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Review Article

Optimizing Women's Health-Utilising Phytochemicals for Functional Food Development

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ABSTRACT

Objectives: The major objective of this review is to systematically evaluate and synthesize recent evidence on functional foods and phytochemicals in relation to women's health outcomes. Functional foods have emerged as an important dietary component that extend beyond basic nutrition by delivering bioactive compounds with targeted health benefits. **Materials and Methods:** A systematic literature review was conducted using PubMed, Scopus, Web of Science and Google Scholar and 74 studies were included in the final synthesis. Only peer-reviewed English articles from 2011-2025 were considered, while editorials and non-peer-reviewed sources were excluded. The screening process followed PRISMA guidelines. **Results:** Among the included studies, 42% focused on phytochemicals in cereals and legumes, 35% on spices and herbs and 23% on fruits and vegetables. Approximately 65% reported significant benefits in managing PCOS, menopause and metabolic disorders. Functional foods such as cereals, millets, legumes, fruits, vegetables, herbs and spices contain phytochemicals that modulate oxidative stress, inflammation and hormone metabolism. These functional components demonstrate therapeutic potential in addressing women-specific health challenges such as polycystic ovary syndrome, menstrual irregularities, menopause, anemia, thyroid dysfunction, obesity and cancer. **Conclusion:** This review highlights the importance of integrating functional foods into dietary guidelines, especially in women's health programs targeting PCOS, anemia, menopause, obesity and menstrual irregularities. Policymakers and healthcare practitioners should encourage functional food based interventions as complementary strategies to conventional therapies. Further clinical studies are recommended to standardize dosages, evaluate long-term safety and develop functional food products tailored to different stages of women's life cycles.

Keywords: Anemia, Functional Foods, Menopausal Symptoms, Menstrual Irregularities, Phytochemicals, Polycystic Ovary Syndrome.

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INTRODUCTION

In recent decades, there has been growing interest with respect to the role of diet not just for basic nutrition, but as a key tool in disease prevention, health promotion and enhancement of quality of life. Functional foods are defined as food ingredients that provide a health benefit beyond the traditional nutrients it generally contains. Emerging scientific evidence has ignited public interest over the past decade, particularly with respect to the potential of addressing women's health concerns. Similarly, modern definitions acknowledge that functional foods may be conventional or modified foods ranging from whole, natural foods rich in bioactive components to fortified or enhanced products which provide scientifically validated health effects when regularly consumed as part of a varied diet.[1] Functional foods contain biologically active ingredients such as nutrients, dietary fiber, phytochemicals, or probiotics at levels sufficient to confer health benefits or reduce disease risk beyond normal nutrition. This aligns with the concept that functional foods not only maintain basic physiological functions but also promote optimal health.[2] Women's health challenges such as PCOS, anemia, thyroid dysfunction and menopause remain globally prevalent and conventional dietary approaches often fall short in addressing them. Functional foods rich in phytochemicals offer a promising, cost-effective and sustainable solution, making this review timely and significant.

Phytochemicals or plant-derived bioactive compounds are key contributors to the functional effects of many foods.[3] They include classes like polyphenols (such as flavonoids and phenolic acids), terpenoids (such as carotenoids) and other secondary

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metabolites (such as thiols) commonly found across a variety of fruits, vegetables, grains and spices.[4] While not classified as essential nutrients, numerous phytochemicals exhibit biologically active properties such as antioxidant, anti-inflammatory or hormonal modulation that may influence health outcomes.[5]

In India, traditional dietary patterns and readily available plant sources provide a rich foundation of functional foods especially relevant to women's health. Traditional Indian cereals, pulses, spices, oils and leafy greens are especially rich sources of dietary fiber, antioxidants and phenolic compounds that may help prevent chronic diseases such as diabetes, cardiovascular disorders and certain cancers. The inclusion of these foods in daily meals can facilitate the nexus between diet and women's health.[6]

Traditional Indian functional foods including whole grains and millets such as jowar, ragi, bajra, brown rice and oats offer high fiber along with micronutrients like iron and calcium that are valuable for menstrual health, metabolic regulation and bone strength.[6] Millets are diverse groups of small seeds that have experienced a resurgence in recognition due to their high nutrient density, gluten-free nature, low glycemic index and rich content of fiber, minerals and phytochemicals that may help in mitigating lifestyle-related disorders. For instance, recent reviews highlight millet's potential benefits in managing metabolic risk factors, immunity support and women's nutritional needs.[7] Similarly, ingredients such as turmeric and fenugreek are widely consumed and hold promise for women's health. Turmeric contains curcumin, a polyphenolic phytochemical known for its anti-inflammatory and antioxidant effects, with emerging evidence supporting its roles in hormone regulation and metabolic health.[8] Fenugreek on the other hand is rich in phytoestrogens and fiber; studies suggest it may improve insulin sensitivity and manage menstrual or menopausal symptoms both important for women's metabolic and reproductive health.[9] Green leafy vegetables such as methi or fenugreek leaves (*Trigonella foenum-graecum*), moringa, spinach (*Spinacia oleracea*) and amaranth (*Amaranthus* spp.) are rich in iron, fiber, protein and phytonutrients that support liver function, detoxification, reproductive well-being and general women's nutrition.[10]

These functional foods are particularly important for women's health in India, where micronutrient deficiencies (e.g., iron, calcium, folate) and metabolic stresses (e.g., gestational diabetes, menopause-related changes) are common public health challenges. Integrating functional foods into the regular diet may support reproductive health, bone health, glycemic control and overall well-being through combined nutritive and phytochemical contributions.[6] The objective of this review is to systematically analyze recent evidence on the role of functional foods and phytochemicals in women's health, focusing on their therapeutic properties, nutritional value, disease prevention potential and practical applications. Although prior studies have examined functional foods in general, few reviews have systematically synthesized evidence focusing exclusively on women's health outcomes, particularly across diverse conditions such as reproductive disorders, metabolic diseases and menopausal transitions. This review addresses this gap by linking functional food bioactives with women-specific health concerns. Unlike earlier reviews, this study incorporates evidence published between 2011 and 2025, applies a structured SLR approach with PRISMA methodology and integrates nutritional, functional and therapeutic insights across multiple life stages in women. This makes the review broader in scope, methodologically rigorous and more directly relevant to contemporary dietary recommendations. This review aims to consolidate current evidence on functional foods and phytochemicals in women's health, identify key therapeutic potentials and highlight knowledge gaps to inform future research and practical dietary interventions.

MATERIALS AND METHODS

This review adopted a structured Systematic Literature Review (SLR) approach consisting of database identification, search strategy formulation, application of inclusion and exclusion criteria, screening and selection of studies and synthesis of findings to ensure transparency, replicability and relevance. The review focused on functional foods and phytochemicals in relation to women's health, particularly their roles in nutrition, therapeutic potential and disease prevention. Literature searches were conducted in PubMed, Scopus, Web of Science and Google Scholar using descriptors such as "functional foods AND women's health," "phytochemicals AND reproductive health," "functional foods AND menopause," "bioactive compounds AND chronic diseases" and "dietary phytochemicals AND hormone regulation." Articles were included if they were peer-reviewed journal papers, reviews, or book chapters published in English between 2011 and 2025 that reported findings on functional foods and their impact on women's health outcomes including PCOS, menstrual irregularities, anemia, thyroid dysfunction, obesity, menopausal symptoms and hormone-related cancers. Editorials, letters, non-peer-reviewed sources and studies unrelated to functional foods were excluded, with Google Scholar results further filtered by journal quality and citation strength. The screening process followed PRISMA guidelines (Figure 1): a total of 252 records were retrieved (PubMed, Scopus, Web of Science: 136; Google Scholar: 116). After removing 41 duplicates, 211 titles/abstracts were screened, of which 137 were excluded as irrelevant. Finally, 74 full-text articles met the inclusion criteria and were included in the synthesis. Data were extracted manually and organized into thematic categories covering phytochemical classes, functional properties and disease-specific outcomes. Due to heterogeneity in study designs, no statistical meta-analysis was conducted instead, a comparative thematic synthesis was performed to identify patterns, therapeutic potentials and research gaps.

Reference management was carried out using Zotero to ensure citation accuracy.

RESULTS

To provide structured insights, the keywords were categorized into three sections: (i) Phytochemicals and classification (ii) Functional foods and their properties and (iii) Functional foods for various disease conditions in women. These sections reveal how research in this field is distributed, highlighting dominant areas such as functional foods while also showing interdisciplinary connections, particularly between phytochemicals and women's health.

Phytochemicals

Plant Metabolites are classified into two broad categories based on their functions in the body. The first group, known as primary metabolites, includes substances such as carbohydrates, proteins and lipids. The second group, called secondary metabolites, comprises compounds like alkaloids, essential oils, flavonoids, terpenoids, saponins and various phenolic compounds, each offering distinct health benefits.[5] Phytochemicals are biologically active low-molecular-weight secondary metabolites produced by plants. Unlike primary metabolites, they are non-nutritive compounds that plants produce to protect themselves from environmental stresses such as pests, pathogens and ultraviolet radiation and contribute to plant color, flavor and growth regulation. In human contexts, while not formally classified as nutrients, they have been linked to potential health effects.[11] These compounds exhibit diverse biological properties, including antioxidant, anti-inflammatory, anticancer, cardioprotective, neuroprotective and immune-modulating effects. They are structurally diverse and classified into different groups such as polyphenols, terpenoids and thiols, each demonstrating unique modes of action. A key characteristic of phytochemicals is their variable bioavailability, as they undergo extensive metabolism through gut microbiota and hepatic enzymes, which may enhance or reduce their biological activity. Furthermore, genetic variation among individuals influences their absorption and efficacy, highlighting their complex role in health promotion and disease prevention.[4,12]

Classification of Phytochemicals

Phytochemicals can be broadly classified into polyphenols, terpenoids and thiols (Figure 2).[13] Each class exhibits distinct bioactive properties contributing to antioxidant, anti-inflammatory, anticancer and protective health effects.

Polyphenols

Polyphenols are widely recognized phytochemicals in human nutrition, encompassing a vast array of compounds that range in structure from simple monomers to complex high molecular weight polymers.[14] They are a structurally diverse group of plant-derived metabolites defined by the presence of multiple hydroxyl groups on aromatic rings, giving them a high degree of conjugation and resonance stabilization. They are broadly divided into flavonoids, phenolic acids and non-flavonoids (Figure 2).[15] Flavonoids are built on a C6-C3-C6 skeleton and are subdivided into different classes like flavonols (e.g., quercetin, in green tea), flavones (e.g., apigenin, in parsley), isoflavones (e.g., daidzein, in soybeans), flavanones (e.g., hesperidin, in citrus), flavan-3-ols (e.g., catechins, in grapes), flavanolols, anthocyanidins (e.g., cyanidin, in berries) and dihydrochalcones (e.g., phloretin, in apples).[16] Phenolic acids include hydroxybenzoic acids (e.g., gallic acid) and hydroxycinnamic acids (e.g., caffeic, ferulic, coumaric acids) differs on whether the carboxylic group is directly attached to the aromatic ring or extended by a propenoic side chain.[17] Non-flavonoid polyphenols cover tannins (polymeric proanthocyanidins), stilbenes (e.g., resveratrol, C6-C2-C6 skeleton), lignans (dimeric phenylpropanoids such as secoisolariciresinol) and curcuminoids (diarylheptanoids from turmeric). Despite their varied structural classes, the unifying chemical feature is the presence of phenolic hydroxyl groups capable of undergoing redox, conjugation, or esterification reactions.[14,15]

Terpenoids

Terpenoids also known as isoprenoids constitute an expansive and structurally diverse family of naturally occurring compounds derived from terpenes. They are unified by their biosynthesis from isoprene units (C5H8) via Isopentenyl Pyrophosphate (IPP) and Dimethylallyl Pyrophosphate (DMAPP). Classification is based on the number of isoprene units: Monoterpenoids (C10), Sesquiterpenoids (C15), Diterpenoids (C20), Triterpenoids (C30) and Tetraterpenoids (C40, carotenoids). Distinguished by the incorporation of oxygen-containing functional groups, many terpenoids are multi-ringed frameworks featuring various oxidized moieties.[18] This broad class of compounds encompasses both carotenoid and non-carotenoid terpenoids (Figure 2). Carotenoids, a widely recognized subgroup within terpenoids, are C_{40} tetraterpenoids constructed from eight isoprene units and are responsible for the red, orange and yellow hues commonly found in foods and various living organisms. They include linear and cyclic tetraterpenes such as α-, β- and γ-carotene, lutein, zeaxanthin, lycopene and astaxanthin, characterized by extended polyene systems responsible for conjugation and electronic transitions.[19] Non-carotenoid terpenoids exhibit wide structural diversity, such as saponins (glycosylated triterpenoids in soy), limonene (a cyclic monoterpene in citrus), perillyl alcohol (hydroxylated monoterpene in mint), phytosterols (triterpenoids with a steroidal backbone in legumes), ursolic acid (a pentacyclic triterpenoid in cranberries) and ginkgolides (diterpenoids with terpene trilactone structures). Their chemistry is marked by cyclization patterns, oxidation states and substitution on the

isoprene skeleton, resulting in an array of linear, monocyclic, bicyclic and polycyclic frameworks.[20]

Thiols

Thiols represent sulfur-containing phytochemicals characterized by the sulfhydryl (-SH) functional group or sulfur-linked structural motifs. They are commonly grouped into glucosinolates, allylic sulfides and indoles (Figure 2).[21] Glucosinolates are thioglucosides consisting of a β-thioglucose moiety, a sulfonated oxime group and an amino acid derived side chain; they are abundant in cruciferous vegetables such as broccoli and cauliflower. Their hydrolysis yields diverse sulfurous intermediates.[22] Allylic sulfides, found in onion and garlic relatives, are aliphatic organosulfur compounds with varying sulfur chain lengths (diallyl sulfide, disulfide, trisulfide) that exhibit distinctive reactivity due to sulfur-sulfur and sulfur-carbon bonding.[23] Indole derivatives, such as indole-3-carbinol in broccoli, are heteroaromatic structures where a fused benzene and pyrrole ring system integrates nitrogen, while in plant thiols these are often linked to sulfur-rich side chains derived from glucosinolates. The unique chemistry of thiols arises from sulfur's high nucleophilicity and ability to undergo oxidation-reduction transformations, forming sulfoxides, sulfones and disulfides under physiological or environmental conditions.[21]

Functional foods and their therapeutic properties

Functional foods are nutrient-rich foods or food components that provide health benefits beyond basic nutrition which plays a powerful role in women's health. They offer antioxidant, anti-inflammatory, hormone-modulating, antimicrobial and anticancer effects that are particularly relevant to menstrual cycles, fertility, pregnancy, menopause and hormone-sensitive cancers.[1] The following are the various therapeutic properties found in functional foods.

Antioxidant Properties

Oxidative stress is an imbalance between Reactive Oxygen Species (ROS) and antioxidant defenses that contributes to many women's health issues such as menstrual pain, preeclampsia, infertility and aging-related diseases. Functional foods rich in antioxidants help counter these effects. A review of nutraceuticals confirms that many functional foods (e.g. polyphenol-rich fruits, vegetables, spices, herbs) reduce intracellular ROS and upregulate antioxidant enzymes via the Nrf2 pathway, while suppressing inflammation via NF-κB modulation.[24] Specific foods studied in women: for example, tomato juice rich in lycopene reduced markers of lipid peroxidation (TBARS) in healthy women over 2 months. These antioxidant effects can protect ovarian function, improve egg quality, reduce oxidative damage in pregnancy (risking complications like miscarriage or preeclampsia) and slow the aging of reproductive tissues.[25]

Anti-Inflammatory Activity

Chronic or acute inflammation is implicated in conditions such as endometriosis, Polycystic Ovarian Syndrome (PCOS), irregular menstruation, cramps and menopausal symptoms. Certain functional foods help in modulating inflammatory responses. Plant foods like green tea (catechins), turmeric (curcumin) and various spices have been shown in human studies to reduce markers like CRP, TNF-α, IL-6 via suppression of NF-κB and modulation of macrophage polarization. For women, anti-inflammatory foods relieve menstrual pain, reduce heavy bleeding, improve symptoms in PCOS and lessen symptoms during menopause such as joint pain and hot flashes.[24,25]

Hormone Modulation

Hormone balance is central to female reproductive health like phytoestrogens and other functional food components can mimic or modulate hormonal activity. Soy isoflavones (genistein, daidzein, glycitein) are phytoestrogens that can bind estrogen receptors. In pre-menopausal women, they may act anti-estrogenically when endogenous estrogen is high and in post-menopausal women act like weak estrogen when estrogen is low. This dual effect helps modulate hormone levels and reduce risks associated with hormone fluctuations.[26] Studies show soy intake is associated with a modest reduction in breast cancer risk in both pre- and post-menopausal women; meta-analyses report inverse correlation between soy/isoflavone consumption and breast cancer incidence. This hormone modulation assists with menopausal symptoms (e.g. hot flashes), reduces risk of endometrial and breast cancers, supports menstrual regularity and may improve fertility.[27]

Antimicrobial Effects

Maintaining a healthy microbial balance is critical for women's genital and urinary tract health; functional foods can contribute to antimicrobial defense and microbiome modulation. Garlic (allicin, sulfur compounds) shows antibacterial activity and is considered useful in immune boosting and in fighting pathogens.[28] Probiotics and fermented functional foods (e.g. yogurt, fermented soy, lactic acid bacteria) isolated from post-menopausal vaginal fluid display strong adhesion, survival and antimicrobial capabilities helps suppress pathogens and restore healthy vaginal flora. These antimicrobial/frost-microbial modulation properties help prevent Urinary Tract Infections (UTIs), Bacterial Vaginosis (BV), yeast infections and may aid recovery during antibiotic therapy.[29]

Anticancer Properties

Many functional foods contain bioactive compounds that inhibit carcinogenesis, especially in hormone-sensitive cancers (e.g. breast, endometrial), by multiple mechanisms. Foods such as citrus fruits, berries, pomegranate, soy, tomatoes, cruciferous vegetables, garlic, green tea and turmeric have demonstrated

anticancer actions including antioxidant and anti-inflammatory effects; induction of apoptosis; cell cycle arrest; inhibition of angiogenesis and migration; epigenetic modifications; and modulation of tumor microenvironment.[25] Studies found that each increment of 10 mg/day isoflavones was associated with about 3% lower risk of breast cancer. Systematic reviews show that in breast cancer survivors, moderate soy/isoflavone intake may reduce recurrence and mortality, especially among post-menopausal and estrogen receptor positive patients.[27]

Functional foods in different food groups and specific biological properties

Functional foods are defined as foods that provide health benefits beyond basic nutrition, owing to the presence of bioactive components that influence physiological functions and reduce the risk of chronic diseases.[30] These foods are rich in bioactive compounds including polyphenols, terpenoids and other phytochemicals, which contribute to disease prevention and improved well-being (Table 1).

Spices and beverages

Spices are a concentrated source of phytochemicals that support metabolic balance and aid in the prevention and management of chronic conditions, many of which disproportionately affect women, including obesity, diabetes, cardiovascular disorders and certain cancers. Turmeric (*Curcuma longa*), a widely used spice in both culinary and medicinal practices, contains curcumin, a polyphenolic compound known for its anti-inflammatory, antioxidant, anti-obesity and anti-cancer properties. In women, curcumin supplementation has been linked to improved metabolic health, reduction in menstrual pain (dysmenorrhea) and potential protective effects against breast and ovarian cancers.[31,32] Cumin (*Cuminum cyminum*) seeds contain cuminaldehyde, which exhibits antioxidant, anti-allergic, hypoglycemic and anti-platelet aggregation activities. These properties are especially relevant in women's health for the management of metabolic syndrome, gestational diabetes and cardiovascular complications. Ginger (*Zingiber officinale*), another staple spice, contains bioactive constituents such as gingerol, zingiberene and shogaols. These compounds exert anti-inflammatory, anti-obesity and immunomodulatory effects, which can benefit women suffering from Premenstrual Syndrome (PMS), Polycystic Ovary Syndrome (PCOS), menopausal symptoms and inflammatory conditions like rheumatoid arthritis.[33] Garlic (*Allium sativum*) is rich in allicin and sulfur-containing compounds that help regulate body weight, lipid profiles and blood glucose levels. Regular intake has been shown to reduce the risk of type 2 diabetes and cardiovascular disease, both of which are major concerns in women, particularly after menopause. When consumed alongside turmeric, garlic demonstrates synergistic effects against dyslipidemia and hyperglycemia, offering potential protection against chronic metabolic diseases.[32]

Green tea (*Camellia sinensis*), a widely consumed beverage, contains catechins particularly Epigallocatechin Gallate (EGCG) which is a powerful antioxidant with strong anti-carcinogenic and anti-obesity properties. EGCG has been shown to suppress angiogenesis and tumor progression in breast, colon and ovarian cancers, conditions that have high prevalence among women. In addition, green tea catechins enhance fat oxidation, reduce lipid absorption and support weight management, which is especially beneficial in reducing the risk of obesity, PCOS and postmenopausal metabolic disorders.[33,34] Overall, spices and functional beverages like green tea provide women with dietary phytochemicals that not only promote general health but also target gender-specific conditions such as hormonal imbalances, reproductive cancers and postmenopausal complications.

Fruits and vegetables

Fruits are among the richest sources of dietary phytochemicals, including polyphenols, flavonoids and anthocyanins, which are strongly associated with reducing risks of obesity, cardiovascular disease and hormone-related cancers in women.[35] Tomatoes are abundant in lycopene which possess antioxidant and anti-carcinogenic effects that protects against breast and cervical cancers, while also supporting weight management which is a key concern for women, especially during postmenopausal years.[36] Citrus fruits such as lemons and oranges supply phenolic acids, flavonoids and carotenoids and have been associated with anti-obesity and anti-cancer properties, making them beneficial in reducing risks of breast and ovarian cancers.[37] Grapes are rich in resveratrol, a polyphenolic compound shown to regulate adipocyte proliferation and improve metabolic health. When combined with other bioactives such as quercetin, genistein, or vitamin D, resveratrol has been reported to enhance obesity management in women, particularly those with Polycystic Ovary Syndrome (PCOS) or postmenopausal weight gain.[38] Pomegranates, with high levels of anthocyanins, ellagitannins and phenolic acids, demonstrate hypoglycemic and cholesterol-lowering effects, supporting cardiovascular health and metabolic balance in women who face increased risks of diabetes and dyslipidemia during midlife.[33] Bananas, containing syringic acid, dopamine, gallic acid and quercetin, support mood regulation and energy metabolism, which are essential for women's reproductive and mental health. Similarly, mangoes provide bioactive compounds with anti-cancer potential, offering protective benefits against hormone-driven cancers such as breast cancer.[35]

Vegetables also play a critical role in women's health due to their diverse phytochemical content. Carrots are rich in alpha- and beta-carotenoids, which have been shown to protect against cancers, particularly breast cancer, one of the most prevalent malignancies among women.[39] Cruciferous vegetables, including broccoli and cabbage, contain isothiocyanates and cucurbitacins compounds which are associated with anti-cancer and detoxification pathways. These phytochemicals may be

particularly beneficial for women by supporting estrogen metabolism and reducing risks of hormone-dependent cancers.[33] Additionally, chillies are an excellent source of capsaicin, which enhances metabolism, supports healthy weight maintenance and has been identified as a chemo-preventive agent with tumor-suppressing effects, relevant to the prevention of cervical and breast cancers.[40] Collectively, fruits and vegetables provide women with essential bioactive compounds that not only support reproductive, metabolic and cardiovascular health but also offer protection against chronic diseases and cancers that disproportionately impact female populations.

Legumes and Pulses

Legumes and pulses, including peas, chickpeas, lentils, pigeon peas and soybeans, are nutrient-dense foods rich in proteins, fibers and bioactive phytochemicals that support women's overall health. Among them, soybeans are particularly well-studied for their high content of isoflavones, a class of phytoestrogens with estrogen-like activity. Isoflavones mainly daidzein, genistein and glycitein play an important role in regulating hormone-dependent conditions that are highly relevant to women, such as menopausal symptoms, cardiovascular disease, hormone-driven cancers and osteoporosis.[33] By mimicking estrogen, isoflavones help alleviate hot flashes, improve bone density and reduce postmenopausal cardiovascular risk. Genistein, one of the most potent isoflavones, has been shown to lower BMI, body fat and waist circumference, making it beneficial for women struggling with obesity or metabolic syndrome, conditions that frequently worsen after menopause. Additionally, genistein exhibits broad-spectrum anticancer activity, with particular effectiveness against breast cancer along with gastric, leukemia and lung cancers.[41] Black soybeans, another variant, are rich in anthocyanins, which provide strong antioxidant, anti-obesity and anti-inflammatory effects. These compounds may help in managing type 2 diabetes, reducing inflammation linked to reproductive health disorders like PCOS and supporting healthy aging in women.[42] Similarly, pigeon pea contains phytosterols and linoleic acid that act synergistically to reduce dyslipidemia and oxidative stress. Such effects are particularly valuable for women in midlife, who are at increased risk of cardiovascular disease and lipid imbalances due to declining estrogen levels.[43] Overall, legumes and pulses not only provide essential nutrition but also deliver gender-specific benefits through their phytochemicals, supporting hormonal balance, reproductive health, metabolic stability and long-term disease prevention in women.

Cereals and Millets

Cereals and millets are increasingly recognized as functional foods due to their rich composition of bioactive compounds, making them particularly beneficial for women's health. Fiber plays a pivotal role in maintaining digestive regularity, reducing risks of constipation, diverticulitis and supporting a healthier gut overall but also has wider implications for women, from hormonal balance to metabolic health. Beyond gut function, the fiber in these cereals helps stabilize blood sugar levels and lowers LDL cholesterol, both of which are critically important in reducing the risk of type 2 diabetes and cardiovascular disease conditions whose prevalence tends to rise after menopause and with advancing age.[44] Whole cereals such as wheat, brown rice provide dietary fiber, B vitamins and minerals that support cardiovascular health, regulate blood glucose levels and improve digestive function, which are crucial for reducing the risk of metabolic disorders that disproportionately affect women.[45] Oats, in particular, are known for their β-glucan content, which plays a significant role in lowering cholesterol and managing blood pressure. Moreover, cereal-based diets contribute to hormonal balance and reduce the risk of postmenopausal complications such as osteoporosis and cardiovascular diseases.[46]

Millets including finger millet, pearl millet, buckwheat and foxtail millet, are rich in polyphenols, flavonoids and essential micronutrients like iron and calcium, which play a vital role in preventing anemia and supporting bone health, especially during pregnancy, lactation and postmenopausal stages. Finger millet is particularly rich in calcium, making it valuable in preventing osteoporosis and maintaining bone strength in postmenopausal women.[47] Millets also have a low glycemic index, making them suitable for managing gestational diabetes and reducing the risk of type 2 diabetes among women. Moreover, the antioxidant and anti-inflammatory properties of cereal and millet bioactives contribute to hormonal balance and protection against chronic diseases such as osteoporosis, cardiovascular disorders and certain cancers.[48] Thus, the regular inclusion of cereals and millets in the diet serves as a sustainable and accessible strategy for promoting women's overall health and wellbeing.

Health concerns in Women and moderation with functional foods

Women face diverse health challenges across their lifespan, including reproductive disorders (e.g., PCOS, menstrual disorders) and non-reproductive conditions (e.g., anemia, obesity, thyroid). These conditions significantly affect quality of life and global health burden. Integrating functional foods that possess bioactive compounds in the diets with conventional care offers a preventive, holistic approach to improving women's health outcomes and reducing disease risk.

Polycystic Ovarian Syndrome (PCOS)

Polycystic Ovary Syndrome is a complex disorder affecting women during their reproductive years, characterized by hormonal imbalances, impaired ovarian activity and metabolic dysfunctions.[49] Foods rich in bioactive components include fruits, vegetables, whole grains, legumes, medicinal herbs, meat and fish are recognized for their diverse health-promoting properties, including antioxidant, anti-inflammatory and

hormone-modulating effects. These compounds play a potential role in preventing and managing PCOS by improving insulin sensitivity, mitigating oxidative stress, regulating hormonal activity and enhancing lipid metabolism.[50] The beneficial effects of phytochemicals in PCOS are likely the result of multiple mechanisms. Phytochemicals like flavonoids, lignans and polyphenols can boost insulin sensitivity by facilitating glucose uptake, enhancing pancreatic β-cell performance and decreasing insulin resistance. Moreover, phytochemicals can influence sex hormone biosynthesis and signaling, aiding in the correction of hormonal disturbances commonly seen in PCOS.[51] Extensive research supports the use of herbal remedies and isolated phytochemicals in alleviating PCOS symptoms. Compounds such as curcumin, rutin and fisetin have been shown to regulate the reproductive cycle by reducing testosterone levels and balancing the luteinizing hormone to follicle-stimulating hormone ratio.[52] Mechanistically, these functional foods act via multiple pathways: boosting insulin sensitivity by modulating signaling, reducing oxidative stress and lipid peroxidation. Animal studies also show effects on ovarian morphology (fewer cystic follicles, more normal follicle development) when functional foods are provided.[53]

Anaemia

Anemia is a prevalent public health issue defined as a reduction in Red Blood Cells (RBCs) or Haemoglobin (Hb) content (below 13.5 g/dL in men and 12.5 g/dL in women) in blood which is necessary for carrying oxygen to meet various physiological needs. The major causes include diminished Hb production due to iron, vitamin B12, or folate deficiencies, as well as structural hemoglobin defects that accelerate RBC destruction.[54] Anemia affects individuals across all age groups, with particularly high prevalence in pregnant women (41.8%) and preschool children

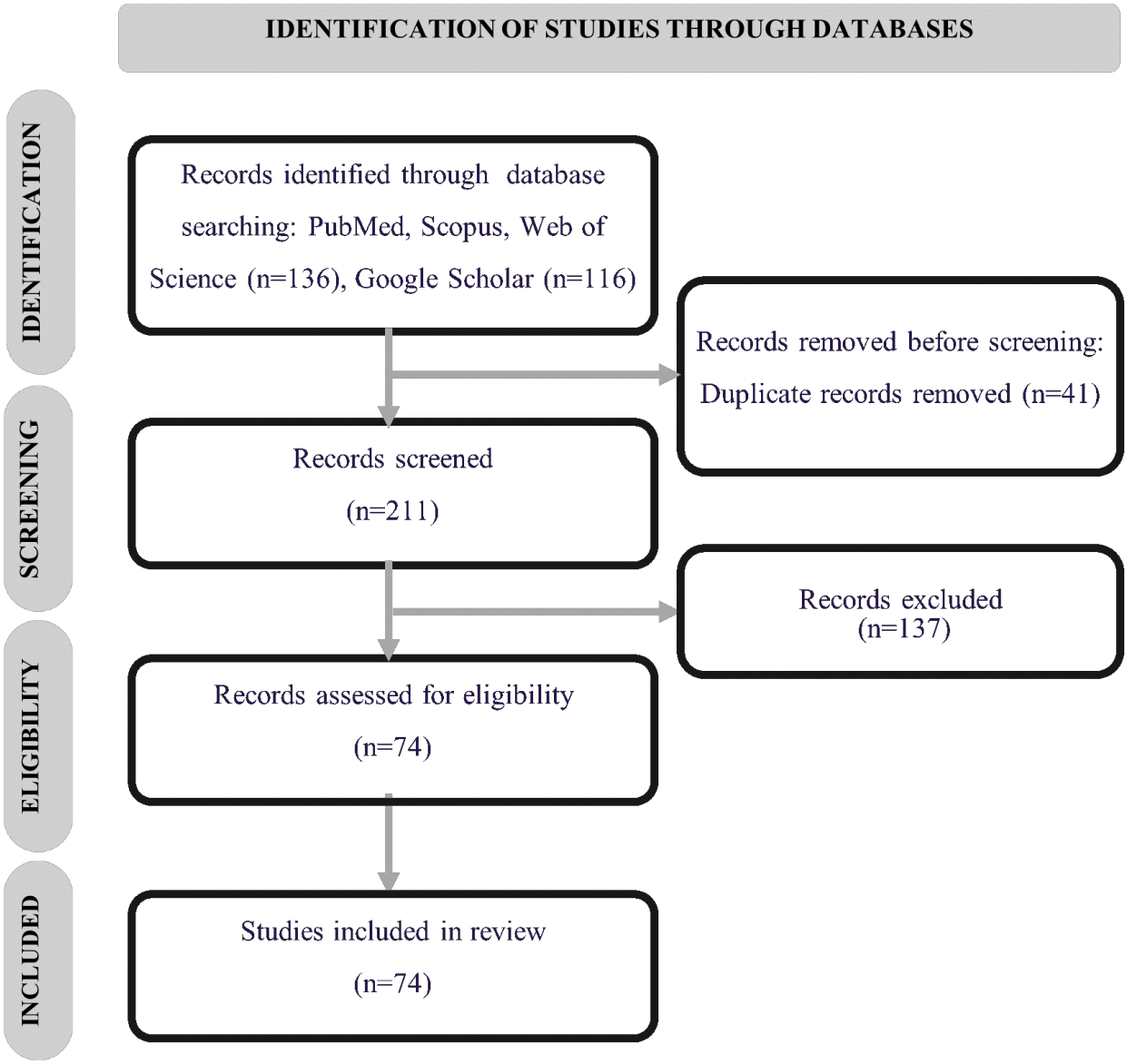

Figure 1: PRISMA Flow Diagram. "Original figure created by the authors using Canva (Canva Pty Ltd, Australia)."

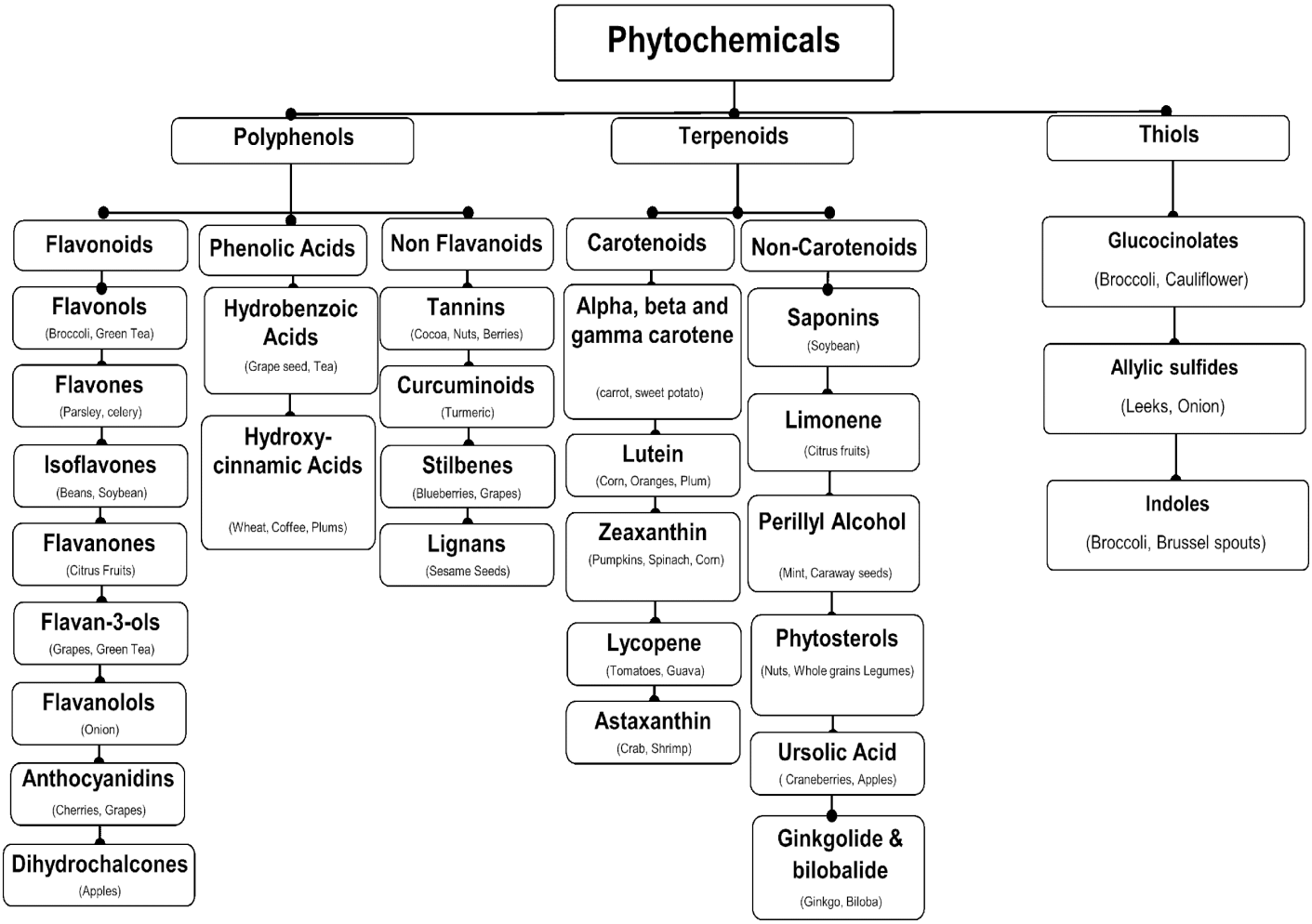

Figure 2: Classification of Phytochemicals. "Original figure created by the authors using Canva (Canva Pty Ltd, Australia)."

(47.4%), contributing to neonatal and perinatal mortality, low birth weight, premature birth and developmental delays. Clinical symptoms include pallor, fatigue, dizziness, dyspnea and weakness, while chronic unmanaged anemia can impair cognitive function, weaken immunity and increase mortality risk.[55] Functional foods rich in bioactive compounds show promising results in anemia management through antioxidant, anti-inflammatory and iron-modulating activities. Phytochemicals like flavonoids and polyphenols possess iron-chelating abilities. Lipophilic chelators enhance iron absorption and storage, aiding iron-deficiency anemia, while hydrophilic chelators facilitate excess iron removal and exhibit antioxidant activity.[56] For example, curcumin, a phytochemical present in turmeric, can alter iron metabolism by increasing transferrin receptor 1 expression and reducing ferritin levels. Flavonols such as quercetin, present in onions, broccoli, spinach and apples can influence iron regulation by protecting RBCs from iron-induced oxidative stress.[57] Collectively, these functional foods offer therapeutic potential in both iron-deficiency anemia and iron overload, through mechanisms involving improved iron bioavailability, modulation of iron metabolism and protection against oxidative stress.[58]

Obesity and Metabolic Syndrome

Obesity is a multifactorial condition characterized by metabolic alterations that disrupt gut microbiota, trigger inflammation and compromise intestinal barrier function. Its development is influenced by genetic predisposition, social determinants and environmental factors, with dietary habits, urbanization and lifestyle playing significant roles in prevalence.[59] The impact of obesity is especially severe in children and adolescents, where it reduces life expectancy more than in adults. It also heightens the risk of several cancers, including those of the liver, pancreas, kidney, gallbladder, uterus, breast and colon and is estimated to contribute to 4-8% of cancer cases worldwide.[60] Functional foods rich in compounds such as vitamins, carotenoids, polyphenols, curcuminoids, polyunsaturated fatty acids, proteins, peptides, dietary fibers, oligosaccharides and minerals are vital for maintaining metabolic health. Phytonutrients have demonstrated anti-obesogenic and anti-diabetic effects through multiple physiological mechanisms, such as improving insulin sensitivity, regulating appetite and enhancing energy metabolism.[61] Polyphenols and terpenoids such as resveratrol, quercetin, catechins, β-carotene, zeaxanthin, lycopene and anthocyanins exhibit strong anti-obesity activity by promoting

lipolysis, enhancing thermogenesis and reducing appetite. Similarly, alkaloids including caffeine, capsaicin and ephedrine contribute to weight regulation via increased energy expenditure and fat mobilization.[62] Omega-3 Polyunsaturated Fatty Acids (PUFAs) found in nuts and oilseeds improve insulin sensitivity, reduce hepatic steatosis and lower systemic inflammation, thereby mitigating obesity-related metabolic dysfunction.[63] Overall, functional foods represent an affordable, safe and effective dietary approach to combating obesity and metabolic syndrome by targeting multiple biochemical and physiological pathways simultaneously.

Thyroid dysfunction

Thyroid dysfunction, ranging from hypothyroidism and hyperthyroidism to autoimmune thyroiditis (e.g., Hashimoto's) and thyroid cancers, disrupt endocrine balance affecting

Table 1: Functional foods, bioactive components and their therapeutic properties.

Food Group	Sources	Bioactive Component	Therapeutic Properties
Spices and Beverages	Garlic (*Allium sativum*)	Allicin	Antimicrobial and anticancer properties, reduces LDL cholesterol.[32]
	Turmeric (*Curcuma longa*)	Curcuminoids	Antioxidant, anti-inflammatory, anticarcinogenic, antibacterial, antifungal properties, lowers blood sugar level, blood pressure and LDL cholesterol.[31]
	Fenugreek (*Trigonella foenum-graecum*)	Vitexin, Isovitexin Apigenin,	Antioxidant properties, lowers blood sugar level and LDL cholesterol.[46]
	Cinnamon (*Cinnamomum cassia*)	Cinnamaldehyde	Anti-inflammatory, antibacterial and antifungal properties.[46]
	Ginger (*Zingiber officinale*)	Gingerols	Antioxidant, anti-inflammatory, antimicrobial, anticancer, anti-obesity properties and prevents cardiovascular and respiratory disorders.[33]
	Black Pepper (*Piper nigrum*)	Piperine and piperidines	Antimicrobial properties, Improves digestion, reduces asthma, congestion and fever.[46]
	Green Tea (*Camellia sinensis*)	Flavanols-Epigallocatechins-3-gallate	Antioxidant, anti-inflammatory properties, lowers blood sugar level, LDL cholesterol and maintains heart health.[33]
Fruits and Vegetables	Carrots, Oranges, Papaya, Green Leafy Vegetables	Carotenoids	Antioxidant properties[33,37,39]
	Green Leafy Vegetables	Lutein	Reduce age-related macular degeneration.[33]
	Tomato	Lycopene	Antioxidant, anticancer properties, lowers LDL cholesterol and maintains heart health.[36]
	Grapes, Apples, Berries	Flavanols, Anthocyanins	Antioxidant, hypolipidemic, anticancer, immunomodulatory properties.[38,46]
	Citrus Fruits	Flavanoids, Limonene	Antibacterial, antifungal, anti-Inflammatory, anticancer and cardioprotective properties.[37]
	Berries, cherries, red grapes	Flavanols, Anthocyanins	Antioxidant properties and support brain health.[38,46]
Legumes and Pulses	Soybean and its Products	Isoflavones-Genistein and Daidzein	Anticancer, antiestrogen, anti-osteoporotic and antiproliferative properties.[33]
	Peas, Beans	Phytosterols	Reduces the risk of coronary heart diseases and some types of cancer.[43,46]
Cereals and millets	Brown Rice	Alkaloids, phenolic compounds	Anti-Inflammatory, hepato protective, anticancer, anti-rheumatic, hypocholesterolemic properties.[45]
	Oats, barley, rye	Beta glucan	Alleviates risk of coronary heart disease.[46]
	Whole Grains, Oats	Dietary Fiber	Lowers serum cholesterol, Alleviates dyslipidemia.[45,46]

metabolism, immunity and growth (T4, T3, TSH homeostasis). Hypothyroidism, often caused by iodine deficiency or autoimmune destruction, impairs hormone production, while hyperthyroidism reflects hormone excess. Hashimoto's involves chronic inflammation and autoantibodies.[64] Anaplastic Thyroid Cancer (ATC), though rare, is highly aggressive and resistant to conventional therapies.[65] Emerging interest in functional foods has highlighted both protective and modulatory roles in thyroid pathology. A comprehensive review notes that certain plant constituents, including polyphenols, flavonoids and cyanogenic glucosides, may inhibit thyroid peroxidase or hormone synthesis, especially when consumed in large amounts or under iodine-deficient conditions.[66] Quercetin, a flavonoid abundant in onions, apples and tea, exhibits anti-inflammatory and anti-proliferative effects. It acts by scavenging free radicals, downregulating NF-κB and modulating MAPK pathways.[67] While resveratrol, a polyphenol from grapes and berries, has been shown to inhibit proliferation and induce apoptosis in thyroid cancer cells via modulation of PI3K/Akt and STAT3 signaling pathways. In thyroid cancers, phytochemicals like resveratrol and quercetin demonstrated anti-cancer effects via apoptosis induction, cell cycle arrest and anti-angiogenesis though drug resistance remains a challenge.[65] Collectively, evidence suggests that functional foods contribute to thyroid health by improving hormone balance, attenuating inflammation and offering protective effects against thyroid autoimmunity and cancer progression.

Menstrual irregularities

Menstrual irregularities such as dysmenorrhea and Premenstrual Syndrome (PMS) significantly affect women's quality of life. Dysmenorrhea is characterized by painful uterine cramps due to elevated prostaglandins whereas PMS involves a range of emotional and physical symptoms during the luteal phase. Functional foods have gained attention as complementary therapies for managing these conditions. Turmeric contains curcumin which has shown to significantly reduce dysmenorrhea severity and PMS symptoms, likely due to its anti-inflammatory, antioxidant and antidepressant properties.[68] Cinnamon (*Cinnamomum cassia*) provides anti-inflammatory and analgesic effects through organic acids, monoterpene glucosides and trans-cinnamaldehyde, respectively.[69] Folk medicine also highlights several other phytochemicals with promising activity like chamomile reduces prostaglandin production and provides sedative effects, saffron regulates cortisol, estrogen and serotonin while its carotenoids act as antioxidants.[70] Overall, functional foods currently have the strongest clinical backing, emerging evidence on phytochemicals provides promising avenues for integrative management of dysmenorrhea and PMS.

Menopausal Symptoms

Menopause is a natural biological transition marked by the permanent cessation of menstruation, typically occurring between the ages of 45 and 55. It is associated with a decline in estrogen and progesterone levels, leading to a broad spectrum of symptoms. Menopausal symptoms includes vasomotor (hot flashes, night sweats), urogenital (vaginal dryness, mood swings, dyspareunia and recurrent urinary tract infections), psychological (mood swings, anxiety, depression, irritability and cognitive decline), sleep disturbances and long-term health consequences include increased risk of osteoporosis, cardiovascular disease and metabolic syndrome.[71] Functional foods are increasingly being explored as safe, non-pharmacological options for managing these symptoms. Functional foods, particularly those rich in phytochemicals like phytoestrogens, have been studied for their ability to modulate or mitigate these symptoms. Phytoestrogens are plant-derived compounds that structurally or functionally mimic estrogen. They are abundant in soy and its derivatives. For instance, dietary soy supplementation (Approx 90 mg of isoflavones daily) showed comparable improvement in psychological, somatic and urogenital symptoms versus low-dose hormone therapy over 16 weeks in symptomatic postmenopausal women.[72] A more recent meta-analysis of 12 trials involving perimenopausal women found that soy isoflavone supplementation led to modest but statistically significant reductions in psychosocial symptoms, depression, headaches and palpitations.[73] Similarly, omega-3 Polyunsaturated Fatty Acids (PUFAs), abundant in nuts and oilseeds, have been investigated for their role in reducing vasomotor symptoms and improving mood. Evidence suggests Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA) supplementation reduces hot flashes and night sweats, though results for sleep quality and depression are heterogeneous.[74] Therefore, functional foods serve as a complementary strategy, but further high-quality, long-term clinical trials are needed to establish their role in managing menopausal health.

DISCUSSION

Functional foods rich in phytochemicals have demonstrated remarkable potential in promoting women's health by exerting antioxidant, anti-inflammatory, hormone-modulating, antimicrobial, and anticancer effects. These bioactive compounds, including polyphenols, flavonoids, carotenoids, phytosterols, and thiols, influence multiple physiological pathways that are vital for maintaining hormonal balance, reproductive health, and metabolic stability.[1]

One of the most significant mechanisms through which functional foods contribute to health improvement is by mitigating oxidative stress. Reactive Oxygen Species (ROS) are known to disrupt cellular integrity and accelerate aging, inflammation, and hormonal imbalances.[2] Polyphenols and carotenoids found in fruits, vegetables, and beverages such as green tea and tomato

juice modulate redox-sensitive transcription factors, thereby enhancing antioxidant defense and suppressing inflammatory responses.[11] For instance, lycopene from tomatoes and catechins from green tea have been shown to reduce lipid peroxidation and cytokine production, thereby supporting cardiovascular and reproductive health.[33-35] Hormone-modulating effects of phytochemicals, particularly phytoestrogens, play a vital role in women's well-being. Isoflavones from soy and lignans from flaxseed structurally resemble estrogen and can bind to estrogen receptors, exerting mild agonistic or antagonistic effects.[33] This property makes them beneficial in alleviating menopausal symptoms such as hot flashes, mood swings, and bone loss, while also potentially lowering the risk of hormone-dependent cancers, including breast and endometrial cancer.[71] Similarly, dietary polyphenols and flavonoids can influence hormonal pathways associated with Polycystic Ovary Syndrome (PCOS), improving insulin sensitivity and reducing androgen levels.[50]

Functional foods also play a preventive role in metabolic disorders common among women, such as obesity, anemia, and thyroid dysfunction. Compounds like curcumin, quercetin, and catechins help regulate glucose metabolism, lipid profiles, and thyroid hormone activity.[60] Polyphenol-rich foods such as turmeric, berries, and whole grains modulate inflammatory markers and enhance metabolic flexibility, contributing to the prevention of cardiovascular disease and metabolic syndrome. Furthermore, iron-regulating phytochemicals from green leafy vegetables and pulses assist in mitigating anemia, a prevalent condition in women of reproductive age.[57-58]

Another important dimension is the influence of functional foods on the gut microbiota. Garlic, onions, and fermented foods provide prebiotic compounds and bioactive metabolites that enhance beneficial gut flora, which in turn regulate estrogen metabolism and immune response. This gut-hormone axis contributes significantly to hormonal regulation, mood stability, and immune resilience in women.[35] Overall, integrating phytochemical-rich functional foods into daily diets offers a safe, sustainable, and natural strategy to address gender-specific health concerns. Nevertheless, the bioavailability and synergistic interactions of these compounds warrant further investigation. Standardization of dosage, long-term clinical validation, and personalized dietary interventions remain critical for translating these functional food benefits into practical dietary recommendations.

CONCLUSION

Functional foods provide a diverse range of bioactive compounds that can significantly improve women's health and quality of life. Evidence indicates their multifaceted roles in reducing oxidative stress, regulating hormonal balance, alleviating menstrual and reproductive disorders and preventing chronic conditions including cardiovascular diseases, obesity, thyroid dysfunction and hormone-related cancers. Compounds such as polyphenols, terpenoids and thiols, demonstrate synergistic benefits that extend from reproductive health to long-term disease prevention. While traditional diets, particularly in regions like India, already incorporate many of these functional foods, there remains a need for greater awareness, evidence-based dietary recommendations and clinical validation to optimize their use. This review provides unique value by consolidating evidence on functional foods and phytochemicals specifically targeting women's health, offering a multidimensional perspective that spans nutritional, therapeutic and sustainability considerations. By synthesizing 74 studies, it advances both scientific understanding and practical dietary strategies. Strategies should prioritize integrating functional foods into women's health programs, nutrition curricula and community-based interventions. Awareness campaigns, dietary guidelines and training for healthcare providers can strengthen practical adoption at local and national levels. Further empirical research, particularly large-scale randomized controlled trials and longitudinal studies, is needed to validate the clinical effectiveness, safety and dosage of functional foods across different stages of women's life cycles. In conclusion, functional foods represent a vital and accessible approach to improving women's health, bridging nutrition and preventive medicine for holistic well-being.

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ABBREVIATIONS

PCOS: Polycystic Ovary Syndrome; **SLR:** Systematic Literature Review; **PRISMA:** Preferred Reporting Items for Systematic Reviews and Meta-Analyses; **ROS:** Reactive Oxygen Species; **NF-κB:** Nuclear Factor kappa B; **TBARS:** Thiobarbituric Acid Reactive Substances; **CRP:** C-Reactive Protein; **TNF-α:** Tumor Necrosis Factor alpha; **IL-6:** Interleukin 6; **UTIs:** Urinary Tract Infections; **BV:** Bacterial Vaginosis; **EGCG:** Epigallocatechin Gallate; **BMI:** Body Mass Index; **RBCs:** Red Blood Cells; **Hb:** Haemoglobin; **PUFAs:** Polyunsaturated Fatty Acids; **EPA:** Eicosapentaenoic Acid; **DHA:** Docosahexaenoic Acid; **PMS:** Premenstrual Syndrome.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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AUTHOR CONTRIBUTION

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SUMMARY

Functional foods enriched with phytochemicals such as polyphenols, flavonoids, carotenoids, and phytoestrogens play a crucial role in promoting women's health by providing antioxidant, anti-inflammatory, hormone-regulating, and anticancer benefits. These bioactive compounds modulate oxidative stress pathways, reduce inflammation, and help maintain hormonal balance. Isoflavones from soy and lignans from flaxseed alleviate menopausal symptoms and lower the risk of hormone-dependent cancers, while polyphenols and flavonoids aid in managing PCOS, improving insulin sensitivity, and regulating androgen levels. Additionally, compounds like curcumin and catechins support metabolic and thyroid health, and iron-regulating phytochemicals help combat anemia. Functional foods such as garlic, onions, and fermented products also enhance gut microbiota, influencing estrogen metabolism and immune function. Overall, incorporating phytochemical-rich foods into daily diets represents a natural, sustainable strategy to prevent and manage women's health disorders. However, further research on bioavailability, dosage standardization, and personalized applications is necessary to fully harness their therapeutic potential.

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