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Nutritional approaches to disease management: Exploring functional diets for PCOS

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Abstract
Polycystic Ovary Syndrome (PCOS) is a prevalent endocrine disorder among women of reproductive age, characterized by hyperandrogenism, anovulation, and insulin resistance. Nutritional interventions play a crucial role in disease management, offering therapeutic benefits beyond pharmacological treatments. Functional diets rich in whole grains, lean proteins, healthy fats, antioxidants, probiotics, and micronutrients have been increasingly recognized for their potential to regulate hormonal balance, improve insulin sensitivity, reduce inflammation, and alleviate metabolic and reproductive complications. This review explores the role of dietary strategies and functional foods in the management of PCOS, emphasizing evidence-based approaches that integrate nutrition with lifestyle modifications.

Keywords: Human health, PCOS, functional foods, therapeutic nutrition, insulin sensitivity

Introduction

Polycystic Ovary Syndrome (PCOS) affects approximately 6–20% of women globally, depending on diagnostic criteria. It is a multifactorial condition associated with metabolic, reproductive, and psychological disturbances, including obesity, insulin resistance, dyslipidemia, menstrual irregularities, infertility, and increased risk of type 2 diabetes and cardiovascular diseases. Nutritional interventions are considered first-line therapy in managing PCOS, as diet directly influences hormonal regulation, metabolic status, and weight control. Emerging evidence highlights the significance of functional foods and specialized dietary patterns in modulating disease outcomes.

Pathophysiology of PCOS and Nutritional Implications

- **Insulin resistance:** Present in ~50–70% of PCOS patients, contributing to hyperinsulinemia and hyperandrogenism.
- **Inflammation and oxidative stress:** Chronic low-grade inflammation and elevated reactive oxygen species exacerbate metabolic dysfunction.
- **Hormonal imbalance:** Increased luteinizing hormone (LH) to follicle-stimulating hormone (FSH) ratio and elevated androgens impair ovulation.
- **Obesity and metabolic syndrome:** Common comorbidities worsen insulin resistance and cardiovascular risk.

Nutrition-based interventions can modulate these pathophysiological pathways by improving glucose metabolism, reducing inflammatory markers, and restoring hormonal balance.

Functional Diets in PCOS Management

1. Low Glycemic Index (GI) and Mediterranean Diet

Low glycemic index (GI) diets and the Mediterranean dietary pattern have been shown to provide significant benefits in women with PCOS by improving insulin sensitivity, reducing fasting glucose levels, and supporting weight management. These diets emphasize nutrient-dense foods such as whole grains, fruits, vegetables, legumes, nuts, olive oil, and fish, which collectively contribute to improved metabolic outcomes and reduced risk of insulin resistance (Marsh *et al*., 2010 [16]; Salari-Moghaddam *et al*., 2021) [24]. Clinical studies indicate that adherence to a Mediterranean diet is associated with improved menstrual regularity and ovulatory function, largely due to its anti-inflammatory and antioxidant properties (Barrea *et al*., 2019) [2]. Furthermore, low-GI foods slow carbohydrate absorption, thereby lowering postprandial glucose excursions and reducing insulin demand, which is particularly beneficial for women with PCOS, who often exhibit hyperinsulinemia (Moran *et al*., 2013) [19]. Collectively, these dietary strategies serve as effective nutritional approaches to improve reproductive and metabolic health in PCOS patients.

2. High-Protein and Moderate-Carbohydrate Diet

A high-protein and moderate-carbohydrate dietary approach has been widely investigated in the management of PCOS due to its ability to promote satiety, stabilize blood glucose levels, and reduce postprandial insulin spikes. Increased protein intake supports lean muscle mass preservation and enhances resting metabolic rate, thereby assisting in weight control and improving insulin sensitivity in obese and insulin-resistant PCOS patients (Moran *et al*., 2006 [21]; Gower & Goss, 2015) [7]. Studies suggest that replacing a portion of dietary carbohydrates with protein not only facilitates greater weight loss but also improves reproductive hormone balance, menstrual regularity, and ovulatory function (Moran *et al*., 2003) [20]. Additionally, moderate carbohydrate restriction reduces hyperinsulinemia and hyperandrogenism, which are central features of PCOS pathophysiology (Liu *et al*., 2017) [15]. Collectively, high-protein and moderate-carbohydrate diets present a practical nutritional intervention that addresses both metabolic and reproductive complications associated with PCOS.

3. Anti-Inflammatory Diet

An anti-inflammatory dietary pattern has gained significant attention in the management of PCOS due to the syndrome's

strong association with chronic low-grade inflammation. This diet emphasizes foods rich in omega-3 fatty acids, antioxidants, and polyphenols, which collectively help modulate immune responses and improve metabolic outcomes. Nutrients from fatty fish, flaxseeds, chia seeds, turmeric, green tea, and berries have been shown to reduce systemic inflammatory markers such as C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α) (Kalgaonkar & Tappia, 2014 [12]; González *et al*., 2012) [6]. Incorporating these bioactive compounds into the daily diet not only improves insulin sensitivity but also reduces oxidative stress, thereby improving ovarian function and menstrual cyclicity in women with PCOS (Cussons *et al*., 2009) [4]. Moreover, the anti-inflammatory diet's high content of polyphenols and omega-3s offers cardioprotective benefits, addressing the elevated cardiovascular risks commonly observed in PCOS patients.

4. Functional Foods and Nutraceuticals

Functional foods and nutraceuticals represent promising adjuncts in the dietary management of PCOS, as they directly target key metabolic and reproductive disturbances. Inositol, particularly myo-inositol and D-chiro-inositol, has been shown to enhance insulin sensitivity, restore ovulatory cycles, and improve oocyte quality, making it a widely recommended supplement for women with PCOS (Unfer *et al*., 2017) [25]. Vitamin D plays a critical role in regulating insulin secretion and follicular development, with deficiency often linked to worsened insulin resistance and reproductive dysfunction in PCOS (Pal *et al*., 2016) [23]. Omega-3 fatty acids, derived from sources such as fish oil and flaxseed, help improve lipid profiles while reducing inflammatory markers, thereby offering cardiometabolic benefits (Moini *et al*., 2015) [17]. Emerging evidence also highlights the potential role of probiotics in modulating gut microbiota composition, which can influence insulin sensitivity and androgen regulation (Khodaverdi *et al*., 2019) [13]. Additionally, bioactive compounds such as cinnamon and fenugreek have demonstrated insulin-sensitizing effects and improvements in menstrual cyclicity, providing natural alternatives for glycemic and hormonal control (Kort & Lobo, 2014) [14]. Collectively, these functional foods and nutraceuticals provide valuable tools for a holistic and individualized approach to PCOS management.

Table 1. Functional Diets in PCOS Management

Dietary Approach	Key Components	Physiological Benefits	Evidence/Findings	References
Low Glycemic Index (GI) & Mediterranean Diet	Whole grains, legumes, vegetables, fruits, nuts, olive oil, fish	Improves insulin sensitivity, reduces fasting glucose, enhances menstrual regularity and ovulatory function	Women with PCOS adhering to low-GI or Mediterranean diets showed better metabolic control and improved reproductive outcomes	Marsh *et al*. (2010) [16]; Barrea *et al*. (2019) [2]; Salari-Moghaddam *et al*. (2021) [24]
High-Protein, Moderate-Carbohydrate Diet	Lean meats, legumes, eggs, dairy, moderate complex carbs	Promotes satiety, reduces postprandial glucose, preserves lean muscle mass, supports weight loss	High-protein diets led to greater reductions in body weight, body fat, and insulin resistance in PCOS women compared to high-carb diets	Moran *et al*. (2003) [20]; Moran *et al*. (2006) [21]; Goss *et al*. (2014)
Anti-Inflammatory Diet	Omega-3 fatty acids (fish, flaxseed, chia), turmeric, green tea, berries	Reduces CRP, IL-6, TNF-α, improves insulin sensitivity, lowers oxidative stress	Anti-inflammatory foods reduced systemic inflammation and improved ovarian function in PCOS	Cussons *et al*. (2009) [4]; González *et al*. (2012) [6]; Kalgaonkar & Tappia (2014) [12]
Functional Foods & Nutraceuticals	Inositol, Vitamin D, Omega-3, Probiotics, Cinnamon, Fenugreek	Improves insulin signaling, regulates follicular development, balances gut microbiota, enhances menstrual cyclicity	Inositol supplementation restored ovulation, Vitamin D improved insulin secretion, probiotics reduced hyperandrogenism, cinnamon improved cycle regularity	Unfer *et al*. (2017) [25]; Pal *et al*. (2016) [23]; Moini *et al*. (2015) [17]; Khodaverdi *et al*. (2019) [13]; Kort & Lobo (2014) [14]
Micronutrients & Phytochemicals	Magnesium, Zinc, Selenium, Resveratrol, Curcumin, Catechins	Antioxidant effects, reduced oxidative stress, anti-androgenic and anti-inflammatory benefits	Supplementation improved insulin sensitivity, ovarian function, and reduced hyperandrogenism in PCOS models	Jamilian *et al*. (2019) [9]; Oner & Muderris (2013) [22]; Furat Rencber *et al*. (2018) [5]; Zhu *et al*. (2017) [27]

5. Role of Micronutrients and Phytochemicals

Micronutrients and phytochemicals play a vital role in modulating the metabolic and reproductive disturbances associated with PCOS, primarily through their antioxidant, anti-inflammatory, and insulin-sensitizing properties. Magnesium and zinc are essential cofactors in glucose metabolism and insulin signaling pathways, and their adequate intake has been linked to reduced oxidative stress and improved insulin sensitivity in women with PCOS (Jamilian *et al*., 2019) [9]. Selenium, a potent antioxidant, contributes to the reduction of oxidative damage and may enhance ovarian function by supporting follicular development and reducing inflammation (Oner & Muderris, 2013) [22]. Additionally, phytochemicals such as polyphenols—particularly resveratrol, curcumin, and catechins—have demonstrated anti-inflammatory and anti-androgenic effects in both clinical and experimental models of PCOS (Furat Rencber *et al*., 2018 [5]; Zhu *et al*., 2017) [27]. These bioactive compounds not only improve metabolic outcomes but also target hyperandrogenism, thereby promoting better reproductive health. Incorporating micronutrient-rich foods and polyphenol-containing functional foods may therefore serve as an adjunctive nutritional strategy for comprehensive PCOS management.

Table: 2 Role of Micronutrients and Phytochemicals in PCOS Management

Nutrient/Phytochemical	Mechanism of Action	Evidence in PCOS Management	References
Magnesium & Zinc	Act as cofactors in insulin signaling; reduce oxidative stress	Supplementation improves insulin sensitivity and reduces inflammation	Jamilian *et al*., 2019 [9]
Selenium	Antioxidant role via glutathione peroxidase activity; supports ovarian function	Enhances follicular development and reduces oxidative damage	Oner & Muderris, 2013 [22]
Resveratrol	Polyphenol with anti-inflammatory and anti-androgenic properties	Improves ovarian morphology, reduces androgen levels	Furat Rencber *et al*., 2018 [5]
Curcumin	Potent antioxidant and anti-inflammatory	Attenuates insulin resistance and reduces inflammatory markers	Zhu *et al*., 2017 [27]
Catechins (Green Tea)	Antioxidant polyphenols; modulate androgen activity	Reduce hyperandrogenism and oxidative stress in PCOS models	Zhu *et al*., 2017 [27]

Lifestyle Integration with Diet

Lifestyle modification is considered the cornerstone of PCOS management, with dietary interventions yielding greater benefits when integrated with physical activity and behavioral changes. Even modest weight loss of 5–10% of body weight has been shown to significantly improve insulin sensitivity, restore ovulatory cycles, and enhance fertility outcomes in overweight and obese women with PCOS (Moran *et al*., 2011) [18]. Exercise acts synergistically with functional diets, as both aerobic and resistance training contribute to improved body composition, reduced visceral adiposity, and better glucose regulation (Harrison *et al*., 2012) [8]. Beyond diet and exercise, behavioral strategies such as mindful eating, stress reduction, and structured lifestyle counseling play a key role in improving adherence and preventing disordered eating patterns, which are commonly reported in women with PCOS (Kakoly *et al*., 2018) [11]. Thus, a comprehensive lifestyle approach that combines functional nutrition, physical activity, and psychosocial support offers the most effective non-pharmacological strategy for long-term management of PCOS.

Conclusion

Nutritional approaches, particularly functional diets and targeted supplementation, represent effective non-pharmacological strategies for PCOS management. Diets emphasizing low GI foods, anti-inflammatory components, and functional bioactives like inositol, probiotics, and omega-3 fatty acids can significantly improve metabolic, reproductive, and psychological outcomes. An integrated approach that combines personalized nutrition, physical activity, and lifestyle modification offers the most promising strategy for managing PCOS and enhancing women's overall health.

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