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REVIEW

Chocolate as a functional delivery platform for sexual-wellness nutraceuticals: A critical review of current evidence

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ABSTRACT

Sexual dysfunction, including reduced desire, impaired arousal, erectile difficulties, orgasmic problems, and sexual dissatisfaction, is a multifactorial health concern influenced by vascular, endocrine, neurological, psychological, metabolic, and relational factors. Although pharmacological treatments are effective for many individuals, interest in nutraceutical approaches has increased because of their potential to support multiple biological pathways and provide alternative delivery formats. This critical narrative review, supported by a structured literature search, evaluates chocolate as a potential functional delivery matrix for sexual-wellness nutraceuticals and examines the ingredient-level evidence relating to cocoa flavanols, maca, epimedium-derived compounds, and dehydroepiandrosterone (DHEA). Current evidence suggests that chocolate possesses physicochemical and sensory characteristics that may support the incorporation of selected bioactives, including lipid compatibility, palatability, Phytochemical protection and intrinsic cocoa-derived vascular effects. Ingredient-level studies indicate possible relevance to endothelial function, Nitric OxideO (NO) signalling, sexual desire, neuroendocrine regulation, stress adaptation, and hormonal pathways. However, the strength and consistency of evidence vary considerably across ingredients, populations, doses, study designs, and outcomes. Evidence supporting controlled release, superior bioavailability, improved long-term adherence, or potentially complementary effects within a complete chocolate-based combination remains limited. The inclusion of DHEA also introduces important safety, regulatory, and population-specific concerns. Overall, chocolate-based sexual-wellness formulations should be regarded as biologically plausible and hypothesis-driven rather than clinically validated. Direct pharmacokinetic, stability, safety, interaction, adherence, and randomized clinical studies are required before efficacy, superiority, or formulation-level synergy can be established.

KEYWORDS

Functional chocolate; Sexual wellness; Nutraceuticals; Libido; Cocoa flavanols; Macaroot; Epimedium

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Introduction

Sexual wellness is increasingly being recognized as a key component of overall health, encompassing physiological functioning, emotional intimacy, psychological well-being, relational satisfaction, and reproductive health. Sexual dysfunction is a common problem affecting a large proportion of adults worldwide. It is emerging as an important but often overlooked public health concern. Sexual dysfunction includes a wide range of conditions such as Erectile Dysfunction (ED), reduced libido, difficulties in arousal, orgasmic disorders, and sexual dissatisfaction. Epidemiological data suggest that about 30–35% of the adult male population globally suffers from ED, and Female Sexual Dysfunction (FSD) prevalence estimates range from 35% up to over 60%, depending on age, health status, and sociocultural context [1-3]. Sexual dysfunction is increasingly linked to chronic stress, metabolic syndrome, obesity, cardiovascular disease, diabetes, endocrine imbalance, sleep disturbances, and mental health disorders, suggesting it is not only a quality-of-life concern but also an indicator of broader systemic dysfunction [3].

The biological basis of sexual function is complex, involving coordinated interactions between neurological, vascular, endocrine and psychological systems. NO-induced vasodilation is central to sexual arousal, increasing genital blood flow and promoting smooth muscle relaxation via activation of the Cyclic Guanosine Monophosphate (cGMP) pathway. Disrupted pathways include endothelial dysfunction, oxidative stress, chronic inflammation, decline in hormones, and impaired neurotransmitter signalling, all of which can adversely affect sexual performance. Sustained activation of the Hypothalamic-Pituitary-Adrenal (HPA) axis worsens dysfunction by raising cortisol levels, suppressing anabolic hormones and impairing vascular responsiveness. There is growing evidence for a multifactorial model of sexual dysfunction, in which vascular impairment, endocrine dysregulation, and psychological stress interact in a reciprocal manner to influence sexual health [4,5].

Traditional treatment of sexual dysfunction has been largely based on Phosphodiesterase-5 (PDE5) inhibitors, such as Viagra and Cialis, which improve erectile function by enhancing NO-cGMP signalling. These agents have shown clinical efficacy, but their use is restricted by adverse effects, contraindications for patients on nitrates for cardiovascular conditions, insufficient mechanistic coverage and low long-term adherence. PDE5 inhibitors primarily enhance the NO–cGMP pathway and do not directly address all psychological, endocrine, relational, inflammatory, neurological, or metabolic contributors to sexual dysfunction. The limitations have led to increased interest in integrative therapeutic strategies that can target multiple biological determinants at the same time [6,7].

Sexual dysfunction is heterogeneous and may arise from vascular disease, metabolic syndrome, diabetes, endocrine disorders, neurological disease, medication effects, chronic inflammation, depression, anxiety, trauma, relationship distress, sleep disturbance, menopause-related changes, pelvic-floor dysfunction, and sociocultural factors. Consequently, no single nutraceutical or

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pharmacological strategy can be assumed to address all forms of sexual dysfunction.

Although endothelial dysfunction and NO signalling are central to many forms of ED, sexual wellness is inherently multidimensional. Psychological distress, relationship quality, endocrine status, medication use, neurological disorders, menopausal changes, and sociocultural influences all contribute to sexual health. Accordingly, nutraceutical interventions should be interpreted within a broader biopsychosocial framework rather than as single-mechanism solutions.

These constraints have fuelled a global interest in nutraceutical-based approaches towards sexual wellness. The increasing preference for nutraceuticals is because they can simultaneously address endothelial function, oxidative stress, hormonal balance, neurotransmitter signalling and stress adaptation, and usually are better tolerated than pharmacological agents. Botanicals such as maca, epimedium, *Panax ginseng*, saffron and cocoa-derived flavanols have been studied extensively for their potential to improve libido, sexual satisfaction, vascular responsiveness and psychophysiological resilience. Multi-component nutraceutical formulations may provide more holistic systems-level support and be a better fit with the multifactorial nature of sexual dysfunction than single-target pharmaceuticals.

Also, delivery-system engineering has become a critical factor in the efficacy of nutraceuticals. The efficacy of bioactive compounds depends on the selection of ingredients, bioavailability, phytochemical stability, controlled release and consumer compliance. Conventional tablets and capsules are often poorly adhered to, less absorbable, and less engaging over time. An interesting alternative are functional food matrices, which combine therapeutic benefits with sensory attractiveness. Chocolate has emerged as a promising functional-food matrix for nutraceutical delivery because of its sensory acceptability, lipid-rich composition, and intrinsic cocoa bioactives. Nevertheless, its suitability depends on ingredient characteristics, formulation objectives, and supporting comparative evidence.

Chocolate is inherently therapeutic in its bioactivity and offers benefits for pharmaceutical delivery. Cocoa is rich in flavanols such as catechin, epicatechin and procyanidins, which are antioxidants, anti-inflammatories and endothelial protectants. Recent intervention studies show that cocoa flavanols improve flow-mediated dilation, vascular elasticity, and endothelial reactivity, mainly by increasing NO bioavailability and reducing oxidative stress [8-10]. Cocoa flavanols have been shown to protect against stress-induced endothelial dysfunction and may therefore be relevant to stress-related sexual impairment [8,11].

In addition to its vascular effects, chocolate also affects sensory neuroscience and reward biology. Chocolate consumption activates neurochemical pathways associated with dopamine, serotonin, anandamide, phenethylamine and theobromine, thus influencing pleasure, motivation, mood, hedonic reinforcement and stress perception. The neuropsychological effects may be especially relevant to sexual wellness, as libido and arousal are highly influenced by reward circuitry and emotional state. Functional chocolate offers a unique combination of vascular improvement, mood modulation, sensory pleasure and behavioural adherence that makes it particularly suitable for long-term nutraceutical delivery.

One example of this formulation concept is a proprietary chocolate-based combination incorporating cocoa bioactives, maca, epimedium, and DHEA. Throughout this review, this formulation is discussed only as an illustrative application of current ingredient-level evidence rather than as a clinically validated intervention. It is not intended to be a lone aphrodisiac mechanism, but rather to support multiple complementary pathways such as NO signalling, PDE5 modulation, endocrine optimisation, oxidative stress reduction, endothelial repair, and stress adaptation. This mechanistic convergence may provide greater therapeutic potential than traditional single-ingredient nutraceuticals. This review critically evaluates chocolate as a functional delivery vehicle and examines the scientific basis for the proposed formulation within the context of current sexual wellness nutraceuticals.

This review aims to address three objectives:

- Assess chocolate as a functional nutraceutical delivery matrix;
- Critically review the mechanistic and clinical evidence for the key ingredients of the proposed formulation; and
- Critically compare the proposed formulation rationale with existing sexual-wellness nutraceutical approaches, while identifying uncertainties and evidence gaps.

Review Methodology

This review employed a structured critical review methodology with systematic literature identification and narrative evidence synthesis. The review was designed to evaluate ingredient-level clinical evidence, mechanistic plausibility, formulation-science considerations, safety, and research gaps relevant to chocolate-based sexual-wellness nutraceuticals.

A thorough search of the literature was conducted through five major scientific databases including PubMed, Scopus, Web of Science, Embase and Cochrane Library. The databases were selected because of their extensive coverage of nutrition science, endocrinology, pharmacology, sexual medicine and research into functional food . Furthermore, backward citation tracking of the recent systematic reviews and meta-analyses was conducted to retrieve relevant studies that were not identified in the initial search via a manual search.

The search period was from January 2000 to March 2026, but with a focus on studies published between 2021 and 2026 to ensure modern scientific relevance. Search terms included combinations of controlled vocabulary and free-text terms relating to functional chocolate, cocoa flavanols, sexual dysfunction, libido, erectile function, female sexual function, nutraceutical delivery, maca, epimedium, icariin, DHEA, NO, endothelial function, formulation stability, and bioavailability.

Because the literature comprised heterogeneous clinical trials, mechanistic investigations, food-science studies, and regulatory evidence, findings were synthesized narratively rather than quantitatively. Evidence relating to the complete formulation was distinguished from ingredient-level evidence throughout the review.

The first search resulted in 1284 records. After deduplication, 986 studies were screened on title and abstract. A detailed review of 214 articles was performed and 108 studies were selected based on the eligibility criteria and included in the qualitative synthesis.

Given the considerable heterogeneity in study design, dosage, duration of intervention and outcome measures, a narrative evidence synthesis method was used. Results of published meta-analyses were included in comparative evidence visualisation including evidence heat maps and aggregated directional effect interpretation where sufficient consistency existed.

Heterogeneity in study design, dose regimens, standardization of ingredients and reporting of outcomes limited the ability to perform a quantitative meta-synthesis across all studies included, despite following a systematic search protocol (Table 1).

Table 1. Search methodology framework.

Component	Description
Databases	PubMed, Scopus, Web of Science, Embase, Cochrane
Search Period	2000–2026
Priority Window	2021–2026

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Table 1 (continued)

Component	Description
Included Studies	RCTs, meta-analyses, systematic reviews, mechanistic studies
Excluded Studies	Duplicates, abstracts, case reports, non-peer-reviewed
Initial Records	1,284
Final Included Studies	108
Quality Tools	Evidence synthesis: structured literature identification and critical narrative synthesis

Searches were conducted in PubMed, Scopus, Web of Science, Embase, and the Cochrane Library. Reference lists of relevant systematic reviews were also screened. Studies were considered according to their relevance to clinical efficacy, mechanism, bioavailability, formulation science, safety, regulatory status, and sex-specific sexual-health outcomes. Human evidence was prioritized over animal and *in vitro* evidence, while preclinical findings were used only to explain biological plausibility.

The literature screening and study selection process followed an evidence selection workflow to ensure systematic identification, screening, eligibility determination, and final inclusion of relevant studies on sexual wellness nutraceuticals and functional chocolate delivery systems (Figure 1).

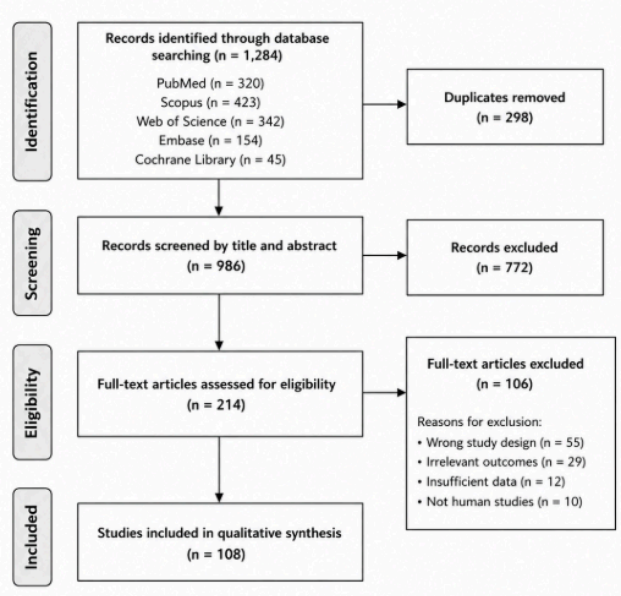

Figure 1. Structured literature identification and evidence-selection workflow.

Note. PRISMA is the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. The search produced 1284 records. 298 duplicates were removed, and 986 records were screened. A total of 214 full-text articles were assessed for eligibility, and 108 studies were included in the final qualitative synthesis.

Chocolate as a Potential Functional Nutraceutical Matrix

Chocolate has increasingly been investigated as a candidate functional-food matrix for nutraceutical incorporation because of its lipid content, sensory acceptability, and intrinsic cocoa-derived bioactives. Nevertheless, its performance as a delivery system depends on compound properties, processing conditions, dosage requirements, and comparative formulation evidence. Chocolate-based delivery also presents practical limitations, including caloric burden, sugar exposure, heat sensitivity, dose-volume constraints, variability in cocoa composition, and the need to demonstrate formulation-specific stability and pharmacokinetic performance. Recent developments in food science indicate that chocolate has a unique set of properties including intrinsic bioactivity, lipid-enhanced absorption, phytochemical stabilization, controlled release and strong consumer loyalty, that make it particularly well suited to wellness-focused formulations. Chocolate, unlike traditional oral dosage forms such as tablets and capsules, provides therapeutic benefits and sensory enjoyment, which improves long-term adherence, a critical factor in nutraceutical efficacy. Functional chocolate products have therefore become a growing sector in health-oriented food innovation.

Cocoa bioactive and their vascular significance

The functional value of chocolate is mainly derived from cocoa rich in polyphenols, flavanols, methylxanthines, minerals and bioactive lipids. Cocoa flavanols including catechin, epicatechin and procyanidins have attracted much scientific interest because of their antioxidant, anti-inflammatory and endothelial protective properties. Cocoa is one of the most abundant dietary sources of flavanols, which are important for reducing oxidative stress and maintaining vascular integrity.

The vascular relevance of cocoa is especially important for sexual health because sexual arousal and erectile function are highly dependent on proper endothelial function and genital blood flow. Cocoa flavanols increase Endothelial Nitric Oxide Synthase (eNOS) activity, leading to increase NO synthesis and vasodilation via the NO–cGMP pathway. This increases smooth muscle relaxation and vascular responsiveness, mechanisms directly relevant to erectile physiology. Recent clinical evidence demonstrates that cocoa flavanol consumption improves flow mediated dilation, arterial elasticity and microvascular function, showing significant benefits to systemic endothelial health [8-10].

Cocoa inhibits the reactive oxygen species involved in the oxidative breakdown of NO. The dual action increases NO synthesis and decreases its breakdown, improving vascular signalling, and possibly sexual function, especially in those with endothelial dysfunction, diabetes, obesity, or cardiometabolic stress.

Delivery mode chocolate

Apart from its own bioactivity, chocolate is a sophisticated delivery system for nutraceuticals. The therapeutic effect is mainly due to the physicochemical properties of cocoa butter, a lipid-rich matrix composed predominantly of triacylglycerols. This lipid structure provides many formulation advantages.

The lipid matrix promotes solubilization and absorption of lipophilic bioactives, resulting in an improvement in oral bioavailability of botanical compounds that generally show poor intestinal uptake. Poor absorption of some phytochemicals like sterols, flavonoids and certain alkaloids is observed in dry capsule dosage form. Lipid-rich matrices can improve the solubilization of selected lipophilic compounds, but the magnitude of this effect is compound-specific and cannot be assumed for all botanical constituents without direct pharmacokinetic testing.

Secondly, chocolate acts as a protective shield for sensitive compounds against oxidative damage, moisture, and thermal instability, thereby preserving the phytochemical efficacy throughout storage and consumption. This protective effect is particularly advantageous for multi-ingredient formulations with different botanical actives.

Thirdly, Chocolate may alter dissolution and gastrointestinal release because of its fat composition and melting characteristics.

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However, classification as a controlled-release system requires validated dissolution testing and pharmacokinetic comparison, which are currently unavailable for the complete formulation. With a melting point close to body temperature, it can achieve slow dissolution of compounds within the matrix as it travels through the mouth, stomach and intestine. This may influence dissolution characteristics and gastrointestinal exposure; however, comparative pharmacokinetic evidence remains unavailable.

The formulation properties make chocolate especially suitable for the delivery of complex nutraceutical combinations such as kalories® where ingredient synergy is partially dependent on consistent bioavailability.

Neurochemical and sensory neuroscience

Reward and sensory neuroscience is one of the major advantages of chocolate over traditional nutraceutical delivery systems. Eating chocolate stimulates neural pathways linked to pleasure, motivation, stress relief and emotional regulation, which are highly relevant to sexual wellness [12,13].

Chocolate acts on a number of neuroactive substances.

- Dopamine: ambition, reward, motivation
- Serotonin: mood and emotional stability
- Anandamide: pleasurable enjoyment and tranquillity
- Phenethylamine: Euphoria and Stimulation
- Theobromine: a mild stimulant that boosts alertness

These compounds enhance chocolate's ability to generate hedonic pleasure and emotional comfort. Because reward circuitry and psychological states play a major role in libido and arousal, chocolate may indirectly contribute to sexual wellness by improving mood and reducing stress.

Chronic stress may reduce sexual desire and arousal through neuroendocrine, psychological, and vascular mechanisms. Chocolate can improve mood and lower perceived stress, which can help to reduce psychogenic factors that may contribute to reduced libido and impaired arousal.

Acceptability, adherence, and behavioural considerations

Even very effective nutraceuticals are ineffective when compliance is poor. Given pill fatigue, stigma and changing motivation to use continuously, adherence by consumers is a major issue in sexual wellness supplementation.

Chocolate may improve short-term acceptability and sensory appeal. However, palatability should not be equated with adherence. Long-term persistence, dose accuracy, overconsumption, treatment satisfaction, caloric burden, storage convenience, and comparison with tablets, capsules, gummies, or emulsions remain to be evaluated empirically.

From a translational perspective, adherence is a behavioural component and a key predictor of therapeutic efficacy. Improved adherence has the potential to enhance real-world effectiveness, although comparative adherence studies for chocolate-based nutraceutical delivery remain unavailable.

A chocolate-based formulation may integrate vascular, endocrine, neurochemical, and behavioural considerations within a single functional-food matrix; however, comparative adherence benefits remain to be demonstrated.

In summary, chocolate is a scientifically valid nutraceutical delivery system based on its unique combination of intrinsic bioactivity, enhanced bioavailability, phytochemical stability, sensory neuroscience and high consumer compliance. It is these different properties that are the main reason for its use in sexual wellness preparations.

Besides the selection of ingredients, the design of delivery systems is important for the bioefficacy of nutraceuticals since it influences absorption, stability, release kinetics and consumer compliance. Figure 2 shows that chocolate acts as a functional matrix, enhancing translational performance through a number of formulation benefits.

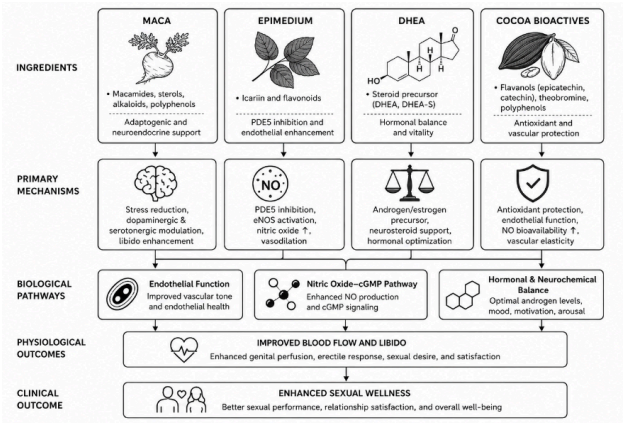

Figure 2. Functional benefits of chocolate as a nutraceutical vehicle: chocolate delivery matrix model.

Observation

The chocolate matrix improves lipid-assisted absorption, phytochemical stability, controlled release, and consumer adherence through superior palatability. Together, these properties increase the translational potential of embedded bioactive compounds.

These characteristics advocate chocolate as an active component as well as a carrier matrix in therapeutic efficacy.

Scientific Assessment of Ingredients

The proposed formulation incorporates four principal bioactive components selected to target complementary physiological pathways associated with sexual wellness. It is not a single-ingredient aphrodisiac, but a multi-pathway systems approach that simultaneously targets vascular function, hormonal balance, endothelial health, stress adaptation, and psychophysiological modulation. In this section, each ingredient is critically evaluated for its scientific rationale, clinical evidence, and translational significance.

Maca Root (*Lepidium meyenii)*

Maca (*L. meyenii*) is a cruciferous root from the Peruvian Andes that has been traditionally used to improve fertility, energy, stamina and sexual performance. Maca has been investigated as a botanical intervention for sexual desire, fatigue, and reproductive outcomes, although the evidence base remains limited by small samples, short treatment durations, heterogeneous preparations, and variable outcome measures.

The primary active constituents of maca include macamides, macaenes, glucosinolates, sterols, alkaloids and polyphenols. Their neuroactive and adaptogenic properties make macamides signature bioactives. Unlike androgenic supplements, maca has not been shown to have a direct effect on testosterone levels but provides benefits via neuroendocrine modulation.

Maca influences sexual wellness in three primary ways. It initially modulates the hypothalamic–pituitary–adrenal axis, reducing chronic stress and fatigue, the primary contributors to low libido. Maca affects dopaminergic and serotonergic signalling leading to increased motivation, mood and sexual desire. Third, emerging evidence indicates modest support for NO signalling and reproductive physiology, indirectly affecting vascular responsiveness and fertility-related outcomes.

Improvements in sexual desire, subjective libido, semen quality and overall vitality have been demonstrated in clinical trials,

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particularly in men with mild sexual dysfunction or reduction of libido due to stress. Available reviews suggest possible modest benefits for selected sexual-function outcomes, but certainty is limited by the small number and methodological quality of primary studies [14,15]. Reported adverse effects are rare, mostly limited to mild occasional gastrointestinal discomfort.

Within a multi-ingredient formulation, maca is primarily intended to support libido, stress adaptation, and neuroendocrine function. However, these proposed benefits have not been validated within the complete combination. No study has established that maca produces equivalent effects when incorporated into the proposed chocolate matrix, and dose equivalence between the reviewed studies and the complete formulation has not been demonstrated.

Epimedium (*Epimedium sagittatum*)

One of the most researched traditional aphrodisiac plants is Epimedium, also known as Horny Goat Weed. The primary functional importance is attributed to the compound icariin, a prenylated flavonoid that has vasodilatory and endothelial supportive properties. Icariin has demonstrated PDE5-inhibitory activity in experimental models, but its potency, pharmacokinetics, and clinical effect are not equivalent to approved PDE5 inhibitors. Icariin is a weak to moderate inhibitor of PDE5 that prolongs cGMP signalling and enhances NO-induced vasodilation. This mechanism leads to smooth muscle relaxation and increased blood flow, both of which directly and positively impact erectile function [16,17].

Besides PDE5 modulation, epimedium influences a number of signalling pathways important for vascular health:

- The PI3K/Akt pathway supports endothelial survival and repair.
- eNOS activation increases the synthesis of NO.
- AMPK signalling facilitates mitochondrial energy metabolism.
- Endothelial repair – increases elasticity of the vessels

These mechanisms together improve endothelial responsiveness and microcirculatory performance, both of which are essential for sexual arousal and erectile function. Epimedium appears to have some preclinical data to support a role in supporting testosterone biosynthesis and leydig cell function, but human data is lacking. Most evidence for icariin and epimedium remains preclinical. Human clinical evidence is limited, and conclusions regarding erectile-function efficacy should therefore remain cautious.

Epimedium is generally well tolerated at nutraceutical doses, but excessive intake can cause palpitations, dizziness, overstimulation and mild sympathomimetic effects. Therefore, the standardization of the concentration of icariin is critical.

Within the proposed formulation, epimedium is intended to contribute predominantly to vascular and endothelial support through PDE5-related mechanisms.

Dehydroepiandrosterone (DHEA)

DHEA is an endogenous adrenal steroid and a precursor of androgens and oestrogens. Circulating levels of DHEA are progressively decreased with ageing and are associated with decreased libido, fatigue, mood disorders, and loss of vitality [18-20].

DHEA improves sexual wellness mainly through endocrine and neurosteroid mechanisms. Following its synthesis, DHEA is sulfated to DHEA-S, which acts as a circulating hormonal reservoir. In peripheral tissues, DHEA is converted to active sex natural steroids, such as testosterone and oestradiol, depending on the local enzyme activity.

Through this conversion, DHEA can impact sexual wellness through four primary pathways:

- Hormonal optimization increases availability of androgens.
- Neurosteroid modulation of mood and motivation
- Vascular responsiveness is increased by endothelial support.
- Promotes anabolic equilibrium – vitality enhancement

Mixed clinical evidence exists for DHEA supplementation. Those with a proven hormonal deficiency, age-related decline, adrenal insufficiency or decreased libido due to endocrine imbalance seem to benefit the most. Numerous clinical studies document enhancements in sexual desire, erection retention and overall sexual satisfaction, although benefits in hormonally normal populations appear limited [19,20]. DHEA supplementation may not be appropriate in hormone-sensitive patients, further emphasizing the importance of clinical oversight and standardized dosing.

One important aspect of DHEA is the inconsistency of regulation. It is available as a dietary supplement in some countries, but in others it is more tightly regulated as it is classified as a hormone. This has implications for commercialization globally.

Side effects can include acne, hormone changes, mood changes and endocrine disruption with higher dosages. It is therefore imperative to standardize the dosage.Within the proposed formulation, DHEA is intended to provide endocrine-related support; however, the benefit–risk profile of this inclusion cannot be established without population-specific clinical and regulatory evaluation.

Safety and contraindications

DHEA may be inappropriate for pregnant or breastfeeding individuals, persons with hormone-sensitive malignancies, prostate disorders, polycystic ovary syndrome, significant liver disease, selected mood disorders, or those receiving hormonal therapies. Potential adverse effects include acne, hirsutism, altered lipids, mood changes, menstrual irregularity, androgenic effects, and endocrine disruption.

Regulatory status

The legal classification of DHEA varies substantially across jurisdictions. It may be marketed as a dietary supplement in some countries, regulated as a prescription or hormonal substance in others, and prohibited in competitive sport. Its inclusion may therefore alter the regulatory classification of a food-like product.

Product-format risk

Incorporating a hormone precursor into a palatable chocolate format raises additional concerns regarding dose control, repeated consumption, sharing, accidental child exposure, labelling, and the need for medical oversight.

Bioactive compounds of cocoa

Within a chocolate-based formulation, cocoa serves both as the delivery matrix and as a source of intrinsic bioactive compounds.

Key cocoa bioactives include:

- Epicatechin (EC)
- Catechins
- Proanthocyanidins
- Theobromine
- Polyphenols

Epicatechin is particularly relevant because there is strong evidence that it protects the endothelium and increases NO.

Cocoa stimulates sexual wellness mainly through vascular and antioxidant mechanisms. Cocoa flavanols have been found to increase NO production, improve endothelial function, decrease oxidative stress and increase arterial elasticity. The effects strongly support a mechanistic basis for sexual performance, since erectile physiology is highly dependent on vascular integrity.

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Recent randomized trials suggest that supplementation with cocoa flavanols improves:

- Vasodilation induced by flow
- vascular elasticity
- microvascular function
- endothelial reactivity
- oxidative stress biomarkers

These vascular effects may be relevant to sexual function where endothelial impairment contributes to dysfunction; however, improvement in systemic vascular biomarkers should not be interpreted as direct evidence of improved sexual outcomes.

Cocoa-flavanol content varies substantially according to cocoa variety, fermentation, roasting, alkalization, storage, and manufacturing. Therefore, the biological activity of a chocolate formulation depends on quantified flavanol content rather than cocoa presence alone.

Cocoa also provides potent antioxidant protection, reducing reactive oxygen species that impair NO signalling. It helps to maintain long-term endothelial function and vascular performance.

Cocoa has effects on neurochemicals through methylxanthines and flavanols that affect mood, cognition and pleasure response beyond its vascular physiology. These benefits may also indirectly benefit libido by increasing motivation, reducing stress, and improving emotional receptivity.

Cocoa has a good safety profile at nutraceutical doses and is generally considered safe. Prolonged use can produce mild stimulant-like effects in sensitive individuals. In the kalories® stack, cocoa acts as a bioactive enhancer and delivery vehicle. It aids NO signalling, provides antioxidant protection, modulates mood and improves formulation bioavailability (Table 2).

Table 2. Ingredient evidence Briefs.

Ingredient	Principal Bioactives	Dominant Biological Targets	Evidence Strength	Safety Profile
Maca [15]	Macamides, sterols	HPA modulation, libido	Moderate–High	High
Epimedium [16]	Icariin	PDE5 inhibition, NO	Moderate	Moderate–High
DHEA [19]	Steroid precursor	Hormonal support	Moderate	Moderate
Cocoa [8,9,12,13]	Flavanols, polyphenols	Endothelial, NO	High	High

Note. Evidence ratings refer to individual ingredients only and should not be interpreted as evidence supporting the efficacy, safety, or potentially complementary action of the complete formulation.

The principal physiological mechanism involved in sexual arousal and erectile function is NO-induced vasodilation. As shown in Figure 3, the proposed formulation contains multiple components that act through increasing NO signalling, endothelial responsiveness, and smooth muscle relaxation.

Observation. NO, eNOS, PDE5, cGMP, PKG, protein kinase G. NO activates guanylate cyclase, which increases cGMP signalling. This causes smooth muscle relaxation, vasodilation and increased genital blood flow.

Overall, ingredient-level evidence supports mechanistic complementarity across vascular, endocrine, and neuroendocrine pathways. This figure should be interpreted as a conceptual representation rather than direct evidence for formulation efficacy.

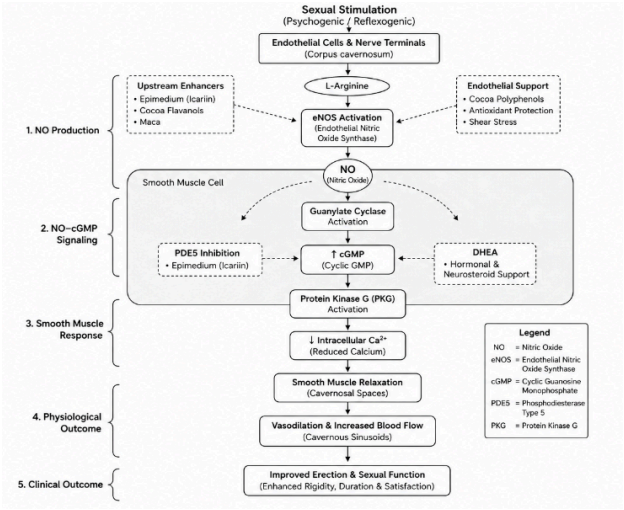

Figure 3. Essential nutraceutical mechanisms modulating the NO signalling pathway in sexual function.

Comparative Evidence for Sexual-Wellness Nutraceuticals

While many nutraceuticals have been studied for sexual wellness, most commercial products are based on a single dominant mode of action such as NO or testosterone support, or stress relief, or large herbal mixes with little mechanistic consistency. The proposed formulation combines ingredients with distinct biological rationales, but its comparative efficacy and safety have not been tested against single-ingredient or conventional interventions.

Distinguishing complementarity from synergy

Ingredients acting on different biological pathways may be complementary, but this does not establish pharmacological synergy. Demonstration of synergy requires experimental designs that compare individual and combined components at equivalent doses and test whether the combined effect exceeds expected additive effects. No such study has yet evaluated the complete formulation.

Comparative Analysis of Key Nutraceutical Competitors

There are numerous nutraceuticals advertised for sexual wellness including: *Tribulus terrestris*, *P. ginseng*, Ashwagandha, L-Arginine, Saffron and Yohimbine. Their effectiveness varies depending on the mechanism, quality of evidence, safety and bioavailability.

T. terrestris is often marketed as a testosterone-boosting supplement, but recent clinical data demonstrate inconsistent hormonal effects and minimal evidence of significant sexual function enhancement. Its efficacy seems to be limited by certain endocrine targeting and inconsistent extract standardization.

P. ginseng remains one of the most scientifically supported botanical interventions. Meta-analyses reveal moderate improvements in erectile function and sexual satisfaction, mostly through NO boosting, endothelial support and fatigue resistance increases. However, differences in the content of ginsenosides may affect reproducibility.

Ashwagandha has strong evidence for decreasing stress, modulating cortisol levels and increasing psychophysiological resilience. The big plus is that it reduces the stress-induced suppression of libido, although direct vascular effects are minimal.

A compelling mechanistic rationale is provided by L-Arginine and related NO precursors, as they directly augment NO synthesis. Mild ED has been shown to be beneficial in clinical studies but gastrointestinal intolerance, limitations on dosage

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and dependence on one pathway limit use.

Saffron mainly modulates serotonergic pathways and mood with moderate benefits in libido and sexual dysfunctions related to antidepressants. The evidence base is promising but narrow in mechanistic breadth.

Yohimbine has been historically proven to be effective by adrenergic stimulation, however safety issues such as anxiety, hypertension, tachycardia, and overstimulation severely limit its translational applicability.

Competitor analysis shows that the majority of single-ingredient interventions focus on one or two pathways at a time and rarely reflect the full biological complexities of sexual dysfunction.

Mechanistic complementarity of the proposed formulation of Kalories®

The scientific effectiveness of chocolate-based formulation is not in the superiority of one or another ingredient, but in its cohesive formulation structure. Each individual ingredient has different but potentially complementary physiological effects.

- Maca is mainly an aphrodisiac, and also an adaptogen, helping to regulate mood by modulating the HPA-axis and supporting the neuroendocrine system.
- Epimedium improves vascular function by inhibiting PDE5, thus enabling NO signalling and improving endothelial repair.
- DHEA helps with hormonal balance, energy, and sexual desire from neurosteroids.
- Cocoa flavanols improve endothelial function, antioxidant defence, vascular responsiveness and mood.

These mechanisms converge at three main biological nodes:

- **Hormonal optimization**: Boosted libido, motivation, vitality and reproductive signals.
- **Endothelial enhancing**: Improves vascular elasticity and genital perfusion.
- **NO signalling**: Enhances vasodilation and blood flow.

This convergence at the systems level allows chocolate-based formulation to address not only the physiological but also the psychogenic factors influencing sexual wellness, providing a wider mechanistic coverage than most traditional nutraceuticals.

Evidence interpretation and visualization in combination formulation

Integrated evidence mapping further supports the rationale for formulation. Comparative evidence heat mapping shows that cocoa flavanols, *P. ginseng* and L-arginine have the strongest independent evidence for vascular enhancement, while maca and ashwagandha have the best evidence for psychogenic and stress-related areas. For people who have hormonal deficiencies, DHEA is especially helpful.

A heat map of the evidence was created to allow for multidimensional comparison across key evidence domains, summarising the relative scientific strength of each of the primary ingredients in the proposed formulation. Figure 4 presents a comparative overview of the strength of ingredient-level evidence, bringing together efficacy evidence, mechanistic support, clinical quality, safety evidence and translational potential.

Note. Shading represents qualitative interpretation of the published literature and does not constitute a validated quantitative evidence-grading system.

View: Lighter shading indicates less or inconsistent evidence for support across the domains assessed; darker shading indicates stronger evidence. Evidence domains include efficacy outcomes (libido, erectile function, sexual satisfaction), mechanistic support (NO-cGMP signalling, endothelial function, hormonal pathways),

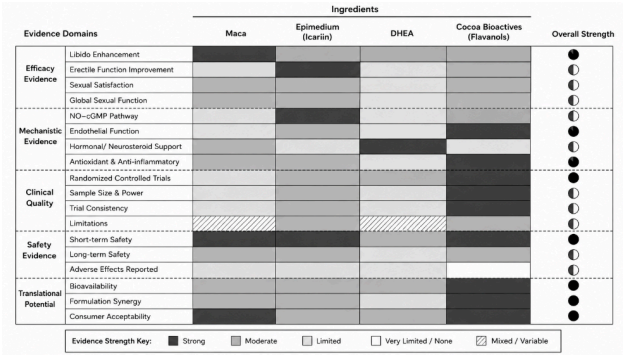

Figure 4. Comparative evidence heat map of the key constituents in the chocolate-based formulation intimacy formula.

clinical quality (randomized controlled trials, adequacy of sample, consistency), safety evidence and translational potential. NO, nitric oxide; cGMP, cyclic guanosine monophosphate.

A review of forest plots from published meta-analyses suggests that the largest clinical effects are seen in sexual wellness with interventions targeting vascular pathways, especially those that boost NO and restore endothelial function. However, these advantages may not be sufficient in the presence of a preponderance of hormonal or psychogenic dysfunction.

Chocolate-based formulation combination formulation model overcomes this limitation by incorporating upstream and downstream mechanisms into a single formulation. The chocolate matrix enhances bioavailability, phytochemical stability and consumer adherence, leading to better translational potential than just the potency of the ingredients.

Crucially, compliance is an underappreciated component of effectiveness in the real world. Compliance over the long term is often poor, and this is why many otherwise effective nutraceuticals do not perform as well as expected. chocolate-based formulation merges therapeutic ingredients with a delicious chocolate formula to transform supplementation from a medical obligation into a lifestyle and potentially improve long-term adherence. Table 3 summarises the comparative positioning of chocolate-based formulation versus well-studied nutraceutical interventions.

In short, chocolate-based formulation provides a significant edge in formulation science by combining vascular enhancement, hormonal support, stress modulation, antioxidant protection and excellent adherence in a single functional chocolate delivery platform. Although there is no direct randomised clinical evidence for the whole formulation, the evidence at the ingredient level provides a compelling mechanistic rationale for further clinical validation.

The scientific efficacy of the proposed formulation is based on its multi-pathway systems architecture where different ingredients target complementary physiological pathways that culminate to improve sexual wellness outcomes. Figure 5 shows the integrated formulation model.

Table 3. Comparative nutraceutical evaluation.

Intervention	Main mechanism	Evidence strength	Safety	Key evidence limitation
Tribulus	Testosterone support	Low	High	Broader coverage
P ginseng	NO / Endothelium	High	High	Comparable vascular support
Ashwagandha	Stress reduction	High	High	Complementary

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Table 3 (continued)

Intervention	Main mechanism	Evidence strength	Safety	Key evidence limitation
L-Arginine	NO precursor	High	High	Single pathway only
Saffron	Mood / Libido	Moderate	High	Narrow mechanism
Yohimbine	Adrenergic	Moderate	Low	Superior safety
Hypothetical chocolate-based multi-ingredient formulation	Multi-pathway complementarity	Ingredient-level evidence	High	Integrated formulation

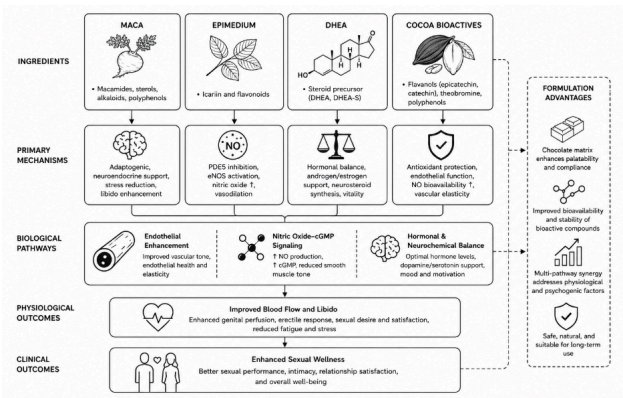

Figure 5. Hypothesized systems-level model of a chocolate-based multi-ingredient sexual-wellness formulation.

Observation. Maca is mainly for stress adaptation and libido improvement, epimedium works by inhibiting PDE5 and promoting NO production, DHEA is for hormonal balance and neurosteroid signalling, cocoa bioactives improve endothelial function and increase antioxidant defence. These pathways result in improved vascular perfusion, libido and overall sexual health.

Discussion

This review provides a critical synthesis of the scientific rationale for chocolate as a functional delivery vehicle for sexual wellness nutraceuticals, using a proposed chocolate-based formulation as an illustrative case application. Sexual dysfunction is a complex condition that is influenced by vascular, hormonal, neurological, oxidative, and psychological factors, as evidenced by Thus, interventions targeting a single biological mechanism may not be sufficient for therapeutic benefit. The principal formulation rationale of chocolate-based formulation is in its multi-pathway formulation architecture, which more truly represents the complex pathophysiology of sexual dysfunction than traditional single-ingredient supplements.

The main advantage of the formulation is that it contains complementary bioactives with unique but complementary physiological functions. Maca acts mainly on libido suppression due to psychological problems and stress via neuroendocrine and adaptogenic mechanisms. PDE5 modulation and NO enhancement provide vascular support from Epimedium. DHEA is an important hormone that helps to balance other hormones and increase energy for those whose hormones are declining with age. Cocoa flavanols offer endothelial protection, antioxidant defence, vascular support and neurochemical benefits. Combined, these elements represent a systems-level intervention that targets both physiological arousal and psychological readiness.

The strongest biological rationale for chocolate-based formulation is the combination of vascular optimization and behavioural compliance. Vascular support is important as sexual function is highly dependent on endothelial health and NO signalling. But even very effective nutraceutical ingredients often fail to perform in real-world applications due to poor compliance over the long term. This highlights the translational significance of delivery-system engineering. The main advantage of chocolate is to combine therapeutic intent with a pleasurable sensory experience. Chocolate may improve palatability and reduce the impact of supplementation fatigue leading to improved adherence and thus increase real world efficacy.

Beyond biological efficacy, commercial scalability will depend on dosage standardization, sensory homogeneity, shelf stability, and regulatory classification from a translational product development standpoint.

This review emphasizes that in the development of modern nutraceuticals, formulation science is becoming as important as ingredient science. Typical nutraceutical research often focuses on ingredients in isolation, without considering the interplay of bioavailability, matrix effects, release kinetics and consumer behaviour. chocolate-based formulation is a formulation-science approach where the delivery matrix and bioactive synergy are intentionally co-engineered. This is in line with wider trends in functional food innovation and precision nutrition, where consumer experience and mechanistic efficacy are increasingly coming together.

Yet, there are a number of limitations to be acknowledged despite these benefits. Currently, the strongest evidence concerns individual ingredients rather than whole formulations. Maca, epimedium, cocoa flavanols, and DHEA have mechanistic and/or clinical support to varying degrees, but there are no direct randomized clinical trials for the complete proposed formulation. Thus, efficacy claims for the combination formulation are inferential, not clinically validated. Publication bias in favour of positive nutraceutical outcomes may exaggerate a pre-existing evidence base.

Additional limitations include the absence of formulation-specific pharmacokinetic studies, stability testing, dose-uniformity assessment, interaction studies, and long-term safety evaluation. Furthermore, most published evidence concerns male sexual function, whereas evidence for female sexual health remains comparatively limited.

Second, there is considerable heterogeneity among published nutraceutical studies. Differences in the standardization of extracts, dosage, length of intervention, characteristics of participants, and outcome measurement make it difficult to compare studies directly. Third, DHEA presents regulatory complexities as its legal classification varies in international markets, potentially affecting scalability and product standardization.

From a translational perspective, future development of chocolate-based nutraceuticals will depend on rigorous formulation validation, manufacturing quality control, regulatory compliance, and clinical evaluation rather than formulation concept alone. Consumer demand is shifting towards solutions that have a focus on wellness, natural ingredients, discretion and pleasurable consumption instead of explicit pharmaceutical reliance. Thus, chocolate-based delivery systems could be a highly scalable sector in future nutraceutical innovation.

Future Directions

Future research should include randomized placebo-controlled clinical trials to evaluate the complete chocolate-based formulation using validated sexual wellness metrics, including libido scores, erectile function indices and sexual satisfaction assessments. Pharmacokinetic studies are needed to quantify the bioavailability of

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ingredients in the chocolate matrix and to evaluate the absorption advantages of the matrix as compared to traditional delivery systems.

Main areas of research are metabolomics, biomarker-driven personalization, interactions with the gut microbiome and the development of precision nutraceuticals. Future formulations may increasingly use personalized strategies based on vascular risk, hormonal status, age, stress profile and metabolic phenotype. Biomarker-driven approaches could enhance efficacy and enable precision sexual wellness interventions.

Future clinical studies should categorize participants according to sex, age, endocrine status, cardiometabolic risk and baseline severity of sexual dysfunction to identify efficacy patterns for subgroups. Longitudinal safety studies and dose-response trials are important to find optimal therapeutic windows.

Conclusion

Chocolate possesses several physicochemical, sensory, and intrinsic bioactive characteristics that make it a promising functional matrix for the delivery of selected nutraceutical ingredients. Its lipid-rich composition, consumer acceptability, and cocoa-derived flavanols provide a biologically plausible basis for investigating chocolate-based delivery systems in sexual-wellness applications. Beyond acting as a food matrix, cocoa may contribute vascular, antioxidant, and neuropsychological effects that are relevant to sexual health.

The evidence reviewed in this article indicates that cocoa flavanols, maca, epimedium-derived compounds, and DHEA influence partially distinct biological pathways associated with endothelial function, NO signalling, hormonal regulation, stress adaptation, and neuroendocrine function. These complementary mechanisms provide a scientific rationale for exploring multi-ingredient nutraceutical formulations. However, the available evidence relates predominantly to individual ingredients rather than to the complete combination, and the quality, consistency, and clinical applicability of published studies vary substantially across ingredients, populations, doses, and outcome measures.

Consequently, the proposed chocolate-based formulation should be regarded as a biologically plausible and hypothesis-generating concept rather than a clinically validated intervention. At present, there is insufficient evidence to conclude that combining these ingredients within a chocolate matrix improves bioavailability, produces synergistic physiological effects, enhances long-term adherence, or provides superior clinical outcomes compared with existing delivery systems or single-ingredient interventions.

Future progress in this field will depend on rigorous formulation science together with well-designed randomized controlled trials, pharmacokinetic investigations, stability testing, dose-uniformity assessment, interaction studies, long-term safety evaluation, and regulatory assessment. Such evidence will be essential before formulation-level efficacy, safety, or comparative advantages can be established. Until then, chocolate-based sexual-wellness nutraceuticals should be considered a promising area for translational research rather than an evidence-established therapeutic approach.

Conflict of Interest

Dr. Rakesh Gandla is affiliated with chocolate-based formulation Nutra Solutions Private Limited, whose formulation is discussed solely as an illustrative case example based on publicly available scientific literature. This affiliation is disclosed for transparency. The remaining authors declare no competing interests.

Authors' Contribution

Rakesh Gandla – Conceptualization and literature review

Ravi Kishore – Medical validation

Uma Maheswara Rao – Proofreading and editing

U R Sri Veena – Toxicological angle of ingredients literature

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Generative AI tools were used only for language editing and manuscript refinement. The authors independently verified all scientific content, interpretations, references, and conclusions.

Ethics Declaration

Not applicable

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