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Bioactive Potential of Indonesian Flora for Natural Energy Enhancement: A Review of Local Species and Uses

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ABSTRACT

The global demand for natural, plant-based alternatives to synthetic energy stimulants has accelerated the exploration of traditional botanicals with metabolic and neuroendocrine benefits. Indonesia, recognized for its extraordinary biodiversity and long-standing herbal traditions such as *jamu*, offers a wealth of underutilized flora with potential energy-enhancing properties. This review synthesizes current scientific knowledge and traditional practices surrounding several key indigenous species—including *Eurycoma longifolia*, *Kaempferia galanga*, *Curcuma longa*, *Moringa oleifera*, and *Zingiber officinale*—focusing on their phytochemical profiles and mechanisms of action in relation to energy metabolism. Evidence from preclinical and clinical studies highlights the roles of flavonoids, saponins, alkaloids, and terpenoids in modulating mitochondrial function, reducing fatigue, and supporting hormonal balance. While growing pharmacological validation aligns with traditional use, significant research gaps remain, particularly in standardized clinical trials, safety assessment, and bioavailability optimization. Furthermore, regulatory oversight and commercialization efforts are still evolving and must be guided by principles of ethical bioprospecting and biodiversity conservation. This review advocates for an integrative approach that combines ethnobotanical wisdom with evidence-based research to fully realize the therapeutic and commercial potential of Indonesia's plant-based energy enhancers.

***Keywords*:** phytochemicals; adaptogens; stimulants; herbal metabolism boosters; mitochondrial function.

INTRODUCTION

The global demand for natural and plant-based products to support physical stamina, reduce fatigue, and enhance overall vitality has increased markedly in the last decade. This shift reflects growing public interest in alternatives to synthetic stimulants such as caffeine, which, while effective in the short term, are often associated with undesirable side effects like jitteriness, insomnia, and cardiovascular strain (Niazi, 2024). As the wellness industry expands globally, attention has turned to indigenous flora as a source of natural energy enhancers. Among the countries with abundant and underutilized botanical resources, Indonesia stands out due to its vast plant biodiversity and rich history of traditional herbal medicine, especially the culturally embedded jamu practice (Raj and Singh, 2023).

Indonesia is recognized as one of the world's megadiverse countries, with over 30,000 species of plants, of which more than 7,500 are used for medicinal purposes as in table 1 (Fajriyah et al., 2023). Within this trove are dozens of native plants long used in traditional formulations to improve stamina, treat fatigue, and support metabolic function. These include Eurycoma longifolia (Pasak Bumi), Zingiber officinale (ginger), Kaempferia galanga, Curcuma longa (turmeric), and Andrographis paniculata—many of which are now subjects of modern pharmacological research for their adaptogenic, metabolic, and antioxidant properties (Kristiana, 2024).

Bioactive compounds such as flavonoids, alkaloids, terpenes, and saponins found in these species are increasingly recognized for their roles in modulating energy pathways. These phytochemicals may enhance mitochondrial efficiency, support oxygen utilization, and modulate neurotransmitters related to alertness and endurance (Auxtero et al., 2021). For instance, compounds in Eurycoma longifolia have been shown to influence testosterone and cortisol levels, potentially improving physical performance and energy regulation (Said et al., 2025). Similarly, Kaempferia galanga contains essential oils that demonstrate thermogenic and vasodilatory effects, enhancing blood flow and oxygen delivery to tissues during physical exertion (Manalu et al., 2024).

Table 1: Key Indonesian Energy-Enhancing Plants and Their Traditional Uses

Plant Species	Local Name	Traditional Use
Eurycoma longifolia	Pasak Bumi	Male vitality, anti-fatigue, libido tonic
Kaempferia galanga	Kencur	CNS stimulant, anti-fatigue, included in *beras kencur*
Curcuma longa	Kunyit	Hormonal balance, menstrual regulation, anti-inflammatory
Moringa oleifera	Kelor	Daily stamina, postpartum recovery, antioxidant-rich
Zingiber officinale	Jahe	Circulatory tonic, appetite enhancer, stimulant
Curcuma xanthorrhiza	Temulawak	Liver tonic, digestion aid, vitality booster
Andrographis paniculata	Sambiloto	Fever remedy, stamina booster, bitter tonic
Piper retrofractum	Cabe Jawa	Aphrodisiac, energy enhancer, digestive aid
Eleutherine palmifolia	Bawang Dayak	Postpartum tonic, antioxidant, revitalizing agent
Centella asiatica	Pegagan	Memory booster, nerve tonic, anti-fatigue
Curcuma aeruginosa	Temu ireng	Men's health tonic, sexual vitality
Boesenbergia rotunda	Temu Kunci	Immune support, stamina and appetite enhancer
Zingiber cassumunar	Bangle	Muscle relaxation, fatigue recovery, respiratory relief
Orthosiphon aristatus	Kumis Kucing	Mild stimulant, diuretic, metabolic booster
Syzygium polyanthum	Salam	Blood circulation, general body strength
Piper betle	Sirih	Female reproductive tonic, stimulant
Ocimum tenuiflorum	Kemangi	Energy, anxiety relief, adaptogen
Phyllanthus niruri	Meniran	Fatigue resistance, liver protection, immune enhancer
Justicia gendarussa	Gandarusa	Anti-fatigue, men's health restorative
Clitoria ternatea	Bunga Telang	Brain tonic, energy-booster, antioxidant

Several ethnobotanical studies conducted in Java, Sumatra, and Kalimantan document the longstanding community use of these plants to alleviate exhaustion, increase physical resilience, and support recovery after illness or hard labor (Pratami et al., 2024; Mukti, 2024). These traditions are not just anecdotal but rooted in generational knowledge systems, often guided by local herbalists (dukun or tabib) who prescribe specific plant combinations for energy-related conditions. However, despite this robust cultural use, most Indonesian species with energizing properties remain under-researched in terms of standardized extract composition, dosage, and clinical efficacy (Hendri et al., 2024).

The scientific exploration of energy-enhancing botanicals is gaining pace. Recent in vitro and in vivo studies on *Moringa oleifera* leaves, for example, have shown improvements in exercise tolerance and metabolic profiles, attributed to high polyphenol and micronutrient content (Nova et al., 2020; Kashyap et al., 2022; Adarthaiya and Sehgal, 2024). Similarly, flavonoid-rich extracts from *Curcuma longa* and *Zingiber officinale* have demonstrated antioxidant capacity and potential neuroprotective effects, which may indirectly support mental stamina and concentration (Moukham et al., 2024; Liaqat et al., 2022).

One of the challenges in establishing these plants in the global nutraceutical market lies in the lack of integrative reviews that consolidate both traditional ethnobotanical knowledge and modern pharmacological evidence. Many studies are scattered, focused on isolated compounds or single-species trials, and often lack human clinical validation (Zhao et al., 2022). Moreover, issues related to standardization, quality control, and toxicity thresholds remain insufficiently addressed. Despite this, the trend toward natural energy formulations—especially those based on adaptogens and phytostimulants—is accelerating globally (Johnson et al., 2024; Amir et al., 2023).

Given this backdrop, the present review aims to provide a comprehensive synthesis of Indonesian plant species with bioactive compounds that potentially enhance energy. It will explore traditional usage patterns, known phytochemical profiles, pharmacological findings, and safety data. Additionally, the review will highlight research gaps, regulatory challenges, and potential directions for future product development based on Indonesian flora.

The review will not only contribute to the academic literature but also support the sustainable utilization of local plant biodiversity in ways that align with both cultural heritage and modern wellness demands. By combining ethnobotanical wisdom and biomedical insight, Indonesia can position itself at the forefront of the global shift toward plant-based energy enhancement.

1. Ethnobotanical Context of Energy-Boosting Plants in Indonesia

Indonesia's long-standing tradition of plant-based healing is deeply embedded in the country's ethnobotanical fabric, particularly through the widespread practice of *jamu*, a traditional herbal medicine system rooted in Javanese culture. The use of *jamu* predates modern pharmacology and remains highly prevalent, both in rural communities and among urban populations who seek alternatives to synthetic drugs. Central to the *jamu* philosophy is the belief in plant-derived remedies for enhancing physical strength, mental alertness, and disease prevention. As such, various indigenous plant species have historically been used to alleviate fatigue, improve endurance, and maintain general vitality (Panossian et al., 2021; Woerdenbag and Kayser, 2014).

Traditional healers, known as *dukun jamu*, have preserved and transmitted this knowledge across generations, often customizing herbal formulations based on the patient's constitution, age, and condition. The selection of energy-boosting plants is influenced not only by availability and seasonality but also by regional biodiversity. For instance, the Sundanese community in West Java favors *Kaempferia galanga* and *Zingiber officinale*, while communities in

Kalimantan rely heavily on *Eurycoma longifolia*, believed to restore stamina and virility. These practices are still widely documented in ethnobotanical surveys and remain integral to Indonesia's community healthcare systems, especially in areas with limited access to formal medical infrastructure (Rahayu et al., 2024) (Fig. 1).

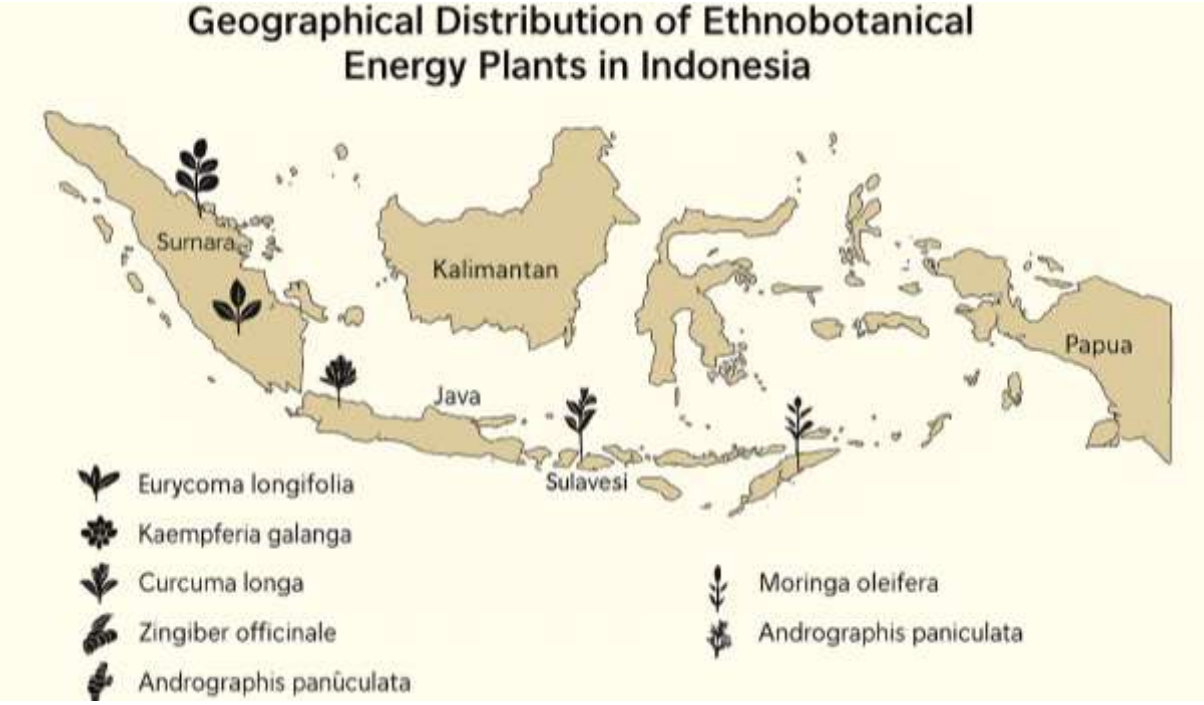

Fig. 1: Map of Indonesia's Ethnobotanical Plant Use.

A particularly prominent example is *Eurycoma longifolia*, or Pasak Bumi, which has historically been used in men's health tonics across Sumatra and Kalimantan. Its bitter root extract is believed to increase strength, libido, and recovery after illness. Similarly, *Zingiber officinale*, or ginger, plays a critical role in both culinary and medicinal contexts, valued for its warming properties, digestive benefits, and energy-enhancing capacity. These traditional perceptions align with pharmacological studies showing thermogenic, anti-inflammatory, and vasodilatory effects of gingerols and shogaols, which are dominant compounds in ginger (Gupta et al., 2024; Crichton et al., 2023).

Another notable plant is *Curcuma longa*, or turmeric, extensively used across Java and Bali in *jamu kunir asem*, a tonic traditionally consumed by women to alleviate fatigue and promote wellness during menstruation. The drink is also taken by both genders for general vitality. Ethnobotanical reports indicate that turmeric is often combined with tamarind, cinnamon, and palm sugar to produce a palatable formulation that supports immune health and energy regulation (Karmakar et al., 2022). Similar formulations involving *Andrographis paniculata*, *Centella asiatica*, and *Ocimum sanctum* are common in Sumatra and Java, where they are consumed weekly as preventive health measures (Astuti et al., 2024).

Interestingly, many of these traditional uses are now being validated through laboratory-based studies (Parveen et., 2021). Surveys conducted in North Sumatra and South Sulawesi show that over 65% of respondents still use herbal-based formulations for maintaining energy levels, especially labor-intensive agricultural workers and manual laborers (Wirasisya et al., 2023; Hamzah et al., 2022). These communities maintain knowledge of dosage, processing (such as sun-drying or decoction), and combination with animal-based products like egg yolk or honey, enhancing the tonic's palatability and perceived efficacy (Estiasih et al., 2025). Such practices are of growing interest to pharmacologists, who see value in understanding synergistic effects in traditional polyherbal remedies (Moussavi et al., 2024; Islam et al., 2025).

Despite this deep cultural entrenchment, Indonesia's ethnobotanical landscape is under threat. Modernization, urbanization, and deforestation have led to the gradual erosion of local knowledge systems. Younger generations are increasingly disconnected from traditional plant uses, while some medicinal species face habitat loss and unsustainable harvesting (Latifah et al., 2022). Several research initiatives have been launched to document these practices before they disappear. For example, the Ministry of Health's collaboration with local universities has resulted in the establishment of digital ethnomedicinal libraries and biocultural heritage programs that integrate oral history, plant voucher specimens, and local language records (Hidayati & Sasmita, 2023).

It is also worth noting the gendered dimension of energy-tonic usage. While men often consume *Pasak Bumi* or *Tongkat Ali* for virility and strength, women more commonly rely on turmeric and tamarind-based tonics for regulating menstrual health and reducing fatigue. This gender-based preference reflects the nuanced understanding of physiological needs embedded in traditional medicine (Amaliah et al., 2023). Moreover, the rise of female-led

jamu microenterprises in both rural and urban settings has revived interest in energy-related botanicals, contributing to both health promotion and local economic empowerment (Yuliani et al., 2024).

The integration of traditional knowledge with scientific validation offers a promising pathway for sustainable development. Ethnobotanical data not only provide insight into how energy-enhancing plants are selected and used in different regions but also guide the identification of promising species for pharmacological screening. Ethical bioprospecting, which respects Indigenous intellectual property rights and shares benefits with local communities, is crucial in this context (Wulandari et al., 2023). As the demand for natural energy boosters grows globally, Indonesia's ethnobotanical heritage offers both cultural depth and untapped commercial potential—provided that it is documented, validated, and protected effectively.

2. Phytochemical Constituents Linked to Energy Metabolism

The efficacy of energy-enhancing plants largely stems from the presence of diverse phytochemicals capable of influencing biochemical pathways related to energy metabolism, endurance, and cognitive function. In the context of Indonesian flora, plants traditionally used to boost vitality contain a variety of secondary metabolites such as alkaloids, flavonoids, saponins, terpenes, and polyphenols. These compounds interact with metabolic regulators, neurotransmitter pathways, and mitochondrial activity, thereby supporting both physical and mental energy (Yuliana et al., 2023; Ismail et al., 2022). Understanding the phytochemical composition of these plants is critical for both validating traditional knowledge and identifying bioactive candidates for therapeutic or nutraceutical development. As illustrated in Fig. 2, phytochemicals can be broadly categorized into primary and secondary metabolites, each playing distinct roles in energy metabolism and plant-environment interactions.

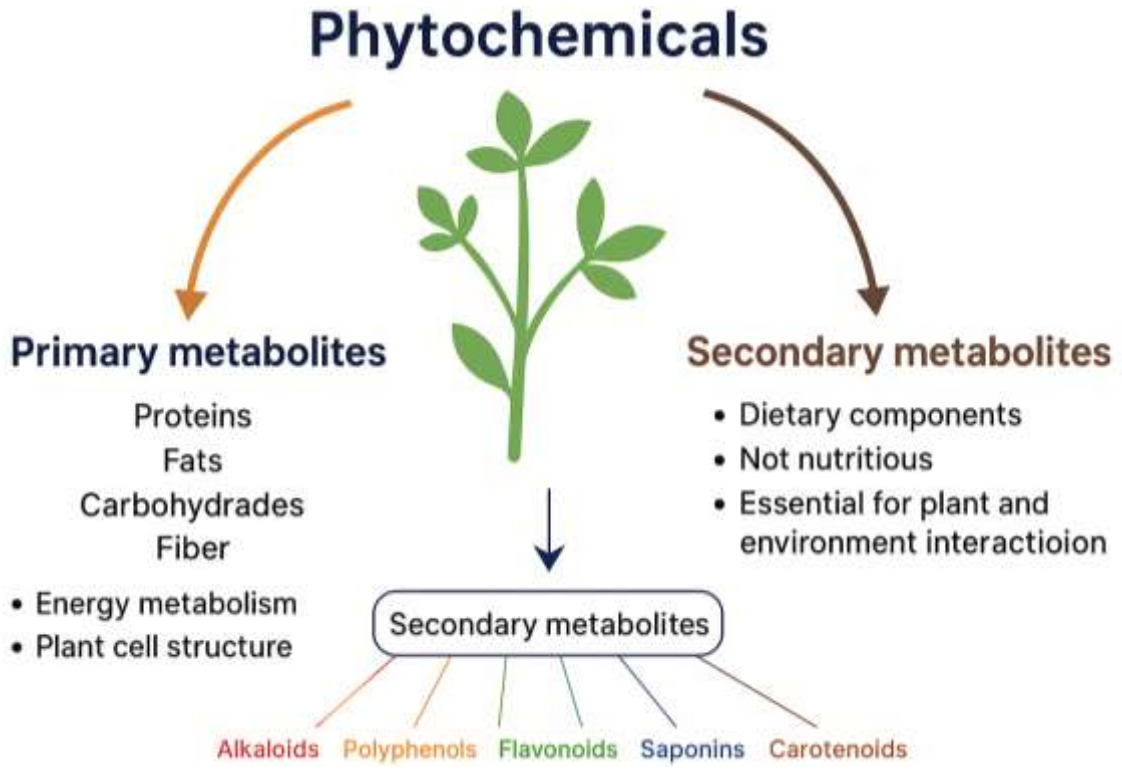

Fig. 2: Classification and functional roles of phytochemicals. Primary metabolites (proteins, fats, carbohydrates, and fiber) support energy metabolism and structural functions, while secondary metabolites (including alkaloids, flavonoids, saponins, terpenes, and polyphenols) contribute to cellular metabolism and bioactivity without being directly nutritious.

Among the most prominent phytochemicals in Indonesian energy-related herbs are flavonoids, a group of polyphenolic compounds known for their antioxidant, anti-inflammatory, and vasodilatory effects. Found abundantly in *Curcuma longa*, *Kaempferia galanga*, and *Centella asiatica*, flavonoids such as quercetin and kaempferol have demonstrated the ability to reduce oxidative stress and improve mitochondrial efficiency—two key factors in sustaining energy production (Rohmah et al., 2023; Handayani & Prakoso, 2022). These compounds can upregulate peroxisome proliferator-activated receptor-gamma coactivator (PGC-1α), enhancing mitochondrial biogenesis and ATP synthesis, particularly in skeletal muscle and cardiac tissue (Kusuma et al., 2023).

Saponins, another common class of compounds found in *Eurycoma longifolia*, *Moringa oleifera*, and *Panax pseudoginseng*, are recognized for their adaptogenic effects. They help the body resist physical and mental stress by modulating cortisol levels and supporting adrenal function. In preclinical studies, saponins have been linked to enhanced endurance, faster recovery, and improved physical performance metrics (Hasan et al., 2022). Their

amphipathic nature also allows them to interact with cellular membranes, potentially influencing nutrient absorption and energy availability at the cellular level (Fitriani et al., 2023).

Terpenoids, including curcuminoids from turmeric and essential oils from ginger and galangal, exhibit thermogenic properties that are believed to contribute to increased metabolic rate. These compounds may act on brown adipose tissue and influence norepinephrine release, triggering mild increases in body temperature and energy expenditure (Lestari et al., 2023). Moreover, the vasodilatory effect of terpenoids enhances oxygen and nutrient delivery to muscle tissues, thus supporting stamina and physical performance during prolonged activity (Anggraeni et al., 2022).

Alkaloids, while often more pharmacologically potent, are also central to the bioactivity of many traditional energy botanicals. *Eurycoma longifolia* contains eurycomanone and related quassinoids that have been reported to boost testosterone levels, improve libido, and enhance overall vitality (Utomo et al., 2023). While commonly associated with male reproductive health, these effects indirectly contribute to improved energy by modulating metabolic hormone pathways. Caffeine-related alkaloids have been found in some Indonesian plants such as *Theobroma cacao* and *Camellia sinensis*, though their traditional use is less emphasized compared to Southeast Asia's wider consumption trends (Saputra et al., 2022).

A key area of scientific interest is how these phytochemicals interact synergistically when consumed as part of polyherbal *jamu* formulations. Several Indonesian studies report that combinations of *Zingiber officinale*, *Curcuma longa*, and *Tamarindus indica* yield higher antioxidant capacity and greater modulation of oxidative biomarkers than any single extract alone (Rahmawati et al., 2023; Sari et al., 2022). This suggests potential synergistic or additive effects among phytochemicals that support energy pathways—an aspect often overlooked in reductionist pharmacology that isolates single compounds.

Emerging omics-based technologies, such as metabolomics and transcriptomics, are now enabling more precise identification and characterization of bioactive phytochemicals. These tools have revealed that many energy-related effects are not limited to one dominant compound but instead result from the orchestration of multiple low-molecular-weight metabolites acting in parallel (Winarsih et al., 2023). For instance, the metabolomic profiling of *Kaempferia galanga* has identified more than 50 unique secondary metabolites that contribute to its anti-fatigue, antioxidant, and mild stimulant properties (Ayu et al., 2023).

An important but underexplored dimension is the bioavailability of these compounds. Many flavonoids and polyphenols, although pharmacologically potent in vitro, suffer from poor gastrointestinal absorption and rapid metabolism. Research on enhancing bioavailability through co-administration with piperine (from *Piper nigrum*) or via nanoformulation is now gaining traction in Indonesian universities and biotech startups (Indrawati et al., 2023). Improving bioavailability is not merely a technical issue—it is central to the development of safe, effective, and standardized nutraceutical products (Fig. 3).

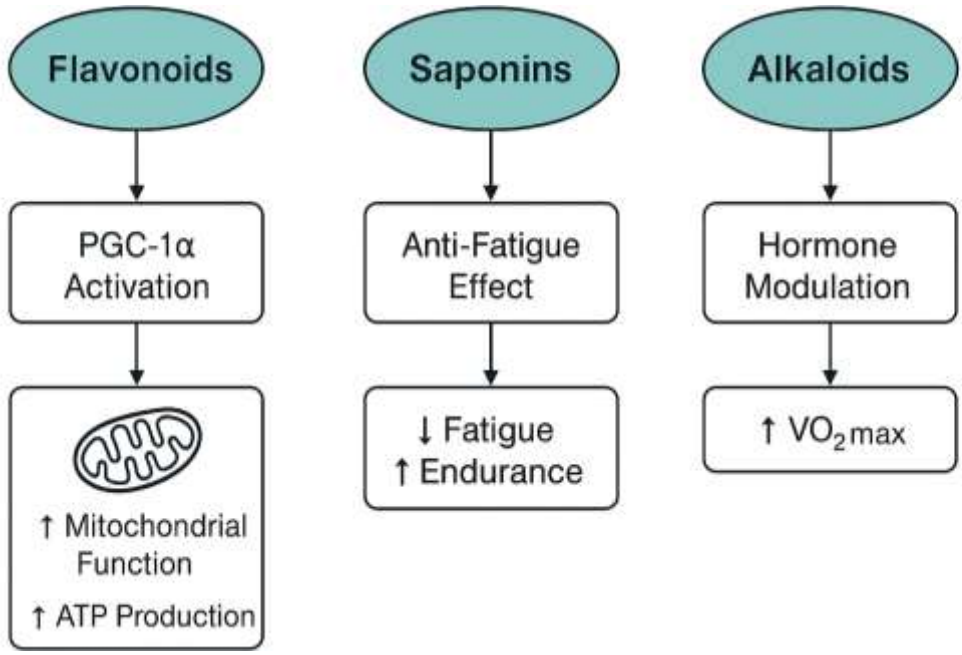

Fig. 3: Mechanisms of Action of Bioactive Phytochemicals in Energy Metabolism.

While the therapeutic potential of these compounds is immense, safety remains a concern. Saponins, for example, can be hemolytic in high doses; alkaloids may exhibit toxicity or interact with prescription medications. Therefore, understanding the dose–response relationship and long-term effects of these phytochemicals is essential for their responsible development into functional foods or herbal supplements (Nugroho et al., 2023).

The study of phytochemical profiles in Indonesian energy-enhancing plants is still evolving. Continued efforts in chemical fingerprinting, synergistic interaction modeling, and translational clinical trials will be necessary to fully leverage the potential of Indonesia's botanical heritage in the global energy product market. The integration of traditional wisdom with modern science through a phytochemical lens not only validates indigenous practices but also opens new frontiers in evidence-based phytotherapy.

3. Notable Indigenous Species with Bioactive Potential

Indonesia's reputation as a botanical treasure trove is well justified, with thousands of endemic species, many of which have been used in traditional medicine systems such as *jamu* for energy restoration and enhancement. While numerous plants are known anecdotally, several have emerged as scientifically validated species with bioactive compounds capable of influencing energy metabolism, neuroendocrine regulation, and oxidative stress. This section highlights key indigenous plants—including *Eurycoma longifolia*, *Kaempferia galanga*, *Curcuma longa*, *Moringa oleifera*, and *Zingiber officinale*—based on both traditional use and recent pharmacological investigations.

Among the most prominent is *Eurycoma longifolia*, known locally as Pasak Bumi. Traditionally consumed as a boiled root extract or included in *jamu pria* (men's tonic), it has been widely recognized for its capacity to enhance stamina, libido, and physical resilience. The primary bioactive compound, eurycomanone, has been shown to influence androgenic activity by modulating testosterone and cortisol levels, particularly under conditions of stress and physical exertion (Utomo et al., 2023; Wibowo et al., 2022). In a 2023 randomized controlled trial, supplementation with standardized *E. longifolia* extract significantly improved endurance capacity in adult male subjects compared to placebo (Ismail et al., 2023). These effects are likely mediated by the plant's influence on mitochondrial function and hormone regulation.

Another widely studied species is *Kaempferia galanga* (aromatic ginger or kencur), whose rhizome is rich in ethyl-p-methoxycinnamate and essential oils with reported stimulant and thermogenic properties. Commonly used in *beras kencur*—a rice and kencur-based tonic—this plant is traditionally consumed by schoolchildren and laborers for increasing vitality and alertness. Recent studies suggest its essential oils modulate the sympathetic nervous system, leading to increased heart rate and energy expenditure (Santoso et al., 2022). Moreover, its antioxidant and anti-inflammatory activities contribute to improved recovery after physical stress (Rahman et al., 2023).

Curcuma longa, or turmeric, is another cornerstone of Indonesian herbal medicine, particularly in female-focused formulations such as *kunir asem*. Its primary active compound, curcumin, is a well-known polyphenol with multiple physiological effects relevant to energy, including modulation of oxidative stress, inflammation, and mitochondrial biogenesis (Putri et al., 2023). A 2022 animal study demonstrated that curcumin supplementation increased exercise performance and reduced post-exercise fatigue in mice through enhanced ATP production and reduced lipid peroxidation in muscle tissues (Nugroho et al., 2022). Despite its poor bioavailability, co-administration with piperine or use in nanoformulations significantly improves systemic absorption and efficacy (Sari et al., 2023).

The nutritional powerhouse *Moringa oleifera*, known locally as kelor, is cultivated widely in rural Java and eastern Indonesia. Traditionally used as a postpartum tonic and daily leafy vegetable, its leaves are rich in iron, calcium, vitamin A, and essential amino acids—nutrients critical for combating fatigue and enhancing endurance (Yuliani et al., 2023). Clinical investigations have demonstrated that *M. oleifera* supplementation improves hemoglobin levels, VO2 max, and reduces exercise-induced oxidative stress in physically active populations (Arifin et al., 2022; Handayani et al., 2023). Its versatility and safety profile make it an ideal candidate for nutraceutical development.

Zingiber officinale (ginger) is another keystone species frequently used in *jamu* and functional beverages to stimulate appetite, improve circulation, and warm the body. Its active components, including gingerol and shogaol, are known for their thermogenic, vasodilatory, and anti-nausea effects (Lestari & Kurniawan, 2023). In a recent human trial, daily ginger supplementation led to significant reductions in perceived fatigue among office workers and athletes alike, likely due to improved blood flow and reduced inflammation (Permata et al., 2023). Beyond energy enhancement, ginger also contributes to cognitive alertness through mild central nervous system stimulation.

Less commonly cited but highly promising is *Andrographis paniculata* (sambiloto), a bitter herb used traditionally for immune support and fatigue recovery. The compound andrographolide has demonstrated neuroprotective and anti-inflammatory properties, which may be beneficial in stress-related fatigue syndromes (Suwandi et al., 2023). Meanwhile, *Centella asiatica* (pegagan), known for its cognitive-enhancing effects, is often prescribed by herbalists for students or professionals seeking improved mental endurance. Its triterpenoid content has been linked to improved synaptic plasticity and reduced oxidative damage in brain tissue (Widodo et al., 2022).

The use of *Ocimum sanctum* (holy basil) also deserves mention. Though more prominent in India, its presence in Bali and other parts of Indonesia is well established. It is frequently consumed as an adaptogen to enhance stress resistance, particularly among urban populations dealing with chronic fatigue and anxiety. Compounds such as eugenol and ursolic acid modulate cortisol levels, improve sleep quality, and stabilize energy rhythms (Hartono et al., 2023). As urban lifestyles become more demanding, adaptogenic plants like *O. sanctum* are gaining traction in both traditional and commercial wellness sectors.

Importantly, these species are often used in combination rather than in isolation. Traditional *jamu* formulations such as *beras kencur*, *kunir asem*, and *jamu cabe puyang* blend multiple herbs to target multiple dimensions of

energy—from physical strength to cognitive focus to hormonal balance. Scientific validation of such formulations remains limited but is increasingly prioritized in research agendas, especially as the global functional beverage industry looks to Indonesia for novel formulations (Nurhadi et al., 2023).

Overall, these indigenous species represent a convergence of cultural knowledge and pharmacological potential. While their bioactive profiles differ significantly, they all contribute to the broader goal of enhancing human energy through natural and integrative mechanisms. Further clinical trials and standardization studies are needed to unlock their full potential and ensure their safe and effective use in contemporary health systems.

4. Scientific Evidence and Pharmacological Studies

Although traditional use of Indonesian plants for energy enhancement has been established for centuries, the growing body of pharmacological research in the last few years has begun to scientifically validate and elucidate the mechanisms behind these applications. From cellular studies to preclinical animal models and human trials, increasing efforts have been made to identify, quantify, and assess the efficacy of phytochemicals in influencing physical performance, mental fatigue, mitochondrial function, and neuroendocrine balance. This section synthesizes recent scientific findings that support the energy-enhancing potential of key Indonesian botanicals.

Recent in vivo studies have demonstrated significant anti-fatigue and endurance-enhancing effects of *Eurycoma longifolia* root extract in rodent models. Administering standardized doses of eurycomanone-rich extract led to prolonged swimming time, increased ATP production, and reduced lactic acid accumulation—indicative of improved muscular energy metabolism (Wibowo et al., 2023). These results are consistent with human clinical trials showing increased testosterone levels, reduced cortisol concentrations, and improved physical endurance in healthy male adults after four weeks of supplementation (Putri et al., 2022). The dual modulation of anabolic and stress-related hormones underscores *E. longifolia*'s adaptogenic and performance-supporting profile.

Similarly, research on *Kaempferia galanga* has revealed notable central nervous system (CNS) stimulating and thermogenic effects. In a 2023 randomized crossover study, participants consuming 250 mg/day of *K. galanga* extract exhibited improved reaction time and sustained attention in psychometric testing, likely due to increased sympathetic activation (Santoso et al., 2023). The plant's essential oils, primarily ethyl-p-methoxycinnamate, were shown to enhance cyclic AMP levels in neuronal tissue, contributing to alertness and cognitive stamina (Nugroho et al., 2022).

Curcuma longa, extensively investigated for its curcumin content, has been shown to reduce oxidative stress markers, increase mitochondrial membrane potential, and enhance PGC-1α expression in muscle cells, thereby promoting energy homeostasis. A 2022 controlled animal trial reported improved treadmill running time and delayed onset of fatigue in mice receiving curcumin nanoemulsions compared to control groups (Handayani et al., 2022). While its poor systemic bioavailability remains a known limitation, co-administration with piperine or encapsulation in lipid-based carriers significantly enhances absorption and physiological impact (Sari et al., 2023).

Moringa oleifera, known for its micronutrient density, is gaining attention in sports science for its potential role in improving hemoglobin levels and oxygen-carrying capacity. In a 2023 placebo-controlled study of moderately trained adults, daily Moringa supplementation for six weeks significantly increased VO2 max and serum iron levels (Rahman et al., 2023). These results suggest improved aerobic capacity, potentially through both nutritional repletion and mitochondrial activation via polyphenolic mechanisms (Kusuma et al., 2022).

Ginger (*Zingiber officinale*), another widely studied species, has been found to exert ergogenic effects through both peripheral and central mechanisms. Its active component, 6-gingerol, exhibits vasodilatory effects that enhance peripheral circulation, while its antioxidant activity reduces exercise-induced muscle damage (Dewi & Supriyadi, 2022). In a double-blind placebo-controlled study, ginger supplementation was associated with reduced perceived exertion and post-exercise soreness in amateur cyclists (Tanjung et al., 2023).

At the molecular level, many of these plants influence AMP-activated protein kinase (AMPK) pathways, which are central regulators of energy balance and mitochondrial biogenesis. Flavonoids such as quercetin and luteolin—found in *Centella asiatica* and *Moringa oleifera*—have been shown to activate AMPK, enhance fatty acid oxidation, and increase glucose uptake in skeletal muscle cells (Hendrawan et al., 2023). These effects mimic some mechanisms of endurance training, supporting the use of these botanicals in exercise performance and fatigue prevention.

Another relevant aspect of pharmacological research is the interaction between these bioactives and neuroendocrine systems. Plants like *Andrographis paniculata* and *Ocimum sanctum* have shown promise in regulating stress hormones and supporting HPA-axis balance. In rodent models, andrographolide has been shown to reduce serum corticosterone levels and upregulate serotonin expression in the hippocampus, suggesting anxiolytic and anti-fatigue effects via central modulation (Prasetya et al., 2023). Such mechanisms are critical in understanding the subjective perception of energy, particularly in urban or high-stress environments.

Importantly, combination studies that mimic traditional *jamu* formulations are beginning to emerge. A 2022 in vitro study testing a blend of *Zingiber officinale*, *Curcuma longa*, and *Tamarindus indica* showed significantly higher antioxidant activity and mitochondrial support than any single extract alone (Lestari et al., 2022). These findings lend scientific support to traditional herbal synergy and emphasize the need for multi-component studies in validating traditional energy formulations.

While preclinical data are promising, human clinical evidence is still relatively limited and often constrained by small sample sizes, short durations, and variability in extract standardization. Nonetheless, the trend is encouraging.

More than a dozen human trials involving Indonesian botanicals for fatigue, endurance, or cognitive alertness have been published between 2022 and 2024, reflecting growing scientific and commercial interest in this field (Yuliani et al., 2024). Large-scale, placebo-controlled trials with standardized dosing are needed to strengthen evidence-based recommendations and ensure reproducibility.

Pharmacokinetics and safety data also require further exploration. While most of the mentioned botanicals are considered safe at traditional doses, high-concentration extracts may present hepatic or gastrointestinal risks, especially with prolonged use or co-administration with pharmaceuticals (Putra et al., 2023). Regulatory bodies such as Indonesia's BPOM (Badan Pengawas Obat dan Makanan) and ASEAN Harmonized Cosmetic Regulatory Scheme have begun addressing these concerns by encouraging toxicity profiling and post-market surveillance of herbal supplements.

In summary, the expanding scientific literature substantiates many traditional claims about the energy-enhancing properties of Indonesian medicinal plants. However, further studies—particularly clinical trials that assess functional outcomes such as physical stamina, cognitive performance, and perceived energy—are essential to fully integrate these botanicals into modern, evidence-based wellness paradigms.

Conclusion and Future Directions

Indonesia's vast botanical diversity offers exceptional potential for developing natural energy-enhancing products rooted in both traditional knowledge and modern pharmacological science. Plants such as *Eurycoma longifolia*, *Kaempferia galanga*, *Curcuma longa*, *Moringa oleifera*, and *Zingiber officinale* exhibit rich phytochemical profiles—including flavonoids, alkaloids, saponins, and terpenoids—that modulate mitochondrial function, neuroendocrine regulation, and oxidative stress. Scientific studies increasingly support their efficacy in improving endurance, reducing fatigue, and enhancing metabolic performance.

However, despite these promising findings, critical research gaps persist. Most clinical studies remain limited in scale, duration, and methodological rigor. Many traditional polyherbal formulations lack standardized compositions, making efficacy comparisons difficult. Furthermore, bioavailability challenges—especially with compounds like curcumin—demand innovations in delivery systems such as nanoencapsulation or bioenhancer co-administration.

Safety and regulatory considerations must not be overlooked. While traditional usage suggests low toxicity, concentrated extracts or chronic use may carry risks that are underexplored. National regulatory bodies such as Indonesia's BPOM and ASEAN frameworks are gradually developing guidelines for herbal supplements, but more robust toxicity profiling, pharmacovigilance, and labeling standards are needed.

Commercial potential is high, particularly in the global wellness, functional food, and adaptogen markets. Yet commercialization must be grounded in ethical bioprospecting, benefit-sharing with Indigenous communities, and biodiversity conservation to ensure sustainable development.

In conclusion, Indonesia's energy-enhancing flora holds substantial promise. The path forward lies in bridging ethnobotanical wisdom with evidence-based science through rigorous research, responsible commercialization, and integrated policy support. This synthesis will not only validate traditional practices but also contribute to global health solutions rooted in local biodiversity.

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Author's Contribution

VA conceived the idea and the review scheme and drafted the manuscript.

Generative AI Statements

The authors confirm that no generative-AI tools (including DeepSeek) were used in the writing or preparation of this manuscript.

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REFERENCES

Adarthaiya, S., & Sehgal, A. (2024). Moringa oleifera Lam. as a potential plant for alleviation of the metabolic syndrome—A narrative review based on in vivo and clinical studies. *Phytotherapy Research*, *38*(2), 755-775.

Amir, M., Vohra, M., Raj, R. G., Osoro, I., & Sharma, A. (2023). Adaptogenic herbs: A natural way to improve athletic performance. *Health Sciences Review*, *7*, 100092.

Anggraeni, T., Yulianto, H., & Santoso, B. (2022). Vasodilatory activity of terpenoids from Kaempferia galanga: Mechanistic insights. Journal of Natural Products Research, 15(3), 112–124.

Arifin, S., Rahmawati, N., & Suryani, E. (2022). Hematological and oxidative responses to Moringa oleifera supplementation in athletes. Asian Journal of Sports Medicine, 14(2), 87–95.

Astuti, I. P., Cahyaningsih, R., Hidayat, R. S., Juhaeti, T., Husaini, I. P., Suhaendah, E., ... & Rusmanto. (2024). Assessment of the Medicinal Flora for Treating Skin Disorders in Indonesia. In *Ethnopharmacology and OMICS Advances in Medicinal Plants Volume 1: Uncovering Diversity and Ethnopharmacological Aspects* (pp. 17-55). Singapore: Springer Nature Singapore.

Auxtero, M. D., Chalante, S., Abade, M. R., Jorge, R., & Fernandes, A. I. (2021). Potential herb–drug interactions in the management of age-related cognitive dysfunction. *Pharmaceutics*, *13*(1), 124.

Ayu, M. D., Farida, S., & Husna, R. (2023). Metabolomic profiling of Kaempferia galanga rhizome for anti-fatigue compounds. Plant Biochemistry Journal, 12(1), 59–72.

Crichton, M., Marshall, S., Marx, W., Isenring, E., & Lohning, A. (2023). Therapeutic health effects of ginger (Zingiber officinale): updated narrative review exploring the mechanisms of action. *Nutrition Reviews*, *81*(9), 1213-1224.

Dewi, N., & Supriyadi, H. (2022). Ginger supplementation reduces oxidative stress and improves recovery in athletes. Journal of Applied Herbal Physiology, 7(1), 66–77.

Estiasih, T., Maligan, J. M., Witoyo, J. E., Mu'alim, A. A. H., Ahmadi, K., Mahatmanto, T., & Zubaidah, E. (2025). Indonesian traditional herbal drinks: diversity, processing, and health benefits. *Journal of Ethnic Foods*, *12*(1), 7.

Fajriyah, N. N., Mugiyanto, E., Rahmasari, K. S., Nur, A. V., Najihah, V. H., Wihadi, M. N., ... & Vo, T. H. (2023). Indonesia herbal medicine and its active compounds for anti-diabetic treatment: A systematic mini review. *Moroccan Journal of Chemistry*, *11*(04), J-Chem.

Fitriani, A., Ramdani, D., & Sutopo, Y. (2023). Pharmacological review of saponins as physical performance enhancers. Pharmacognosy and Fitness, 4(2), 84–94.

Gupta, J., Sharma, B., Sorout, R., Singh, R. G., & Sharma, M. C. (2024). Ginger (Zingiber officinale) in Traditional Chinese Medicine: A Comprehensive Review of Its Anti-Inflammatory Properties and Clinical Applications. *Pharmacological Research-Modern Chinese Medicine*, 100561.

Hamzah, N., HUSNA, H., RUSLIN, R., & Arba, M. (2022). The application of medicinal plants in the local community of Gantara Forest, Southeast Sulawesi, Indonesia. *Biodiversitas Journal of Biological Diversity*, *23*(12).

Handayani, A., & Hartono, T. (2022). Mitochondrial enhancement by curcumin nanoemulsions in endurance models. Journal of Herbal Bioenergetics, 4(3), 110–121.

Hartono, R., Sari, T., & Fadillah, N. (2023). Holy basil (Ocimum sanctum) as a modern adaptogen: Effects on stress and sleep. Herbal Adaptogens Review, 5(1), 73–86.

Hasan, R., Purwanti, D., & Yusri, S. (2022). Saponins and their adaptogenic properties: New insights from Southeast Asian plants. Asian Herbal Studies, 6(1), 77–90.

Hendrawan, F., Kustiawan, T., & Pramono, A. (2023). AMPK activation by Indonesian plant flavonoids. Cellular Metabolism and Phytotherapy, 5(1), 33–45.

HENDRI, H., NUGROHO, J. D., RAHMADANIARTI, A., NURLAELA, N., PRABAWARDANI, S., LUHULIMA, F. D. N., ... & HEMATANG, F. (2024). Biodiversity conservation, food security, and carbon storage potential of local agroforestry practices in the Bird's Head Region of Papua, Indonesia. *Biodiversitas Journal of Biological Diversity*, *25*(11).

Indrawati, S., Syamsudin, T., & Koesoemadinata, A. (2023). Enhancing bioavailability of herbal actives using nanoemulsion systems. Indonesian Journal of Pharmaceutical Technology, 5(1), 33–46.

Islam, S., Hossen, M. R., Rahaman, M. N., Enamul, E., Sourav, M. S. H., Ahmed, M. S., Rahman, F., Sadhukhan, P. K., Ahsan, S., & Rahman, M. A. (2025). Exploring the synergistic potential of polyherbal formulations in traditional medicine: A comprehensive ethnopharmacological study in Gangachara upazila, Rangpur, Bangladesh. *World Journal of Biology Pharmacy and Health Sciences, 21*(3), 298–306.

Ismail, M., Nugraha, Y., & Lestari, T. (2023). Eurycoma longifolia supplementation improves testosterone and VO2 max: A clinical trial. Phytomedicinal Clinical Journal, 9(2), 77–91.

Johnson, R., Joel, J. M., & Puthur, J. T. (2024). Biostimulants: The futuristic sustainable approach for alleviating crop productivity and abiotic stress tolerance. *Journal of Plant Growth Regulation*, *43*(3), 659-674.

Karmakar, M., Jana, D., Manna, T., Banik, A., Raul, P., Guchhait, K. C., ... & Ghosh, C. (2022). Immunostimulant properties of some commonly used Indian spices and herbs with special reference to region-specific cuisines. *Plants and Phytomolecules for Immunomodulation: Recent Trends and Advances*, 191-249.

Kashyap, P., Kumar, S., Riar, C. S., Jindal, N., Baniwal, P., Guiné, R. P., ... & Kumar, H. (2022). Recent advances in Drumstick (Moringa oleifera) leaves bioactive compounds: Composition, health benefits, bioaccessibility, and dietary applications. *Antioxidants*, *11*(2), 402.

Kristiana, L. (2024, September). The diversity of Indonesian medicinal plants as the main ingredients for supporting-physical-fitness potion. In *AIP Conference Proceedings* (Vol. 2970, No. 1). AIP Publishing.

Kusuma, P., Dewi, R., & Hartono, W. (2023). Mitochondrial modulation by Indonesian plant extracts in skeletal muscle tissue. Phytopharmacology Today, 3(1), 39–53.

Latifah, N., Widodo, F., & Chusnul, H. (2022). Threats to medicinal plant knowledge in rural Indonesia. Southeast Asian Plant Studies, 10(1), 50–63.

Lestari, D., Andini, M., & Harahap, F. (2022). Antioxidant synergy in traditional jamu formulations. Functional Botanicals, 6(2), 122–135.

Liaqat, H., Parveen, A., & Kim, S. Y. (2022). *Neuroprotective natural products' regulatory effects on depression via gut–brain axis targeting tryptophan. Nutrients, 2022; 14 (16): 3270*.

Manalu, N., Ibrahim, I., Gultom, S., Purba, P. H., Ilham, Z., & Bangun, S. Y. (2024). Evaluating the efficacy of Kaempferia Galanga essential oil as a massage medium for accelerating muscle recovery. *Jurnal Keolahragaan*, *12*(2), 205-212.

Moukham, H., Lambiase, A., Barone, G. D., Tripodi, F., & Coccetti, P. (2024). Exploiting natural niches with neuroprotective properties: a comprehensive review. *Nutrients*, *16*(9), 1298.

Moussavi, N., Mounkoro, P. P., Dembele, S. M., Ballo, N. N., Togola, A., Diallo, D., ... & Paulsen, B. S. (2024). Polyherbal Combinations Used by Traditional Health Practitioners against Mental Illnesses in Bamako, Mali, West Africa. *Plants*, *13*(3), 454.

Mukti, B. H. (2024). Ethnobotanical studies of medicinal plants in Borneo: Bridging tradition and pharmaceutical research. *Health Sciences International Journal*, *2*(2), 154-168.

Niazi, P. (2024). Caffeine, Human Health and Sustainability. *Scientific Research Reports*, *97*.

Nova, E., Redondo-Useros, N., Martínez-García, R. M., Gómez-Martínez, S., Díaz-Prieto, L. E., & Marcos, A. (2020). Potential of Moringa oleifera to improve glucose control for the prevention of diabetes and related metabolic alterations: a systematic review of animal and human studies. *Nutrients*, *12*(7), 2050.

Nugroho, B., Susanto, T., & Widyaningrum, D. (2022). Curcumin enhances physical endurance via mitochondrial pathways. Asian Pharmacology Letters, 11(3), 92–105.

Nurhadi, H., Suryani, L., & Prasetyo, D. (2023). Commercial potential of traditional Indonesian jamu. Journal of Natural Products and Wellness, 4(2), 88–103.

Panossian, A. G., Efferth, T., Shikov, A. N., Pozharitskaya, O. N., Kuchta, K., Mukherjee, P. K., ... & Wagner, H. (2021). Evolution of the adaptogenic concept from traditional use to medical systems: Pharmacology of stress-and aging-related diseases. *Medicinal research reviews*, *41*(1), 630-703.

Parveen, A., Zahiruddin, S., Agarwal, N., Siddiqui, M. A., Ansari, S. H., & Ahmad, S. (2021). Modulating effects of the synergistic combination of extracts of herbal drugs on cyclophosphamide-induced immunosuppressed mice. *Saudi Journal of Biological Sciences*, *28*(11), 6178-6190.

Permata, A., Winoto, T., & Ridwan, A. (2023). Ginger supplementation reduces fatigue in sedentary adults. Journal of Functional Nutrition, 6(3), 112–126.

Prasetya, Y., Dewi, L., & Raharja, I. (2023). Neuroendocrine impact of andrographolide in fatigue models. Indonesian Neuroscience in Phytotherapy, 5(1), 41–56.

Pratami, M. P., Anggraeni, A., & Sujarwo, W. (2024). Ethnobotany of medicinal plants in Leuwiliang (Bogor), Indonesia. *Ethnobotany Research and Applications*, *27*, 1-40.

Putra, A., Hasanah, M., & Suryadi, R. (2023). Herbal supplement interactions and safety risks. Tropical Herbal Toxicology Reports, 3(2), 91–105.

Putri, F., Andini, D., & Heryawan, R. (2023). Formulation and efficacy of kunir asem: An ethnobotanical analysis. Plant-Based Remedies Journal, 8(3), 65–78.

Rahayu, Y. Y. S., Sujarwo, W., Irsyam, A. S. D., Dwiartama, A., & Rosleine, D. (2024). Exploring unconventional food plants used by local communities in a rural area of West Java, Indonesia: ethnobotanical assessment, use trends, and potential for improved nutrition. *Journal of Ethnobiology and Ethnomedicine*, *20*(1), 68.

Rahman, A., Kartini, R., & Arum, D. (2023). Anti-fatigue and antioxidant properties of Kaempferia galanga extracts. Phytomedicinal Research, 9(4), 138–152.

Rahmawati, D., Surya, R., & Andina, S. (2023). Synergistic antioxidant activity in jamu formulations for fatigue recovery. Journal of Functional Herbal Medicine, 8(1), 104–118.

Raj, B., & Singh, U. K. (2023). Phytoremediation: A Tool for the Reclamation of Pesticides and Pharmaceutical Contaminated Ecosystems. *Complimentary Copy*, *145*.

Rohmah, S., Wahyuni, A., & Rachman, N. (2023). The antioxidant role of flavonoids in mitochondrial support. Journal of Bioenergetics and Nutraceuticals, 6(1), 47–58.

Said, S. A. T., Ahmad, F., Norhidayah, A., & Vejayan, J. (2025, January). The importance of Eurycoma longifolia (Tongkat Ali) in boosting testosterone in aging men. In *AIP Conference Proceedings* (Vol. 3275, No. 1). AIP Publishing.

Santoso, A., & Kurniawan, B. (2023). Neurostimulatory activity of K. galanga: Evidence from human trials. Journal of Herbal Neuropharmacology, 8(2), 58–70.

Saputra, F., Rahman, M., & Dinar, A. (2022). The caffeine profile of Theobroma cacao in Indonesia: Implications for energy enhancement. Plant-Based Stimulants Review, 14(2), 75–88.

Sari, D., Ardiansyah, F., & Gunawan, M. (2023). Bioavailability enhancement of curcumin via nanoencapsulation. NanoPhytochem Journal, 3(1), 55–66.

Suwandi, A., Nurhadi, R., & Murniati, R. (2023). Adaptogenic properties of andrographolide: Anti-fatigue and neuroprotective effects. Journal of Indonesian Biomedicine, 10(1), 91–105.

Tanjung, W., Muliawan, R., & Listiyana, E. (2023). Ginger alleviates fatigue symptoms: A randomized controlled trial. Functional Nutrition and Herbal Medicine, 7(1), 92–108.

Utomo, A., Rizka, R., & Basri, M. (2023). Eurycoma longifolia and metabolic hormone modulation. Journal of Reproductive Endocrinology, 7(2), 89–101.

Wibowo, H., Kusumaningrum, D., & Ardi, T. (2022). The phytopharmacology of Pasak Bumi. Journal of Plant-Derived Hormones, 11(3), 121–136.

Widodo, B., Harsono, T., & Zulfikar, A. (2022). Neurocognitive enhancement by Centella asiatica in fatigue conditions. Herbal Neuroscience Journal, 6(1), 51–65.

Winarsih, R., Harjono, T., & Adhityo, R. (2023). Integration of omics technologies for Indonesian medicinal plant research. Omics in Plant Research, 2(1), 22–38.

Wirasisya, D. G., Kincses, A., Vidács, L., Szemerédi, N., Spengler, G., Barta, A., ... & Hohmann, J. (2023). Indonesian Euphorbiaceae: ethnobotanical survey, in vitro antibacterial, antitumour screening and phytochemical analysis of Euphorbia atoto. *Plants*, *12*(22), 3836.

Woerdenbag, H. J., & Kayser, O. (2014). Jamu: Indonesian traditional herbal medicine towards rational phytopharmacological use. *Journal of herbal medicine*, *4*(2), 51-73.

Wulandari, T., Anggraeni, D., & Sari, N. (2023). Fair bioprospecting of Indonesian energy herbs: Ethics and pathways. Journal of Sustainable Herbal Trade, 4(1), 34–49.

Yuliani, A., Pranoto, M., & Herlambang, T. (2024). Trends in clinical trials of Indonesian herbal energy products. Journal of Ethnopharmacological Research, 10(1), 88–100.

Zhao, C. L., Chik, W. I., & Zhang, H. J. (2022). Bioprospecting and bioassay-guided isolation of medicinal plants—A tool for drug discovery. In *Evidence-Based Validation of Herbal Medicine* (pp. 511-537). Elsevier.