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The Role of *Lactobacillus rhamnosus* as a probiotic in managing polycystic ovary syndrome in female rats: An experimental study

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ABSTRACT

Polycystic ovary syndrome (PCOS), a common endocrine disorder characterized by hyperandrogenism, ovulatory dysfunction, insulin resistance, and chronic inflammation, is increasingly linked to gut microbiota dysbiosis. This study evaluated the therapeutic potential of *Lactobacillus rhamnosus* in a letrozole-induced PCOS rat model, assessing oxidative stress, hormonal regulation, inflammatory mediators, and histopathology. Twenty-four female rats were assigned to negative control, PCOS (positive control), and probiotic-treated PCOS groups. After 8 weeks, probiotic supplementation significantly improved oxidative stress markers, increasing SOD (173.5±2.34 to 289.8±6.41, $p<0.001$) and GSH (64.15±3.40 to 140.9±3.46, $p<0.0001$), while MDA remained unchanged ($p=0.064$). Hormonal profiles improved with decreased LH (9.94±0.52 to 5.20±0.52, $p=0.001$), reduced testosterone (29.51±1.07 to 21.75±0.72, $p<0.001$), and restored FSH (3.52±0.45 to 7.55±0.58, $p=0.001$), supporting follicular development. Insulin levels dropped (20.66±0.95 to 5.44±0.68, $p=0.0001$), indicating enhanced insulin sensitivity. Inflammatory cytokines IL-6 (169.6±1.48 to 142.01±2.97, $p=0.001$) and IL-18 (46.62±1.30 to 40.02±0.85, $p\leq0.001$) were reduced. Histopathology confirmed ovarian architecture restoration with increased corpora lutea, decreased follicular cysts, and improved liver morphology. These results demonstrate that *L. rhamnosus* mitigates PCOS manifestations via oxidative stress reduction, hormonal balance restoration, inflammation suppression, and tissue pathology improvement, highlighting its potential as an adjunctive therapy for PCOS management.

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Introduction

Polycystic ovary syndrome (PCOS) is a prevalent endocrine and metabolic condition affecting women with fertility age, characterized by ovulatory dysfunction, hyperandrogenism, and polycystic ovarian morphology. Besides reproductive symptoms, PCOS is significantly associated with metabolic disorders, such as insulin resistance, obesity, dyslipidaemia, and chronic low-grade inflammation (Jasim & Oleiwi 2023, Wesołowska et al. 2023). Oxidative stress is significantly associated with the pathogenesis of PCOS, as it leads to dysregulation steroidogenesis, folliculogenesis, and chronic inflammation (Palomba et al. 2015, Kareem et al. 2025).

Recently published research indicates the crucial role of the gut microbiota in the pathophysiology of PCOS, with dysbiosis-an inequality in gut microbial composition-

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contributing to metabolic and hormonal disturbances observed in affected women (Wang et al. 2024).

Probiotics, well-defined as live microorganisms that provides health assistances when administered in adequate quantities, have received attention as a potential supplementary treatment for PCOS. Probiotic supplementation has been demonstrated to alter gut microbiota composition, restore microbial balance, and improve gut barrier function, consequently diminishing systemic inflammation and metabolic endotoxemia (Allam et al. 2018, Fu & Kuang 2023). Numerous randomized clinical trials and systematic reviews had indicated that probiotics may improve lipid profiles, insulin resistance, and body mass index (BMI) in women with PCOS, and might also exert beneficial effects on hormonal parameters (Calcaterra et al. 2023). Specific strains, including *Lactobacillus* and *Bifidobacterium*, are associated to improved insulin sensitivity, reduced inflammation, and lower fasting insulin levels (Al-Khafaji et al. 2024, Ahmad et al. 2024).

Furthermore, probiotics may affect the hypothalamic-pituitary-adrenal (HPA) axis, regulate immunological responses, and augment the construction of short-chain fatty acids (SCFAs), which are accompanying with glucose homeostasis and appetite regulation (Angoorani et al. 2023).While the optimal strains, dosages, and duration of probiotic therapy are yet to be completely defined, existing evidence supports the potential of probiotics as a complementary approach in the managing of PCOS, especially for its metabolic and inflammatory factors (Al-Hebshi et al. 2023, Guevara et al. 2024).

Although previous studies have linked PCOS to gut microbiota dysbiosis, there remains a gap in understanding the direct effects of specific probiotic strains on the underlying pathophysiological mechanisms of this disorder. This study aims to bridge this gap by evaluating the impact of *Lactobacillus rhamnosus* on biochemical, inflammatory, and hormonal markers, as well as histopathological changes in a letrozole-induced PCOS rat model, providing a deeper perspective on probiotic-based adjunct therapy.

Materials and Methods

Twenty-four adults' females' rats, aged between 8 to 10 weeks, with an average weight between 200 and 250 grams. After a 15-day acclimatization period in metal cages under controlled environmental conditions (temperature about 23±2 °C, light/dark cycle conducted by12 hours for each); with unrestricted access to water and food, the rats were randomly assigned into three groups, each containing eight animals. Upon conclusion of the trial period, blood samples were collected for biochemical and immunological testing. Subsequently, animals were euthanized to remove specific organs (ovaries and livers), each of which was isolated individually. The organs were assigned numbers for utilization in the histological section. The research was done at the College of Veterinary Medicine/University of Kerbala, from October 2024 to February 2025.

Experiments design

In this study, 24 female rats were equally separated into three groups (n=8 per group). Group I (negative control) received daily distilled water for 41 days. Group II (positive control) was injected with a single dose of letrozole (1 mg/kg) to induce PCOS over 21 days (Kar et al. 2024). Group III (treatment group) consisted of letrozole-induced PCOS rats administered *Lactobacillus rhamnosus* probiotics (250 mg/kg body weight) (Sunshine/USA) daily via oral gavage for 20 days (Rani et al. 2023). At the end of the experimental period, blood serum was obtained from all animals for biochemical analysis.

Parameters studied

Oxidative stress parameters, involving malondialdehyde (MDA), superoxide dismutase (SOD), and glutathione (GSH), were quantified in blood serum using ELISA kits (Sunlong, China). Sexual hormone stages such as luteinizing hormone (LH), follicle-stimulating hormone (FSH), and testosterone were similarly measured via ELISA (Sunlong, China). Immunological parameters (interleukin-6 (IL-6) and interleukin-18 (IL-18) were also analysed.

Pathohistological examination of ovaries and livers

At the termination of the experiment, animals were euthanized using chloroform anaesthesia. Subsequently, their ovaries and livers were dissected and isolated individually. These organs were then preserved in 10% formalin within sterile plastic containers; each marked with a unique identification for histological analysis. Eosin and Haematoxylin stains were prepared in accordance with the staining protocol and researchers 'guidelines (Overmyer et al. 2015).

Statistical Analysis

The statistical software Graph Pad Prism 8.0 employed the t-test, with $P \leq 0.05$ established as the standard of significance. The data points were existing as mean± standard deviation (SD).

Results

The Effect of Probiotics on Oxidative Stress Parameters

This study evaluated the therapeutic effect of probiotics on the oxidative stress biomarkers MDA, GSH and SOD in comparison to letrozole-induced PCOS, as shown in (Table 1).

Table 1. The effect of Probiotics on oxidative stress parameters MAD, SOD and GSH

Parameter	Groups			P-Value
	Group I	Group II	Group III	
MAD mean± SD	8.00±0.44	11.78±0.36	12.16±0.33	0.064
SOD mean± SD	244.41±2.34	173.5±2.34	289.8±6.41	< 0.001*
GSH mean± SD	127.8±0.54	64.15±3.40	140.9±3.46	< 0.001*

P value ≤ 0.05 is significant

The levels of MDA were significantly elevated in the PCOS group compared to the negative control ($p < 0.001$), indicating enhanced lipid peroxidation. Treatment with the group of probiotics demonstrated no significant reduction in MDA compared to positive control. In contrast, the results of GSH clearly indicated that letrozole-induced PCOS rats Positive control had significantly reduced GSH levels in comparison to the negative control group ($p < 0.0001$), confirming a condition of oxidative stress. Furthermore, treatment with probiotics revealed significant differences ($p < 0.0001$) compared to positive control group. Moreover, SOD activity was significantly reduced in the PCOS group ($p < 0.001$), indicating compromised enzymatic antioxidant defence. The restoration of SOD was most significant in the group treated with probiotics ($p < 0.001$).

Luteinizing hormone (LH) is essential for ovulation and androgen production. Elevated LH is a characteristic of PCOS, caused by increased GnRH pulse frequency and reduced negative feedback. The letrozole-induced PCOS group revealed a significant increase in LH levels compared to the negative control ($p < 0.01$). The treatment group had significant reduction of that hormone, with a p value of 0.001. However, FSH facilitated follicular growth and maturation; the suppression of FSH in PCOS resulted in anovulation and follicular arrest. The findings of this study indicated a significant reduction in FSH levels in positive control group ($p < 0.001$) compared to the negative control. The probiotics group demonstrated significant restoration of FSH compared to the positive control ($p < 0.001$). Furthermore, LH-induced stimulation of theca cell demonstrated that positive control displayed significantly higher testosterone values in comparison to negative control group ($p < 0.0001$), confirming successful induction of PCOS, the probiotics group exhibited a significant reduction in testosterone levels ($p < 0.001$).

Table 2. The effect of probiotics on reproductive hormones FSH, LH, testosterone and insulin

Parameter	Groups			P-Value
	Group I	Group II	Group III	
LH mean± SD	5.92±0.854	9.94±0.52	5.20±0.52	0.001*
FSH mean± SD	7.42±0.58	3.52±0.45	7.55±0.58	0.001*
Testosterone mean± SD	18.45±0.27	29.51±1.07	21.75±0.72	< 0.00*1
Insulin mean± SD	13.52±0.56	20.66±0.95	5.44±0.68	0.0001*

P value ≤ 0.05 is significant

The effect of probiotics on reproductive hormones and insulin

The effect of probiotics on the reproductive hormones LH, FSH and testosterone, in comparison to the control group is presented in Table 2, and the results indicated significant differences among groups under study.

The consequence of probiotics on insulin levels was demonstrated, revealing significant hyperinsulinemia ($p \leq 0.001$) in the positive control (PCOS-induced) group compared to negative control group, confirming insulin resistance (IR) as a defining characteristic of PCOS. For treatment, probiotics significantly reduced insulin levels with a p value of 0.0001 compared to the positive control group.

The effect of probiotics on IL-6 and IL-18

The effect of probiotics on the cytokines (IL-6 and IL-18) is presented in Table 3. The results indicate a significant elevation of IL-6 levels in the negative control group (PCOS) compared to the negative control group, confirming systemic inflammation resulting from PCOS induction.

Table 3. The effect of Probiotics on cytokines, IL-6 and IL-18

Parameter	Groups			P-Value
	Group I	Group II	Group III	
IL-6 mean± SD	75.60±2.94	169.6±1.48	142.01±2.97	0.001*
IL-18 mean± SD	35.04±1.61	46.62±1.30	40.02±.85	≤0.001*

P value ≤ 0.05 is significant

The group of probiotics significantly reduces IL-6 levels (p=0.001), to the results indicated the significant

increase in IL-18 levels in the positive control group in comparison to the negative control with a p value of ≤ 0.0001. A group of probiotics demonstrated a significant reduction in IL-18 (p≤0.001).

Histopathological Examination

Histopathological analysis of the ovaries and livers for each study group was conducted, with results illustrated in the following figures. Figure 1 (A) depicts the histological section of the ovary from negative control group at 41 days post challenge, showcasing a preovulatory follicle containing a mature oocyte surrounded by granulosa cells, regular zona pellucida corpus luteum characterized by regular luteal cells (CL) and medulla exhibiting standard vascularity, This histological evidence revealed that the negative control preserved normal ovarian physiology, serving as a dependable baseline for comparison with the PCOS-induced group. Unlike the degenerative and cystic ovarian morphology observed in letrozole-induced PCOS models.

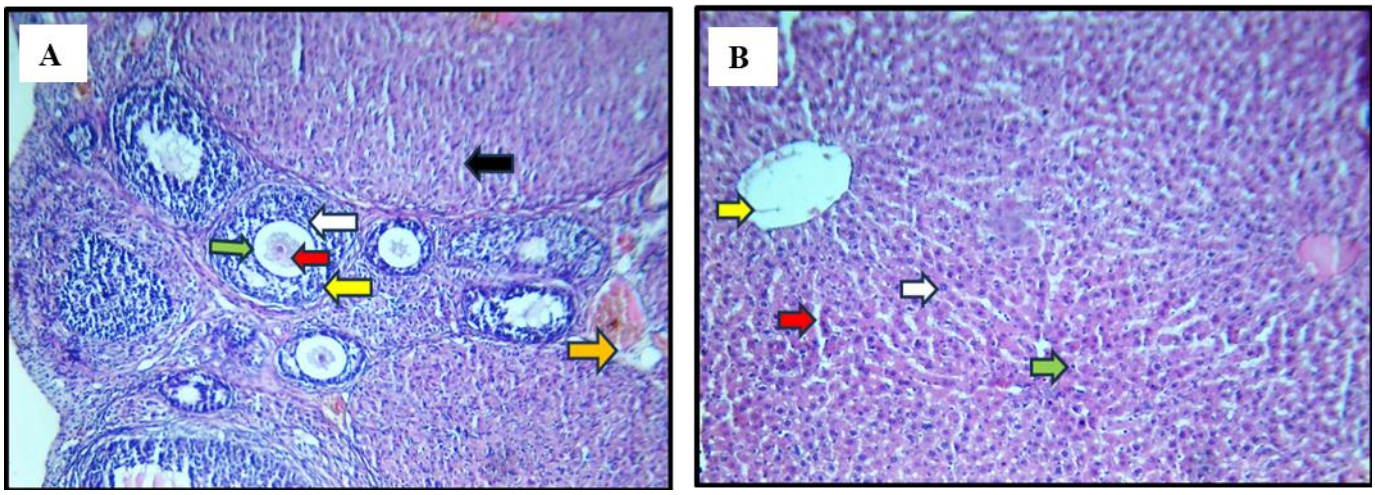

Fig 1. Histology of ovary (A) and liver (B) in the negative control group at 41 days post-challenge. (A) Ovary showing preovulatory follicle with mature oocyte (red), granulosa cells (white), zona pellucida (green), corpus luteum (black), and normal medullary vasculature (orange) (H&E, X10). (B) Liver showing central vein (yellow), large hepatocytes (white) separated by sinusoids (red), and Kupffer cells (green) (H&E, X10).

While figure **1: B** illustrates the histological section of the liver from negative control group, displaying a central vein with a regular arrangement of hepatocytes characterized by a large rounded shape, separated by sinusoids with accompanied by some Kupffer cells.

Histopathological section of the ovary in the negative control group, as illustrated in figure 2 (A) exhibits characteristics of large cystic follicles, thin granulosa layers, stromal hyperplasia, and the absence of corpora lutea which are indicative of letrozole-induced PCOS. These findings validate letrozole as a model for investigating pathophysiology of PCOS and potential treatments.

The histopathological alterations in the liver section of positive control illustrated in Fig 2. (B) revealed vascular congestion, inflammatory infiltration, and necrosis. These findings demonstrated the extensive systemic effects of letrozole beyond ovarian dysfunction, including both direct and indirect hepatic damage through oxidative stress, inflammation, and metabolic dysregulation.

The histopathological imaging from the probiotics group provided persuasive visual evidence of the therapeutic effects of probiotics in PCOS management. The elevated quantity of corpora lutea and reduced follicular cysts indicated the restoration of ovulatory function and improved follicular growth, as illustrated in Fig 3. (A).

The liver histopathology in the probiotic group as illustrated in Fig 3 (B) demonstrated significant improvement compared to negative control group. The reduction in fatty alteration, limited fibrosis, mild congestion, and preserved architecture all indicated that probiotic supplementation had effectively alleviated PCOS-induced liver damage.

Discussion

Probiotics unexpectedly increased MDA levels beyond those treated in the untreated PCOS group, despite simultaneous elevations in antioxidant enzymes. Probiotic treatment elevated MDA levels and did not fully restore them to baseline, while also reducing of lipid

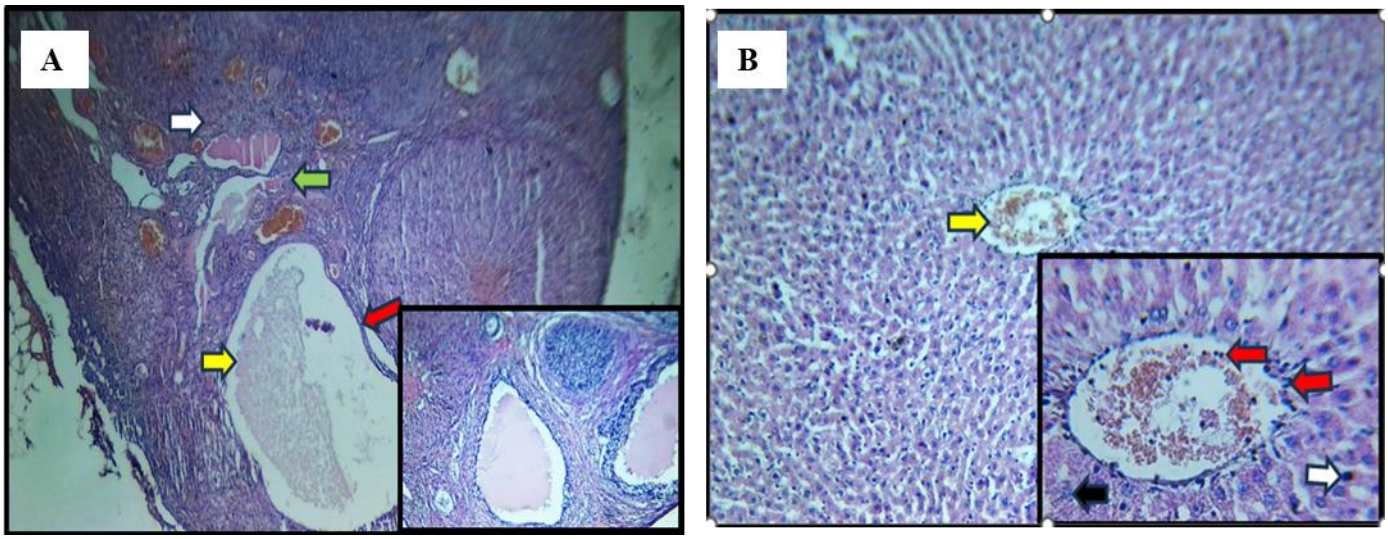

Fig 2. Histology of ovary (A) and liver (B) in the positive control group at 20 days post-challenge. (A) Ovary showing subcapsular multiple cystic follicles (yellow), thin granulosa cells (red), absent oocyte with large antrum, congested stromal vessels (green), and reduced corpus luteum development (white) (H&E, X4+10). (B) Liver showing congested vessels (yellow), peri- and intravascular inflammatory infiltration (red), necrotic lesions with pyknosis (white) and karyolysis (black) (H&E, X10+40).

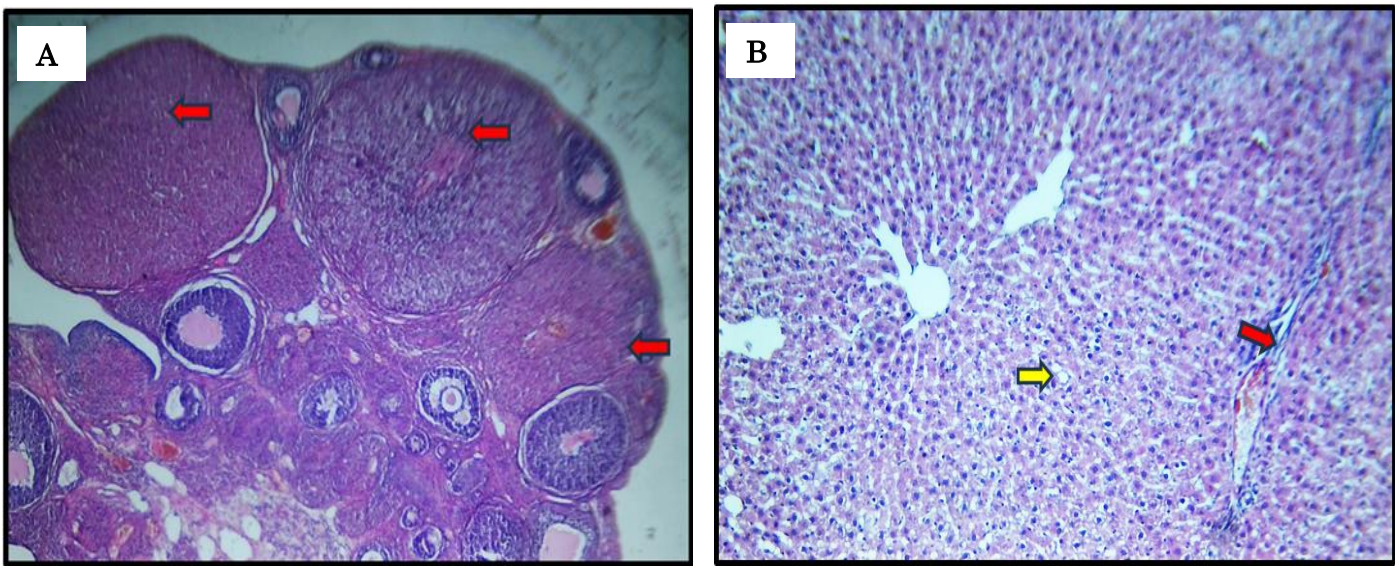

Fig 3. Histology of ovary (A) and liver (B) in the probiotics group at 41 days post-challenge. (A) Ovary showing improved architecture, increased corpora lutea (red), and reduced follicular cysts (H&E, X4). (B) Liver showing reduced fatty change (yellow), mild congestion, and mild pericentral fibrosis (red) (H&E, X10).

peroxidation. these findings contradict (Rautava et al. 2012) who indicated that *Lactobacillus spp*. is recognized for reducing oxidative damage by modulating gut-ovary signalling and enhancing the host's endogenous antioxidant system. (Abdelmotilib & Abdel-Azeem 2022, Ramzan et al. 2025) discovered that, *Lactobacilli* probiotics reduced MDA by modulating host redox-sensitive gene expression and maintaining intestinal epithelial.

Integrity, although probiotics can enhance antioxidant defences, including SOD and GSH, the restoration of membrane integrity and the elimination of lipid peroxidation products, such as MDA may require prolonged treatment. Durations Lipid radicals generated

during the initial oxidative phase can endure, and MDA, as a persistent end product, may accumulate despite the recovery of antioxidant systems (Lee &Kang 2022). The study conducted by (Tremellen & Pearce 2012) confirmed this results indicating that probiotic supplementation improved antioxidant markers in PCOS, although did not immediately reduce lipid peroxidation levels, suggesting a temporal lag between antioxidant activity and lipid Corrie et al. (2023) demonstrated that *Lactobacillus spp.* enhances endogenous GSH production by modulating gut microbiota and reducing systemic inflammation. Probiotics significantly elevated GSH levels in this study, a finding consistent with results by (Qumsani 2025), who attributed the antioxidant effect of probiotics to enhanced short-chain fatty acid production and reduced pro-inflammatory cytokine activity. Specific probiotic strains have the ability to synthesize and secrete glutathione. Frequent consumption of fermented products with these strains had been demonstrated to elevate systemic GSH levels, therefore enhancing the body's antioxidant defences (Rehema et al. 2015).

The probiotic group established a significant increase in SOD activity, validating the hypothesis that *Lactobacillus spp.* may enhance antioxidant enzyme production, probably through the modification of inflammatory and redox-related genes (Corrie et al. 2023, Erzaiq 2025). Certain probiotic strains, specifically lactic acid bacteria (LAB), have intrinsic antioxidant systems, comprising enzymes such as SOD and catalase. These enzymes allow probiotics to directly eliminate reactive oxygen species (ROS), therefore enhancing the host's antioxidant defences (Musazadeh et al. 2023).

The probiotic group also attained LH normalization, possibly through microbiota-mediated control of systemic inflammation and Hypothalamic-Pituitary-Ovarian (HPO) feedback (He et al. 2020). Probiotics affect the gut–brain–ovary axis, a communication network linking the gastrointestinal tract, central nervous system (CNS), and reproductive organs. Probiotics can modify gut microbiota composition, influencing GnRH secretion from the hypothalamus, consequently affecting LH and FSH release from the pituitary gland. This modulation helps in restoring hormonal balance in patients with PCOS (Li et al. 2023).

Probiotics likely enhance FSH by indirectly inhibiting inflammatory cytokines such as TNF-α and IL-6, which are known for impairing FSH receptor signalling (Mora et al. 2025). The reduction of inflammatory cytokines (IL-6 and TNF-α) by probiotic may enhance FSH receptor expression and promote follicular function (Li et al. 2025). Probiotics provide a comprehensive strategy for managing hormonal imbalances in PCOS by influencing the gut–brain–ovary axis, enhancing insulin sensitivity, and demonstrating anti-inflammatory properties. These mechanisms collectively facilitate the normalization of LH, FSH, and testosterone levels, emphasizing the potential of probiotics as an effective adjunct therapy in PCOS management (Esmaeilinezhad et al. 2020).

Probiotics treatment significantly decreased testosterone levels, supporting recent evidence that gut microbiota regulates androgen production through metabolic and immunological signalling pathways (Lv et al. 2024). He et al. (2020) suggested that modulation of gut microbiota reduced systemic endotoxemia, thus suppressing inflammation-induced androgen excess. The introduction of probiotics in the management PCOS has been shown to lower total testosterone levels, hence alleviating hyperandrogenic symptoms (Rahman et al. 2023). In animal models, combined administration of metformin and probiotics led to elevated FSH levels and enhanced folliculogenesis, resembling the hormonal profile of healthy controls (Darvishi et al. 2021).

Clinical trials have shown that probiotic supplementation effectively reduces fasting insulin levels and enhances resistance indicators in women with PCOS, hence supporting its use as an adjunctive therapy (Calcaterra et al. 2023). Strains such as *Lactobacillus* and *Bifidobacterium*, positively influenced the composition of gut microbiota, resulting in increased production of short-chain fatty acids including butyrate, propionate, and acetate. This modulation significantly enhanced insulin sensitivity by activating G-protein-coupled receptors that stimulated the release of incretin hormones, which regulated glucose metabolism and maintained intestinal barrier integrity. Consequently, this process reduced systemic inflammation that impairs insulin signalling, and modulated immune responses to decrease chronic low-grade inflammation associated with insulin resistance (Guevara et al. 2024).Probiotics have been shown to positively influence lipid metabolism by reducing triglycerides and very low-density lipoprotein cholesterol (VLDL-C) while increasing high-density lipoprotein cholesterol (HDL-C); Consequently, improved lipid profiles correlate with enhanced insulin sensitivity and reduced cardiovascular risk in patients with PCOS (Shamasbi et al. 2020).

The probiotic group showed elevated IL-6 levels compared to other treatment modalities, however these levels remained significantly lower than those of positive control. Probiotics are recognised for their anti-inflammatory properties which can reduce circulating levels of pro-inflammatory cytokines, such as IL-6 (Kochar et al. 2024). Probiotic supplementation had been demonstrated to reduce pro-inflammatory cytokines,

including TNF-α and IL-6, strengthen the intestinal barrier, and reduces the translocation of lipopolysaccharides into the bloodstream (Angoorani et al. 2023). Nonetheless, the specific probiotic strain or dosage employed may have limited effectiveness in improving the inflammatory aspect of PCOS. This finding requires additional research into optimal probiotic formulations for the management of PCOS (Ramzan et al. 2025). Probiotics administration leads to a moderate reduction in IL-6 levels associated with modifications in gut microbiota and systemic inflammation reduction (Kelley et al. 2016).

Probiotics have moderate effects by restoring gut microbiota and reducing systemic inflammation, however their contribution to PCOS is supplementary (Kaur et al. 2022). Prior research conducted by Miao et al. (2021) demonstrated inconsistent effects on IL-18, indicating that only certain strains such as *Lactobacillus reuteri* might considerably reduce IL-18 levels (Esan et al. 2023).

Histological analysis revealed that, in contrast to the normal preovulatory follicle observed in the negative control section, the letrozole-induced PCOS ovaries typically exhibited arrested follicular development. Consequently, the administration of letrozole led to a significant reduction in primordial, secondary, and tertiary follicles, accompanied by a notable increase in cystic follicles (Kar et al. 2024). These cystic follicles characteristically lacked oocytes and the features of corona radiata that are prominently seen in normal follicle. In letrozole-induced PCOS, the granulosa cell layer undergoes significant shrinking and degeneration. The structural change is linked to hormonal dependence, specifically the letrozole-induced inhibition of aromatase, which reduced estrogen levels essential for granulosa cell viability (Morsi et al. 2022).

Several studies have indicated that letrozole administration increases oxidative stress in the liver, resulting in lipid peroxidation, mitochondrial dysfunction, and hepatocyte necrosis (Dolanbay et al. 2024). Histopathological changes may compromise liver function, as seen by elevated serum transaminases and altered lipid profiles in letrozole-induced PCOS models This may arise from elevated portal pressure, endothelial dysfunction, or secondary effects of systemic inflammation (Makav et al. 2023).

The results aligned with prior studies indicating that probiotics could significantly improve the ovarian morphological anomalies associated with PCOS, presumably by modulating gut microbiota, regulating sex hormones, and reducing systemic inflammation (Rani et al. 2023). The elevated quantity of corpora lutea indicated the restored ovulatory function, demonstrating that the probiotics-treated group exhibited a decrease in follicular cysts and an increase in the number of corpora lutea. The presence of corpora lutea indicated the effective completion of follicular development and ovulation (Habib et al. 2024). The reduction in follicular cysts indicated that probiotics facilitated the restoration of normal follicular development. Consequently, probiotic treatment resulted in a significant increase in the quantity of corpora lutea and graafian follicles, alongside a significant decline in the number of follicular cysts in comparison with PCOS group (Ramzan et al. 2025).

Probiotics have been demonstrated to regulate sex hormones, with *Lactobacillus plantarum* exhibiting a protective role contrary to ovarian pathological changes and restoring levels of LH, FSH and testosterone. This hormonal balance is essential for normal follicular development and ovulation (He et al. 2020). Probiotic supplementation reduced inflammatory markers; potentially alleviating inflammatory processes associated with PCOS pathology. Clinical research suggested that probiotic supplementation had demonstrated reductions in inflammatory cytokine levels and other markers of systemic inflammation (Kochar et al. 2024). The efficacy of probiotics in treating PCOS seems to operate by regulating sex hormone associated gut microbiota. Specific probiotic strains belonging to *Bifidobacterium, Lactobacilli*, *Clostridium*, *Enterococcus,* and other LAB have demonstrated effectiveness by inhibiting the growth of pathogenic microorganisms, reducing intestinal permeability, enhancing intestinal mucus layer production, and modulating the gastrointestinal immune system (Gautam et al. 2024).

The significant decrease in fatty change observed in the liver section aligned with previous studies indicating that probiotics may reduce steatosis, lipogenesis, oxidative stress, and inflammation in the liver in metabolic liver diseases. Probiotics appear to enhance hepatic lipid metabolism by promoting fatty acid oxidation and reducing lipogenesis, thereby reducing intracellular fat accumulation in hepatocytes (Li et al. 2025).

Probiotics reduced the fibrotic impact in experimental liver fibrosis models. The mechanism probably involves modulation of hepatic stellate cell activation and decreases in TGF-β signalling (Alwan & Al-Saeed 2023). Research has demonstrated that probiotics can significantly reduce pro-inflammatory cytokines such as IL-6 and TNF-α, potentially contributing to reduced vascular congestion and inflammatory cell infiltration (Sabirin et al. 2022). Probiotics may improve the liver histology by positively benefitting ovarian morphology, hormonal balance, and metabolic parameters in PCOS, (Angoorani et al. 2023).

Conclusion

This study demonstrated that probiotic supplementation significantly improved oxidative stress, hormonal balance, and inflammatory markers in a letrozole-induced PCOS rat model. Probiotics also contributed to the restoration of ovarian and hepatic histology by increasing corpora lutea, reducing cystic follicles, and alleviating liver steatosis. These findings highlight probiotics as a promising complementary approach for managing both reproductive and metabolic complications of PCOS. However, further research is needed to validate these benefits, optimize probiotic formulations, and assess their long-term clinical efficacy in human applications.

Authors' contributions

The authors planned the study, analysed the information, and contributed to the manuscript's drafting. All authors reviewed and permitted the final manuscript.

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Conflicts of interest

The authors declare that they have no conflict of interest.

Ethical Approval

The study was approved by college of Veterinary Medicine/ University of Kerbala. It is comparable ethical standards or amendments of the national and/or the institutional research. The study's methodology, consent form and subject information, were reviewed and permitted by a local ethics committee. reference number (UOK.VET.PH. 2024.102).

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