International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Scholarly Publisher
RS Global Sp. z O.O.
ISNI: 0000 0004 8495 2390

Dolna 17, Warsaw,
Poland 00-773
+48 226 0 227 03
editorial_office@rsglobal.pl

ARTICLE TITLE	THE ROLE OF SOY AND OTHER SOURCES OF EXOGENOUS ESTROGENS IN MODIFICATION OF PCOS SYMPTOMS AND OTHER HORMONAL DISORDERS IN WOMEN
DOI	https://doi.org/10.31435/ijitss.4(48).2025.4234
RECEIVED	28 October 2025
ACCEPTED	21 December 2025
PUBLISHED	24 December 2025
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

THE ROLE OF SOY AND OTHER SOURCES OF EXOGENOUS ESTROGENS IN MODIFICATION OF PCOS SYMPTOMS AND OTHER HORMONAL DISORDERS IN WOMEN

Marianna Latour *(Corresponding Author, Email: mariannalatour@gmail.com)*
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0000-0002-2568-5080

Zofia Laska
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0009-0001-0326-8251

Honorata Juniewicz
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0009-0001-0060-992X

Zuzanna Kudlińska
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0009-0003-4422-7784

Patryk Heryć
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0009-0004-9121-2670

Karolina Kananowicz
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0009-0009-1229-6797

Ryszard Łagowski
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0009-0007-8441-054X

Julia Koszęda
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0009-0008-7742-2814

Anna Jędrasiak
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0009-0001-3739-2066

Jakub Piotrowski
Pomeranian Medical University, Szczecin, Poland
ORCID ID: 0009-0007-8889-713X

ABSTRACT

Background: Polycystic ovary syndrome (PCOS) is one of the most common endocrine disorders in women of reproductive age, characterized by hyperandrogenism, ovulatory dysfunction, and metabolic abnormalities. Despite pharmacological and dietary advances, there remains a growing interest in natural therapeutic approaches. Phytoestrogens—plant-derived compounds structurally similar to endogenous estrogens—have gained attention as potential modulators of hormonal and metabolic balance.
Aim: This review summarizes current knowledge on the role of soy and other dietary sources of phytoestrogens in modulating PCOS symptoms and related hormonal disorders, with emphasis on their mechanisms of action, bioavailability, and clinical effects.
Methods: A comprehensive literature search was conducted using PubMed, PubMed Central, and Google Scholar, including clinical trials, experimental studies, and meta-analyses assessing the effects of phytoestrogens—mainly isoflavones, lignans, and stilbenes—on hormonal and metabolic parameters in women with PCOS and during menopause.
Results: Soy isoflavones, particularly genistein and daidzein, selectively bind to estrogen receptors ERα and ERβ, influencing hormonal profiles, insulin sensitivity, and the LH/FSH ratio. Flaxseed lignans may enhance SHBG levels and regulate estrogen bioavailability. The efficacy of phytoestrogens depends on their form, processing, and gut microbiota composition.
Conclusion: Phytoestrogens appear to be a promising adjunct in the management of PCOS and other hormonal disorders, offering potential benefits for endocrine and metabolic regulation. However, further large-scale, well-designed clinical studies are required to establish optimal dosage, long-term safety, and individualized therapeutic potential.

KEYWORDS

Phytoestrogens, PCOS Natural Therapy, Hormonal Normalization, Soy, Pulses

CITATION

Marianna Latour, Zofia Laska, Honorata Juniewicz, Zuzanna Kudlińska, Patryk Heryć, Karolina Kananowicz, Ryszard Łagowski, Julia Kosęda, Anna Jędrasiak, Jakub Piotrowski. (2025) The Role of Soy and Other Sources of Exogenous Estrogens in Modification of PCOS Symptoms and Other Hormonal Disorders in Women. *International Journal of Innovative Technologies in Social Science*. 4(48). doi: 10.31435/ijitss.4(48).2025.4234

1.Introduction

Polycystic Ovary Syndrome (PCOS) is a complex metabolic disorder that affects women of reproductive age. It is characterized by hyperandrogenism (clinical or biochemical), ovulatory dysfunction (oligo- or anovulation), and often polycystic ovarian morphology on ultrasound examination. According to the Rotterdam criteria, the diagnosis requires the presence of at least two of these three features [1].

The pathogenesis of PCOS involves multiple factors, including disturbances of the hypothalamic–pituitary–ovarian axis, insulin resistance and hyperinsulinemia, as well as abnormalities in gonadotropin signaling and steroidogenesis, which collectively result in increased LH secretion and hyperandrogenism. Although this disorder is relatively common, its precise etiology remains unclear. Numerous studies emphasize that PCOS is a multifactorial condition with genetic, epigenetic, and environmental components, such as diet and lifestyle [2].

According to epidemiological data, between 5% and 20% of women of reproductive age are affected by PCOS, which significantly impairs their quality of life and fertility [3].

Pharmacotherapy remains a key element of treatment and is tailored to the patient's reproductive goals: *clomiphene citrate* is used to induce ovulation in women seeking pregnancy [4], whereas hormonal contraceptives are recommended for those who wish to postpone or avoid conception [5,6].

Considerable emphasis is also placed on lifestyle modification, including increased physical activity and dietary interventions aimed at reducing insulin resistance, given the metabolic nature of the disorder [7]. However, growing attention has recently been directed toward bioactive compounds naturally present in food.

Many plants contain phytoestrogens, which are therefore suggested as potential adjuncts to pharmacological therapy by enriching the diet of women with PCOS.

The present review aims to analyze the current evidence regarding foods capable of increasing estrogen levels and to assess their actual impact on well-being and clinical symptom relief in PCOS and related endocrine disorders. The goal is to deepen the understanding of their therapeutic potential and possible application as supportive treatment.

2. Methodology

In order to prepare our literature review we focused on current knowledge about phytoestrogens and their use in PCOS treatment.

2.1. Source selection

Included were original research articles as well as systematic reviews published between 1995 - 2025.

2.2. Inclusion criteria

Articles were included if they: -Adressed the topic of phytoestrogens effects on women with PCOS and women in general,- Described mechanisms of estrogen effects caused by phytoestrogens,- Contained information about current use of phytoestrogens as functional food.

2.3 Content Analysis and data synthesis

The review directly utilized 37 publications. Data from the analyzed articles were grouped thematically and then described accordingly.

2.4 Methodological limitations

The data may be affected by methodological diversity and population heterogeneity. Some of the discussed trial methods are still in preclinical or early clinical trial phases, which should be considered when interpreting results.

3. Characteristic of phytoestrogens

Phytoestrogens are a heterogeneous group of compounds naturally occurring in various parts of plants consumed by humans. These compounds are classified into three main categories: lignans, among which secoisolariciresinol and matairesinol are distinguished; stilbenes, such as resveratrol; and isoflavonoids, which include isoflavones, isoflavanones, isoflavanes (the latter two being metabolites of daidzein found exclusively in animal organisms), and coumestans. One of the most important subgroups consists of isoflavones, which include genistein, daidzein, glycitein, and biochanin A.

The primary dietary sources of lignans are flaxseed and sunflower seeds. Resveratrol is found, for example, in the skin of mulberries and grapes; wine produced from grapes—particularly red wine—also contains significant amounts of this stilbene. For this reason, moderate consumption of red wine was historically considered beneficial. However, it is now understood that there is no safe level of alcohol consumption, and alcohol is therefore not recommended for health-promoting purposes. The main dietary sources of isoflavones are legumes, among which soybeans contain by far the highest concentrations. Smaller amounts of these compounds can also be found in cereal products, fruits, vegetables, and even certain alcoholic beverages such as beer and bourbon. Coumestans occur in alfalfa and clover sprouts, as well as in soybeans[8].

Table 1. [9]

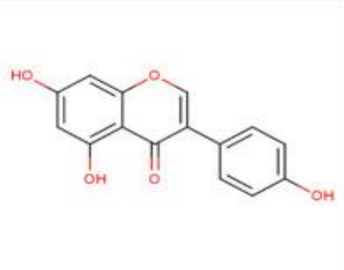
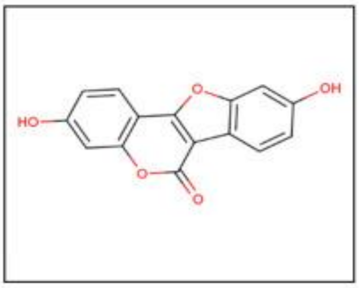
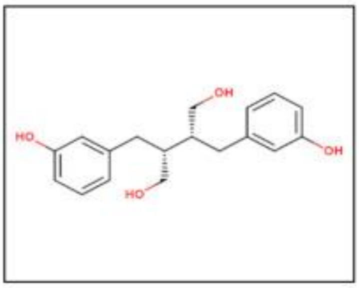
Isoflavones	Coumestans	Lignans
		
▪ Genistein ▪ Daidzein ▪ Glycitein ▪ Biochanin	▪ Coumestrol ▪ Wedelolactone ▪ Plicadin	▪ Enterodiol ▪ Enterolactone ▪ Pinoresinol ▪ Secoisolariciresinol ▪ Matairesinol ▪ Sesamin

Table 2. [8]

<table>
<tr><td colspan="2">TYPE</td><td>SUBTYPE</td><td>SOURCES</td></tr>
<tr><td colspan="2" rowspan="2">LIGNANS</td><td>secoisolariciresinol</td><td>grains</td></tr>
<tr><td>matairesinol</td><td>flaxseeds, sunflower seeds</td></tr>
<tr><td colspan="2">STILBENES</td><td>resveratrol</td><td>grape skin, wine, mulberry skin, peanuts</td></tr>
<tr><td rowspan="5">ISOFLAVONOID</td><td rowspan="4">ISOFLAVONES</td><td>genistein</td><td rowspan="4">soybeans, peanuts
lentils, green beans, peas</td></tr>
<tr><td>biochanin A</td></tr>
<tr><td>glycitein</td></tr>
<tr><td>daidzein</td></tr>
<tr><td>COUMESTANS</td><td>coumestrol</td><td>alfaalfa (lucerne), soybeans, clover sprouts</td></tr>
</table>

4.Mechanism of action of phytoestrogens

When discussing the effects of phytoestrogens on human cells, it is essential to consider their structural similarity to estradiol — particularly the presence of a phenolic ring and the spatial arrangement of hydroxyl groups — which enables them to interact with and cause either agonistic or antagonistic effects on nuclear estrogen receptors ERα and ERβ [10].

ERα expression is predominant in the uterus, breast, bone, cardiovascular system, and central nervous system, whereas ERβ is more abundant in the urogenital tract and intestine. Generally, estradiol binding to ERα promotes cell proliferation, while activation of ERβ tends to induce apoptosis, a mechanism that can be utilized in the inhibition of tumor cell growth[11].

It is well established that flavonoids bind to estrogen receptor α with varying affinities, depending on differences in the position of hydroxyl groups and the number of rotatable C–C bonds, which determine their degree of hydrophobicity[12]. Further investigation into their molecular structure offers the potential for a more targeted selection of specific phytoestrogens based on the desired receptor-mediated effect.

In addition to their direct interaction with estrogen receptors, phytoestrogens also exhibit nongenomic activity, including the inhibition of tyrosine kinases and enzymes involved in sex hormone biosynthesis (such as cytochrome P450 aromatase, 17β-hydroxysteroid dehydrogenase, and 5α-reductase). There is also evidence suggesting that they may increase sex hormone–binding globulin (SHBG) levels, thereby modulating the bioavailability of circulating estrogens, although study results on this matter remain inconsistent[9].

Furthermore, phytoestrogens may influence inflammatory processes. Studies on genistein have demonstrated its ability to suppress the production of proinflammatory cytokines, including IL-1, IL-6, IL-8, and TNF-α.

Through both genomic and nongenomic mechanisms of estrogen receptor modulation, phytoestrogens may exert selective estrogen receptor modulator (SERM)-like effects. However, their practical substitution for pharmacological SERMs would require precise determination of the dietary intake, absorption rates, and metabolically active concentrations.

The absorption pathway of dietary isoflavones, which are the most common phytoestrogens found in soy, follows a biphasic model: initial metabolism by β-glucosidase in the upper small intestine and by gut microbiota in the colon, followed by glucuronidation and sulfation in enterocytes and the liver. Ultimately, only the unconjugated forms remain metabolically active, resulting in a bioavailability often below 5%[13].

The gut microbiota itself plays a crucial role in determining the availability of active phytoestrogens. Research indicates that the presence of specific microbial gene clusters, collectively known as the estrobolome, can influence the conversion of natural phytoestrogens into more biologically active metabolites (e.g., equol). Alterations in gut microbiota composition have been linked to hormonal imbalances such as those observed in PCOS[14].

5. Soybeans

Soybeans are the richest dietary source of phytoestrogens, primarily genistein, the content of which can reach 26.8–102.5 mg/100 g of dry weight[15], as well as daidzein and glycitein. Currently, no recommended daily intake of soy has been established; however, a dose of 50 mg per day is considered safe. The consumption of soy—and therefore isoflavones—is significantly higher in Asian countries, where average daily intake ranges from approximately 30–50 mg (e.g., in Japan), compared with the United States, Canada, and Europe, where intake is substantially lower and often does not exceed 3 mg/day[16].

In a study conducted by Mehri Jamilian and Zatollah Asemi, which investigated the effects of 12-week soy isoflavone supplementation, participants receiving the supplement demonstrated improvements in alopecia areata compared to the placebo group, as well as significant reductions in serum insulin concentrations, HOMA-IR and HOMA-B indices, and an increase in the QUICKI score. No improvement was observed regarding acne lesion control[17].

In another study by Christoph Haudum et al., the effects of soy isoflavone supplementation in women with PCOS were compared with those observed in women without PCOS. Short-term supplementation resulted in improvements in fasting glycemia and insulin sensitivity; however, these effects were limited to women diagnosed with PCOS[18].

Soy isoflavone supplementation has also been shown to reduce testosterone levels in patients with PCOS, although no effect on FSH concentrations was noted. Meanwhile, a 2023 meta-analysis by Vali Musazadeh et al. reported no significant effect of flaxseed supplementation on sex hormone levels in healthy adults, including FSH, total testosterone, SHBG, and DHEAS[19].

It is also necessary to consider a study investigating interactions between soy isoflavones and medications such as celecoxib, theophylline, paclitaxel, midazolam, imatinib, carbamazepine, valproic acid, repaglinide, omeprazole, and danofloxacin—which metabolism involves CYP3A4, CYP2C9, CYP1A2 or transport proteins such as P-glycoprotein or BCRP—indicates that caution should be exercised when consuming a diet rich in isoflavonoids concurrently with these drugs[20].

6. Flaxseed

A study conducted in 2025 by Zahra Najdgholami et al., involving 12-week flaxseed supplementation in women with PCOS, demonstrated an increase in FSH levels and an improvement (decrease) in the LH/FSH ratio compared with PCOS patients receiving placebo. However, no effects were observed on AMH, LH, estradiol, DHEAS, or androstenedione concentrations[21].

In an animal study performed on rats, the combined supplementation of flaxseed and spearmint—a herb with anti-androgenic properties—was evaluated in rats with induced PCOS. A markedly greater potential therapeutic effect was observed compared with studies in which these components were administered individually. The effects of such combined therapy included reductions in testosterone levels (likely due to the anti-androgenic activity of spearmint) and estrogen levels (as lignans induce increased SHBG production, thereby reducing the amount of free estrogen in circulation), as well as increases in progesterone and DHEA concentrations compared with the control group. However, once again, no significant hormonal differences were detected between the non-supplemented control group and the control group receiving supplementation[22].

7.Pulses (lentils, chickpeas)

The phytoestrogens present in chickpeas are primarily isoflavones, with formononetin (0.14 mg/100 mg) and biochanin A (approximately 1400 μg/100 mg of Kabuli-type chickpea seeds) being the dominant compounds. In other pulses, such as lentils, isoflavone concentrations are much lower — around 0.5 μg/kg — yet they are discussed together here, as both contain similar types of isoflavones and are often grouped in research studies[23].

The total concentration of isoflavones in these legumes is 10–100 times lower than that in soybeans, which might suggest a limited biological effect [24]. However, studies have shown that a pulse-based diet (including legumes such as lentils and chickpeas), when compared to the Therapeutic Lifestyle Changes (TLC) Diet, had beneficial effects on lipid and carbohydrate metabolism in women with PCOS, although sex hormone levels were not assessed in that study [25].

Another clinical trial involving women with PCOS compared these two diets in terms of ovarian follicle count, ovarian volume, androgen index, and menstrual cycle length. The results demonstrated improvements in ovarian morphology, cycle regularity, and reductions in hyperandrogenism lasting up to six months after dietary intervention; however, the degree of change was similar between both diet groups [26].

To date, there is still a lack of studies directly evaluating the effect of pulses on specific sex hormone levels. It can only be hypothesized that their action may resemble that of other isoflavone-containing plants, but current data do not provide definitive confirmation of this relationship.

Interestingly, sprouting chickpea seeds significantly increases the content of formononetin and biochanin A — by up to 150-fold — through deglycosylation of bound isoflavone forms. Consequently, researchers suggest that sprouted chickpeas may serve as a promising functional food with enhanced phytoestrogenic activity [27].

8. Other sources of phytoestrogens

In addition to the plants discussed above, there are many other potential dietary sources of phytoestrogens. However, the concentrations of phytoestrogens in these foods are considerably lower, and therefore their impact on metabolic and hormonal regulation is presumed to be weaker and less extensively studied.

An example of such products includes oilseeds, such as sesame. Their main phytoestrogens are lignans, similar to those found in flaxseed. Lignans are generally less biologically active than isoflavones, and their intestinal absorption varies greatly between individuals[24]. Animal studies conducted on rats have shown that sesame seed supplementation regulated estrogen, testosterone, and progesterone levels in models of PCOS; however, comparable studies in humans are lacking.

Another potential but poorly explored source of phytoestrogens is vegetables. Studies have demonstrated that diets rich in carrots and spinach, as well as those containing cauliflower and broccoli, resulted in increased urinary excretion of lignans, suggesting enhanced phytoestrogen intake and metabolism[28].

Herbs such as rosemary, fennel, and mint are also recommended in diets with estrogenic or hormone-balancing potential. However, they contain only small amounts of weak phytoestrogens and exhibit limited or negligible direct affinity for estrogen receptors. Their beneficial effects in PCOS appear to result primarily from the presence of terpenes, which possess antiandrogenic properties but are not classified as phytoestrogens. Nonetheless, these compounds may serve as complementary agents in supportive dietary or therapeutic strategies for hormonal regulation[24].

9. Menopause

It should be noted that PCOS is not the only condition in which it may be beneficial to enrich the diet with foods containing high amounts of phytoestrogens. The perimenopausal period, due to hormonal changes such as decreases in estrogen and progesterone levels as well as a relative increase in androgenic activity, can lead to troublesome symptoms including hot flashes, vaginal dryness, muscle and joint pain, osteoporosis, mood swings, sleep disorders, night sweats, decreased libido, urinary incontinence, and pelvic organ prolapse[29].

The impact of an isoflavone-rich diet on reducing climacteric symptoms is not fully clear. In an analysis from 2025 conducted by Haodi Luan et al., the authors indicate that although, according to some assessment scales, menopausal symptoms were reduced to a small but statistically significant degree, this effect was minimal, and according to other scales had no significant impact on symptom reduction or lacked clinical relevance[30].

According to a meta-analysis reviewing 12 studies on red clover supplementation (a source of isoflavones) in perimenopausal women, a significant reduction in the frequency of hot flashes was demonstrated compared to placebo groups[31].

In a study conducted by Costa et al., the effects of hormone replacement therapy (HRT), black mulberry supplementation, and placebo on menopausal symptom severity were compared. A significant improvement—measured using the Blatt–Kupperman Menopausal Index (BKMI)—in symptoms such as hot flashes, paresthesia, insomnia, nervousness, fatigue, and headaches was observed, with the magnitude of the positive changes only slightly lower than in the HRT group. An increase in free thyroxine and estradiol levels was also documented. However, elevated FSH and HDL levels were observed only in the HRT group. All three groups showed an increase in fasting blood glucose levels. In none of the groups was improvement in vaginal atrophy reported[32].

Juliene G. Costa et al. conducted a study comparing the reduction of menopausal symptoms following aerobic and resistance exercise combined with either phytoestrogen supplementation or placebo. Both groups demonstrated improvement in symptom severity, and no additional beneficial effect of isoflavone supplementation was observed[33].

10. The effect of food processing on phytoestrogen activity

When considering the actual bioavailability of active phytoestrogens in food, it is essential to take into account the processing methods used during food preparation.

The isoflavone content in raw soybeans is more than 2.5 times higher than in boiled, unsalted soybeans[34]. Most legumes require soaking and cooking in water, and the shorter the cooking time, the smaller the loss of beneficial compounds (with chickpeas requiring the longest cooking time and lentils the shortest). Comparisons between different cooking methods—pressure cooking, covered boiling, and open-pan boiling—have shown that increased pressure and the absence of a lid negatively affect both isoflavone concentration and total flavonoid content (TFC)[35].

In addition, seed germination significantly enhances estrogenic activity, with the duration of germination being a key factor. Some studies have reported that the isoflavone bioavailability in soy milk increases only after seven days of germination[36].

Many soy-based products are also consumed after fermentation, which further enhances their estrogenic potential by activating β-glucosidase and increasing the concentration of biologically active phytoestrogen forms[37].

Discussion

Data available in the literature indicate that phytoestrogens—particularly isoflavones present in soy and other legumes, as well as lignans derived mainly from flaxseed—may significantly influence the hormonal balance of women through a mechanism similar to that of selective estrogen receptor modulators. However, this effect has been confirmed only in women with PCOS. In this population, phytoestrogens improve metabolic parameters, including reductions in insulin resistance and normalization of lipid profiles. In addition, they reduce hyperandrogenism, improve the LH/FSH ratio, and contribute to a decrease in the dysmorphic ovarian appearance observed on ultrasound. Beyond their potential application in women of reproductive age, their ability to alleviate menopausal symptoms is also noteworthy. It is important, however, to consider interindividual variability, the diversity of phytoestrogens characteristic of specific plant species, and changes in compound activity depending on food processing methods.

In summary, phytoestrogens—particularly those found in soy, flaxseed, and chickpeas—represent a promising adjunct in the management of hormonal disorders in women, including PCOS. Nevertheless, despite an increasing number of studies, recommended dosing strategies and administration forms remain insufficiently defined, particularly with regard to variability in gut microbiota and absorption. This makes it difficult to establish a clearly predictable response to these substances.

Author's contributions:
Conceptualization: Marianna Latour, Zofia Laska
Methodology: Karolina Kananowicz, Patryk Heryć
Software: Ryszard Łagowski, Honorata Jurkiewicz
Check: Anna Jędrasiak, Zuzanna Kudlińska
Formal analysis: Julia Kosęda, Ryszard Łagowski
Investigation: Jakub Piotrowski, Anna Jędrasiak
Resources: Julia Kosęda, Ryszard Łagowski
Data curation: Jakub Piotrowski, Julia Kosęda
Writing - rough preparation: Marianna Latour, Zofia Laska
Writing - review and editing: Zuzanna Kudlińska, Patryk Heryć
Visualization: Karolina Kananowicz, Anna Jędrasiak
Supervision: Anna Jędrasiak, Honorata Jurkiewicz
Project administration: Jakub Piotrowski, Julia Kosęda

All authors have read and agreed with the published version of the manuscript.

Conflict of Interest Statement: Authors have declared no conflict of interests.

Declaration of the use of generative AI and AI - assisted technologies in the writing process: In preparing this work, the authors used ChatGPT for the purpose of improving language and readability. After using this tool, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

REFERENCES

1. Escobar-Morreale, H. F. (2018). *Polycystic ovary syndrome: Definition, aetiology, diagnosis and treatment*. Nature Reviews Endocrinology, 14(5), 270–284. https://doi.org/10.1038/nrendo.2018.24
2. Rosenfield, R. L., & Ehrmann, D. A. (2016). *The pathogenesis of polycystic ovary syndrome (PCOS): The hypothesis of PCOS as functional ovarian hyperandrogenism revisited.* Endocrine Reviews, 37(5), 467–520. https://doi.org/10.1210/er.2015-1104
3. Azziz, R., Carmina, E., Chen, Z., Dunaif, A., Laven, J. S. E., Legro, R. S., Lizneva, D., Natterson-Horowtiz, B., Teede, H. J., Yildiz, B. O., & … (2016). *Polycystic ovary syndrome*. *Nature Reviews Disease Primers, 2*(16057). https://doi.org/10.1038/nrdp201657
4. Davidson, R., Motan, T., & Korownyk, C. (2016). *Clomiphene for anovulatory infertility.* Can Fam Physician, 62(6), 492–493. PMCID: PMC4907558.
5. Tyler, B., Walford, H., Tamblyn, J., Keay, S. D., Mavrelos, D., Yasmin, E., & Al Wattar, B. H. (2022). Interventions to optimise embryo transfer in women undergoing assisted conception: A comprehensive systematic review and meta-analyses. Human Reproduction Update, 28(4), 480–500. https://doi.org/10.1093/humupd/dmac009

6. Amiri, M., Nahidi, F., Bidhendi Yarandi, R., & Ramezani Tehrani, F. (2020). Effects of oral contraceptives on the quality of life of women with polycystic ovary syndrome: A crossover randomized controlled trial. Health and Quality of Life Outcomes, 18(1), 293. https://doi.org/10.1186/s12955-020-01544-4
7. Lim, S. S., Hutchison, S. K., Van Ryswyk, E., Norman, R. J., Teede, H. J., & Moran, L. J. (2019). *Lifestyle changes in women with polycystic ovary syndrome.* Cochrane Database of Systematic Reviews, 2019(3), CD007506. https://doi.org/10.1002/14651858.CD007506.pub4
8. Domínguez-López, I., Yago-Aragón, M., Salas-Huetos, A., Tresserra-Rimbau, A., & Hurtado-Barroso, S. (2020). *Effects of dietary phytoestrogens on hormones throughout a human lifespan: A review*. Nutrients, 12(8), 2456. https://doi.org/10.3390/nu12082456
9. Chmielewska, N. (2013, 29 października). *Wpływ fitoestrogenów na funkcjonowanie układu rozrodczego*. Biotechnologia.pl. https://biotechnologia.pl/biotechnologia/wplyw-fitoestrogenow-na-funkcjonowanie-ukladu-rozrodczego,13099
10. Patra, S., Gorai, S., Pal, S., Ghosh, K., Pradhan, S., & Chakrabarti, S. (2023). *A review on phytoestrogens: Current status and future direction.* Phytotherapy Research, 37(7), 3097–3120. https://doi.org/10.1002/ptr.7861
11. Falsetti, I., Palmini, G., Iantomasi, T., Brandi, M. L., & Tonelli, F. (2024). *Mechanisms of action of phytoestrogens and their role in familial adenomatous polyposis*. Pharmaceutics, 16(5), 640. https://doi.org/10.3390/pharmaceutics16050640
12. Ye, H., & colleagues. (2019). Food flavonoid ligand structure/estrogen receptor-α affinity: Molecular modelling studies of a flavonoid library. *Biochemical Pharmacology*, *172*, 113–123. https://doi.org/10.1016/S0278-6915(19)30192-9
13. Ferrière, F., Aasi, N., Flouriot, G., & Pakdel, F. (2025). *Exploring the complex mechanisms of isoflavones: From cell bioavailability to cell dynamics and breast cancer.* Phytotherapy Research, 39(2), 957-979. https://doi.org/10.1002/ptr.8417
14. Kumari, N.,Kumari, R., Dua, A., Singh, M., Kumar, R., Singh, P., Duyar-Ayerdi, S., Pradeep, S., Ojesina, A. I., & Kumar, R. (2024). *From gut to hormones: Unraveling the role of gut microbiota in (phyto)estrogen modulation in health and disease. Molecular Nutrition & Food Research, 68*(6), e2300688. https://doi.org/10.1002/mnfr.202300688
15. Kim, I.-S. (2021). *Current perspectives on the beneficial effects of soybean isoflavones and their metabolites for humans*. Antioxidants, 10(7), 1064. https://doi.org/10.3390/antiox10071064
16. Messina, M. (2016). *Soy and health update: Evaluation of the clinical and epidemiologic literature.* Nutrients, 8(12), 754. https://doi.org/10.3390/nu8120754
17. Jamilian, M., & Asemi, Z. (2016). The effects of soy isoflavones on metabolic and hormonal parameters in women with polycystic ovary syndrome. The Journal of Clinical Endocrinology & Metabolism, 101(9), 3386–3394. https://doi.org/10.1210/jc.2016-1762
18. Haudum, C., Lindheim, L., Ascani, A., Trummer, C., Horvath, A., Münzker, J., & Obermayer-Pietsch, B. (2020). Impact of short-term isoflavone intervention in polycystic ovary syndrome (PCOS) patients on microbiota composition and metagenomics. Nutrients, 12(6), 1622. https://doi.org/10.3390/nu12061622
19. Zilaee, M., Amirhosseini, M., Raeisi, S., Ghaedi, M., & Mehrabi, Y. (2020). The effects of soy isoflavones on total testosterone and follicle-stimulating hormone levels in women with polycystic ovary syndrome: A systematic review and meta-analysis. *European Journal of Contraception & Reproductive Health Care, 26*(4), 189-198. https://doi.org/10.1080/13625187.2020.1761956
20. Soyata, A. (2021). *Isoflavones in soybean as a daily nutrient: Mechanisms of action and how they alter the pharmacokinetics of drugs.* Turkish Journal of Pharmaceutical Sciences, 18(3), 299-316. https://doi.org/10.18502/tjps.v18i3.8744 (PMCID: PMC8744443)
21. Najdgholami, Z., Sedgi, F. M., Ghalishourani, S. S., Feyzpour, M., & Rahimlou, M. (2025). Flaxseed intervention and reproductive endocrine profiles in patients with polycystic ovary syndrome: An open-labeled randomized controlled clinical trial. Frontiers in Endocrinology, 16, Article 1531762. https://doi.org/10.3389/fendo.2025.1531762
22. Mehraban, M., Jelodar, G., & Rahmanifar, F. (2020). A combination of spearmint and flaxseed extract improved endocrine and histomorphology of ovary in experimental PCOS. *Journal of Ovarian Research, 13*, Article 32. https://doi.org/10.1186/s13048-020-00633-8
23. Jukanti, A. K., Gaur, P. M., Gowda, C. L. L., & Chibbar, R. N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): A review. *British Journal of Nutrition*, 108 (S1), S11–S26. https://doi.org/10.1017/S0007114512000797
24. Canivenc-Lavier, M.-C., & Bennetau-Pelissero, C. (2023). *Phytoestrogens and health effects.* Nutrients, 15(2), 317. https://doi.org/10.3390/nu15020317
25. Kazemi, M., McBreairty, L. E., Chizen, D. R., Pierson, R. A., Chilibeck, P. D., & Zello, G. A. (2018). A comparison of a pulse-based diet and the Therapeutic Lifestyle Changes diet in combination with exercise and health counselling on the cardio-metabolic risk profile in women with polycystic ovary syndrome: A randomized controlled trial. *Nutrients, 10*(10), 1387. https://doi.org/10.3390/nu10101387 (PMCID: PMC6212867)

26. Kazemi, M., Pierson, R. A., McBreairty, L. E., Chilibeck, P. D., Zello, G. A., & Chizen, D. R. (2020). A randomized controlled trial of a lifestyle intervention with longitudinal follow-up on ovarian dysmorphology in women with polycystic ovary syndrome. *Clinical Endocrinology (Oxford)*, 92(6), 525-535. https://doi.org/10.1111/cen.14179
27. Gao, Y., Yao, Y., Zhu, Y., & Ren, G. (2015). Isoflavone content and composition in chickpea (Cicer arietinum L.) sprouts germinated under different conditions. *Journal of Agricultural and Food Chemistry, 63*(10), 2701–2707. https://doi.org/10.1021/jf5057524
28. Kirkman, T. R., Lampe, J. W., Slavin, J. L., Winkel, A., Qiao, N., & Duncan, C. W. (1995). Urinary lignan and isoflavonoid excretion in men and women consuming controlled diets. *Cancer Epidemiology, Biomarkers & Prevention, 4*(5), 459–465. https://pubmed.ncbi.nlm.nih.gov/7491293/
29. Makara-Studzińska, M. T., Kryś-Noszczyk, K. M., & Jakiel, G. (2014). Epidemiology of the symptoms of menopause – an intercontinental review. *Menopause Review / Przegląd Menopauzalny, 13*(3), 203–211. https://doi.org/10.5114/pm.2014.43827
30. Luan, H., Liu, Q., Guo, Y., Fan, H., A, S., & Lin, J. (2025). *Effects of soy isoflavones on menopausal symptoms in perimenopausal women: A systematic review and meta-analysis.* PeerJ, e19715. https://doi.org/10.7717/peerj.19715
31. Kanadys, W., Barańska, A., Błaszczuk, A., Polz-Dacewicz, M., Drop, B., Kanecki, K., & Malm, M. (2021). Evaluation of clinical meaningfulness of red clover (Trifolium pratense L.) extract to relieve hot flushes and menopausal symptoms in peri- and post-menopausal women: A systematic review and meta-analysis of randomized controlled trials. Nutrients, 13(4), 1258. https://doi.org/10.3390/nu13041258 (PMCID: PMC8069620)
32. Costa, J. P. L., Brito, H. O., Galvão-Moreira, L. V., Brito, L. G. O., Costa-Paiva, L., & Brito, L. M. O. (2020). Randomized double-blind placebo-controlled trial of the effect of Morus nigra L. (black mulberry) leaf powder on symptoms and quality of life among climacteric women. International Journal of Gynaecology & Obstetrics, 148(2), 243-252. https://doi.org/10.1002/ijgo.13057
33. Costa, J. G., Brito, H. O., Brito, L. M. O., Galvão-Moreira, L. V., Costa-Paiva, L., & Brito, L. G. O. (2017). Combined exercise training reduces climacteric symptoms without the additive effects of isoflavone supplementation: A clinical, controlled, randomised, double-blind study. *Lifestyle Medicine*, 13(4), 353-361. https://doi.org/10.1177/0260106017727359
34. U.S. Department of Agriculture, Agricultural Research Service. (2008). *USDA database for the isoflavone content of selected foods, Release 2.1* [Data set]. https://www.ars.usda.gov/ARSUserFiles/80400525/Data/isoflav/Isoflav_R2-1.pdf
35. Deorukhkar, A., & Ananthanarayan, L. (2021). *Effect of thermal processing methods on flavonoid and isoflavone content of decorticated and whole pulses.* Journal of Food Science and Technology, 58(2), 465-473. https://doi.org/10.1007/s13197-020-04555-7
36. Chiarello, M. D., Le Guerroué, J.-L., Chagas, C. M. S., Franco, O. L., Bianchini, E., & João, M. J. (2006). Influence of heat treatment and grain germination on the isoflavone profile of soymilk. *Journal of Food Biochemistry, 30*(2), 234–247. https://doi.org/10.1111/j.1745-4514.2006.00058.x
37. Li-Jun, Y., Hai-Ming, S., Fang, Z., Xue, Z., & Xia, Z. (2004). Changes in isoflavone contents and composition of sufu (fermented soybean curd) during processing. *Food Chemistry*, 88(3), 365-370. https://doi.org/10.1016/S0308-8146(04)00378-8