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Probiotics and Their Therapeutic Application in Kidney Stone Disease: An Overview of Cellular, Animal, and Human Models

Probióticos e Sua Aplicação Terapêutica na Doença de Cálculos Renais: Uma Visão Geral de Modelos Celulares, Animais e Humanos

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Abstract: Probiotics are live microorganisms that, when administered in sufficient quantities, confer health benefits to the host. In recent years, there has been increasing interest in the therapeutic use of probiotics for various conditions, including kidney stone disease. The objective of this study is to provide a comprehensive overview of the effects of probiotics in the treatment of kidney stones, through an examination of cellular, animal, and human models. This review involved a systematic search of peer-reviewed articles from reputable databases, such as PubMed, Scopus, and Web of Science, up to the year 2025. Selected studies were analyzed based on their investigation of the effects of probiotics on kidney stone formation. The findings indicate that various probiotic strains can reduce urinary oxalate levels, calcium oxalate (CaOx) crystals, and intestinal inflammation. Probiotics such as *Lactobacillus paracasei* GR-10 and *Pediococcus acidilactici* GR-11 significantly enhance oxalate degradation, while *Lactiplantibacillus plantarum* and *Bifidobacterium* species improve gut microbiota composition and help prevent kidney stone formation. Additionally, studies have shown that probiotics can lower serum creatinine and urea nitrogen levels, suggesting their protective effects on kidney function. Other studies, including those involving fecal microbiota transplantation (FMT), have confirmed the beneficial effects of probiotics in preventing calcium oxalate stones and kidney damage. The results of this review suggest that probiotics, particularly strains of *Lactobacillus* and *Bifidobacterium*, may be effective in the prevention and treatment of kidney stones. These microorganisms offer protective effects on the kidneys by reducing urinary oxalate levels, CaOx crystal formation, and intestinal

inflammation. Further research is needed to explore the full potential of probiotics in the management of kidney stone disease.

Keywords: Probiotics, Urology, Kidney Stones, Treatment

Resumo: Os probióticos são micro-organismos vivos que, quando administrados em quantidades suficientes, conferem benefícios à saúde do hospedeiro. Nos últimos anos, houve um crescente interesse no uso terapêutico de probióticos para diversas condições, incluindo a doença de cálculos renais. O objetivo deste estudo é fornecer uma visão abrangente dos efeitos dos probióticos no tratamento de cálculos renais, por meio de uma análise de modelos celulares, animais e humanos. Esta revisão envolveu uma busca sistemática de artigos revisados por pares em bases de dados renomadas, como PubMed, Scopus e Web of Science, até o ano de 2025. Os estudos selecionados foram analisados com base na investigação dos efeitos dos probióticos na formação de cálculos renais. Os resultados indicam que várias cepas de probióticos podem reduzir os níveis de oxalato urinário, cristais de oxalato de cálcio (CaOx) e a inflamação intestinal. Probióticos como *Lactobacillus paracasei* GR-10 e *Pediococcus acidilactici* GR-11 aumentam significativamente a degradação de oxalato, enquanto *Lactiplantibacillus plantarum* e espécies de *Bifidobacterium* melhoram a composição da microbiota intestinal e ajudam a prevenir a formação de cálculos renais. Além disso, estudos mostraram que os probióticos podem reduzir os níveis de creatinina sérica e nitrogênio ureico, sugerindo efeitos protetores na função renal. Outros estudos, incluindo os que envolvem transplante de microbiota fecal (FMT), confirmaram os efeitos benéficos dos probióticos na prevenção de cálculos de oxalato de cálcio e danos renais. Os resultados desta revisão sugerem que os probióticos, particularmente as cepas de *Lactobacillus* e *Bifidobacterium*, podem ser eficazes na prevenção e no tratamento de cálculos renais. Esses micro-organismos oferecem efeitos protetores nos rins, reduzindo os níveis de oxalato urinário, a formação de cristais de CaOx e a inflamação intestinal. Mais pesquisas são necessárias para explorar todo o potencial dos probióticos no manejo da doença de cálculos renais.

Palavras-chave: Probióticos, Urologia, Cálculos Renais, Tratamento

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Introduction

Probiotics are live microorganisms that, when consumed in adequate amounts, can confer health benefits to the host (CREMON et al., 2018). These microbial agents primarily impact the health of the digestive system and immune response (CREMON et al., 2018, DABBAGHZADEH et al.,2023).

However, recent research has demonstrated that probiotics may have therapeutic applications beyond the digestive system (BERMÚDEZ-BRITO et al., 2012). Among these applications, the effects of probiotics in the prevention and treatment of various diseases, including kidney stones, have garnered considerable attention (BERMÚDEZ-BRITO et al., 2012, SHAFI et al., 2016). Urological diseases are of significant concern as they can markedly affect the function of the urinary system and kidneys, potentially leading to complications such as renal failure, urinary disorders, and infertility (SADRI et al., 2025; HEMMATI GHAVSHOUGH et al., 2025).

Early diagnosis and appropriate treatment of these conditions can improve patients' quality of life and prevent more serious complications (MOUSAVI et al., 2024; NAYERI et al., 2020). Kidney stones are a common urological condition that can cause severe pain and disrupt kidney function (KHAN et al., 2016).

This condition is typically associated with the accumulation of mineral crystals, such as calcium oxalate, in the kidneys (SAKHAEE et al., 2012). The etiology of kidney stones often involves the accumulation of mineral crystals, including calcium oxalate, calcium phosphate, or uric acid, within the kidneys (Evan, 2010). Various factors, such as dehydration, excessive salt intake, metabolic disorders, urinary tract infections, and poor diet, can predispose individuals to kidney stone formation (SOHGAURA AND BIGONIYA, 2017).

The pathophysiology of kidney stones involves the formation of mineral crystals in urine, which may result from changes in the chemical composition of urine, reduced urine volume, or increased mineral concentration. These crystals may gradually grow and eventually form kidney stones (BARGAGLI et al., 2025). Inflammation and damage to kidney tissues caused by the stones can lead to functional problems such as urinary obstruction, urinary tract infections, and severe pain (BARGAGLI et al., 2025). In many cases, the prevention and treatment of kidney stones necessitate medical interventions, dietary

changes, and, in some instances, surgery (FRASSETTO AND KOHLSTADT, 2011).

However, the use of probiotics as a novel therapeutic approach has gained attention in recent years (FRASSETTO AND KOHLSTADT, 2011). This approach is of particular interest because probiotics can help regulate and enhance the gut microbiota, potentially influencing biochemical processes in the digestive and urinary systems (FRASSETTO AND KOHLSTADT, 2019). Among these effects, oxalate degradation and the reduction of oxalate crystal accumulation in the kidneys are particularly noteworthy, as they may contribute to the prevention of kidney stone formation (FINGER et al., 2023).

Conventional treatments for kidney stones generally involve medications for pain relief, muscle relaxants to facilitate stone passage, and drugs to reduce urinary oxalate or calcium concentrations (XU et al., 2013). Drugs such as tamsulosin and alprostadil are used to alleviate pain and assist in stone passage, while chemical agents like potassium citrate are prescribed to prevent the formation of calcium oxalate and phosphate stones (XU et al., 2013).

However, the use of chemical treatments for kidney stones can be associated with side effects, including gastrointestinal discomfort, metabolic disturbances, and cardiovascular issues, particularly with prolonged use of medications like potassium citrate or tamsulosin (YORK et al., 2015). This review explores the effects of probiotics in the treatment of kidney stones through cellular, animal, and human models. The objective of this study is to gather and analyze existing evidence on the use of probiotics as adjunctive or preventive therapy for kidney stones.

Methods

This review aims to investigate the therapeutic effects of probiotics in kidney stone disease by analyzing relevant studies from cellular, animal, and human models. The research process was conducted as follows:

Literature Search:

A systematic search was performed in reputable databases, including PubMed, Scopus, and Web of Science, to identify relevant articles. Studies published up to the year 2025 were considered. The search terms included "probiotics," "kidney stones," and other related keywords.

Inclusion Criteria:

Only articles published in English that focused on the therapeutic effects of probiotics in the treatment of kidney stones,

encompassing cellular, animal, and human studies, were included. Articles that provided insufficient data or ambiguous results were excluded. Additionally, studies addressing indirect effects or topics unrelated to kidney stone disease were excluded from consideration.

Data Synthesis and Analysis:

Data extracted from the selected studies were synthesized both descriptively and, where applicable, quantitatively. Descriptive statistics were used to summarize the findings, and meta-analysis was conducted if sufficient data were available. This phase also involved examining and analyzing any discrepancies and consistencies in the results obtained from different models (cellular, animal, and human).

Results

This review examined the effects of probiotics in the treatment of kidney stones through various models and found that probiotics can be effective in reducing kidney stone formation, improving kidney function, and lowering urinary oxalate levels.

Animal Studies: In animal models, probiotics, particularly species of *Lactobacillus* and *Bifidobacterium*, were shown to reduce urinary oxalate levels and the formation of calcium oxalate crystals. Several studies highlighted the anti-inflammatory and antioxidant effects of probiotics, which were especially notable in mitigating kidney damage and preventing kidney stone formation. Additionally, some studies demonstrated the positive impact of probiotics in modulating gut microbiota, as well as in preventing hyperuricemia and hyperparathyroidism.

Human Studies: In human models, although some studies did not observe significant effects, a few demonstrated a reduction in crystalluria and improvements in patient conditions, suggesting potential therapeutic benefits.

These findings suggest that probiotics may represent a promising therapeutic option for the prevention and management of kidney stones. However, further research, particularly clinical trials, is necessary to confirm their effectiveness. The detailed results are summarized in Table 1.

Table 1: Probiotics and Kidney Stone Treatment

Author(s) and Year	Probiotics	Study Type	Main Results	Final Evaluation
CHEN et al., 2024	*Lactobacillus paracasei* GR-10, *Pediococcus acidilactici* GR-11	Animal	62.7% oxalate degradation and 28.6% uric acid degradation; 57.2% reduction in urinary oxalate	Potential for kidney stone prevention
YANG et al., 2025	-	Review	Probiotics reduce oxalate degradation and prevent stone formation	Improvement in future therapeutic outcomes
XU et al., 2024	*Lactiplantibacillus plantarum* AR342, AR1089	Animal	Reduction in creatinine and urea nitrogen; reduction in calcium oxalate crystals	Potential treatment for kidney stones
MASOLEH et al., 2023	*Lactobacillus* species, *Bifidobacterium*	Animal	Reduction in urinary oxalate; prevention of kidney stones	Effective prevention method
WEI et al., 2021	*Lactiplantibacillus plantarum* N-1	Animal	Reduction in kidney crystals and intestinal inflammation	Prevention of kidney stones via microbiota modulation
KULLIN et al., 2016	*Lactobacillus*, *Bifidobacterium*	Review	Oxalate degradation in the gut by probiotics	Need for more research in humans
TIAN et al., 2022	*Lactiplantibacillus plantarum* J-15	Animal	Reduction in CaOx crystals and improvement in intestinal barrier	Reduction of kidney stones through microbiota restoration

SREEJA et al., 2024	*Lactobacillus* species	Animal	Reduction in urinary oxalate and improvement in kidney tissue	Effective treatment for kidney stones
TAVASOLI et al., 2024	*Lactobacillus acidophilus*, *Bifidobacterium*	Clinical	No significant change in urinary oxalate	Further research needed
VITTORI et al., 2024	*Lactobacillus paracasei* LPC09, *Bifidobacterium breve* BR03	Clinical	Reduction in crystalluria in patients	Probiotics effective for reducing crystalluria
GOMATHI et al., 2015	*Lactobacillus*, Quercetin	Animal	Reduction in oxalate and CaOx crystals	LAB and QE combination for kidney stone prevention
LI et al., 2025	*Lactiplantibacillus plantarum*, *Bifidobacterium breve*	Animal	Improvement in microbiota and reduction in oxalate accumulation	Synbiotics effective for kidney stone prevention
MARTINS et al., 2018	*Lactobacillus casei* 01 (Probiotic cheese)	Animal	Reduction in stone size and urinary mineral excretion	Positive effects of probiotic cheese for kidney stone prevention
LIU et al., 2022	Vinegar	Animal	Reduction in CaOx crystals and improvement in gut microbiota	Vinegar for kidney stone prevention

AKBARIBAZM et al., 2024	*Lactobacillus* species	Animal	Reduction in creatinine and increased antioxidant activity	Kidney protection from oxidative damage
MEHRA et al., 2022	*Lactobacillus paragasseri*, *Lacticaseibacillus paracasei*	Animal	Reduction in urinary oxalate and kidney damage	Prevention of kidney damage due to hyperoxaluria
HUNTHAI et al., 2024	FMT (Fecal Microbiota Transplantation)	Animal	Urinary disorders similar to those in patients	Gut dysbiosis as a risk factor for kidney stones
ANEGKAMOL et al., 2025	*Lactobacillus salivarius* LBR228, *Bifidobacterium longum* BFS309	Animal	Reduction in serum phosphate levels and improvement in gut function	Synbiotics effective for hyperphosphatemia and hyperparathyroidism
PAUL et al., 2017	Oxalate-degrading *Probiotics*	Animal	Reduction in urinary oxalate and prevention of stone formation	*OxdC* enzyme secretion for effective treatment
YANG et al., 2025	*Lactobacillus plantarum* LB12	Animal	Reduction in urinary oxalate, serum creatinine, and urea nitrogen	Prevention of kidney stone formation
SASIKUMAR et al., 2014	*Lactobacillus plantarum* OxdC-producing	Animal	Reduction in urinary oxalate and prevention of stone formation	Effective treatment for kidney stone prevention

LIU et al., 2021	*Lactiplantibacillus plantarum* N-1	Animal	Reduction in CaOx crystals in kidneys	Prevention of kidney stones through arginine metabolism regulation
MANI et al., 2025	*Oxalobacter formigenes*, *Lactobacillus*, *Bifidobacterium*	Review	Reduction in oxalate and prevention of kidney stones	Probiotics can be beneficial for preventing urolithiasis
VISWANATHAN, 2018	*Lactobacillus*, *Bifidobacterium*	Review	Oxalate degradation and reduction in kidney stones	Need for more research on safety and efficacy of probiotics
SASIKUMAR et al., 2014	*Lactobacillus plantarum* OxdC-producing	Animal	Reduction in urinary oxalate and prevention of stone formation	*OxdC*-producing probiotics can prevent kidney stone formation
BRENNAN et al., 2019	Probiotics, FMT	Review	Prevention of calcium oxalate stone formation through microbiota changes	Fecal microbiota transplantation and probiotics for effective treatment
ZHOU et al., 2025	Human Fecal Microbiota Transplantation (hFMT)	Animal	Reduction in CaOx crystal formation and kidney damage	Fecal microbiota transplantation for kidney stone prevention
TORZEWSKA et al., 2021	*Lactobacillus plantarum*, *Lactobacillus brevis*	Laboratory	Increased pH and reduced crystallization of *P. mirabilis*	Positive effects on reducing kidney stones in some cases

CHEIN et al., 2022	*Lactobacillus plantarum* TCI227	Animal	Reduction in serum and urinary uric acid; changes in gut microbiota	Prevention of hyperuricemia and improvement of microbiota
LIU et al., 2023	*Lactobacillus*, *Muribaculaceae* (FMT)	Animal	Reduction in urinary oxalate and CaOx stone formation	Role of fecal microbiota transplantation in kidney stone prevention
TAVASOLI et al., 2024	*Lactobacillus acidophilus*, *Bifidobacterium*	Clinical	No significant impact on urinary oxalate	Probiotics had no significant effect in this study
LIU et al., 2025	*Lactobacillus rhamnosus*, *Lactobacillus casei*, *Lactobacillus holoticus*	Animal	Reduction in creatinine, urea, and malondialdehyde levels	Kidney protection from oxidative damage induced by PbAc

Discussion

Kidney stones are one of the most common diseases of the urinary system, primarily caused by the accumulation of calcium oxalate crystals in the kidneys. This condition results in chronic pain, debilitating complications, and, in some cases, the need for surgery. Common treatments, such as surgery and chemical drugs, often come with side effects. In this context, the use of probiotics has been considered as a novel strategy for preventing kidney stone formation. Probiotics, with their beneficial effects on gut microbiota regulation and oxalate degradation, may serve as adjunct therapies in the treatment of kidney stones.

Several studies have shown that probiotics can effectively reduce calcium oxalate stone formation. Chen et al. (2024) demonstrated in a study on mice that *Lactobacillus paracasei* GR-10 and *Pediococcus acidilactici* GR-11 could degrade 62.7% of oxalate and 28.6% of uric acid. This finding is particularly important as it indicates that probiotics can reduce oxalate absorption in the gut, thereby preventing kidney stone formation (Chen et al., 2024). Similarly, Xu et al. (2024) observed a significant reduction in serum creatinine, urea nitrogen, and calcium oxalate crystals in mice treated with *Lactiplantibacillus plantarum* AR342 and AR1089, suggesting that probiotics can improve kidney function and prevent kidney stone formation (Xu et al., 2024).

One of the prominent effects of probiotics in kidney stone treatment is their ability to reduce inflammation and oxidative stress. In the study by Tian et al. (2022), *Lactiplantibacillus plantarum* J-15 consumption in mice led to a reduction in calcium oxalate crystals and improvement of the intestinal barrier. This study also showed that probiotics could effectively reduce intestinal inflammation and enhance intestinal barrier function, which may be particularly useful in preventing kidney stones associated with chronic inflammation (TIAN et al., 2022).

Several studies have also highlighted the potential of probiotics to regulate gut microbiota, which could positively impact kidney stone prevention. Wei et al. (2021) showed that *Lactiplantibacillus plantarum* N-1 could regulate gut microbiota and prevent calcium oxalate stone formation. These findings emphasize the importance of gut microbiota regulation in preventing metabolic diseases, including kidney stones (WEI et al., 2021).

While many animal studies have reported considerable success in reducing

kidney stones with probiotics, Tavasoli et al. (2024) found in a clinical study that *Lactobacillus acidophilus* and *Bifidobacterium* probiotics did not have a significant effect on urinary oxalate. These results suggest that the effects of probiotics may not be as clear in humans as they are in animal models, highlighting the need for further research to confirm their effectiveness in clinical settings (TAVASOLI et al., 2024). Based on these findings, it can be concluded that probiotics, particularly those capable of oxalate degradation, may be used as adjunct therapies for the prevention and treatment of kidney stones. Probiotics can help prevent calcium oxalate stone formation by degrading oxalate, reducing intestinal inflammation, and regulating gut microbiota. Although probiotics show considerable therapeutic potential, there are several limitations and challenges in this area.

Clinical studies are limited, and some of them provide contradictory results. Research on the effectiveness of probiotics in humans is still in its early stages. Furthermore, the long-term effects of probiotics in preventing kidney stones have not been fully explored, and additional studies are needed in this regard.

Conclusion

The use of probiotics as an adjunct treatment for the prevention and management of calcium oxalate kidney stones holds significant promise. Probiotics, through their regulation of gut microbiota, reduction of inflammation, and oxalate degradation, may prevent kidney stone formation. However, there is a need for larger clinical trials and further research to confirm the effectiveness of these methods in humans.

Declaration

Conflict of Interest

The authors declare that they have no competing interests relevant to the content of this article.

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Authors' Contributions

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Ethical Considerations

The authors have fully adhered to ethical standards, ensuring that no issues related to plagiarism, misconduct, data fabrication, falsification, duplicate publication or submission, or redundancy have occurred.

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