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RECEIVED 09 April 2025

ACCEPTED 30 June 2025

PUBLISHED 15 July 2025

CITATION

López-Moreno M and López-Gil JF (2025)
Debunking the myth: are soy isoflavones truly
a public health concern?
Front. Nutr. 12:1608814.
doi: 10.3389/fnut.2025.1608814

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Debunking the myth: are soy isoflavones truly a public health concern?

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KEYWORDS

isoflavones, children, endocrine, hormones, soy, phytoestrogens

1 Introduction

Isoflavones are phytoestrogens, which are plant-derived compounds found in high concentrations in soy and other legumes, such as chickpeas and lentils. These molecules exhibit estrogen-like activity, which has been linked to both potential health benefits, such as reducing menopausal symptoms, improving bone health, and preventing hormone-related cancers, and concerns about their endocrine-disrupting effects (1, 2). Children, as a developing population, are considered particularly vulnerable to exposure to substances with endocrine activity due to their ongoing hormonal, metabolic and reproductive development (3). Despite the growing use of soy-based products in pediatric nutrition, especially in the form of infant formulas and plant-based alternatives, regulatory agencies have issued inconsistent recommendations, reflecting a lack of consensus on the interpretation of the available evidence. This study aims to analyze in detail the recommendations issued by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) regarding isoflavone consumption in children, evaluating the basis of these measures in light of broader scientific evidence, with a particular focus on studies conducted in humans.

2 ANSES recommendations

ANSES conducted a comprehensive review to assess the safety of isoflavones, analyzing numerous toxicological and epidemiological studies on isoflavone consumption and its potential effects on human health (4). As a result of this review, the ANSES defines the toxicological reference value (TRV) for daily isoflavone intake. For the general population, a TRV of 0.02 mg per kg of body weight per day was established. For vulnerable populations, which include children before puberty, women of reproductive age, and pregnant women, the TRV was halved to 0.01 mg per kg of body weight per day. ANSES revealed a substantial risk of exceeding these TRVs among individuals who consumed soy-based foods. Importantly, the ANSES report focuses on concerns about isoflavones and hormone-related effects but does not evaluate the benefits of soy, soy products, or isoflavones themselves. In Europe, risk and benefit assessments are handled separately, so ANSES's conclusions do not consider any potential positive effects of soy consumption. While these limits may appear conservative, the unilateral focus on potential risks without consideration of benefits warrants scrutiny.

3 Limitations of the animal studies

ANSES bases its concerns primarily on preclinical evidence derived from animal studies. Animal studies have historically formed the foundation for concerns about isoflavones as endocrine disruptors. These studies, while valuable for exploring biological mechanisms, face significant limitations when applied to human health assessments. Rodents have significantly less efficient phase II metabolism via glucuronidation, which leads to a reduced capacity for isoflavone conjugation and results in markedly higher plasma concentrations of unconjugated genistein than humans do (5, 6). These metabolic differences raise concerns about the reliability of rodent models for evaluating the effects of isoflavones on human tissues, particularly estrogen-sensitive breast tissue. Many animal studies use doses of isoflavones that far exceed typical human dietary intake, which can exaggerate effects not observed at realistic consumption levels (6). Additionally, the routes of administration in animal experiments, such as injections or gavage, bypass the digestive processes that occur in humans, altering the bioavailability and activity of the compounds (7, 8). Furthermore, the gut microbiota plays a crucial role in metabolizing isoflavones into active metabolites such as equol, and this microbiota composition varies significantly between species, influencing outcomes (9). These factors collectively limit the applicability of animal data to human contexts and underscore the need for caution when extrapolating findings across species.

4 Human studies: a reassuring perspective

In contrast to the animal data, evidence from human studies offers a far more reassuring picture regarding isoflavone exposure. Systematic reviews and meta-analyses have demonstrated no significant association between soy-based infant diets and the onset of puberty in humans, including precocious puberty or age at menarche (10). These findings contradict earlier concerns based on animal studies, which suggested that phytoestrogens in soy formulas could disrupt hormonal development (11–13). Human data consistently show that soy consumption during infancy does not pose a risk to normal pubertal timing. The disparity between ANSES's approach and that of other international health authorities highlights a pressing need for harmonized, evidence-based guidelines.

Long-term evaluations of children fed soy protein formulas have shown no evidence of estrogen-like hormonal effects. Bone metabolism markers remain within normal ranges, and there are no signs of precocious puberty or gynecomastia in children consuming soy-based diets (14). Although infants fed soy formulas present higher levels of isoflavones than do those fed cow milk formula or breast milk, these concentrations do not correlate with hormonal changes, indicating minimal biological impact (15).

Further longitudinal and cross-sectional studies confirmed that pubertal development trajectories are unaffected by soy

consumption. For example, breast bud diameter and hormone concentrations in girls fed soy formula are comparable to those in those fed cow milk formula, and no differences in estradiol levels are detectable in boys between these groups (16). Additionally, adolescent girls with varying levels of soy intake show no differences in age at menarche, reinforcing the conclusion that soy-based diets do not influence pubertal timing or hormonal development (17). Although the majority of human studies report no adverse effects of soy on pubertal development, many are observational and subject to potential confounding. Nevertheless, the consistency of findings across diverse populations strengthens the reliability of the overall conclusion.

5 Precautionary principles vs. evidence-based recommendations

ANSES's restrictive stance on isoflavones, and consequently soy-based products, reflects an application of the precautionary principle—a strategy aimed at minimizing potential risks when scientific uncertainty exists. While this approach prioritizes safety, it may inadvertently disregard substantial evidence supporting the potential benefits of soy products in humans.

Organizations such as the European Food Safety Authority (EFSA) have evaluated the safety of isoflavones, particularly as food supplements for postmenopausal women, and found no evidence of harm to the mammary glands, uterus, or thyroid function at typical supplementation levels (18). Canada's Dietary Guidelines include soy in its dietary guidelines as a healthy food, indicating a general acceptance of soy consumption as part of a balanced diet (19). The Australian Dietary Guidelines include soy products as part of a healthy diet for children and adolescents (20). The U.S. National Institutes of Health considers soy a safe food for most people, suggesting a broad consensus on its safety in the general population (21). The Scientific Report of the 2025 Dietary Guidelines Advisory Committee highlights the inclusion of soy products as part of a healthy diet during childhood, emphasizing their role in providing high-quality protein and essential micronutrients critical for growth and development. Furthermore, in adults, replacing processed or unprocessed red meat with plant-based protein sources, including soy, is associated with a reduced risk of cardiovascular disease morbidity (22).

6 Conclusion

The debate over soy isoflavones exemplifies the complexities of translating scientific research into public health policy. While animal studies have raised valid concerns about their endocrine activity, robust human data consistently refute their classification as endocrine disruptors or harmful to health. Moving forward, dietary recommendations should prioritize evidence-based approaches that consider both safety and nutritional value. Future research should aim to strengthen causal inference through studies with detailed dietary assessments and long-term follow-up, as well as mechanistic studies that clarify the biological pathways through which isoflavones exert their effects.

Abbreviations: ANSES, French Agency for Food, Environmental and Occupational Health and Safety; EFSA, European Food Safety Authority; TRV, Toxicological Reference Values.

Ultimately, fostering collaboration among regulatory agencies and researchers will ensure that public health policies are informed by comprehensive scientific understanding rather than isolated findings. Soy foods remain a safe and valuable component of human diets when consumed responsibly, a conclusion supported by decades of research across diverse populations. Rather than focusing solely on potential risks, public health policy should also recognize and embrace the well-established benefits of soy consumption in the context of overall dietary quality and sustainability.

Author contributions

ML-M: Conceptualization, Writing – original draft. JL-G: Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

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