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From probiotics to postbiotics: microbial approaches in male reproductive health

Gamze ZENGİN * [1], Kerem AZKESKİN[2], Fatih KAR[2]
ORCID: 0000-0002-5215-6088; 0009-0002-7609-8617; 0000-0001-8356-9806.

[1] Kütahya University of Health Sciences, Department of Medical Biology, Kütahya, 43000, Türkiye
[2] Kütahya University of Health Sciences, Department of Medical Biochemistry, Kütahya, 43000, Türkiye

Abstract

Objective: Fertility refers to an individual's reproductive health and reproductive capacity, whereas infertility is defined as the inability to achieve pregnancy and represents a significant clinical problem affecting male reproductive health. In recent years, increasing attention has been paid to the role of the gut microbiota in male reproductive functions. The aim of this review is to evaluate the effects of microbial approaches, such as probiotics, postbiotics, and fecal microbiota transplantation (FMT), on male reproductive health and to present current scientific evidence regarding the improvement of fertility.
Methods: This study is based on a systematic review of the current literature published in the PubMed, Google Scholar, Scopus, and Web of Science (WOS) databases. Experimental and clinical studies examining the relationship between male reproductive health and the microbiota were evaluated, with a focus on microbiome-based therapeutic approaches, including probiotics, postbiotics, and FMT.
Results: The reviewed studies indicate that dysbiosis of the gut microbiota negatively affects sperm production, sperm quality, and testosterone levels. In contrast, microbiome-based interventions such as prebiotics, probiotics, postbiotics, and FMT have been reported to restore microbial balance, support beneficial microorganisms, and improve spermatogenesis and hormonal balance through biologically active metabolites.
Conclusion: This review highlights the significant potential of microbial therapeutic approaches in improving male reproductive health. Targeting the gut microbiota offers promising new strategies for the prevention and treatment of male infertility. The findings provide a strong scientific basis for the future clinical application of microbiome-based approaches in reproductive medicine.

Keywords: Microbiota, Infertility, Prebiotics, Probiotics, Postbiotics, FMT.

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Probiyotiklerden postbiyotiklere: erkek üreme sağlığında mikrobiyal yaklaşımlar

Özet
Amaç: Fertilite, bireyin üreme sağlığını ve üreme kapasitesini ifade ederken; infertilite, gebeliğin elde edilememesi durumunu tanımlar ve erkek üreme sağlığını etkileyen önemli bir klinik sorundur. Son yıllarda, bağırsak mikrobiyotasının erkek üreme fonksiyonları üzerindeki rolü giderek daha fazla ilgi görmektedir. Bu derlemenin amacı, probiyotikler, postbiyotikler ve fekal mikrobiyota transplantasyonu (FMT) gibi mikrobiyal yaklaşımların erkek üreme sağlığı üzerindeki etkilerini değerlendirmek ve fertilitenin iyileştirilmesine yönelik güncel bilimsel bulguları ortaya koymaktır.
Yöntem: Bu çalışma, PubMed, Google Scholar, Scopus ve Web of Science (WOS) veri tabanlarında yayımlanmış güncel literatürün sistematik olarak taranmasına dayanmaktadır. Erkek üreme sağlığı ile mikrobiyota arasındaki ilişkiyi inceleyen deneysel ve klinik çalışmalar değerlendirilmiş; probiyotikler, postbiyotikler ve FMT gibi mikrobiyom temelli tedavi yaklaşımlarına odaklanılmıştır.
Bulgular: İncelenen çalışmalar, bağırsak mikrobiyotasındaki dengesizliğin sperm üretimi, sperm kalitesi ve testosteron düzeyleri üzerinde olumsuz etkiler oluşturduğunu göstermektedir. Buna karşılık, prebiyotikler, probiyotikler, postbiyotikler ve FMT gibi mikrobiyom temelli müdahalelerin

* *Corresponding author*: Tel.: +902742600043; Fax.: +902742652191; E-mail: gamzezengin043@gmail.com
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mikrobiyal dengeyi yeniden sağladığı, faydalı mikroorganizmaları desteklediği ve biyolojik olarak aktif metabolitler aracılığıyla spermatogenezi ve hormonal dengeyi iyileştirdiği bildirilmiştir.
Sonuç: Bu derleme, mikrobiyal tedavi yaklaşımlarının erkek üreme sağlığını iyileştirmede önemli bir potansiyele sahip olduğunu ortaya koymaktadır. Bağırsak mikrobiyotasının hedeflenmesi, erkek infertilitesinin önlenmesi ve tedavisinde umut vadeden yeni stratejiler sunmaktadır. Elde edilen bulgular, üreme tıbbında mikrobiyom temelli yaklaşımların gelecekteki klinik uygulamaları için güçlü bir bilimsel temel oluşturmaktadır.

Anahtar Kelimeler: Mikrobiyota, İnfertilite, Prebiyotikler, Probiyotikler, Postbiyotikler, FMT.

1. Introduction

According to the World Health Organization (WHO, 2024), infertility is defined as a medical condition in which a couple is unable to achieve conception despite engaging in regular unprotected sexual intercourse for a period of at least twelve months. This condition is not limited to a specific region but is recognized as a significant global health issue, as it is estimated to affect approximately 8% to 12% of couples within the reproductive age group worldwide. When considered in the context of Turkey, the prevalence of infertility appears to be even higher, with reports indicating that between 10% and 20% of couples of reproductive age experience difficulties in conceiving [1]. According to the data from the Turkish Society of Histology and Embryology Specialists (2025), there are 22 provinces in Turkey providing in vitro fertilization (IVF) services, with a total of 179 centers.

Today, infertility is becoming an increasingly significant source of concern. Couples dealing with this condition face not only biological challenges but also emotional, social, and economic difficulties. This underscores the importance of effective and sustainable treatment approaches [2]. Approximately 20% of infertility cases are solely due to male factors, while male factors contribute to 30% to 40% of all cases [3].

2. Gut Microbiota and Male Reproductive Physiology

The gut microbiota plays an significant role in male reproductive physiology and can influence sperm quality. Research has shown that the gut microbiota can improve sperm motility through bacteria such as *Rikenellaceae* [4]. Probiotic supplementation has been found to correct spermatogenic disorders [5]. These physiological and pathological effects are largely mediated through a variety of metabolites synthesized by the gut microbiota, which serve as crucial signaling molecules that influence host metabolic processes, immune system regulation, and overall homeostasis. For example, the metabolism of tryptophan by gut bacteria leads to the secretion of 5-HT, which enhances sperm motility. 5-HT accelerates Ca^{2+} flux in sperm cells, thereby increasing motility and improving sperm quality. By modulating tryptophan metabolism, the gut microbiota can increase 5-HT production, a mechanism that may have a significant impact on sperm function [6].

The gut microbiota stabilizes the sperm membrane and preserves sperm motility by influencing metabolites such as unsaturated fatty acids (UFAs), particularly polyunsaturated fatty acids (PUFAs). PUFAs exhibit anti-inflammatory and antioxidant effects, supporting reactive processes [7]. The gut microbiota can enhance these effects by altering systemic PUFA levels. Additionally, gut bacteria can influence PUFA absorption, thereby improving male reproductive function. These metabolites are crucial for maintaining sperm motility and testicular cells' ability to reduce inflammation [8].

The metabolites of the gut microbiome can enhance sperm motility by supporting energy supply. In testicular tissue, Sertoli cells produce lactate via glycolysis, which provides energy to spermatogenic cells. The gut microbiota can support glycolysis, thereby enhancing sperm motility [9]. For instance, certain bacteria improve glycolysis to increase energy availability, while metabolites such as those from tryptophan metabolism and 5-HT can also activate glycolysis. Furthermore, the gut microbiota regulates blood glucose levels, supporting testicular glycolysis and, consequently, sperm motility. The microbiota can also promote spermatogenesis by increasing growth factors such as IGF-1.

The gut microbiota is increasingly recognized as a crucial regulator of sex hormones, as it influences their synthesis, metabolism, and bioavailability through complex interactions involving microbial enzymes and metabolites that act on endocrine pathways. It can influence the hypothalamic–pituitary–testicular (HPT) axis to modulate levels of hormones such as testosterone. Gut bacteria also produce enzymes that metabolize testosterone and other steroid hormones, potentially altering their activity. Additionally, the gut microbiota can affect the circulation and reabsorption of active hormone forms in the body. Moreover, it can influence sexual behavior; microbiota-derived compounds can induce changes in the brain and central nervous system, thereby shaping sexual arousal and behavior [9].

3. Therapeutic Approaches for Dysbiosis

The gut microbiota plays a critical regulatory role in sperm motility, sperm quality, and spermatogenesis. It also supports male reproductive health by stabilizing the sperm membrane. Numerous studies have highlighted the positive effects of the gut microbiota on male reproduction by influencing the blood–testis barrier. These findings clearly indicate that gut dysbiosis (disruptions in the gut microbiota) can negatively affect male reproductive functions. Today, gut dysbiosis is a common condition, which may adversely impact male fertility. This review discusses the potential effects of prebiotic, probiotic, and postbiotic treatments on male reproduction. Additionally, the effects of fecal microbiota transplantation (FMT), a topic that has gained increasing attention in recent years, on reproductive health are examined.

3.1. Prebiotics

The term *prebiotic* was originally introduced in 1995 by Glenn Gibson and Marcel Roberfroid , who described it as a non-digestible dietary component capable of exerting beneficial effects on the host's health. This positive influence was explained by the ability of prebiotics to selectively stimulate the growth and/or metabolic activity of specific bacterial groups within the gut microbiota, rather than affecting the entire microbial community, thereby contributing to improved overall well-being.

Several essential characteristics must be satisfied for a substance to qualify as a prebiotic compound: (i) the molecule must demonstrate stability against gastric acidity, remain unaffected by mammalian digestive enzymes, and avoid absorption throughout the gastrointestinal passage; (ii) the compound should serve as a fermentation substrate for intestinal microorganisms, and (iii) it must selectively promote the growth and/or metabolic functions of beneficial bacterial populations residing in the gut environment [10].

Although revisions to the prebiotic definition have been proposed over time, the definition established in 2008 is widely accepted today. While a universally agreed-upon definition is still lacking, the common denominator of both the original and subsequent definitions is the positive impact of prebiotic consumption on human health. The concept of "selectivity," highlighted in the original definition—meaning that prebiotics target specific microbial species—has been a subject of discussion in recent years [11].

Contrary to earlier beliefs, the testis is not a completely sterile organ; it harbors a distinct microbiota that influences its functions. Despite studies on the epididymal microbiota are limited, the testicular microbiota has been shown to share similarities with the gut microbiota and exert significant effects on male reproductive functions. Reduced diversity in the testicular microbiome has been reported in idiopathic non-obstructive azoospermia patients, with notable decreases in Bacteroides and Proteobacteria species. Additionally, analyses performed after decontamination revealed a similar microbial profile, including species such as *Actinobacteria, Firmicutes, Blautia, Clostridium, Bacteroidetes, and Prevotella* [12].

In some studies demonstrated that a high-fat diet in experimental animals led to parallel changes in testicular and gut microbiota. Showed that fecal microbiota transplantation improved both gut and testicular microbiota. Furthermore, increases in glutathione peroxidase activity, protein levels of spermatogenesis-related genes in the testis , and arginine levels were reported to promote spermatogenesis [12].

Studies employing probiotic and prebiotic supplements further indicate the link between male reproductive health and gut bacteria. According to Valcarce et al. [30], Bifidobacterium longum CECT7347 and Lactobacillus rhamnosus CECT8361 improved sperm motility by reducing sperm DNA damage and inhibiting the generation of reactive oxygen species (ROS). These results are in line with those of Abbasi et al., who employed L-glutamine, oligo-fructosaccharides, arabinogalactan, and *Lactobacillus paracasei* B21060. Additionally, it was discovered that supplementing with *Lactobacillus rhamnosus* PB01 improved sperm motility and normal morphology while also favorably influencing the amount of Leydig cells in the testis. It has also been demonstrated that prebiotics like oligofructose promote spermatogenesis and testosterone synthesis [12].

Male reproductive health depends on the regulation of testicular macrophages, which is another important function of the gut microbiota. Macrophages are formed throughout embryonic development in the testes, which are immune-privileged organs. The gut microbiome contributes to the preservation of the immune-privileged environment of the testes by engaging multiple biological pathways and molecules. This protective role is mediated through the activity of anti-inflammatory immune cells and signaling via Toll-like receptor 2 (TLR2), as well as the secretion of cytokines such as interleukin-10 (IL-10). In addition, metabolites like short-chain fatty acids and hormones such as dihydrotestosterone, together with structural proteins including occludin, claudins, and zona occludens, play a key role in sustaining the integrity of the testicular milieu. Pathogenic bacterial overgrowth in the gut, however, upsets this equilibrium and raises pro-inflammatory factors like lipopolysaccharide (LPS). This increase negatively impacts testicular functioning, disturbs the testicular microenvironment, and jeopardizes the testes' immunological privilege [13].

3.2. Probiotics

Probiotics are live microorganisms that exert various beneficial effects on their hosts. Food, particularly fermented products such as yogurt, constitutes the majority of commercial probiotics. Probiotics offer a range of health benefits that can be classified into four main areas: reduction of pathogen growth, strengthening of gut barrier function, modulation of the immune system, and control of pain perception [14]. Therefore, the use of probiotics may have therapeutic value in the treatment of numerous diseases. It is widely accepted that a diverse microbiome exists in animal systems, playing a crucial role in maintaining normal physiology and health. The existence of microbes in both male and female reproductive organs has also been the subject of scientific investigation. Reproductive microbiota was initially detected in male semen, whereas female reproductive systems were found to be colonized by distinct microbiota across all reproductive tissues, each with a specific microbial composition. Commensal microorganisms help balance the reproductive ecosystem, thereby enhancing host fertility and reproductive performance [15].

Wang et al. (2022) emphasize that despite recent intensive efforts to identify causes and develop new therapeutic approaches for male infertility, effective solutions for idiopathic male infertility remain limited [16]. In this context, recent studies have examined various antioxidant supplementation strategies to improve male infertility and their effects on reactive oxygen species (ROS). Vitamins C and E are well-known antioxidants that help neutralize harmful free radicals. In addition, compounds such as glutathione and N-acetylcysteine have been shown to protect cells from oxidative damage.

In addition to the well-known antioxidants, other nutrients play important roles in supporting male reproductive health. For instance, folate contributes to DNA synthesis and repair in sperm cells, zinc is essential for hormone regulation and sperm maturation, selenium acts as a cofactor for antioxidant enzymes protecting sperm from oxidative damage, carnitine supports energy metabolism crucial for sperm motility, coenzyme Q10 enhances mitochondrial function and reduces oxidative stress, and lycopene, a powerful carotenoid, helps protect reproductive tissues from free radical-induced injury. Together, these compounds collectively enhance semen quality and positively influence multiple parameters related to fertility [17].

Probiotics, which are live microorganisms, have been recognized for their potential to promote human health through multiple mechanisms. Oral supplementation with probiotics containing specific bacterial strains such as *Lactobacillus*, *Bifidobacterium*, *Enterococcus*, *Collinsella*, and *Blautia* has been shown to enhance sperm quality by mitigating oxidative stress and reducing inflammatory responses within sperm cells [18]. It has been suggested that the positive effects of probiotics are largely linked to their capacity to influence the Nrf2-Keap1-ARE signaling pathway. By activating this mechanism, probiotics are able to strengthen the body’s antioxidant defense system and promote the neutralization of reactive oxygen species (ROS). Through these combined actions, probiotics may contribute to enhancing sperm concentration and motility, an outcome that is particularly relevant for men struggling with infertility.

Lactobacillus is the most prominent probiotic that may help with male infertility. Lactic acid bacteria's effects and mechanisms on the male reproductive system have been the subject of numerous investigations. Because of its beneficial effects on weight management and capacity to raise endogenous testosterone levels, L. rhamnosus strain NCDC 610 and L. fermentum strain NCDC 400 are specifically recommended as alternatives to medicines [19].

Lactic acid bacteria are reported to exert beneficial influences on male reproductive health, primarily through their ability to regulate and balance the gut microbiota. Experimental studies conducted on rats have demonstrated that these bacteria can stimulate the production of short-chain fatty acids, which are essential metabolites for maintaining intestinal and systemic health. Furthermore, lactic acid bacteria help to prevent gut dysbiosis, thereby supporting microbial stability, and through their antioxidant properties, they provide protection to testicular tissues against the damaging effects of various toxins. Lactobacillus reuteri increases the anti-inflammatory factor IL-10 while reducing pro-inflammatory IL-17 levels, supporting Leydig cell nutrition and improving systemic immunity, metabolic pathways, and tissue homeostasis. This leads to increased testis weight, spermatogenesis, sperm concentration, and motility [20]. *Lactobacillus rhamnosus* provides antioxidant effects, reduces blood lipids, protects Leydig and Sertoli cells, and improves testis size, sperm motility, and hormone regulation; it also increases LH, FSH, and testosterone levels, thereby restoring the HPT axis . *Lactobacillus plantarum* enhances sexual behavior by improving dopamine activity [21]. Lactobacillus paracasei improves gut microbiota in humans, optimizes the prostatic environment, and regulates free radical concentrations in seminal fluid, enhancing sperm quality, ejaculation volume, sperm count, motility, and hormone levels. These studies demonstrate the potential of lactic acid bacteria to improve male reproductive health through various mechanisms [6].

In a study by Sanchez-Rodriguez et al. (2024), the effects of two different probiotics on sperm quality in male mice were examined. The results showed fewer head abnormalities and higher normal sperm morphology in probiotic-treated mice, along with specific changes in sperm motility, indicating the potential of probiotics to improve sperm morphology [22].

Mandar et al. (2025) developed a new set of probiotic strains to support male urogenital health. The selected *Lactobacillus* strains exhibited antagonistic activity against opportunistic bacteria associated with prostatitis, and the probiotic capsules were well tolerated. This study provides promising insights for the development of new probiotics that support male urogenital health [23].

Wu et al. (2024) looked at BPA's impacts, exposure on male reproductive functions and the potential of probiotics to mitigate these effects. *Lactobacillus rhamnosus* and *Lactobacillus plantarum* strains reduced BPA residues, improved gut barrier function, and reversed spermatogenesis impairment. These results imply that probiotics may be effective in combating reproductive issues caused by BPA exposure [24].

In conclusion, probiotics are beneficial microorganisms that can be naturally incorporated into daily diets and play important roles, especially in maintaining gut health. When consumed through the digestive system, these live microorganisms exert positive effects on host health. Their well-known benefits include maintaining gut microbiota homeostasis, modulating the immune system, reducing inflammation, and regulating general metabolic functions. Probiotics support microbial balance by suppressing the colonization of harmful and pathogenic microorganisms in the gastrointestinal tract. They achieve these effects largely through competitive colonization, production of bacterially-derived antimicrobial compounds, and strengthening of the host immune system. In addition to their other beneficial effects, these microorganisms undergo fermentation processes in the gut, resulting in the production of short-chain fatty acids (SCFAs) such as propionate, butyrate, and acetate, which play important roles in maintaining intestinal health and modulating host metabolic and immune functions [24].

SCFAs not only support host metabolism but also aid in preserving intestineepithelial integrity, suppressing inflammation, and enhancing immune tolerance mechanisms. Notably, probiotic bacteria such as *Lactobacillus* and *Bifidobacterium* are directly responsible for producing these metabolites and promote the proliferation of beneficial species within the gut microbiota [25].

In summary, regular consumption of probiotics not only preserves gut microbiota diversity and balance but also positively impacts systemic health, serving as a protective barrier against various diseases.

3.3. Postbiotics

The term “postbiotic” originates from the combination of “biotic,” referring to “related to living organisms,” and the prefix “post,” meaning “after.” The concept that non-viable microorganisms can exert beneficial or health-preserving effects is not new, and various terms have been used to describe such substances; however, over the past decade, the term postbiotic has emerged as the most popular [26].

Postbiotics encompass various bioactive molecules that are either produced by living bacterial cells or emerge following the breakdown of microbial structures. These molecular components include peptidoglycan fragments, polysaccharide compounds, proteinaceous substances, peptide chains originating from organic acids, enzymatic molecules, teichoic acid constituents, and muropeptide structures. These substances demonstrate promising capabilities in supporting reproductive capacity across both genders. In males, the proposed mechanisms involve regulation of testicular physiology, enhancement of sperm parameters, and maintenance of prostatic wellness, while in females, these compounds may support fertility through balancing and reconstructing the vaginal microbial ecosystem [27].

Postbiotics have been reported to increase serum testosterone, LH, and FSH levels, significantly enhance sperm motility and the percentage of progressive sperm, and reduce the percentage of immotile sperm. Some studies suggest that postbiotics exert both direct and indirect effects on male fertility [28]. The direct effect improves spermatogenesis, while the indirect effect increases antioxidant capacity by counteracting the side effects of obesity. Additionally, testosterone levels decline with age, further impacting testosterone beyond obesity as an additional factor [29].

Research on the mechanisms by which postbiotics enhance sperm function has led to several hypotheses to explain their effects. Zhang et al. found that postbiotics derived from Lactobacillus casei significantly mitigated the negative effects of *Pseudomonas aeruginosa*, which reduces sperm motility and impairs mitochondrial function. However, postbiotics alone did not completely eliminate these effects; instead, they appear to suppress the detrimental impact of dominant harmful bacteria, thereby improving sperm quality. Additional studies have demonstrated that postbiotics may affect spermatogenesis and testicular function via modifying the gut microbiota and antioxidant characteristics [30].

In a study linking testicular dysfunction to di-2-ethylhexyl phthalate (DEHP) exposure, postbiotics derived from Lactobacillus plantarum were shown to improve testicular damage and modulate bacterial abundance. These findings suggest that probiotics, by altering the gut microbiota, may help mitigate testicular damage. It is also well-established that oxidative stress can damage sperm DNA, negatively affecting sperm function [31]. Postbiotics derived from *Lactobacillus spp.* have been shown to improve sperm motility, reduce DNA fragmentation, and lower intracellular hydrogen peroxide levels.

3.4. Fecal microbiota transplantation (FMT)

A novel treatment technique called fecal microbiota transplantation (FMT) rebalances the makeup and function of the gut microbiota by introducing fecal material from a healthy donor into the recipient's gastrointestinal tract. The primary goal of this treatment strategy is to correct gut microbiota imbalances, known as dysbiosis, thereby stabilizing the microbial composition and restoring normal physiological functions. In FMT procedures, carefully screened microbial content from a donor is typically delivered to the recipient’s gut via oral capsules, enema, or colonoscopy. As a result of this transfer, pathogenic or dysbiotic microbial structures in the recipient’s gut are suppressed, and a healthy microbial ecosystem is established, leading to improvement in disease symptoms.

FMT has become a viable strategy with the potential to improve male infertility. In the treatment of male infertility, a common strategy involves pharmacologically enriching beneficial bacteria and transferring them via fecal

microbiota.
One notable study was conducted by Zhang et al., demonstrating for the first time that transferring fecal microbiota from alpha-oligosaccharide (AOS) users (AOS-FMT) could treat busulfan-induced male infertility and improve spermatogenesis [32].

Male reproductive dysfunction in individuals with type 1 diabetes (T1D) is associated with gut microbiota dysbiosis. In streptozotocin-induced T1D mice, fecal microbiota transplantation derived from alginate oligosaccharide (AOS)-modulated gut microbiota (A10-FMT) significantly reduced blood glucose levels and markedly improved sperm quality and spermatogenesis. These beneficial effects were reported to be mediated through metabolic regulation via the gut microbiota–testis axis and increased n-3 polyunsaturated fatty acid production [33].
These mechanisms largely involve restoring gut microbiota diversity, regulating host blood metabolism, reducing epididymal inflammation, and re-establishing the balance of spermatogenesis and the testicular microenvironment, thereby improving male infertility [34].

For instance, fecal microbiota transplantation derived from alpha-oligosaccharides (AOS-FMT) has been shown to elevate the levels of important Docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) are examples of polyunsaturated fatty acids both in the bloodstream and within testicular tissues. In addition to these metabolic changes, AOS-FMT was also associated with an increased abundance of several beneficial bacterial groups, including *Campylobacterales*, *Bacteroidales*, *Lactobacillaceae*, *Bifidobacteria*, and *Sphingomonadales*. Through these combined effects, this intervention ultimately contributed to marked improvements in spermatogenesis and enhanced overall semen quality .

In a similar manner, transplantation of *Parabacteroides distasonis* was found to exert multiple beneficial effects on male reproductive parameters. Experimental findings indicated that this intervention not only improved testicular histology, increased the testis index, and elevated circulating testosterone levels, but also increased the expression of spermatogenesis-related genes. Moreover, it was observed that *P. distasonis* transplantation led to higher concentrations of polyamines within both the testis and the cecum. Beyond these direct reproductive benefits, this approach also played a role in lowering inflammatory mediators and alleviating oxidative stress, thereby supporting overall testicular health [35]. In conclusion, fecal microbiota transplantation represents a novel and potential treatment approach that targets the testis-gut microbiota axis to enhance semen quality and male fertility.

5. Conclusion

The intricate and mutually reinforcing relationship among the immune system and the gut microbiome is essential to maintaining healthy reproductive functions in organisms. Through the immune system and this mutually beneficial interaction can more effectively neutralize pathogens, protect reproductive tissues, and support overall reproductive health. The presence of a balanced and healthy microbiota contributes positively to fertility, particularly by supporting sperm production and quality in males. Conversely, certain microbial metabolites can trigger inflammatory processes such as orchitis, highlighting the critical importance of maintaining microbiota balance. Consequently, regular and balanced nutrition, healthy lifestyle habits, and prudent use of medications are essential strategies for sustaining gut microbiota health.

Examining the connection between male infertility and gut microbiome is particularly important for elucidating its effects on spermatogenesis and sperm quality. Dysbiosis in the gut is believed to adversely affect reproductive functions. In this context, the determining gut microbiota's function in male reproduction health has gained increasing attention. Collectively, research has demonstrated how microbiota-derived disruptions can affect the male reproductive system, discussed potential intervention strategies, and provided a theoretical framework for developing novel pharmacological approaches. These efforts hold substantial potential for the future development of innovative therapeutic methods that could be applied clinically.
A lthough a growing body of scientific evidence strongly supports the existence of a close relationship between the gut microbiota and reproductive health, the available data are still not sufficient to provide a complete understanding of this interaction, and further comprehensive studies are required to clarify the underlying mechanisms in greater detail. Many studies agree that the gut microbiota exerts significant effects by modulating gonadal functions, steroid hormones, insulin sensitivity, the immune system, and the gonadal microbiome. Moreover, the consumption of probiotics and prebiotics can influence both gut and gonadal microbiota, thereby affecting gonadal function. The mechanisms underlying gut–gonadal interactions are extremely intricate and still poorly understood; however, the importance of gut microbiota, along with supporting probiotics and prebiotics, should not be overlooked. Human research based on findings from animal models are particularly valuable for couples seeking to conceive, offering potential strategies to mitigate declining fertility rates reported worldwide.

Author Contributions
All authors contributed equally to this study.

Conflict of Interest Statement
The authors declare no conflict of interest.

Research and Publication Ethics Statement
The study was conducted in accordance with research and publication ethics.

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Within this study, the role of the gut–testis–microbiota axis in physiological and pathological processes, the potential therapeutic effects of fecal microbiota transplantation, and other treatments were evaluated in light of the relevant project findings and the current literature.

Ethics Statement
As this study is a review, it did not involve any human or animal experiments and therefore did not require ethics committee approval.

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