quality, *Safed Musli* could also enhance sperm's ability to utilize fructose efficiently for energy, further supporting fertility.[102] The antioxidant properties of *Safed Musli* may indirectly benefit the seminal vesicles by reducing oxidative stress in the reproductive system. This could help ensure that the seminal vesicles function optimally, contributing to normal levels of fructose in seminal fluid.[103]

2.8. Hormonal Influences of *Chlorophytum borivilianum* (Safed Musli) on Male Reproductive Health

Chlorophytum borivilianum (Safed Musli) is widely used in traditional medicine for enhancing male reproductive health, and much of its effectiveness is attributed to its hormonal influences. These effects are primarily mediated through its ability to support the endocrine system, particularly by influencing testosterone levels, improving spermatogenesis, and balancing other hormones related to sexual function and fertility.

Table 5 Hormonal Effects of *Chlorophytum borivilianum* on Male Reproductive Health.

Hormonal Effect	Description	Mechanism/Impact	Reference
Testosterone Production	Safed Musli influences testosterone production, crucial for sperm production, libido, and overall reproductive health.	Steroidal saponins mimic testosterone or act as precursors to androgenic hormones, stimulating Leydig cells and supporting spermatogenesis.	[104]
Influence on LH and FSH	Regulates LH and FSH, which are crucial for testosterone production and sperm production.	Stimulates the pituitary gland to release LH and FSH, supporting testosterone synthesis and spermatogenesis.	[105]
Prolactin Modulation	Helps normalize prolactin levels, which can negatively impact testosterone and sexual function.	Lowers prolactin levels, which in turn enhances GnRH secretion, leading to increased LH and FSH levels and better testosterone production.	[106]
Cortisol Regulation	Reduces cortisol, a stress hormone that negatively affects testosterone levels and reproductive health.	As an adaptogen, Safed Musli helps reduce cortisol, restoring hormonal balance and supporting optimal testosterone production.	[107]
Estrogenic Effects (Low Influence)	Mild estrogenic effects that help maintain hormonal balance between testosterone and estrogen.	Ensures proper hormonal balance, preventing testosterone levels from dipping too low, which would impact sperm production and sexual function.	[108]
Thyroid Function	Safed Musli may regulate thyroid function, which influences testosterone production and overall reproductive health.	Helps regulate thyroid hormone levels, supporting testosterone production and overall male reproductive health.	[109]

Progesterone Regulation	Safed Musli may influence progesterone levels in men, which support testosterone production and overall hormonal balance.	Ensures balanced progesterone levels, helping maintain hormonal harmony and supporting proper testosterone levels.	[110]
Overall Hormonal Balance	Safed Musli promotes overall hormonal balance, creating an optimal environment for male fertility.	By balancing testosterone, LH, FSH, prolactin, cortisol, and thyroid hormones, Safed Musli supports sperm production, sexual function, and reproductive health.	[111]

2.9. Testosterone-like Effects of *Chlorophytum borivillianum* (Safed Musli)

Chlorophytum borivillianum (Safed Musli) has been shown to have testosterone-like effects, which contribute to its reputation as a potent aphrodisiac and fertility-enhancing herb in traditional medicine. These effects are largely due to the presence of bioactive compounds, especially saponins, which can influence the endocrine system and mimic the action of testosterone.[112] The primary compounds in *Safed Musli* that contribute to its testosterone-like effects are steroidal saponins. These compounds have structural similarities to testosterone and other androgenic hormones. Because of this similarity, steroidal saponins can interact with androgen receptors in the body, leading to enhanced testosterone activity.[113] The saponins in *Safed Musli* bind to androgen receptors, similar to testosterone, and activate the signaling pathways involved in testosterone action. This interaction can stimulate processes like spermatogenesis (sperm production) and libido, which are directly regulated by testosterone.[114] In addition to mimicking the effects of testosterone, *Safed Musli* may stimulate the body to produce more of its own testosterone. It is believed that *Safed Musli* may act on the hypothalamic-pituitary-gonadal (HPG) axis, which regulates the release of gonadotropins (LH and FSH). These hormones stimulate the Leydig cells in the testes to produce testosterone.[115] By mimicking testosterone and boosting its production, *Safed Musli* plays a role in supporting spermatogenesis, leading to improved sperm count, motility, and overall sperm quality.[116] The testosterone-like effects of *Safed Musli* extend to sexual health and function. Testosterone is a key regulator of male sexual behavior, including libido, erectile function, and overall sexual drive.[117] As a result of its ability to mimic and stimulate the action of testosterone, *Safed Musli* has been shown to improve libido and sexual desire, making it a commonly used herb in treating male sexual dysfunction and low libido. The plant's testosterone-like effects also enhance blood flow and nitric oxide production, which contribute to better erectile function. By improving these processes, *Safed Musli* can assist men with erectile dysfunction (ED).[118]

2.10. Serum Testosterone Levels and the Impact of Safed Musli

Testosterone is a key hormone for male fertility, sexual function, and overall well-being. Maintaining optimal serum testosterone levels is crucial for spermatogenesis, libido, and general health.[119] Several studies have shown that *Safed Musli* can increase serum testosterone levels. This effect is believed to be mediated by its saponin content, which supports the production of testosterone in the testes. Increased levels of testosterone have a direct impact on reproductive health by stimulating sperm production and improving sperm quality.[120] *Safed Musli* likely exerts its testosterone-boosting effects through its influence on the HPG axis. By enhancing the secretion of gonadotropins (LH and FSH), it stimulates the Leydig cells in the testes, leading to an increase in testosterone production. Elevated testosterone levels, in turn, promote spermatogenesis and improve sexual function.[121] Higher serum testosterone levels are associated with better sperm quality, higher sperm count, and improved motility. For men experiencing low testosterone levels or infertility, *Safed Musli* may provide a natural way to support hormonal balance and enhance reproductive function.[122] As men age, serum testosterone levels tend to decline, leading to symptoms such as decreased libido, reduced energy, erectile dysfunction, and poorer sperm quality. *Safed Musli* has been shown to have rejuvenating effects on male sexual health, including an increase in testosterone levels, which can help mitigate these age-related issues.[123] By boosting testosterone levels, *Safed Musli* may help aging men maintain sexual health and fertility. Increased testosterone can lead to improved energy, libido, and sexual function, as well as better sperm quality, even in older men.[124] For men with low testosterone levels or infertility issues, *Safed Musli* may help restore hormonal balance. By increasing serum testosterone levels, the herb supports the production of healthy sperm and improves overall male fertility.[125] Low testosterone levels are often linked to poor sperm quality and lower sperm count. *Safed Musli's* ability to boost testosterone can improve these parameters, offering a natural remedy for men dealing with fertility issues.[126]

2.11. Comparison of *Chlorophytum borivillianum* (Safed Musli) with Other Vajikaran Rasayana Herbs

Vajikaran Rasayana is a category of Ayurvedic herbs and formulations used to enhance vigor, vitality, and sexual health in men. These herbs are also known for improving fertility, stamina, and reproductive function. *Chlorophytum borivillianum* (Safed Musli) is one of the most renowned herbs in this category. In comparison, other herbs like *Asparagus*

racemosus (Shatavari) and *Curculigo orchioides* (Kali Musli) also hold a prominent place in Vajikaran Rasayana therapy. Below is a comparison of these herbs based on their effects, mechanisms of action, and therapeutic benefits for male reproductive health.

Table 6 Comparison of *Chlorophytum borivilianum* with Other Vajikaran Rasayana Herbs.

Parameter	<i>Chlorophytum borivilianum</i> (Safed Musli)	<i>Asparagus racemosus</i> (Shatavari)	<i>Curculigo orchioides</i> (Kali Musli)
Primary Effect	Direct testosterone-like effects, improves sperm quality, count, motility, and libido.	Hormonal balance, improves vitality, mild estrogenic effects, supports sperm quality.	Strong aphrodisiac, enhances libido, boosts testosterone, supports erectile function.
Testosterone-like Effects	Strong androgenic activity, increases testosterone levels directly.	Milder, more focused on balancing testosterone and other hormones.	Direct action on increasing testosterone, supports sexual performance.
Impact on Sperm Quality	Significant increase in sperm count, motility, and quality.	Improves sperm quality through hormonal balance.	Enhances sperm quality and vitality.
Sexual Function	Improves libido, supports sexual performance.	Balances hormones that indirectly improve libido.	Enhances sexual desire, erectile function, and stamina.
Hormonal Mechanism	Directly stimulates testosterone production.	Supports hormonal balance, particularly for reproductive health.	Direct impact on testosterone and libido, enhancing sexual health.
Common Uses	Male infertility, low testosterone, erectile dysfunction, sexual fatigue.	Male fertility issues related to hormonal imbalance, vitality support.	Erectile dysfunction, low libido, sexual performance enhancement.
Additional Benefits	Antioxidant and immunomodulatory effects, boosts overall health.	Adaptogenic, supports general health and vitality.	Aphrodisiac, energy booster, supports erectile function and sexual health.
Reference	[127]	[128]	[129]

2.12. Mechanisms of Action of *Chlorophytum borivilianum* (Safed Musli)

Chlorophytum borivilianum (Safed Musli) is known for its wide-ranging therapeutic effects, particularly in the realm of male reproductive health. In addition to its aphrodisiac and testosterone-boosting properties, Safed Musli also exerts several other beneficial actions, including antioxidant and immunomodulatory effects.[130] These mechanisms play a crucial role in enhancing overall health, fertility, and sexual function.

2.12.1. Antioxidant Properties

Antioxidants are compounds that protect cells from oxidative stress by neutralizing free radicals. Oxidative stress occurs when there is an imbalance between free radicals and antioxidants in the body, leading to cellular damage. In the context of reproductive health, oxidative stress can negatively affect sperm quality, motility, and overall fertility.[131] The antioxidant properties of *Safed Musli* play a key role in reducing oxidative damage to sperm and other cells involved in reproduction, thus improving fertility and sexual health.[132]

2.13. Mechanisms of Antioxidant Action in Safed Musli

Safed Musli contains several bioactive compounds, including saponins, alkaloids, and flavonoids, which possess strong antioxidant activity. These compounds can neutralize free radicals and reactive oxygen species (ROS), thereby reducing oxidative damage to cells and tissues, including sperm cells.[134] Oxidative stress is one of the major causes of sperm DNA damage, which can lead to reduced sperm motility, lower fertilization potential, and even infertility. The antioxidant compounds in *Safed Musli* help protect sperm DNA by neutralizing ROS, thereby enhancing sperm quality and preventing premature cell death.[135] The antioxidant properties of *Safed Musli* help protect the testes from oxidative damage caused by toxins, environmental stressors, or metabolic byproducts. This protection supports normal

testicular function, including testosterone production and spermatogenesis.[136] Oxidative stress is often accompanied by inflammation. The antioxidant properties of *Safed Musli* also help reduce inflammatory markers in the body, further supporting reproductive health and overall wellness.[137]

2.14. Immunomodulatory Effects

The immune system plays a crucial role in maintaining reproductive health by protecting the body from infections, balancing inflammation, and ensuring the proper functioning of reproductive organs. In the context of male fertility, an overactive immune response can lead to autoimmune reactions against sperm, reduced sperm motility, and infertility.[138] *Safed Musli* has been shown to modulate the immune system, enhancing immune function when needed and suppressing excessive immune responses that may hinder fertility.[139]

2.14.1. Mechanisms of Immunomodulatory Action in Safed Musli

Cytokines are signaling molecules that regulate immune responses. *Safed Musli* has been shown to modulate cytokine production, balancing pro-inflammatory and anti-inflammatory cytokines. By reducing excessive inflammation, *Safed Musli* helps maintain a healthy immune response in the reproductive system.[140] *Safed Musli* boosts the activity of immune cells, such as macrophages and lymphocytes, which play a key role in fighting infections and promoting tissue repair. This immune-enhancing effect is beneficial for overall health and fertility, as it supports the body's defense mechanisms without causing an overactive immune response.[141] Chronic inflammation in the reproductive organs, such as the testes or prostate, can lead to reduced sperm quality, erectile dysfunction, and other reproductive issues. *Safed Musli* has demonstrated anti-inflammatory properties, helping to reduce inflammation in reproductive tissues and improve overall sexual and reproductive health.[142] An important feature of immune system regulation is the ability to tolerate foreign cells, such as sperm. *Safed Musli* helps modulate immune tolerance, preventing the immune system from attacking sperm cells and supporting fertility in individuals with autoimmune-related infertility issues.[143]

2.15. Safety and Toxicity Studies

Vajikaran Rasayana is a category of Ayurvedic herbs used to improve men's vigor, vitality, and sexual health. These herbs are known for improving fertility, stamina, and reproductive function. *Chlorophytum borivillianum* (*Safed Musli*) is a renowned herb in this category, while other herbs like *Asparagus racemosus* (*Shatavari*) and *Curculigo orchioides* (*Kali Musli*) also hold a prominent place in this therapy.[144] *Shatavari* is a perennial herb found in tropical and subtropical regions of India, known for its tuberous roots. It is traditionally used to improve sperm quality, enhance libido, and support overall vitality in men. It has mechanisms of action such as adaptogenic and hormonal balance, testosterone support, and spermatogenesis. While *Safed Musli* has more direct testosterone-like effects, it is generally regarded as more potent in increasing sperm count and motility due to its strong androgenic activity.[145] *Kali Musli*, also known as *Curculigo orchioides*, is a perennial herb found in the Indian subcontinent, used in traditional medicine for various health concerns, including reproductive health. It is traditionally used to improve male sexual health, enhance libido, and treat sexual dysfunction, such as erectile dysfunction and premature ejaculation. Both herbs are considered potent aphrodisiacs that enhance sexual function and fertility, with *Kali Musli* being more associated with boosting sexual drive and performance.[146]

2.16. Future Research Directions

Vajikaran Rasayana is a category of Ayurvedic herbs used to improve men's vigor, vitality, and sexual health. These herbs are known for improving fertility, stamina, and reproductive function. *Chlorophytum borivillianum* (*Safed Musli*) is a renowned herb in this category, while other herbs like *Asparagus racemosus* (*Shatavari*) and *Curculigo orchioides* (*Kali Musli*) also hold a prominent place in this therapy.[147] *Shatavari* is a perennial herb found in tropical and subtropical regions of India, known for its tuberous roots. It is traditionally used to improve sperm quality, enhance libido, and support overall vitality in men. It has mechanisms of action such as adaptogenic and hormonal balance, testosterone support, and spermatogenesis. While *Safed Musli* has more direct testosterone-like effects, it is generally regarded as more potent in increasing sperm count and motility due to its strong androgenic activity.[148] *Kali Musli*, also known as *Curculigo orchioides*, is a perennial herb found in the Indian subcontinent, used in traditional medicine for various health concerns, including reproductive health. It is traditionally used to improve male sexual health, enhance libido, and treat sexual dysfunction, such as erectile dysfunction and premature ejaculation. Both herbs are considered potent aphrodisiacs that enhance sexual function and fertility, with *Kali Musli* being more associated with boosting sexual drive and performance.[149]

3. Conclusion

Chlorophytum borivilianum (Safed Musli) demonstrates significant potential as a therapeutic agent for male reproductive health. Its ability to enhance testosterone levels, improve sperm quality, and support sexual function establishes its role as a cornerstone herb in Vajikaran Rasayana therapy. Safed Musli's superior androgenic and antioxidant properties position it as a powerful natural remedy for male infertility and sexual dysfunction. Comparative analysis with Shatavari and Kali Musli highlights its unique efficacy in addressing diverse reproductive challenges. Future studies should aim to substantiate these findings through rigorous clinical trials and explore its synergistic potential in combination therapies.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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