Regulatory Fragmentation in Nutraceuticals and Herbals: Implications for Safety, Quality Control, and Raw Material Standardisation

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Abstract

The worldwide demand for nutraceuticals and herbal products has grown rapidly due to their growing role in health promotion and disease prevention. Despite their widespread use, regulatory approaches differ substantially among countries, leading to inconsistencies in product quality, safety evaluation, and international commercialization. This review examines and compares the regulatory systems of the United States, the European Union, India, Japan, China, Canada, and Australia, with particular attention to product classification, marketing authorization, quality assurance, raw material standardisation, and post-market monitoring. Evidence from published reports was also assessed to identify the consequences of regulatory gaps. The analysis indicates that differences in regulatory expectations contribute to problems such as adulteration, contamination, incorrect botanical identification, and inconsistent product performance. Well-documented incidents, including Aristolochia-induced nephropathy, cardiovascular events linked to Ephedra-containing products, liver injury associated with Hydroxycut, and heavy metal contamination in certain Ayurvedic preparations, demonstrate the potential health risks arising from inadequate regulatory control. The findings emphasize the need for greater international alignment of regulatory practices, stronger standards for raw material quality, improved surveillance throughout the product lifecycle, and the adoption of emerging technologies such as artificial intelligence to strengthen regulatory decision-making while accommodating country-specific regulatory frameworks.

Keywords: nutraceuticals; herbal products; regulatory framework; product safety; quality assurance; raw material standardisation; international harmonization.

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1. Introduction

Food-derived nutraceuticals and herbal products have become an integral component of modern healthcare, reflecting a global shift toward preventive medicine, healthy ageing, and personalized nutrition. Unlike conventional pharmaceuticals, nutraceuticals are generally consumed to maintain physiological function, improve nutritional status, or reduce disease risk rather than to treat specific pathological conditions. The World Health Organization estimates that nearly 80% of the global population relies partly on herbal medicines for primary healthcare, particularly in developing countries where traditional medicine remains culturally significant (WHO, 2019). [1]

The worldwide nutraceutical market is projected to exceed USD 650 billion within the next decade, driven by increasing prevalence of chronic diseases, ageing populations, and growing consumer awareness regarding diet–health relationships (Grand View Research, 2024). Despite this remarkable expansion, regulatory governance has evolved unevenly across different jurisdictions. The absence of universally accepted definitions has resulted in identical products being regulated as dietary supplements in the United States, functional foods in Japan, natural health products in Canada, complementary medicines in Australia, or novel foods within the European Union.[2]

This diversity reflects differing legislative priorities rather than scientific consensus. Some regulatory systems prioritize consumer accessibility and industry innovation through post-market enforcement, whereas others require extensive pre-market scientific evaluation before commercialization. Consequently, manufacturers face multiple regulatory pathways for identical products, while consumers encounter varying levels

of protection depending on geographical location.[3]

Regulatory fragmentation extends beyond legal definitions and directly influences ingredient approval, manufacturing practices, permissible health claims, contaminant limits, botanical authentication, and post-market surveillance. The resulting inconsistencies have significant implications for public health because botanical materials exhibit substantial natural variability, making robust quality assurance essential. Furthermore, globalization has transformed nutraceutical supply chains into complex international networks where raw materials may be cultivated in one country, processed in another, and marketed worldwide. Such complexity increases the risk of adulteration, contamination, and product substitution if harmonized quality standards are absent.[4]

This review critically evaluates how global regulatory fragmentation influences consumer safety, quality control, and raw material standardisation while highlighting lessons learned from major regulatory failures. It also proposes a future-oriented framework based on scientific interoperability rather than complete legislative harmonization.[5]

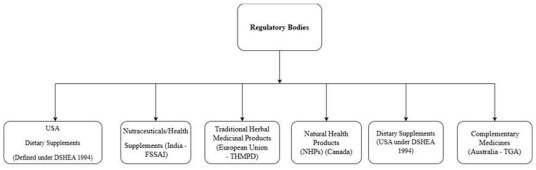

Figure 1. Classification of Nutraceuticals Regulatory Categories Across Major Global Jurisdictions

This is how diversely a single herbal food or nutraceutical is treated and gets regulated accordingly

Ingredients	**Regulated As**			
	Food	**Nutraceutical**	**Medicine**	**Cosmetic**
Iron	Yes	Yes	Yes	-
Licorice (Yashtimadhu)	-	Yes	Yes	Yes
Amla	Yes	Yes	Yes	Yes
Melatonin	-	In the USA	In the EU And Japan	-
Glucosamine	-	In the USA	In The EU	-
Caffeine	Yes	Yes	-	-
Shatavari	-	Yes	Yes	-
Tulsi	-	Yes	Yes	-
Giloy	-	-	Yes	-
Aloe vera	Yes	Yes	Yes	Yes
Ashwagandha	Yes	Yes	Yes	Yes
Neem	-	-	Yes	Yes
Vitamin d	Yes	Yes	Yes	-

Table 1. Different ingredients face varying regulations, each with its own unique set of rules and oversight (In the USA/ Japan/EU means the substance is only considered in a specific country, and it is not regulated as)

2. Materials and Methods

Study design and review approach

This study was designed as a narrative comparative review of international regulatory frameworks governing nutraceuticals, herbal products, dietary supplements, and related health products. The review focused on how differences in regulatory classification, pre-market requirements, quality control expectations, post-market surveillance, and raw material standardisation influence product safety and market oversight across major jurisdictions.

Literature sources and search strategy

A structured literature search was conducted using electronic databases including PubMed, Google Scholar, Scopus, and regulatory/government websites. Official documents and guidance materials were retrieved from major regulatory authorities and public health institutions, including the U.S. Food and Drug Administration (FDA), European Food Safety Authority (EFSA), European Commission, Food Safety and Standards Authority of India (FSSAI), Therapeutic Goods Administration (TGA), National Medical Products Administration (NMPA), Ministry of Health, Labour and Welfare (MHLW), Consumer Affairs Agency (CAA), World Health Organization (WHO), and other relevant national or international sources.

Search terms were used alone and in combination and included: “nutraceutical regulation,” “herbal product regulation,” “dietary supplement safety,” “functional foods regulation,” “raw material standardisation,” “botanical authentication,” “adulteration of herbal supplements,” “regulatory harmonization,” “post-market surveillance,” “quality control of nutraceuticals,” “FSSAI nutraceutical regulations,” “DSHEA dietary

supplements," "EFSA health claims," and "complementary medicines regulation."

Time period covered

The literature search primarily focused on publications, review articles, regulatory guidelines, safety communications, and official reports published between 2015 and 2026 to reflect the current regulatory landscape. However, older landmark references were also included where necessary to describe historically important regulatory events, foundational legal frameworks, and major case studies of safety failure, such as Aristolochia nephropathy, ephedra-related toxicity, and heavy metal contamination in Ayurvedic products.

Eligibility criteria

Sources were included if they met one or more of the following criteria:

1. described regulatory frameworks for nutraceuticals, herbal products, dietary supplements, complementary medicines, or functional foods;
2. addressed safety assessment, health claims, quality control, contaminant monitoring, pharmacovigilance, or raw material standardisation;
3. reported regulatory failures, recalls, adulteration, contamination, or adverse-event case studies relevant to nutraceutical or herbal products;
4. were official documents, regulations, guidance papers, safety notices, or reports issued by recognized national or international regulatory bodies; or
5. were peer-reviewed review articles, original studies, or authoritative reports relevant to global regulatory comparison.

Sources were excluded if they were non-relevant to nutraceutical or herbal regulation, lacked sufficient regulatory or scientific relevance, were duplicate records, or focused on unrelated pharmaceutical regulatory topics without direct applicability to nutraceuticals, herbals, or functional products.

Data synthesis

The extracted information was synthesized narratively and comparatively across jurisdictions, with emphasis on the United States, European Union, India, Australia, China, and Japan.

3. Findings of Review

Regulations and Challenges

a. United States (DSHEA)

The regulation of nutraceuticals in the United States is primarily governed by the Dietary Supplement Health and Education Act (DSHEA) 1994, which amended the Federal Food, Drug, and Cosmetic Act (FD&C Act). Additional regulatory oversight includes Current Good Manufacturing Practices (21 CFR Part 111), New Dietary Ingredient (NDI) Notification Guidelines, and FDA rules governing structure/function claims and labelling requirements. Although these frameworks establish a legal structure for dietary supplements, several critical safety and quality gaps persist.

A major limitation of DSHEA is the absence of mandatory pre-market approval, allowing products to reach the market without a comprehensive safety or efficacy evaluation. The NDI notification pathway does not require FDA authorization, meaning novel herbal ingredients may be marketed despite limited toxicological data, increasing the risk of unforeseen adverse effects.[6]

Under structure/function claim regulations (Section 403(r)(6) of the FD&C Act), manufacturers can describe physiological benefits without demonstrating clinical efficacy. This creates a regulatory gray zone in which consumer perception may exceed the scientific evidence, leading to inappropriate or unsafe self-administration of products.

Although cGMP regulations (21 CFR Part 111) require manufacturing quality controls, enforcement is inconsistent, and variability in botanical raw materials, contamination, and adulteration with undeclared pharmaceutical substances continues to be reported. This directly impacts product consistency and safety.[7]

b. European Union

The European Union regulates nutraceuticals and food supplements under a structured legal framework comprising Directive 2002/46/EC on Food Supplements, Regulation (EC) No. 178/2002 (General Food Law), Regulation (EC) No. 1924/2006 on Nutrition and Health Claims, and the Novel Food Regulation (EU) 2015/2283. Scientific risk assessment for ingredients and health claims is conducted by the European Food Safety Authority (EFSA), while the European Commission implements authorization decisions. Despite this seemingly rigorous pre-market system, several practical limitations affect real-world safety and consistency.[8]

One major challenge is the strict and complex health claim authorization system under Regulation

1924/2006, which results in a very limited number of approved claims.

The issue lies in the Novel Food Regulation (2015/2283), where lengthy and costly approval procedures delay market access for new botanical ingredients. This often leads to reformulation or parallel market entry strategies, increasing variability in product composition across regions.[9]

While EFSA provides strong scientific opinions, implementation and enforcement vary across EU member states, resulting in inconsistent monitoring of product quality, labelling, and contamination control. This fragmentation weakens uniform consumer protection within the internal market.

c. India

In India, nutraceuticals are regulated primarily under the Food Safety and Standards Act (FSSA), 2006, with detailed provisions under the Food Safety and Standards (Health Supplements, Nutraceuticals, Food for Special Dietary Use, Food for Special Medical Purpose, Functional Food and Novel Food) Regulations, 2016, along with amendments and compliance guidelines issued by FSSAI. The framework follows a positive list approach, permitting only approved ingredients within defined limits and requiring prior approval for novel foods.[10]

Despite this structured system, several regulatory gaps persist. A major challenge is implementation inconsistency, where enforcement varies across states, leading to uneven compliance with ingredient standards, labelling norms, and quality checks. Another issue is raw material variability, as herbal sourcing often depends on unregulated supply chains, resulting in inconsistent active ingredient levels and increased risk of adulteration. Additionally, the overlap between FSSAI and AYUSH regulations creates classification ambiguity between nutraceuticals and traditional medicines, leading to regulatory grey zones. Finally, post-market surveillance mechanisms remain relatively weak, delaying detection of substandard or unsafe products. These limitations collectively reduce the effectiveness of India's otherwise structured regulatory framework in ensuring uniform safety and quality assurance.[11] [12]

d. Australia

In Australia, nutraceuticals and herbal products are regulated under the Therapeutic Goods Act 1989 and overseen by the Therapeutic Goods Administration (TGA). Most complementary medicines are listed on the Australian Register of Therapeutic Goods (ARTG) through either listed (lower risk) or registered (higher risk) pathways. Listed medicines rely largely on sponsor self-certification for safety, quality, and efficacy, while registered medicines undergo more stringent pre-market evaluation.

Despite this structured system, several limitations exist. A major concern is the self-regulated listing pathway, where products are included in ARTG based on sponsor declarations rather than full pre-market verification, increasing the risk of inaccurate safety or efficacy claims. Another issue is limited evaluation of traditional herbal evidence, where historical use may substitute for robust clinical validation, potentially masking weak efficacy data. Additionally, post-market compliance monitoring is resource-intensive and reactive, allowing issues such as adulteration or inconsistent ingredient standardisation to persist before detection. Finally, variability in imported herbal raw materials creates challenges in maintaining consistent quality across products. These gaps highlight a system that is structured but still vulnerable to quality and evidence inconsistencies in practice.[13]

e. China

In China, nutraceuticals and functional foods are regulated under the National Medical Products Administration (NMPA) and governed by the Food Safety Law of the People's Republic of China, along with the Administrative Measures for Health Food Registration and Filing. Products are classified as "health foods", which may require either a registration pathway (higher risk products) or a filing system (lower risk products), depending on ingredient novelty and intended function.[14]

Despite this dual framework, several regulatory challenges remain. A key limitation is the complex dual approval system (registration vs. filing), which creates regulatory uncertainty and can delay market access while also encouraging strategic product positioning rather than scientific differentiation. Another issue is historical concerns related to adulteration and economically motivated contamination, where some products have been found to contain undeclared pharmaceutical substances to enhance efficacy. Additionally, variability in enforcement across regional authorities can lead to inconsistent quality inspections and uneven compliance with manufacturing standards. Finally, the rapid expansion of e-commerce channels has made post-market surveillance more difficult, increasing the risk of counterfeit or substandard products reaching consumers. These factors collectively highlight ongoing challenges in ensuring uniform safety and quality control within China's expanding nutraceutical market.[15]

f. Japan

In Japan, nutraceuticals are regulated under a structured functional food system administered by

the Ministry of Health, Labour and Welfare (MHLW) and the Consumer Affairs Agency (CAA). Products are categorized mainly into Foods for Specified Health Uses (FOSHU), Foods with Function Claims (FFC), and Nutrient Function Foods (NFF). FOSHU products require pre-market approval based on scientific evidence, while FFC allows manufacturers to submit function claims with supporting data and market products after notification.[16]

Despite this structured system, several limitations exist. A key issue is the lower evidentiary requirement under the FFC system, where manufacturers can self-substantiate functional claims without full regulatory approval, increasing the risk of weak or selectively interpreted scientific evidence. Another concern is the variation in scientific rigor between FOSHU and FFC pathways, leading to inconsistent product credibility within the same regulatory framework. Additionally, post-market monitoring of functional claims is limited, making it difficult to verify long-term safety or efficacy outcomes. Finally, reliance on industry-submitted data can introduce potential bias in evidence quality, affecting transparency. These gaps highlight a system that is scientifically structured but still partially dependent on manufacturer-driven evidence generation.[17]

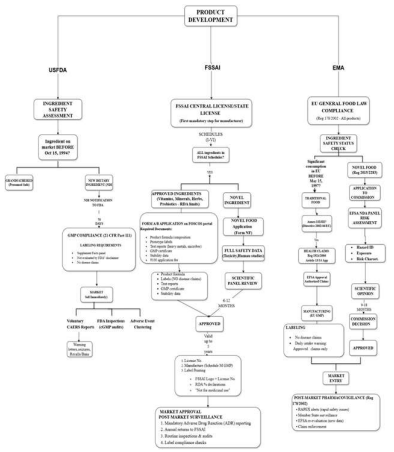

Figure 2. Comparative Regulatory Approval Pathways for Nutraceuticals in the US (FDA), India (FSSAI), and the European Union (EFSA)

4. Case studies and challenges offered but the Multiregulated and regulatory action failures

The Aristolochia nephropathy outbreak in Belgium during the ear0ly 1990s remains one of the most significant botanical safety failures. Women attending a weight-loss clinic developed rapidly progressive kidney failure after consuming herbal preparations in which Stephania tetrandra had been unintentionally substituted with Aristolochia fangchi. Aristolochic acids present in the substituted plant caused irreversible nephrotoxicity and significantly increased the incidence of urothelial carcinoma (Nortier et al., 2000). This event highlighted deficiencies in botanical identification, raw material authentication, and supply-chain quality control, ultimately prompting international restrictions on Aristolochia-containing products.[19]

A second landmark example involved Ephedra (Ma Huang) dietary supplements in the United States. Widely marketed for weight loss and athletic performance, ephedra-containing products were associated with hypertension, myocardial infarction, stroke, and sudden cardiac death. Thousands of adverse event reports accumulated before the FDA prohibited ephedra-containing dietary supplements in 2004 (FDA, 2004). The case illustrated the limitations of reactive post-market regulation, where substantial consumer exposure occurred before decisive regulatory action.[19]

Similarly, Hydroxycut, a popular weight-management supplement, was voluntarily recalled in 2009 following numerous reports of severe liver injury, including cases requiring liver transplantation. Although the precise toxicological mechanism remained uncertain, the incident emphasized the importance of evaluating interactions among multiple botanical ingredients rather than assessing individual components in isolation (FDA, 2009).[20]

Another notable example concerns heavy metal contamination in Ayurvedic herbal products. A landmark investigation published in JAMA found that approximately one-fifth of Ayurvedic products purchased online contained lead, mercury, or arsenic at concentrations capable of causing toxicity (Saper et al., 2008). While some metals originated from intentional traditional formulations, others reflected poor manufacturing quality and inadequate raw material testing. The study demonstrated that localisation of herbal commerce requires internationally harmonised contaminant standards and routine quality verification.[21]

Products containing 1,3-dimethylamylamine (DMAA) were widely sold in pre-workout and weight-loss supplements before FDA enforcement intensified. DMAA was associated with hypertension, cardiovascular complications, cerebral haemorrhage, and deaths, yet it remained on the market because manufacturers argued that it qualified as a dietary ingredient under the DSHEA framework. FDA later concluded that DMAA was not a lawful dietary ingredient and issued warning letters and product seizures. This case showed how

ambiguity in ingredient status and delayed enforcement can allow stimulant-containing products to remain available despite mounting safety concerns.[22]

These products were often marketed as herbal or dietary supplements, meaning consumers unknowingly consumed a potent synthetic drug while believing they were taking a natural product. This case highlights major gaps in supply-chain oversight, online supplement policing, and contaminant/adulterant screening.[23]

Red yeast rice products are frequently marketed for cholesterol support, but their regulatory status remains difficult because some preparations contain monacolin K, which is chemically identical to lovastatin. Commercial products have shown large variability in monacolin concentration, and some have been contaminated with citrinin, a nephrotoxic mycotoxin. This creates a regulatory grey zone in which products may function pharmacologically like statins while being sold as food supplements, often without consistent dose standardisation or medical supervision. The case reflects a broader challenge in nutraceutical regulation: food-derived products can exert drug-like effects without being regulated to drug-level evidence or manufacturing consistency.[24]

5. AI reference solution for detailed mapping of the Raw materials and making regulatory standardisation

Artificial intelligence (AI) may help address regulatory fragmentation in nutraceuticals and herbals by improving supply-chain traceability, raw-material authentication, and cross-border data sharing. Because these products are often sourced, processed, and marketed across multiple countries, gaps in documentation and inconsistent regulatory standards increase the risk of adulteration, contamination, and botanical substitution. AI can support traceability by integrating supplier records, batch histories, contaminant testing, and analytical data such as chromatographic or spectroscopic profiles. This may allow earlier detection of abnormal quality patterns and high-risk materials before products reach consumers. [25]

Kaur et al. (2025) highlighted the role of AI in herbal drug authentication, particularly for detecting adulteration, substitution, and inconsistency in raw materials using analytical fingerprints and molecular data. Similarly, Osemwowa (2026) showed that AI can be applied to food fraud and adulteration analysis by identifying suspicious patterns in testing and surveillance datasets. In a fragmented global market, such tools could also support regulatory interoperability by enabling authorities to share structured safety, quality, and recall information more efficiently. Although AI cannot replace scientific or regulatory judgement, it may serve as a practical decision-support tool for strengthening safety, quality control, and raw material standardisation in globally traded nutraceuticals and herbal products.[26]

Discussion

This review shows that nutraceuticals and herbal products are regulated under markedly different legal and scientific frameworks across countries. Although these systems share the broad goal of protecting public health and product quality, they vary considerably in product classification, pre-market evaluation, quality requirements, and post-market surveillance. Such variation has important practical consequences for safety oversight, health claims, raw-material standardisation, and market control.

The reviewed evidence also indicates that insufficient raw-material authentication, inconsistent contaminant control, and weak post-market monitoring can contribute to serious safety problems, including organ toxicity and exposure to harmful contaminants. Overall, the findings support the need for stronger quality standards, clearer classification principles, improved traceability, and greater international convergence in the regulation of nutraceutical and herbal products.

6. Results

The reviewed literature showed substantial international variation in the regulation of nutraceuticals and herbal products. Major differences were identified in product classification, pre-market requirements, health-claim control, and post-market surveillance across the United States, European Union, India, Australia, China, and Japan. The findings also highlighted recurring concerns related to raw-material standardisation, manufacturing quality, contamination, and adulteration. Case examples such as ephedra toxicity, Hydroxycut-related liver injury, heavy metal contamination in Ayurvedic products, and adulterated slimming supplements demonstrated the safety risks associated with weak regulatory oversight and inconsistent quality control.

Table No. 2: Cases and their

Case Study	Regulatory Framework	Issue	Root Cause	Regulatory Action / Solution	Outcome / Lesson Learned
Pan Pharmaceuticals Recall (2003)	Australia's Therapeutic Goods Administration (TGA) – GMP	Manufacturing deviations resulted in substandard medicines and supplements, raising concerns about product safety and efficacy.	Poor adherence to Good Manufacturing Practices (GMP), inadequate quality control, and manufacturing process failures.	TGA suspended the manufacturer's licence, recalled over 1,600 products, and strengthened GMP inspections and compliance requirements.	Demonstrated the importance of strict GMP compliance and proactive regulatory oversight in ensuring product quality and consumer safety.
Heavy Metal Contamination in Ayurvedic Herbal Products (2008)	WHO guidelines, GMP, international contaminant standards	Approximately 20% of Ayurvedic products purchased online contained toxic levels of lead, mercury, or arsenic.	Intentional inclusion of metals in some traditional formulations, inadequate raw material testing, poor manufacturing quality, and environmental contamination.	Strengthened GMP requirements, routine heavy metal testing, supplier qualification, and implementation of internationally harmonized contaminant standards.	Highlighted the need for rigorous contaminant testing and global quality standards for herbal medicines sold internationally.
Ephedra Case (2004)	Dietary Supplement Health and Education Act (DSHEA, 1994); FDA Adverse Event Reporting System	Ephedra-containing supplements caused cardiovascular events, strokes, and deaths while being marketed for weight loss.	Lack of pre-market safety approval under DSHEA allowed products to be marketed before adequate safety evaluation.	FDA collected over 18,000 adverse event reports before banning ephedra-containing dietary supplements in 2004.	Demonstrated the limitations of post-market surveillance and the risks of reactive regulatory systems.
Hydroxycut Case (2009)	DSHEA; Current Good Manufacturing Practices (21 CFR Part 111)	Hydroxycut products were linked to severe liver injury, liver transplantation, and at least one death.	Reformulated products entered the market without comprehensive pre-market safety evaluation despite GMP compliance.	FDA issued safety warnings, and the manufacturer voluntarily recalled Hydroxycut products.	Showed that GMP alone cannot ensure product safety without robust ingredient safety assessment.
Kava Case (2002–2004)	European Union Traditional Herbal Medicinal Products Directive (Directive 2004/24/EC)	Reports of severe liver toxicity associated with kava-containing herbal medicines.	Variability in extraction methods, product quality, and reliance on traditional use rather than comprehensive toxicological evaluation.	Germany suspended kava products; regulatory reassessment later examined manufacturing quality and extraction processes.	Demonstrated that traditional use alone does not guarantee safety and highlighted the importance of toxicological evaluation.
OxyElite Pro Case (2013)	DSHEA; New Dietary Ingredient (NDI) Notification System	Reformulated supplement containing aegeline caused acute liver failure, liver transplants, and deaths.	Novel ingredient entered the market without adequate pre-market toxicological assessment under the NDI notification process.	FDA issued warning letters, product recalls, and enforcement actions against the manufacturer.	Revealed weaknesses in the NDI notification process and emphasized the need for stronger pre-market evaluation of new dietary ingredients.
Valsartan NDMA Contamination	EMA, FDA, ICH Q7 GMP	Carcinogenic nitrosamine (NDMA)	Manufacturing process changes introduced	Global product recalls, revised impurity testing	Led to stricter impurity control strategies and

regulatory Implications

Substance	United States (FDA)	European Union	Australia (TGA)	Japan
Melatonin	Sold as an over-the-counter dietary supplement	Classified as a prescription-only medicinal product	Prescription medicine	Prescription drug
Glucosamine & Chondroitin	Sold as dietary supplements with structure/function claims	Often regulated as medicinal products (e.g., France, Sweden), especially high-dose osteoarthritis products	Generally regulated as complementary medicines; higher doses may require stricter approval	Often regulated as pharmaceuticals rather than food supplements
Bismuth Subsalicylate (Pepto-Bismol)	Widely available as an OTC drug for gastrointestinal disorders	Limited availability; regulation varies by member state	Some formulations require a prescription, depending on strength and indication	Not approved as an OTC product
DHEA (Dehydroepiandrosterone)	Sold as a dietary supplement for anti-aging and hormonal support	Classified as a prescription medicine / controlled hormonal substance	Prescription-only medicine, regulated similarly to anabolic steroids	Classified as a controlled prescription drug

Table 3. International Regulatory Status of Selected Nutraceutical Ingredients Across the USA, the EU, Australia, and Japan

Conclusion

The current regulatory landscape for Food and nutraceutical products is highly fragmented due to the absence of an internationally harmonized definition for nutraceuticals, dietary supplements, functional foods, and related health products, resulting in inconsistent classification and regulatory control across global markets. In many countries, regulatory systems rely more on post-market approaches with limited pre-market evaluation, which may expose consumers to safety risks, while post-market surveillance remains weak, with estimated adverse event reporting rates as low as ~2% for dietary supplements. Additional concerns include inadequate GMP enforcement and quality control deficiencies, leading to issues such as adulteration, contamination, and variability in product quality. There is therefore a strong need for harmonized global definitions and classification systems, standardized quality assurance protocols, strengthened post-market surveillance mechanisms, and clearer evidence-based requirements for safety and efficacy, along with improved international regulatory collaboration and capacity building of regulatory personnel. This study is further necessitated by the rapid expansion of the global nutraceutical market, projected to reach USD 657.84 billion by 2030, increasing reports of adverse events, growing consumer dependence on natural health products, and the lack of comprehensive research that systematically integrates and analyzes global regulatory challenges in this sector.

7. DECLARATIONS

Conflict of Interest

The authors declare that they have no conflicts of interest related to this work.

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No external funding was received for this study

Ethics

Ethical approval was not required for this study because it is a review of published literature, **Author Contributions**

Priti Shelar contributed to the conceptualization of the review, literature searching, data collection, comparative analysis of regulatory frameworks, drafting of the manuscript, and preparation of tables and figures.

Atish Velhal contributed to study supervision, review planning, critical revision of the manuscript, and academic guidance.

Prakash Jadhav contributed to methodological guidance, interpretation of regulatory content, manuscript review, and supervision. Ganesh Khade contributed to literature support, data organization, and manuscript review.

All authors contributed to the article, reviewed the final version of the manuscript, and approved it for submission.

8. References

1. World Health Organization. *WHO Global Report on Traditional and Complementary Medicine 2019*. World Health Organization; 2019. https://www.who.int/publications/i/item/9789241515436
2. Grand View Research. *Nutraceuticals Market Size, Share & Trends Analysis Report*. Grand View Research; 2024. https://www.grandviewresearch.com/industry-analysis/nutraceuticals-market
3. European Parliament and Council. Directive 2002/46/EC on food supplements. *Off J Eur Union*. 2002. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0046
4. U.S. Food and Drug Administration. Dietary supplement current good manufacturing practices (cGMP). Published 2023. Accessed July 7, 2026. https://www.fda.gov
5. World Health Organization. *Quality Control Methods for Herbal Materials*. World Health Organization; 2011. https://apps.who.int/iris/
6. U.S. Food and Drug Administration. Dietary supplement current good manufacturing practice (cGMP) regulations (21 CFR Part 111). Published 2022. Accessed July 7, 2026. https://www.ecfr.gov/current/title-21/chapter-I/subchapter-B/part-111
7. Gurley BJ, Gardner SF, Hubbard MA. Content versus label claims in ephedra-containing dietary supplements. *Am J Health Syst Pharm*. 2000;57(11):963-969. doi:10.1093/ajhp/57.11.963
8. European Parliament and Council. Directive 2002/46/EC on food supplements. *Off J Eur Communities*. 2002. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0046
9. Garcia-Alvarez A, et al. Health claims in the European Union: impact of Regulation 1924/2006. *Trends Food Sci Technol*. 2014;33(2):108-115. doi:10.1016/j.tifs.2013.11.003
10. Food Safety and Standards Authority of India. *Food Safety and Standards (Health Supplements, Nutraceuticals, Food for Special Dietary Use, Food for Special Medical Purpose, Functional Food and Novel Food) Regulations, 2016*. Food Safety and Standards Authority of India; 2016. https://www.fssai.gov.in
11. Ministry of AYUSH. *The Drugs and Cosmetics Act, 1940 and Rules 1945 (Ayurveda, Siddha, Unani Systems Updates)*. Government of India; 2015. https://www.ayush.gov.in
12. Sharma R, Singh A. Regulatory challenges in nutraceuticals and functional foods in India. *J Food Sci Technol*. 2020;57(9):3456-3465. doi:10.1007/s13197-020-04312-3
13. Therapeutic Goods Administration. *Australian Regulatory Guidelines for Complementary Medicines (ARGCM)*. Australian Government Department of Health; 2023. https://www.tga.gov.au/resources/resource/guidance/australian-regulatory-guidelines-complementary-medicines-argcm
14. Li X, Lin Y. Safety and regulatory evaluation of functional foods in China. *Trends Food Sci Technol*. 2021;111:1-10. doi:10.1016/j.tifs.2021.02.012
15. National Health Commission of the People's Republic of China. Health food regulatory framework and classification system. Published 2020. Accessed July 7, 2026. http://en.nhc.gov.cn
16. Shimizu T. Health claims on functional foods: the Japanese regulatory system.

Nutr Rev. 2018;76(3):155-168. doi:10.1093/nutrit/nux065

17. Kondo K, Nishijima M. Functional foods and regulatory challenges in Japan. *Trends Food Sci Technol*. 2020;97:302-310. doi:10.1016/j.tifs.2020.01.018
18. Nortier JL, Vanherweghem JL, et al. Aristolochic acid nephropathy: a clinical and pathological review. *Kidney Int*. 2000;57(6):2510-2521. doi:10.1046/j.1523-1755.2000.00105.x
19. Haller CA, Benowitz NL, Jacob P. Hemodynamic effects of ephedra-free weight-loss supplements in humans. *Am J Med*. 2000;108(8):548-556. doi:10.1016/S0002-9343(00)00367-5
20. Fong TL, Klontz KC, Canas-Coto A, et al. Hepatotoxicity due to Hydroxycut: a case series. *Am J Gastroenterol*. 2010;105(7):1561-1566. doi:10.1038/ajg.2010.5
21. Saper RB, Phillips RS, Sehgal A, et al. Lead, mercury, and arsenic in U.S.- and Indian-manufactured Ayurvedic medicines sold via the Internet. *JAMA*. 2008;300(8):915-923. doi:10.1001/jama.300.8.915
22. U.S. Food and Drug Administration. Recent FDA action on dietary supplements labeled as containing DMBA. U.S. Department of Health and Human Services. Published April 28, 2015. Accessed July 7, 2026.FDA DMBA enforcement update
23. U.S. Food and Drug Administration. Public notification: Sliming Diet contains hidden drug ingredient. U.S. Department of Health and Human Services. Published June 17, 2014. Accessed July 7, 2026. FDA Sliming Diet notification
24. European Food Safety Authority (EFSA) Panel on Food Additives and Nutrient Sources Added to Food. Scientific opinion on the safety of monacolins in red yeast rice. *EFSA J*. 2018;16(8):5368. doi:10.2903/j.efsa.2018.5368
25. U.S. Food and Drug Administration. Final rule declaring dietary supplements containing ephedrine alkaloids adulterated because they present an unreasonable risk. *Fed Regist*. 2004;69(28):6787-6854. https://www.govinfo.gov/content/pkg/FR-2004-02-11/pdf/04-3269.pdf
26. Fong TL, Klontz KC, Canas-Coto A, et al. Hepatotoxicity due to Hydroxycut: a case series. *Am J Gastroenterol*. 2010;105(7):1561-1566. doi:10.1038/ajg.2010.5
27. Teschke R, Lebot V. Kava hepatotoxicity: a clinical review. *J Hepatol*. 2011;55(6):1430-1438. doi:10.1016/j.jhep.2011.04.011
28. Roytman MM, Patel V, Jakate S, et al. Fatal hepatotoxicity due to OxyELITE Pro™ dietary supplement. *Hepatology*. 2014;60(3):985-989. doi:10.1002/hep.27202
29. Kaur R, Baldi A, Baldi A. Artificial intelligence in herbal drug authentication: revolutionizing identification, adulterant detection and standardization. Current Drug Discovery Technologies. Advance online publication. https://doi.org/10.2174/0129503779378012250613194901
30. Osemwowa EU. The application of artificial intelligence in food fraud and adulteration analysis: a review. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess*. Published online 2026. doi:10.1080/19440049.2026.2654716