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HERBAL PREWORKOUT TRANSDERMAL PATCH

[1]Vaishnavi Ambekar, [2]Vivek Agale And [3]Asst. Prof A. Shelar.

[1] Final Year B.Pharm Student, [2] Final Year B.Pharm Student, [3]Assistant Professor

Department of Pharmaceutics,

Sinhgad Institute of Pharmaceutical Sciences, Lonavala-410401, Maharashtra, India.

ABSTRACT:

Pre-workout supplements are widely consumed by fitness enthusiasts and athletes to enhance stamina, energy, and focus during exercise. However, the conventional oral route often results in delayed absorption, gastrointestinal discomfort, and erratic plasma concentrations. The development of a transdermal herbal pre-workout patch offers an innovative and user-friendly alternative for delivering active herbal ingredients directly through the skin into systemic circulation. Herbal actives such as Panax ginseng, Withania somnifera (Ashwagandha), Camellia sinensis (Green tea extract), Rhodiola rosea, and Curcuma longa have shown potent adaptogenic and ergogenic effects that can significantly improve physical performance. The patch system provides controlled drug release, minimizes first-pass metabolism, and ensures sustained energy release without the crash associated with synthetic pre-workouts. This review highlights the formulation strategies, evaluation parameters, and potential benefits of herbal transdermal pre-workout patches, emphasizing their role as a safe, natural, and effective alternative for performance enhancement in modern sports nutrition.

Index Terms: Herbal patch, Pre-workout, Transdermal delivery, Nutraceuticals, Performance enhancer, Herbal actives

1. INTRODUCTION:

The global demand for natural performance-enhancing supplements has grown rapidly due to increasing awareness of health and fitness. Pre-workout supplements are designed to provide instant energy, improve focus, and delay fatigue during physical activity (Patel et al., 2021). Traditional oral formulations such as powders, capsules, and energy drinks, although popular, often exhibit drawbacks such as gastric irritation, fluctuating energy levels, and poor compliance (Rathi et al., 2020). Moreover, the metabolism of synthetic stimulants can lead to side effects such as anxiety, dehydration, and jitteriness.

Transdermal drug delivery systems (TDDS) have emerged as a promising alternative for the controlled and sustained release of bioactive compounds. This system delivers the active ingredient through the skin, directly into systemic circulation, bypassing hepatic first-pass metabolism (Singh and Sharma, 2019). Herbal-based transdermal patches combine the benefits of natural therapeutics with the precision of modern drug delivery technology. Compared to oral intake, transdermal patches maintain steady plasma levels, enhance bioavailability, and improve patient compliance (Kumar et al., 2022).

In the context of pre-workout nutrition, incorporating herbal actives into transdermal systems allows athletes to experience a gradual and sustained energy boost without gastrointestinal disturbances. Herbs such as Panax ginseng, Withania somnifera, and Rhodiola rosea are known adaptogens that enhance resistance to stress and physical fatigue (Joshi et al., 2023). These natural compounds, when formulated into a transdermal patch, can provide multi-hour performance support ideal for gym-goers and endurance athletes.

2. . HERBAL INGREDIENTS FOR PRE-WORKOUT FORMULATIONS

Herbal ingredients have gained significant attention in sports nutrition due to their adaptogenic, antioxidant, and energy-boosting effects. Unlike synthetic pre-workouts containing high caffeine or chemical stimulants, herbal actives provide a safer and more sustainable energy release. The combination of multiple herbal extracts can enhance endurance, focus, and recovery while minimizing fatigue and oxidative stress (Sharma et al., 2022).

Below are some potential herbal ingredients suitable for formulation into transdermal pre-workout patches:

Table 1: Herbal Ingredients for Pre-Workout Transdermal Patches

Herbal Active	**Botanical Name**	**Primary Bioactive Compounds**	**Pharmacological Action**	**Pre-Workout Benefits**	**References**
Ginseng	Panax ginseng	Ginsenosides	Adaptogenic, anti-fatigue	Improves stamina, boosts physical performance	(Kim et al., 2021)
Ashwagandha	Withania somnifera	Withanolides	Anti-stress, strength enhancer	Enhances muscle strength, endurance, and recovery	(Desai et al., 2020)
Green Tea Extract	Camellia sinensis	Catechins, caffeine	Thermogenic, antioxidant	Enhances fat metabolism, improves alertness	(Lee et al., 2019)
Rhodiola rosea	Rhodiola rosea	Rosavin, salidroside	Anti-fatigue, adaptogenic	Reduces stress and improves mental focus	(Mishra et al., 2022)
Guarana Extract	Paullinia cupana	Natural caffeine	CNS stimulant	Provides mild stimulation and energy	(Kumar et al., 2021)
Turmeric	Curcuma longa	Curcumin	Anti-inflammatory, antioxidant	Reduces exercise-induced inflammation	(Patil et al., 2020)
Beetroot Extract	Beta vulgaris	Nitrates	Vasodilatory	Enhances oxygen flow and endurance	(Singh et al., 2023)
Ginkgo Biloba	Ginkgo biloba	Flavonoids, terpenoids	Neuroprotective, antioxidant	Improves blood circulation and focus	(Rao et al., 2021)

These herbs can be incorporated individually or synergistically to produce a balanced pre-workout effect. For instance, Panax ginseng and Ashwagandha act synergistically to reduce fatigue and improve muscle strength, while Green tea extract and Guarana enhance alertness through natural caffeine. Moreover, Curcumin and Beetroot extract can support anti-inflammatory and vasodilatory actions, improving post-workout recovery and oxygen flow (Singh et al., 2023).

Incorporating these herbal actives into a transdermal patch can help maintain steady-state plasma levels, ensuring prolonged activity during workouts without the abrupt energy crash seen with oral energy drinks. Additionally, such patches minimize gastrointestinal side effects and offer a convenient mode of administration for athletes and fitness enthusiasts (Rathi et al., 2020).

3. Transdermal Patch Technology

Herbal transdermal patches combine the strengths of traditional phytomedicine with modern drug delivery technologies, offering a multitude of advantages over conventional oral and topical formulations Transdermal drug delivery systems (TDDS) are designed to deliver bioactive compounds across the skin layers into systemic circulation. They provide a controlled, sustained, and non-invasive route for drug administration (Singh and Sharma, 2019). Compared to oral formulations, TDDS bypasses the hepatic first-pass metabolism, leading to improved bioavailability and consistent plasma concentration. For herbal actives used in pre-workout formulations, transdermal patches are particularly beneficial as they offer prolonged energy release and better compliance for athletes.

The human skin consists of three major layers—epidermis, dermis, and hypodermis. The primary barrier for drug absorption is the stratum corneum, which restricts the entry of hydrophilic and high-molecular-weight compounds. Therefore, herbal actives intended for transdermal delivery require suitable formulation strategies and permeation enhancers to improve their diffusion through the skin (Kumar et al., 2022).

3.1 Mechanism of Drug Absorption through Skin

Drug absorption from a transdermal patch occurs mainly by passive diffusion. The active ingredient passes through the stratum corneum, then into the viable epidermis and dermal capillaries, finally entering systemic circulation. The rate of diffusion depends on the concentration gradient, drug lipophilicity, molecular weight, and the use of permeation enhancers (Patel et al., 2021).

3.2 Types of Transdermal Patches

Type of Patch	Description	Characteristics
Reservoir Type	Drug is enclosed in a compartment between backing and rate-controlling membrane.	Provides controlled release; suitable for potent herbal extracts.
Matrix Type	Drug is uniformly dispersed within a polymer matrix.	Simple design; allows steady drug diffusion.
Drug-in-Adhesive Type	Drug is directly incorporated in the adhesive layer.	Thin, flexible, and comfortable; widely used in commercial patches.
Multilayered Patch	Two or more layers with different release profiles.	Enables combination of fast and sustained release.
Micro-Reservoir Type	Drug is suspended in a polymer with tiny dispersed reservoirs.	Combines advantages of reservoir and matrix systems.

3.3 Components of a Herbal Transdermal Patch

A typical transdermal patch comprises the following key components:

- Backing Layer: Protects the patch from external environment; made from materials like polyester or polyethylene.
- Drug Reservoir/Matrix: Contains the herbal active ingredient dispersed in a suitable polymer such as HPMC, PVP, or Eudragit.
- Adhesive Layer: Ensures close contact between patch and skin; often pressure-sensitive.Release Liner: Removed before application to expose the adhesive layer.
- Permeation Enhancers: Compounds like menthol, DMSO, oleic acid, or essential oils used to enhance skin permeability (Joshi et al., 2023).

3.4 Advantages of Transdermal Patches

Transdermal systems offer several benefits over traditional oral pre-workout supplements:

- Avoid first-pass metabolism
- Provide sustained and controlled release
- Reduce dosing frequency
- Improve patient compliance
- Non-invasive and painless administration
- Minimize gastric irritation and systemic side effects

- Incorporating herbal actives into such systems represents a major advancement in nutraceutical delivery technology, allowing athletes to experience consistent energy and stamina without adverse effects from synthetic stimulants.

4. Formulation and Evaluation Parameters

The formulation of a herbal transdermal pre-workout patch involves combining suitable polymers, herbal actives, and excipients to ensure desired drug release, flexibility, and adhesion. Each ingredient in the formulation plays a crucial role in achieving a stable and effective patch capable of delivering herbal bioactives through the skin (Kumar et al., 2022).

4.1 Polymers Used in Patch Formulation

Polymers act as the matrix or reservoir for the herbal drug. They control the drug release rate and influence mechanical strength and flexibility of the patch. Commonly used polymers include:

- Hydroxypropyl Methylcellulose (HPMC): Provides smooth film formation and sustained release properties.
- Polyvinylpyrrolidone (PVP): Improves flexibility and enhances drug dispersion.
- Eudragit RL/RS: Used for controlled release formulations.
- Ethyl Cellulose (EC): Offers mechanical stability and hydrophobic balance.
- PVA (Polyvinyl Alcohol): Enhances tensile strength and elasticity.

The combination of hydrophilic (HPMC, PVP) and hydrophobic (EC, Eudragit) polymers can be optimized for desired release kinetics (Patel et al., 2021).

4.2 Plasticizers and Permeation Enhancers

- Plasticizers like glycerol, PEG-400, or dibutyl phthalate are added to improve flexibility and reduce brittleness.
- Permeation enhancers such as menthol, oleic acid, and essential oils (eucalyptus or peppermint) help herbal actives penetrate the skin barrier efficiently (Sharma et al., 2022).

These enhancers temporarily disrupt the stratum corneum lipid structure, improving drug diffusion without causing irritation.

4.3 Solvents and Herbal Extract Incorporation

Solvents such as ethanol, isopropanol, or chloroform are used to dissolve polymers and herbal extracts. The selection depends on the solubility of active phytoconstituents. The herbal extract is uniformly dispersed within the polymeric solution, ensuring homogenous drug distribution before casting (Rathi et al., 2020).

4.4 Patch Preparation Methods

The solvent casting method is the most common approach for herbal patch development.
Steps include:

1. Dissolve polymer(s) in a solvent mixture.
2. Add plasticizer and herbal extract under continuous stirring.
3. Pour the solution into a flat glass mold or petri dish.
4. Dry the film under controlled conditions (temperature and humidity).
5. Cut into desired dimensions and store in airtight containers.

Other methods include hot-melt extrusion, microneedle-assisted, and electrospinning approaches for advanced patches (Joshi et al., 2023).

4.5 Evaluation Parameters of Herbal Transdermal Patches

Evaluation ensures the quality, safety, and performance of the formulated patch. Standard parameters include:

Parameter	Purpose	Typical Method
Thickness	To ensure uniformity	Vernier caliper measurement
Weight Variation	Ensures dose consistency	Weighing multiple patches
Folding Endurance	Tests flexibility	Repeated folding until break
Drug Content Uniformity	Confirms equal distribution	Extraction and spectrophotometric analysis
Tensile Strength	Determines mechanical stability	Tensile tester
Moisture Content & Uptake	Indicates storage stability	Desiccator method
Surface pH	Ensures skin compatibility	pH electrode or paper method
In-vitro Drug Release	Measures release profile	Franz diffusion cell
Skin Irritation Test	Assesses safety	Performed on animal or synthetic skin models

These tests confirm that the herbal pre-workout patch is safe, flexible, and capable of sustained drug release during physical activity. The in-vitro release profile often exhibits biphasic behavior — an initial burst release followed by a controlled, steady phase, ensuring prolonged activity throughout the workout duration.

4.6 Optimization and Stability Studies

Optimization is carried out using techniques like Design of Experiments (DoE) or Response Surface Methodology (RSM) to achieve the ideal balance between drug release, adhesion, and mechanical strength. Stability testing (as per ICH guidelines) evaluates the patch under varying temperature and humidity to ensure product durability and shelf life (Patil et al., 2020).

5. Advantages of Herbal Pre-Workout Patches

Herbal pre-workout transdermal patches combine the best of natural pharmacology and modern drug delivery. They offer several advantages over traditional oral pre-workout formulations, which often cause gastric irritation, jitteriness, or inconsistent energy levels. The patch system ensures controlled, safe, and sustained energy enhancement, ideal for athletes and fitness enthusiasts.

5. 1 Pharmacological and Performance Advantages

Sustained Energy Release: Provides gradual stimulation throughout the workout, avoiding sudden energy spikes or crashes.

Improved Bioavailability: Bypasses hepatic first-pass metabolism, resulting in better systemic availability of herbal actives (Rathi et al., 2020).

Reduced Gastrointestinal Side Effects: No irritation or nausea unlike caffeine-heavy oral supplements.

Controlled Dosing: Precise and uniform drug delivery avoids overdose risks.

Enhanced Absorption: Use of permeation enhancers allows higher penetration of herbal actives through the skin.

Targeted Performance Support: Adaptogenic herbs like Ashwagandha and Ginseng help modulate stress, stamina, and recovery in a balanced manner.

5.2 User and Compliance Advantages

Non-Invasive & Easy to Use: No swallowing required; just apply and go.

Discreet Application: Thin and comfortable patches can be worn under clothes.

Better Patient/Consumer Compliance: Especially useful for individuals who dislike the taste or side effects of oral pre-workouts (Patil et al., 2020).

Long-Term Safety: Herbal bioactives provide natural energy without synthetic additives or banned stimulants.

Eco-Friendly Formulation: Utilizes biodegradable polymers and plant-based actives, aligning with sustainable health practices (Sharma et al., 2022).

Overall, herbal transdermal pre-workout patches represent a next-generation nutraceutical delivery system that merges ancient herbal wisdom with advanced pharmaceutical technology. They hold immense potential for revolutionizing the sports supplement industry by providing safer, natural, and more efficient energy solutions.

6. Challenges and Future Scope:

Although herbal transdermal pre-workout patches present a novel and promising approach for natural performance enhancement, several scientific and technical challenges need to be addressed before commercial implementation. Understanding these limitations can help optimize formulation strategies and open new research directions.

6.1 Challenges

1.Skin Permeability of Herbal Actives:

Many herbal phytoconstituents possess large molecular weights and poor lipophilicity, which restrict their diffusion through the stratum corneum (Kumar et al., 2022). Achieving effective skin permeation without irritation remains a major hurdle.

2.Stability of Herbal Extracts:

Herbal compounds such as polyphenols, flavonoids, and alkaloids are sensitive to light, temperature, and oxidation. Maintaining their stability throughout formulation, storage, and application requires protective polymers or encapsulation systems (Rathi et al., 2020).

3.Batch-to-Batch Variation:

The natural variability in herbal extracts can affect consistency in active content, potency, and performance of the patch.

4. Limited Clinical Validation:

Despite promising in-vitro and in-vivo data, there is a lack of well-controlled human clinical trials evaluating the efficacy and safety of herbal pre-workout patches.

5. Adhesion and Comfort Issues:

Some herbal-based formulations may affect adhesive properties, leading to reduced patch adherence during sweating or intense physical activity (Joshi et al., 2023).

6. Regulatory and Standardization Gaps:

The classification of herbal transdermal patches as nutraceuticals, cosmetics, or drugs varies across countries. Clear guidelines for quality control and clinical evaluation are still evolving (Patil et al., 2020).

6.2 Future Scope

Despite current limitations, the future of herbal pre-workout patches looks highly promising. Continued research and innovation are expected to transform these systems into mainstream fitness aids.

Nanotechnology Integration:

The incorporation of herbal nanocarriers (like liposomes, niosomes, and phytosomes) can enhance permeability and stability of active ingredients.

Smart Patches and Wearable Tech:

Emerging trends involve smart herbal patches embedded with micro-sensors or QR codes that monitor dosage, sweat rate, or fatigue levels in real time (Sharma et al., 2022).

Personalized Nutrition Systems:

With advancements in AI-based health monitoring, customized patches tailored to individual body types, metabolism, and workout intensity could become possible.

Sustainable Formulations:

The use of biodegradable polymers and green extraction methods supports eco-friendly product development aligned with clean-label nutraceutical trends.

Clinical Validation and Market Expansion:

Increased academic–industry collaboration can lead to more standardized clinical data, helping these products gain global regulatory acceptance and consumer trust.

7. Conclusion

The concept of herbal pre-workout transdermal patches represents an innovative fusion of traditional herbal therapy and modern pharmaceutical technology. These patches provide a sustained, safe, and non-invasive method for enhancing workout performance and endurance. Compared to conventional oral supplements, transdermal patches bypass first-pass metabolism, maintain steady plasma levels, and eliminate gastrointestinal side effects.

The integration of potent herbal actives such as Panax ginseng, Withania somnifera, Camellia sinensis, and Rhodiola rosea in transdermal systems offers a natural, holistic, and effective approach to sports nutrition. While challenges such as limited permeability, formulation stability, and standardization persist, advancements in nanotechnology, polymer science, and smart patch design continue to drive innovation in this field.

In conclusion, herbal pre-workout patches have immense potential as next-generation nutraceutical delivery systems. With further research, clinical validation, and standardization, they can become a practical, sustainable, and consumer-friendly solution for energy and performance enhancement in modern fitness and sports industries.

9. PATENT POTENTIAL:

The concept of a herbal pre-workout transdermal patch represents an innovative combination of ethnopharmacology and modern transdermal technology. While several patents have been filed for synthetic stimulant patches, very few have focused exclusively on herbal, adaptogenic, or caffeine-free transdermal systems designed for energy enhancement and pre-workout support. This creates a promising opportunity for intellectual property protection and further commercial exploration.

The patent potential lies in several key areas, such as:
Development of novel combinations of herbal actives, including Withania somnifera (Ashwagandha), Panax ginseng, Camellia sinensis (Green Tea), Paullinia cupana (Guarana), and Capsicum annuum (Capsaicin).
Design of innovative patch matrices using polymers like Eudragit, HPMC, or PVP for sustained herbal release.
Integration of smart patch technology with QR-coded data tracking for personalized pre-workout use.
Incorporation of nano-herbal formulations for enhanced skin penetration and bioavailability.
Future research should emphasize clinical validation, skin permeation studies, and safety assessments to establish the therapeutic efficacy of such patches. Additionally, merging wearable sensor technology with herbal patches can lead to personalized fitness and wellness devices, aligning with the growing trend of smart health systems and digital therapeutics.

Thus, the herbal pre-workout transdermal patch concept holds strong potential for patentability, industrial production, and global commercialization in the nutraceutical and sports performance sectors.

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REFERENCES:

1. Prausnitz, M.R. & Langer, R. (2008). Transdermal drug delivery. Nature Biotechnology, 26(11), 1261–1268.

2. Benson, H.A.E. (2012). Transdermal drug delivery: Penetration enhancement techniques. Current Drug Delivery, 9(1), 23–33.

3. Prausnitz, M.R. (2004). Microneedles for transdermal drug delivery. Advanced Drug Delivery Reviews, 56(5), 581–587.

4. Ramteke, K.H., Dighe, P.A., Kharat, A.R. & Patil, S.V. (2012). Transdermal drug delivery system: A review. Journal of Advanced Scientific Research, 3(1), 22–35.

5. Choudhury, H. et al. (2017). Herbal transdermal patches: A new era of herbal drug delivery. International Journal of Pharmaceutical Sciences and Research, 8(2), 481–492.

6. Nanda, S., Saroha, K., & Yadav, B. (2013). Formulation and evaluation of transdermal patches containing herbal extract. Journal of Pharmacy Research, 7(1), 23–28.

7. Sharma, N. & Kaur, G. (2020). Herbal approaches in transdermal drug delivery: A review. Journal of Pharmacognosy and Phytochemistry, 9(3), 179–187.

8. Nandure, H.P. & Pande, V.V. (2015). Design and evaluation of transdermal patches of herbal drugs. World Journal of Pharmaceutical Research, 4(8), 1231–1240.

9. Yadav, V., & Saini, V. (2020). Herbal transdermal patches: A new trend in herbal drug delivery. Journal of Drug Delivery and Therapeutics, 10(5), 159–164.

10. Ghosh, T.K., Pfister, W.R., Yum, S.I. (2008). Transdermal and Topical Drug Delivery Systems. Taylor & Francis.

11. Yadav, A.V., Murthy, M.S., Shete, A.S. & Sakhare, S.S. (2011). Design and evaluation of transdermal films and patches. International Journal of Pharmaceutical Sciences and Research, 2(1), 35–42.

12. Dubey, S., & Rathore, R. (2021). Herbal pre-workout formulations: A review. International Journal of Pharmaceutical Sciences Review and Research, 70(2), 11–16.

13. Ghosh, A., et al. (2019). Herbal nutraceuticals as pre-workout supplements. Journal of Herbal Medicine, 17, 100277.

14. Akhila, S., & Deepa, K. (2020). Natural herbs as performance enhancers: A review. Pharmacognosy Reviews, 14(27), 15–22.

15. Borse, A.U., et al. (2018). Caffeine and herbal stimulants in pre-workout supplements: Pharmacological insights. Current Nutrition & Food Science, 14(3), 247–255.

16. Joshi, R., & Sharma, P. (2019). Role of herbal adaptogens in exercise performance. Asian Journal of Pharmaceutical and Clinical Research, 12(8), 45–52.

17. Singh, R.H., & Rastogi, S. (2011). Rasayana herbs: A key to rejuvenation and endurance. Ayu, 32(3), 378–382.

18. Harish, R., & Shukla, S. (2018). Ashwagandha: A herbal adaptogen for endurance. Phytomedicine, 50, 118–126.

19. Kulkarni, S., & Mahajan, P. (2020). Role of herbal ingredients in enhancing sports performance. Journal of Ayurveda and Integrative Medicine, 11(4), 487–495.

20. Patel, R., & Jain, A. (2017). Formulation and evaluation of caffeine transdermal patches. Indian Journal of Pharmaceutical Sciences, 79(2), 183–189.

21. Kaur, J., & Verma, S. (2015). Transdermal patches of herbal drugs: An overview. International Journal of Research in Pharmacy and Chemistry, 5(1), 77–82.

22. Jain, N.K. (2012). Controlled and Novel Drug Delivery. CBS Publishers, New Delhi.

23. Gupta, R. & Kumar, A. (2021). Herbal transdermal patch technology: A review. Asian Journal of Research in Pharmaceutical Science, 11(2), 111–120.

24. Tiwari, A. & Mishra, R. (2019). Herbal actives for energy and stamina enhancement. Journal of Ethnopharmacology, 235, 210–223.

25. Singh, A., & Chauhan, R. (2022). Phytoconstituents as natural ergogenic aids. Journal of Applied Pharmaceutical Science, 12(4), 66–74.

26. Bhowmik, D. et al. (2012). Herbal remedies for energy boosting: A review. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 3(2), 589–603.

27. Dey, A. & De, J.N. (2020). Herbal adaptogens in physical endurance. Indian Journal of Natural Products and Resources, 11(3), 170–178.

28. Sharma, R., & Mehta, K. (2021). Herbal approaches to improve athletic performance. Journal of Pharmaceutical Innovation, 16(6), 849–861.

29. Singh, D., & Choudhary, A. (2023). Formulation of herbal transdermal patch for energy enhancement. International Journal of Research in Pharmaceutical Sciences, 14(2), 322–330.

30. Ali, J., & Gupta, R. (2016). Recent advances in transdermal delivery systems. Indian Journal of Pharmaceutical Education and Research, 50(4), S543–S551.

31. Park, J. et al. (2017). Caffeine absorption through transdermal patches. Drug Development and Industrial Pharmacy, 43(1), 72–80.

32. Sahoo, S.K., & Mishra, A. (2019). Herbal drugs for fatigue and stamina. Journal of Pharmacognosy and Phytotherapy, 11(6), 95–104.

33. Singh, R., & Kaur, G. (2019). Ginseng and its potential as a natural pre-workout. Journal of Herbal Pharmacotherapy, 8(2), 77–89.

34. Upreti, K., & Gupta, S. (2018). Role of green tea extract in enhancing metabolism. Phytotherapy Research, 32(7), 1221–1228.

35. Sharma, P., & Bhatt, R. (2021). Herbal pre-workout blends: A pharmacological perspective. International Journal of Herbal Medicine, 9(5), 88–94.

36. Kim, S. et al. (2020). Transdermal absorption of herbal compounds: Mechanistic insights. Frontiers in Pharmacology, 11, 987.

37. Patel, M., & Sharma, D. (2022). Herbal caffeine patches: A next-gen delivery route. Journal of Drug Delivery Science and Technology, 72, 103473.

38. Khanna, R., & Jain, S. (2023). Role of natural actives in sports supplements. Nutrition Research Reviews, 36(3), 271–288.

39. Li, W., & Lee, H. (2021). Penetration enhancers in herbal transdermal delivery. Drug Delivery and Translational Research, 11(2), 520–533.

40. Kumar, P., & Tiwari, S. (2020). Comparative evaluation of herbal and synthetic pre-workouts. International Journal of Pharmaceutical Sciences Review and Research, 65(1), 37–44.

41. Tripathi, K.D. (2021). Essentials of Medical Pharmacology, 9th ed. Jaypee Brothers, New Delhi.

42. World Health Organization (WHO). (2023). WHO Guidelines on Herbal Medicine Standardization. Geneva: WHO Press.