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Review Article

Herbal Food Supplements: Trends, Classification, Safety Concerns, and Regulatory Perspectives on Weight Management and Athletic Performance

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Abstract

The global demand for dietary supplements has surged in response to growing public interest in preventive health strategies, nutritional optimization, and enhanced physical performance. This review critically examines the definition, classification, and physiological mechanisms of action of food supplements, with emphasis on herbal products used for weight control and athletic enhancement. It also explores emerging safety concerns related to product adulteration with synthetic pharmacological agents, including anorectics, diuretics, anabolic steroids, and stimulants, many of which are undeclared and banned due to severe health risks. Regulatory frameworks across different jurisdictions are compared, highlighting the dichotomy between the European Union's precautionary model and the United States' market-liberal approach. Post-marketing surveillance systems—including Nutri vigilance and RASFF—are assessed for their roles in monitoring adverse events and ensuring consumer safety.

The study concludes with recommendations for harmonized testing protocols, mandatory transparency measures, and expanded public health education to mitigate risks and guide responsible use. Despite their popularity, concerns persist regarding efficacy, safety, and regulatory oversight.

This review synthesizes recent randomized controlled trials (RCTs), systematic reviews, and case reports, with a focus on global regulatory frameworks—particularly in the Asia-Pacific and Australia. A novel classification system is proposed, and conflicting evidence is discussed. The study fills a critical gap by integrating athlete-specific safety data, doping control implications, and regional regulatory comparisons.

Introduction

The global rise in herbal supplement use reflects a growing preference for natural alternatives in sports and wellness. Athletes are particularly drawn to these products for their perceived benefits in endurance, recovery, and body composition. However, the lack of standardized regulation and scientific consensus raises concerns about safety and legality.

The concept of dietary supplementation has gained significant traction due to the increasing global emphasis on preventive health measures and the critical role of nutrition in maintaining well-being. According to the European Food Safety Authority (EFSA), food supplements are defined as concentrated sources of nutrients—such as vitamins, minerals, amino acids, enzymes, or botanicals—intended to complement the diet and address specific nutritional deficiencies. These products are typically delivered in dosage forms including capsules, tablets, or liquid solutions for oral consumption.

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Within the European Union (EU), food supplements are primarily used to promote general health by supplying essential nutrients, rather than treating disease, aligning with a broader preventive health philosophy. Unlike pharmaceutical agents that target disease symptoms, dietary supplements aim to modulate physiological functions to maintain or improve health. This holistic approach has resonated with the public's growing interest in natural and integrative health solutions.

The demand for food supplements has surged over the past two decades, driven by increasing health consciousness, rising life expectancy, and a heightened prevalence of chronic illnesses. Consumers perceive these products as safer alternatives to traditional medications due to their perceived 'natural' composition. Additionally, the prevalence of self-medication and the proliferation of online content—ranging from health news and social media to user reviews— has expanded awareness and accessibility.

Contemporary lifestyle concerns, including aesthetic ideals and athletic performance, have also contributed to the widespread use of supplements aimed at weight management, sexual vitality, and physical endurance. These trends underscore the diverse applications of food supplements, which encompass a broad spectrum of biologically active compounds used individually or in combination.

Nevertheless, the sector faces significant challenges. These include inconsistent regulatory oversight, variable product quality, and conflicting evidence regarding efficacy and safety. Addressing these issues requires the development of standardized testing methodologies, a scientifically rigorous approach to efficacy evaluation, and a cohesive regulatory framework that safeguards public health without stifling innovation.

The global food supplement market reflects this growing demand. Statista estimates the industry's value at $185.1 billion in 2025, with projections suggesting an increase to approximately $308 billion by 2028. Similarly, Grand View Research reported the market to be worth $102.18 billion in 2024, forecasting a 7.2% annual growth rate through 2030.

In the context of a general trend toward self-medication, one major factor contributing to the surge in demand for supplements is the wide variety of information channels (especially online (news articles, advertisements, social media posts, and forum reviews) and the ease of access from various sources, especially via the internet [1]. At the same time, the significant increase in the use of dietary supplements for weight loss, and to improve sexual, physical, and sports performance reflects current societal concerns related to health, aesthetics, and overall performance [2,3].

This review was conducted using a systematic search across PubMed, Scopus, Web of Science, and the Cochrane Library. Inclusion criteria focused on:

- Peer-reviewed articles published between **2015–2025**
- Studies involving **human subjects**
- Randomized Controlled Trials (RCTs), systematic reviews, and meta-analyses
- Reports addressing **weight management, athletic performance, safety,** and **regulatory frameworks**

Grey literature and case reports were included if they provided unique insights into **doping control** or **regulatory enforcement.**

This study offers a **novel synthesis** by integrating global regulatory comparisons, athlete-specific safety data, and emerging evidence from underrepresented regions like the **Asia-Pacific and Australia,** filling a critical gap in current literature.

- **Herbal supplements:** Products containing plant-based ingredients used to support health or performance.
- **Botanical dietary supplements**: Broader category including extracts, powders, and tinctures.
- **Ergogenic aids**: Substances that enhance physical performance, often used in competitive sports.

Trends in use and market growth

- Market projected to exceed $150 billion by 2028
- High usage among combat athletes, bodybuilders, and recreational fitness enthusiasts
- Popular herbs: *Ginseng*, *Green Tea Extract*, *Tribulus Terrestris*, *Rhodiola Rosea*, *Ephedra*

Challenges and controversies

- **Conflicting efficacy data**: *Tribulus Terrestris* showed no testosterone boost in a 2022 RCT (n = 120), contradicting earlier findings
- **Safety risks**: Adulteration, contamination, and undeclared banned substances
- **Doping control**: Supplements linked to positive tests due to hidden ingredients

Objectives and research gap

This review aims to:

- Classify herbal supplements by function and risk
- Compare international regulatory frameworks
- Present recent clinical evidence and case reports
- Discuss legal implications for athletes

Research gap: Existing literature lacks integration of regional regulations, athlete-specific safety data, and doping-related case documentation.

Classification of food supplements and their physiological mechanisms classification of food supplements and their physiological mechanisms

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Food supplements encompass a diverse range of bioactive substances designed to provide nutritional or physiological benefits. Their effects are mediated through various biochemical pathways, including antioxidant activity, modulation of inflammatory processes, enhancement of immune function, and metabolic regulation.

To facilitate a structured understanding, dietary supplements can be classified according to their composition, functional role, origin, and primary source, as outlined below.

1. **By composition**:

- **Vitamins and minerals:** Essential micronutrients required for metabolic homeostasis (Hassan, et al. 2020; Mishra, et al. 2021; Dwyer, et al. 2018).
- **Herbal extracts:** Derived from botanicals such as tea leaves, turmeric, and ginseng, often rich in polyphenols, flavonoids, and other phytochemicals
- **Amino acids and proteins:** Including collagen, glutamine, and branched-chain amino acids to support tissue repair and muscle synthesis.
- **Fatty acids and antioxidants:** Compounds like omega-3, resveratrol, and coenzyme Q10 with cardioprotective and anti-aging properties.
- **Enzymes and probiotics:** Agents such as lactase and *Bifidobacterium* spp., to improve digestive health and nutrient assimilation.
- **Hormonal and adaptogenic compounds:** Examples include melatonin and herbal adaptogens that support circadian regulation and stress resilience.

2. **By functional role**:

- **General health maintenance:** Multivitamins, minerals, and probiotics aimed at sustaining baseline physiological functions.
- **Cognitive and mental health:** Nootropics and omega-3 fatty acids targeting neuroprotection and mood enhancement.
- **Performance enhancement:** Ergogenic aids like creatine and nitric oxide boosters to optimize physical exertion.
- **Hormonal and sleep support:** Agents such as melatonin and DHEA targeting circadian rhythm and endocrine balance.
- **Weight and metabolic regulation:** Green tea extract and dietary fibres promoting satiety and thermogenesis.

3. **By origin**:

- **Natural:** Extracted from plant, animal, or microbial sources, commonly perceived as safer due to their unmodified state (Sonu, et al. 2024).
- **Synthetic:** Produced via chemical synthesis or biotechnology (e.g., synthetic vitamin C or folic acid).
- **Semi-synthetic:** Naturally derived substances chemically modified to enhance efficacy or stability (e.g., esterified vitamin C or concentrated omega-3).

4. **By primary source**:

- **Phytochemicals:** Plant-derived compounds with bioactive properties, such as flavonoids or saponins.
- **Marine-derived:** Substances like chitosan obtained from marine organisms.
- **Micronutrients:** Basic vitamins and minerals, often isolated or synthesized for inclusion in supplement formulations.

The explosive growth and diversity of this sector are fuelled by evolving consumer needs, rapid innovation cycles, and a cultural emphasis on proactive health maintenance. As such, understanding the classification and mechanistic foundations of dietary supplements is crucial for evaluating their place within therapeutic and preventive health frameworks (Table 1).

Evidence from RCTs and systematic reviews

- **Sellami, et al. [4]**: *Ginseng* improved endurance; *Ephedra* + caffeine enhanced sprint performance
- **Paunescu, et al. [5]**: Systematic review in combat sports showed mixed efficacy and contamination risks
- **IOC Consensus [6]**: Warned against low-evidence supplements and emphasized athlete education

Athlete safety and controversies

- 17% of collegiate female athletes reported herbal supplement use without professional guidance
- Documented adverse effects: hypertension, liver toxicity, positive doping tests
- *Rhodiola* and *Astragalus* are used for recovery, but lack robust performance data

Case reports and legal implications

These cases highlight the strict liability principle in doping control, where athletes are held responsible regardless of intent (Table 2).

Asia-pacific and Australia: Regulatory perspectives (Table 3).

Table 1: Functional Classification of Herbal Supplements.

Category	Example Herbs	Claimed Benefit	Conflicting Evidence
Thermogenic	Green Tea, Cayenne	Enhanced fat metabolism	Mixed RCT results
Adaptogenic	Rhodiola,Ashwagandha	Stress reduction	Limited athlete data
Anabolic	Tribulus, Ginseng	Muscle growth	Inconsistent trials
Stimulant	Ephedra, Guarana	Energy boost	Safety concerns

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Table 2: Documented Cases of Doping Linked to Herbal Supplements.

Year	Location	Herb Involved	Outcome	Legal Implication
1999	Netherlands	Ephedra	Cyclist tested positive	IOC sanction
2020	Germany	Clenbuterol-taintedmeat	Unintentional doping	WADA violation
2023	Switzerland	Mental enhancer supplement	Found steroids like DHEA	Label fraud

Table 3: Regional Comparison of Herbal Supplement Regulations.

Region	Regulatory Body	Classification Approach	Registration Required
Australia	TGA	Complementary Medicines (ARTG)	Yes
Japan	MHLW	Kampo Medicines	Yes
China	NMPA	Traditional Chinese Medicine	Yes
Singapore	HSA	Compliance-based	No (if compliant)
Malaysia	NPRA	Herbal Supplements	Yes

Herbal food supplements for weight management and athletic performance

Herbal food supplements for weight control

Herbal supplements for weight management are widely utilized due to their perceived safety and natural origin. These products typically contain plant-derived ingredients that act on thermogenic, lipolytic, or appetite-regulating pathways. The most frequently used herbal components include:

- **Caffeine (from *Paullinia cupana*, *Cola nitida*, *Ilex paraguariensis*):** A central nervous system stimulant, caffeine enhances thermogenesis and fat oxidation, but tolerance may reduce its long-term effectiveness (Clark, et al. 2019).
- **Guarana (*Paullinia cupana*):** Rich in caffeine, saponins, tannins, and catechins, guarana is valued for its antioxidant and energy-boosting properties (Marques, et al. 2019).
- ***Garcinia cambogia*:** Contains hydroxycitric acid (HCA), which inhibits adenosine triphosphate citrate lyase, potentially suppressing appetite and lipogenesis (Gwaltney-Brant, 2021).
- ***Citrus aurantium* (bitter orange):** Yields synephrine, a protoalkaloid that stimulates lipolysis and mildly suppresses appetite; concerns persist regarding its cardiovascular effects (Koncz, et al. 2022).
- ***Irvingia gabonensis* (African mango):** The IGOB131 extract may reduce leptin levels and LDL-cholesterol while improving satiety and lipid metabolism (Nonsard, et al. 2022).
- **Capsaicin (from *Capsicum* species):** Promotes thermogenesis, satiety, and lipid oxidation, though gastrointestinal side effects may limit its use (Zheng, et al. 2017).
- **Glucomannan**: A soluble dietary fibre derived from *Amorphophallus konjac*, it promotes fullness and stabilizes glycemic and lipid profiles (Catarino, et al. 2018).
- ***Ananas comosus* (pineapple)**: Contains bromelain and vitamin C, which may aid digestion and enhance thermogenic activity (Alyas, et al. 2024).
- ***Fucus vesiculosus***: This iodine-rich brown algae supports thyroid function and metabolic rate, though it must be used with caution due to potential endocrine effects (Catarino, et al. 2018).

Herbal supplements for enhancing physical and sports performance

Dietary supplements for athletes are designed to enhance endurance, reduce fatigue, and support recovery. While pharmacological agents such as anabolic steroids have been widely scrutinized and banned, natural supplements are viewed as viable ergogenic alternatives.

The most common herbal ergogenic aids and their key characteristics include:

Although evidence varies regarding efficacy, these agents are traditionally integrated into athletic regimens for their presumed synergy in enhancing physical performance and resilience. The increasing popularity of such supplements necessitates rigorous quality control and awareness of potential adulteration.

Adulteration risks and synthetic contaminants in dietary supplements

Despite their growing popularity and perceived safety, herbal food supplements—particularly those marketed for weight loss and sports performance—face increasing scrutiny due to the risk of adulteration with synthetic pharmacological agents. These substances are often illicitly added to enhance efficacy, driven by commercial pressures and user demand for rapid results. This adulteration poses significant public health risks and undermines regulatory safeguards.

Common contaminants in weight-loss supplements

Weight-control supplements are frequently found to contain undeclared synthetic compounds, especially anorectics, diuretics, and laxatives, many of which have been banned due to serious adverse effects.

Centrally acting anorectics

***Amfepramone*:** A dopaminergic agent formerly used for weight loss, withdrawn due to links with pulmonary hypertension and dependence (Cercato, et al. 2009).

***Fenfluramine and dexfenfluramine*:** Serotonergic compounds linked to cardiac valvulopathy, removed from global markets in 1997 (Connolly, et al. 1997).

***Sibutramine*:** A serotonin and norepinephrine reuptake

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Herb	Bioactive Compounds	Mechanism of Action	Effects	Potential Adverse Effects
Panax ginseng	Ginsenosides	Stimulates ATP production via HPA axis modulation	Reduces fatigue, enhances stamina	Insomnia, GI discomfort
Withania somnifera	Withanolides	Enhances mitochondrial function, reduces cortisol	Improves muscle strength and recovery	Thyroid dysfunction, GI symptoms
Rhodiola rosea	Rosavins, salidroside	Elevates serotonin and dopamine; reduces oxidative stress	Stress resilience, mental focus	Dizziness, dry mouth
Cordyceps sinensis/ Ophiocordyceps sinensis	Cordycepin, adenosine	Enhances oxygen uptake, increases ATP synthesis	Endurance boost	Allergic reactions
Curcuma longa	Curcumin	Inhibits pro-inflammatory pathways (NF-κB, COX-2)	Anti-inflammatory, recovery support	Bleeding risk, gastric irritation
Paullinia cupana	Caffeine	Blocks adenosine receptors; CNS stimulation	Improved alertness	Anxiety, insomnia
Tribulus terrestris	Saponins	Boosts testosterone via androgen receptor modulation	Muscle mass and libido support	Hormonal imbalance
Juglans regia	Ellagitannins, juglone	Scavenges free radicals and modulates inflammation	Cardiovascular support, endurance	Toxicity at high doses
Camellia sinensis	EGCG, polyphenols, caffeine	Enhances fat oxidation, catecholamine retention	Mental focus, fat metabolism	GI discomfort, palpitations
Ocimum basilicum	Eugenol, rosmarinic acid	Modulates cortisol, enhances antioxidant defences	Stress reduction, energy support	Nausea, hypersensitivity
Astragalus membranaceus	Astragalosides, flavonoids	Promotes immune function and mitochondrial activity	Adaptogen, recovery aid	Gastrointestinal irritation
Schisandra chinensis	Schisandrin lignans	Modulates the HPA axis, increases ATP synthesis	Anti-fatigue, cognitive enhancement	Xerostomia, digestive upset

inhibitor associated with increased cardiovascular risk; banned since 2010 but frequently detected in "natural" slimming supplements (Hayes, et al. 2015; RAPEX, 2023).

Diuretics and laxatives

***Furosemide*:** A loop diuretic that causes fluid loss but no fat reduction; implicated in electrolyte imbalance and nephrotoxicity (Shankar, et al. 2003).

***Phenolphthalein*:** A stimulant laxative withdrawn due to carcinogenicity concerns, yet still detected in unauthorized products (Manore, et al. 2022).

These agents are often added in subtherapeutic amounts to evade detection and may be often disguised under generic or misleading labels (e.g., 'herbal complex,' 'plant extract')

Materials and methods

Analyzed herbal dietary supplements

A total of 34 herbal dietary supplements (capsules, tablets, or powder sachets for oral suspension) were analyzed. These products were purchased online or from specialized stores.

Results

1. HPTLC, HPLC, and GC-MS Analysis of Herbal Supplements

1.1. Qualitative analysis: The results indicate the presence of caffeine in 47% of the analyzed herbal supplements (16 out of 34 products) (Figures 1,2).

The presence of caffeine in all 16 products, except SS19, correlates with their declared composition, as caffeine may originate from natural sources (green tea, green coffee, and guarana are listed as ingredients) or is explicitly added, according to the label (as in products SS12, SS14, and SS20). The presence of caffeine was confirmed by in situ UV spectral recordings, which showed a characteristic absorption maximum at 275 nm for caffeine.

It was demonstrated that three supplements—SS21, SS24, and SS27—were adulterated with sibutramine. In the absence of a reference standard, sibutramine was identified by comparing its in situ UV spectrum with spectra reported in the literature (Figure 3).

The presence of sibutramine was also indicated by a rapid screening test reported in the literature (Liang Q, et al. 2021), based on a precipitation reaction with ammonium reineckate. A positive result is indicated by the formation of a pink precipitate.

Positive results for the presence of sibutramine were confirmed using the GC-MS method (Figure 4). The base peak of sibutramine in the mass spectrum is m/z 114.

In four of the samples (SS3, SS6, SS17, and SS19), phenolphthalein was detected using an HPLC method with diode array detection.

Quantitative analysis

The results of the qualitative analysis suggested high levels of caffeine in most of the analyzed products. Given that many supplements contain one or more caffeine-containing plant products, and some also have added caffeine, caffeine content was evaluated using the HPTLC method. For phenolphthalein, quantitative analysis was performed using the HPLC method. The amount of caffeine ranged from 2.5 mg to 302 mg per unit dose. The highest concentrations were found in supplements with added caffeine (SS12, SS14, and SS20). The quantity of phenolphthalein determined by HPLC in supplements SS3, SS6, SS10, and SS12 ranged from 104 to 293 micrograms per unit dose.

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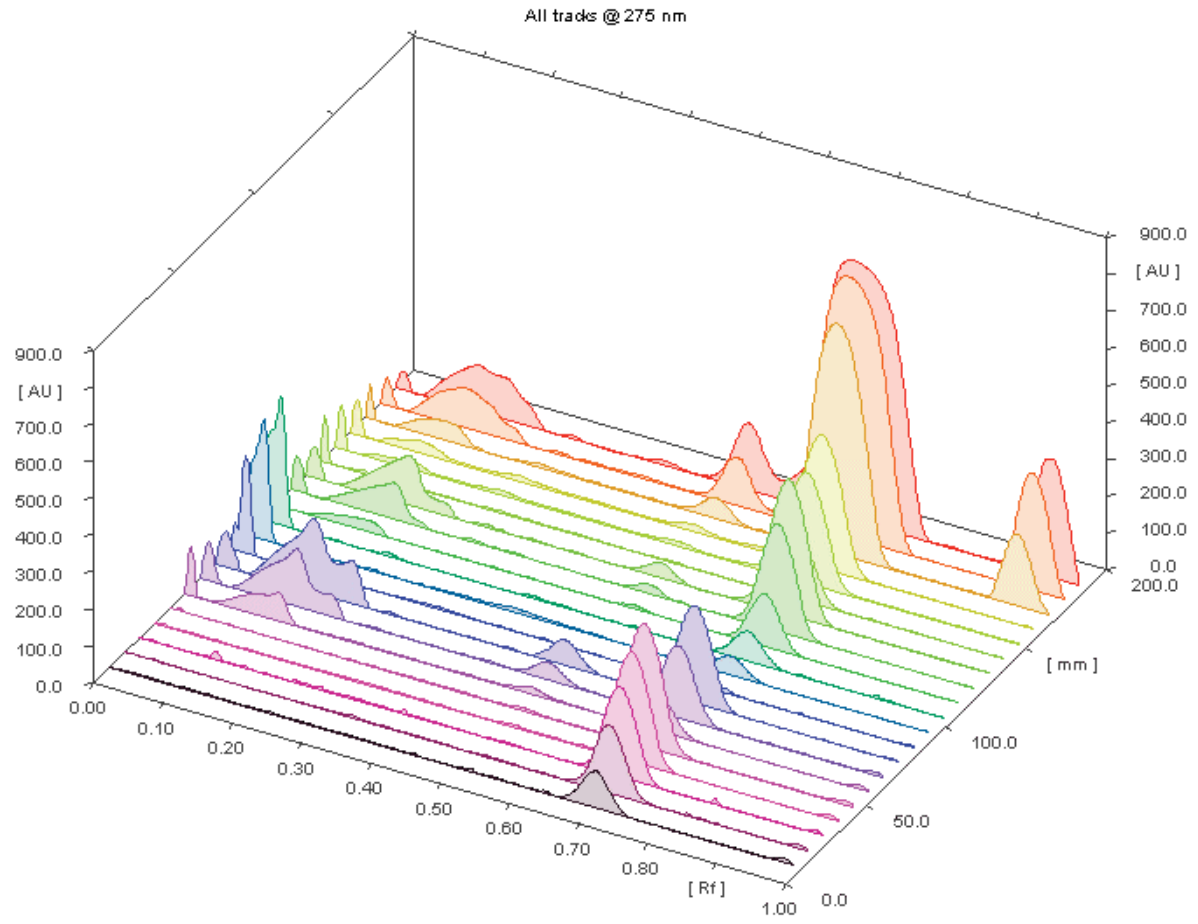

Figure 1: 3D chromatogram for caffeine standard (lanes 1–5) and samples SS2, SS3, SS7, and SS8; detection at λ = 275 nm; samples were applied at three concentration levels.

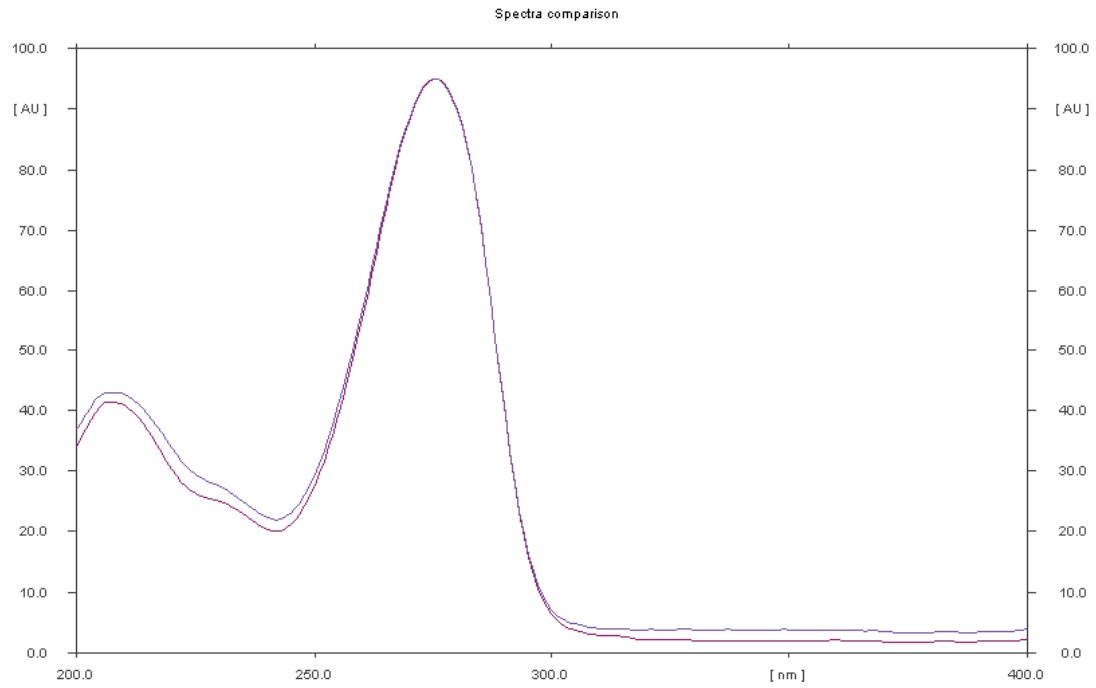

Figure 2: In situ UV spectra in absorbance–reflectance mode of caffeine from the standard solution and sample SS7.

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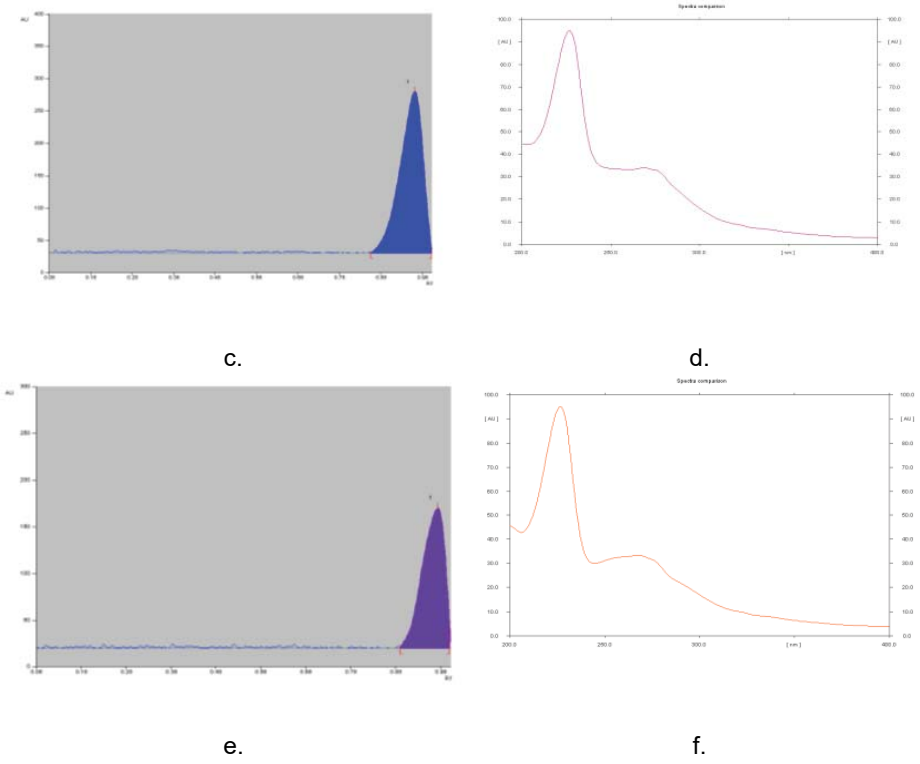

Figure 3: Chromatograms and UV spectra obtained during the identification of sibutramine in supplements SS24 (c, d) and SS27 (e, f) by HPTLC.

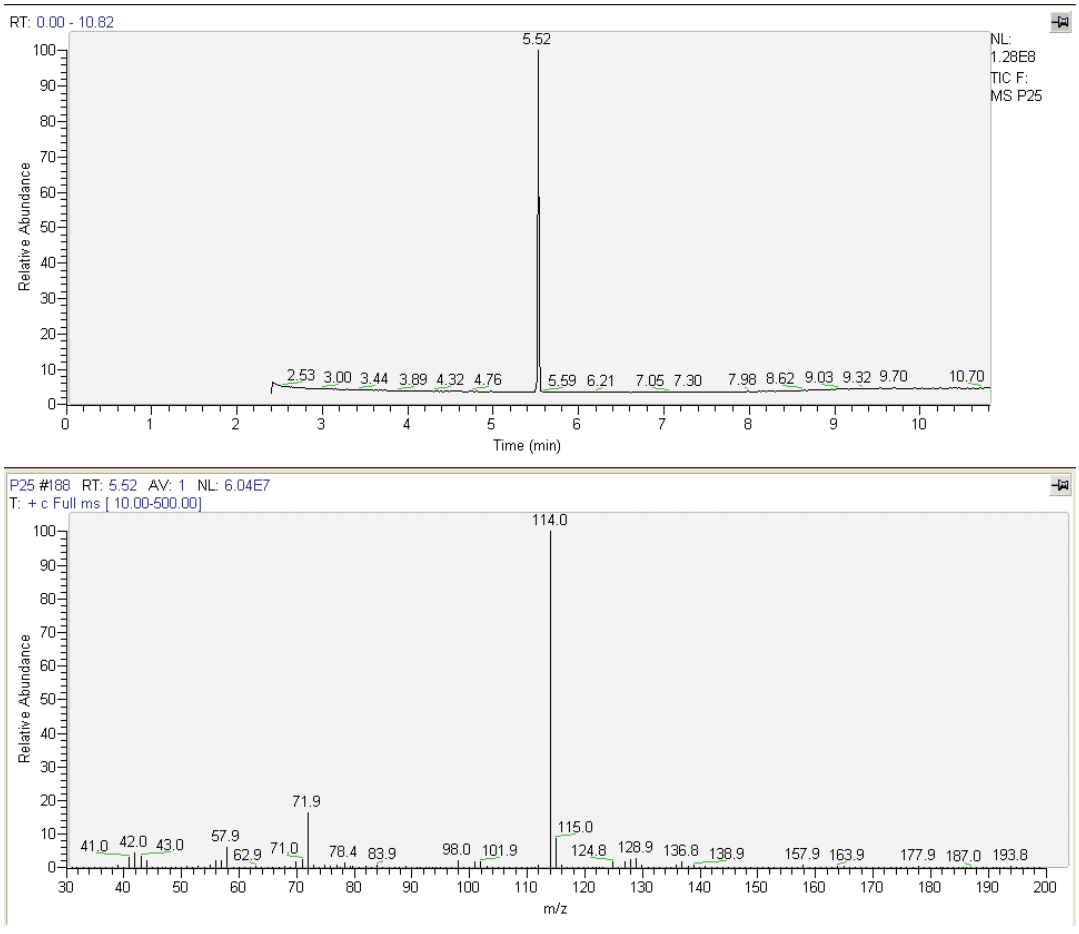

Figure 4: Chromatogram and mass spectrum for sibutramine (sample SS24, Tr = 5.52 min, m/z = 114).

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2. Contaminants in sports and performance-enhancing supplements

The drive for enhanced endurance, muscle growth, and recovery has fuelled interest in supplements marketed to athletes. However, many such products are adulterated with anabolic steroids and stimulants, including banned substances with significant health and regulatory implications.

- **Anabolic agents**: These include synthetic testosterone derivatives or precursors that stimulate muscle hypertrophy through modulation of androgen receptors and nuclear transcription pathways (Zhou & Glowacki, 2018; Kadi, 2008).

  - Chronic use is linked to severe adverse outcomes: cardiovascular disease, infertility, psychiatric disorders, and even early-onset dementia (Windfeld-Mathiasen, et al. 2024; Kaufman, et al. 2019).

  - Illegally fortified supplements often target adolescents and bodybuilders, often misrepresented as safe and natural (Tucker, et al. 2018).

- **Stimulants and related compounds**

  - *Amphetamine analogs* (e.g., β-methylphenylethylamine) are sometimes detected in products containing *Acacia rigidula*.

  - *DMAA, ephedrine, phenylethylamine*, and *sibutramine* are added for their ergogenic, lipolytic, or mood-enhancing properties but carry risks such as arrhythmia, hypertension, and anxiety (Jagim, et al. 2023).

  - *Synthetic caffeine* is frequently used in excess, bypassing disclosure requirements, and may lead to toxic overdose.

The addition of these agents without disclosure poses risks of unintentional doping, particularly among athletes subject to anti-doping regulations. Moreover, the lack of standardized labelling and insufficient regulatory oversight amplifies these risks for the general population.

Regulatory frameworks, post-market surveillance, and proposed safety measures

The regulation of dietary supplements varies significantly across jurisdictions, reflecting divergent philosophical approaches to consumer safety, market freedom, and public health oversight.

1. European Union *vs.* United States: contrasting regulatory philosophies

In both the European Union (EU) and the United States (US), dietary supplements are categorized as food products, not pharmaceuticals. Consequently, they are subject to regulations concerning safety, labelling, and nutritional claims, but are not required to undergo pre-market clinical efficacy evaluations akin to drug approvals.

The EU adopts a precautionary and preventive model, emphasizing pre-market regulation. Under Directive 2002/46/EC, supplements must conform to stringent standards for nutrient content, labelling, and safety. Claims regarding disease prevention or treatment are strictly prohibited. The overarching aim is risk mitigation through harmonized safety protocols across Member States.

Conversely, the US regulatory system, overseen by the Food and Drug Administration (FDA) under the Dietary Supplement Health and Education Act (DSHEA), favors consumer autonomy and post-market control. Manufacturers are responsible for ensuring safety and label accuracy, but pre-market approval is not required. The FDA typically intervenes only when post-marketing safety concerns arise.

This dichotomy reflects fundamental differences in governance philosophy: the EU prioritizes safety, while the US emphasizes freedom of access and informed choice.

2. Post-market surveillance systems and safety monitoring

The proliferation of food supplements, alongside a history of adverse events and product adulteration, has prompted the development of national and regional surveillance systems:

- **EU national systems**:

  - **France:** Operates the **Nutrivigilance system**, under the authority of ANSES (Agence nationale de sécurité sanitaire de l'alimentation). Health professionals and consumers can report suspected adverse effects online. ANSES assesses causality and disseminates safety alerts.

  - **Italy:** Maintains the **VigiErbe (PhytoVigilance)** system under AIFA (Agenzia Italiana del Farmaco), facilitating reports from both clinicians and the public on herbal supplement-related adverse reactions.

- **EU-wide platforms**:

  - EFSA (European Food Safety Authority) conducts risk assessments and issues EU-wide safety guidance.

  - RASFF (Rapid Alert System for Food and Feed) allows Member States to share and act on serious public health alerts in real time. Supplements flagged for contamination, mislabelling, or undeclared ingredients are included in RASFF bulletins.

Despite these efforts, the absence of a centralized, supplement-specific pharmacovigilance database akin to EudraVigilance for pharmaceuticals creates fragmented reporting and limited harmonization.

3. Proposed measures to enhance safety and consumer protection

To bolster regulatory control and consumer safety, several measures have been proposed or implemented:

- **Harmonization of testing and quality standards**:

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Uniform methodologies for verifying ingredient authenticity, potency, and contamination.

- **Mandatory pre-market notification**: Requiring manufacturers to notify regulatory authorities prior to product launch.
- **Clearer labelling guidelines**: Enhanced transparency on ingredient origin, potential interactions, and regulatory status.
- **Public education campaigns**: Increasing consumer awareness about supplement risks, interactions with medications, and the misleading nature of health claims.
- **Enhanced market surveillance**: Proactive sampling and testing, especially for high-risk categories such as weight-loss and performance-enhancing products.
- **Extension of pharmacovigilance principles**: Applying drug-level adverse event reporting to food supplements, especially those marketed for therapeutic effects.
- **Legislative reforms**: Countries such as Italy have proposed that all herbal substances undergo testing analogous to that required for pharmaceuticals (Watanabe, et al. 2020).

This reinforces the need for a well-balanced, science-based regulatory structure—one that protects consumers without stifling innovation.

Conclusion

Herbal food supplements occupy a complex space between traditional use, performance enhancement, and regulatory scrutiny.

This review provides a comprehensive framework for understanding classifications, efficacy, and risks—especially in athletic contexts. By integrating recent clinical data, regional regulations, and doping-related case reports, the study offers a **novel and actionable perspective** for researchers, regulators, and athletes alike.

The widespread appeal of dietary supplements—particularly those marketed for weight control and physical performance—has been accompanied by a troubling increase in product adulteration with undeclared, often hazardous, synthetic compounds. Substances such as sibutramine, anabolic steroids, and amphetamine analogs are frequently introduced under misleading labels or disguised as natural extracts. These practices not only undermine consumer trust but also pose significant risks, including cardiovascular, neurological, and metabolic complications, and in some cases, potential legal consequences for athletes subjected to anti-doping regulations.

Compounding the issue is a fragmented and uneven global regulatory landscape. While the European Union emphasizes pre-market controls and consumer safety, and the United States relies on post-market surveillance and manufacturer accountability, neither system fully addresses the scale and speed at which adulterated products enter the marketplace. The lack of standardized international protocols, coupled with gaps in public awareness and limited adverse event reporting infrastructure, allows unsafe products to persist on the market—often beyond the reach of timely regulatory intervention.

Addressing these challenges requires coordinated policy reform: the establishment of centralized monitoring systems specific to food supplements, harmonization of testing and labeling standards, and enhanced international collaboration. Moreover, regulatory agencies must invest in proactive surveillance and enforcement tools, while also fostering greater public education to empower consumers with reliable information. Only a comprehensive, science-informed, and globally aligned approach can ensure the safety and integrity of dietary supplements.

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