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REVIEW ARTICLE

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Medicinal uses, prevalence, and mechanism of action of Nigerian plants with psychoactive properties

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ABSTRACT

Nigeria's rich biodiversity hosts various psychoactive plants that have been pivotal in traditional medicine and cultural practices. This review examines the medicinal uses, prevalence, and mechanisms of action of prominent Nigerian psychoactive plants, including *Datura stramonium* and *Carica papaya.* These plants, utilized for centuries, exhibit pharmacological activities such as anti-inflammatory, analgesic, and neuroactive effects, driven by their bioactive compounds like alkaloids and flavonoids. Traditional applications range from treating ailments like asthma, depression, and infections to roles in spiritual rituals. However, the recreational use and neurotoxic potential of these plants have raised public health concerns, particularly regarding substance abuse. This review highlights the need for a deeper understanding of their therapeutic benefits and risks, emphasizing the importance of culturally sensitive and evidence-based research. Insights from this study aim to inform clinical practice and shape policies to promote the safe and effective use of these plants in modern medicine.

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Introdu ction

Medicinal plants have long been central to the development of traditional and modern therapeutic practices, serving as invaluable resources for disease prevention and treatment [1]. Globally, approximately 80% of the population in developing countries rely on plant-based remedies for primary healthcare, highlighting the relevance of ethnobotanical knowledge in addressing health challenges [2]. Nigeria, one of the most biodiverse regions in Africa, is home to an extensive array of medicinal plants, many of which have been traditionally used for centuries. These plants play a vital role in both traditional health systems and contemporary biomedical research, forming a bridge between cultural heritage and modern pharmacology [3].

Among Nigeria's numerous medicinal plants, *Datura stramonium* and *Carica papaya* stand out for their distinct biochemical profiles and therapeutic applications [4]. These plants are deeply embedded in Nigerian ethnomedicine, where their usage spans diverse ailments, including respiratory disorders, fever, pain, and infections. Their prevalence in traditional healing underscores their significance in addressing both chronic and acute conditions, particularly in rural and resource-limited settings.

Traditional medicine in Nigeria is characterized by a holistic approach to health, integrating physical, spiritual, and emotional well-being [5]. Medicinal

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plants form the backbone of this system, with healers relying on empirical knowledge passed down through generations. The use of plants such as *D. stramonium* and *C. papaya* reflects a deep understanding of their therapeutic properties, even in the absence of scientific validation [4]. This knowledge is often community-specific, tailored to the ecological and cultural contexts in which the plants grow and are utilized.

Nigeria's biodiversity provides a vast repository of bioactive compounds, which are increasingly being studied for their pharmacological properties [6]. *Datura stramonium*, for instance, contains tropane alkaloids such as atropine, scopolamine, and hyoscyamine, which have been shown to act on the central and peripheral nervous systems [7]. These compounds provide therapeutic benefits for conditions such as asthma, muscle spasms, and pain management. However, their narrow therapeutic index also makes them a source of significant concern, with potential toxic effects when misused.

On the other hand, *C. papaya* is celebrated for its safety and versatility. Its bioactive components, including papain, alkaloids, and flavonoids, exhibit a range of therapeutic activities, such as anti-inflammatory, antioxidant, and anticancer effects [8]. The plant is widely used in Nigeria to treat conditions such as malaria, dengue fever, and digestive disorders. Its availability and relative safety have made it a staple in traditional medicine, even as its pharmacological properties are increasingly validated by modern research [8].

The resurgence of interest in plant-based therapies globally has positioned plants like *D. stramonium* and *C. papaya* as focal points for scientific inquiry [9]. Researchers are exploring their biochemical mechanisms, therapeutic potential, and safety profiles, aiming to integrate traditional knowledge with evidence-based medicine. For example, *D. stramonium*'s alkaloids are being studied for their potential to develop anticholinergic drugs, while *C. papaya*'s compounds are being investigated for their applications in oncology and infectious disease management [10].

Despite these promising developments, several challenges remain. The toxicity associated with *D. stramonium* limits its safe application, while the recreational misuse of its psychoactive components poses public health risks [11]. Similarly, while *C. papaya* is generally considered safe, unregulated usage and inconsistent dosing in traditional practices can lead to variable outcomes. Addressing these challenges requires a concerted effort to bridge the gap between traditional medicine and modern pharmacology.

This review seeks to provide in-depth analyses of the medicinal uses, pharmacological properties, and biochemical mechanisms of *D. stramonium* and *C. papaya*. By examining their historical significance, current applications, and future potential, this review aims to highlight the therapeutic opportunities and challenges associated with these plants. Understanding their role in traditional Nigerian medicine and their transition into modern healthcare systems will provide valuable insights for researchers, clinicians, and policymakers alike.

Significance of Nigerian medicinal plants

Nigeria is recognized as one of the most biodiverse regions in Africa, with a rich array of flora used in traditional medicine. Medicinal plants are an integral part of the cultural and health practices in Nigeria, providing remedies for a wide range of ailments. The significance of these plants extends beyond their therapeutic potential, as they also contribute to the preservation of cultural heritage, support local economies, and serve as a foundation for modern drug discovery [6].

Ethnopharmacological relevance

Traditional medicine in Nigeria often relies on the collective knowledge of local communities. Medicinal plants like *D. stramonium* and *C. papaya* hold profound ethnopharmacological relevance [12].

1. *Datura stramonium* has been traditionally used for its potent anticholinergic and hallucinogenic properties [7]. Its applications in treating respiratory conditions, pain, and neurological disorders underscore its versatility. However, its cultural significance is equally noteworthy, as it has been used in spiritual ceremonies and as a sedative in psychotic episodes.
2. *Carica papaya* is widely regarded as a multipurpose plant, offering both nutritional and medicinal benefits [8]. Its leaves, seeds, fruit, and roots have been used in traditional remedies for fever, malaria, digestive disorders, and wound healing. Additionally, its accessibility and affordability make it a staple in rural health practices.

Biological diversity and health benefits

Nigeria's tropical and subtropical climates provide ideal conditions for the growth of a variety of

medicinal plants. These plants are reservoirs of bioactive compounds with diverse biological activities, including anti-inflammatory, antimicrobial, antioxidant, and neuropharmacological properties [7].

1. Bioactive Compounds of *D. stramonium*: The plant's therapeutic effects are attributed to tropane alkaloids such as atropine, scopolamine, and hyoscyamine, which interact with the central nervous system [7]. These compounds are valuable in treating conditions like asthma, motion sickness, and gastrointestinal disorders. However, their toxicity and potential for misuse highlight the need for cautious application.
2. Bioactive Compounds of *C. papaya*: Papain, a proteolytic enzyme, is one of the key compounds in the plant, contributing to its digestive and wound-healing properties [8]. Other bioactive constituents, such as flavonoids and alkaloids, offer antioxidant and anticancer benefits, making it a versatile plant in traditional and modern medicine.

Socioeconomic impact

The use of medicinal plants in Nigeria extends beyond health, offering economic opportunities for local communities. Cultivating and trading plants like *C. papaya* support livelihoods, particularly in rural areas. Conversely, *D. stramonium*, while not as commercially cultivated, is often harvested in the wild for medicinal or ritualistic purposes [13]. However, the unregulated use of these plants poses challenges, including potential overharvesting and public health risks associated with toxicity or misuse.

Research and development potential

Medicinal plants in Nigeria remain an underutilized resource in global pharmacology. The wealth of traditional knowledge surrounding plants like *D. stramonium* and *C. papaya* provides a foundation for scientific research aimed at discovering new drugs and therapies.

1. For *D. stramonium*, ongoing research is focused on isolating its alkaloids for safe pharmaceutical use while minimizing its toxic effects [9].
2. In the case of *C. papaya*, its bioactive compounds are being investigated for their role in oncology, infectious disease management, and metabolic health [9].

The integration of traditional medicine with modern scientific approaches offers an opportunity to enhance healthcare delivery while preserving Nigeria's cultural heritage. However, achieving this requires robust regulatory frameworks, systematic research, and investment in the sustainable use of medicinal plants.

Ethnobotanical and cultural relevance

The deep-rooted use of medicinal plants in Nigeria highlights their ethnobotanical and cultural importance [2]. Both *D. stramonium* and *C. papaya* hold unique positions in traditional Nigerian medicine, reflecting a blend of spiritual practices, health interventions, and cultural traditions that have been passed down through generations.

Datura stramonium: A plant of dual significance

Datura stramonium is revered and feared in equal measure within Nigerian ethnomedicine. Known locally as Gegemu (Yoruba) or Zakami (Hausa), its historical usage spans across therapeutic and ritualistic domains:

1. Therapeutic Use: Traditional healers have used *D. stramonium* to manage asthma, relieve muscle spasms, and sedate psychotic patients [7]. The plant's anticholinergic properties, derived from its tropane alkaloids, make it effective for respiratory and neurological conditions.
2. Spiritual and Ritual Use: The plant has also been employed in spiritual ceremonies to induce altered states of consciousness. Its hallucinogenic effects, when used with caution, were believed to aid in divination and communication with ancestral spirits [7].

However, its psychoactive properties have made it susceptible to recreational misuse. In some communities, *D. stramonium* seeds and leaves are brewed or smoked for their mind-altering effects, posing significant risks to users due to their high toxicity [7].

Carica papaya: A cultural staple

Unlike *D. stramonium*, *C. papaya* is celebrated primarily for its versatility and safety in traditional medicine [14]. Known as Ibepe (Yoruba) or Gwanda (Hausa), it is a common household remedy for a variety of ailments:

1. Everyday Medicinal Use: The leaves are boiled and consumed to manage fever and malaria, while the fruit is eaten to improve digestion

and prevent constipation. Papaya seeds are recognized for their antibacterial properties and are often used to treat gastrointestinal infections [14].

2. Ritual and Traditional Practices: While *C. papaya* is not commonly used for spiritual purposes, it has symbolic significance in some rituals, where it is used to cleanse and heal during ceremonial practices [14].

The widespread availability and cultural acceptance of *C. papaya* have made it a cornerstone of Nigerian traditional medicine, bridging the gap between everyday health practices and specialized treatments [14].

Shared cultural impact

Both plants reflect the adaptability and ingenuity of Nigerian traditional medicine:

1. *Datura stramonium* exemplifies the cautious use of potent natural compounds, requiring precise knowledge to balance its therapeutic and toxic effects.
2. *Carica papaya* symbolizes accessibility and multipurpose utility, offering both nutritional and medicinal benefits to all socioeconomic classes [8] (Figure 2).

Despite their differences, these plants underscore the broader cultural practice of harnessing nature for health and well-being. Their use not only highlights the richness of Nigerian ethnobotanical knowledge but also emphasizes the importance of preserving this cultural heritage in the face of modernization and global health challenges.

Biochemical composition

***Datura stramonium* (jimson weed)**

Datura stramonium is a plant renowned for its potent biochemical properties, primarily driven by the presence of tropane alkaloids. These compounds include scopolamine, hyoscyamine, and atropine, which exhibit strong anticholinergic effects [15]. These alkaloids work by competitively inhibiting muscarinic acetylcholine receptors, thereby disrupting the parasympathetic nervous system. The effects include pupil dilation (mydriasis), tachycardia, reduced glandular secretions, and smooth muscle relaxation. These properties have been exploited for their therapeutic potential in conditions such as asthma, muscle spasms, and certain types of pain, though their use requires strict regulation due to toxicity.

In addition to alkaloids, *Datura* contains flavonoids with notable antioxidant activities. These flavonoids may reduce oxidative stress by scavenging reactive oxygen species (ROS), potentially modulating inflammatory responses. Furthermore, the plant's glycosides are believed to contribute to its anti-inflammatory and bronchodilatory properties, which have been traditionally used to alleviate respiratory conditions [15] (Figure 1).

However, *D. stramonium* poses significant risks. Ingesting high doses can lead to severe neurotoxicity, including hallucinations, delirium, seizures, and even fatal respiratory depression. This toxicity stems from the same alkaloids responsible for its therapeutic actions, highlighting the narrow margin between medicinal and toxic doses. Contemporary research on *Datura* focuses on its potential applications in controlled environments, such as pre-anesthetic medicine, but its use is otherwise heavily restricted [16].

***Carica papaya* (papaya)**

Carica papaya is a tropical plant widely valued for its nutritional and medicinal properties, underpinned by its diverse biochemical composition [8]. A prominent component is papain, a proteolytic enzyme found in the fruit and latex. Papain facilitates protein digestion, making it a valuable remedy for indigestion and bloating. Its ability to debride necrotic tissue also finds applications in wound healing and treating burns. Another enzyme, chymopapain, has shown promise in treating herniated

Figure 1. *Datura stramonium* [15].

Figure 2. *Carica papaya* male flowering (a) and female fruity (b) [8].

discs by breaking down proteins that contribute to inflammation and pain.

Papaya is rich in vitamins, including Vitamin C, which supports immune function and provides strong antioxidant defence [17]. It also contains Vitamin A (from beta-carotene), essential for vision, skin health, and immunity, and Vitamin E, which works synergistically with Vitamin C to neutralize free radicals and protect cells from oxidative damage. These vitamins contribute to reducing the risk of chronic diseases, including cardiovascular conditions [8].

The carotenoids in papaya, particularly lycopene, exhibit potent antioxidant activity. Lycopene has been studied extensively for its role in cancer prevention, especially prostate cancer, due to its ability to modulate gene expression and reduce oxidative damage. In addition to carotenoids, papaya contains flavonoids such as quercetin and kaempferol, which further enhance its antioxidant and anti-inflammatory properties. These compounds protect against cellular damage, reduce inflammation, and may play a role in cancer prevention [18].

Papaya's nutritional profile is complemented by dietary fiber, which aids in digestive health by promoting bowel regularity and supporting healthy gut microbiota. It also contains essential minerals like potassium, calcium, and magnesium, which contribute to cardiovascular health, bone strength, and muscle function [18].

Unlike *D. stramonium*, *C. papaya* is generally safe for consumption and widely used in traditional medicine and modern health practices [19]. Its mechanisms of action span enzymatic digestion, immune system support, antioxidant defense, and anti-inflammatory effects. Ongoing research continues to uncover its potential in treating chronic diseases and improving overall health outcomes.

General morphological description and taxonomic classification of selected plants

Datura stramonium (jimson weed)

Taxonomic classification:

- Kingdom: Plantae
- Phylum: Tracheophyta
- Class: Magnoliopsida
- Order: Solanales
- Family: Solanaceae
- Genus: Datura
- Species: *Datura stramonium* L.

Morphological Description: *Datura stramonium* is an annual, herbaceous plant known for its psychoactive and medicinal properties. It can grow up to 1.5 m tall, with a branching, green, or purple-tinged stem covered in fine hairs. The leaves are alternate, ovate, and irregularly toothed, measuring about 7–20 cm in length [5]. The flowers are trumpet-shaped, white to pale violet, and typically bloom at night, emitting a strong fragrance. The fruit is a spiny capsule containing numerous small, black seeds. All parts of the plant contain tropane alkaloids, making it highly toxic if ingested [5].

Carica papaya (papaya)

Taxonomic classification:

- Kingdom: Plantae
- Phylum: Tracheophyta
- Class: Magnoliopsida
- Order: Brassicales

- Family: Caricaceae
- Genus: Carica
- Species: *Carica papaya* L.

Morphological Description: *Carica papaya* is a fast-growing, short-lived, herbaceous tree that can reach up to 10 m in height. It has a single, unbranched trunk marked with leaf scars. The large, palmate leaves are deeply lobed, measuring up to 60 cm in diameter, and are attached to long petioles [9]. The plant is dioecious or hermaphroditic, with yellowish-white flowers that develop into large, oval, or round fruits. The fruit, commonly known as papaya, has a thin green to yellow-orange skin, soft orange pulp, and numerous black seeds enclosed in a gelatinous sheath. The latex from the unripe fruit contains the enzyme papain, widely used in medicine and food processing [9].

Objective of the review

This review aims to provide a comprehensive biochemical analysis of *D. stramonium* and *C. papaya*, focusing on their medicinal uses, pharmacological properties, and mechanisms of action. By exploring their ethnobotanical significance and modern applications, the review seeks to highlight their potential contributions to contemporary medicine and public health, emphasizing their therapeutic benefits, possible risks, and the need for further scientific validation to support their safe and effective integration into modern healthcare practices.

Medicinal Uses of Nigerian Plants with Psychoactive Properties

Datura stramonium L. as a potential medicinal tree: An overview

Plants have always played a major role in the treatment of human traumas and diseases worldwide. The demand for medicinal plants is increasing in both developed and developing countries due to the growing recognition of natural products [21]. *Datura stramonium* is a widespread annual plant from the Solanaceae family. It is one of the widely well-known folklore medicinal herbs. It is a wild-growing flowering plant and was investigated as a local source for tropane alkaloids which contain a methylated nitrogen atom (N-CH3) and include the anti-cholinergic drugs atropine, and scopolamine [22]. From ancient civilizations, it was traditionally used for religious visionary purposes throughout the world and used by witchcraft in medieval Europe.

The god lord Shiva was known to smoke *Cannabis* and *Datura*. People still provide the small thorn apple during festivals and special days as offerings in Shiva icons at temples. An extract made from the leaves is taken orally for the treatment of asthma and sinus infections, and stripped bark is applied externally to treat swellings, burns, and ulcers. The incidence of *D. stramonium* poisoning is sporadic with a cluster of poisoning cases in the 1990s and 2000s, The United States media reported some cases occurring mostly among adolescents and young adults who either died or became seriously ill after ingesting *D. stramonium*, often due to its toxic tropane alkaloids, which can cause severe anticholinergic poisoning, hallucinations, respiratory distress, and, in extreme cases, fatal outcomes [22].

Some medicinal uses of the plant are its anti-inflammatory properties of all parts of the plant, stimulation of the central nervous system, respiratory decongestion, treatment of dental and skin infections, alopecia, and the treatment of toothache [23].

It is a hallucinogenic plant that causes serious poisoning. Over consumption of any part of the plant may result in a severe anticholinergic reaction that may lead to toxicity and occasionally cause diagnostic difficulties. Cases of poisoning have been reported after eating the berries. Death may occur from heart failure after ingesting 125 seeds, because the seeds contain the highest concentration and have a rapid onset of action, thus may be potentially useful as an alternative to atropine for the treatment of the muscarinic symptoms of organophosphate (OP) toxicity and some central anticholinergic effects. The wide distribution, the strong toxicity, and the potential for occurrence in foodstuffs are responsible for the numerous incidents in humans [24]. *Datura* genus is distributed over tropical and warm temperate regions of the world. About ten species of *Datura* are found, of which *Datura* anoxia and *D. stramonium* are the most important drug plants. *Datura* has long been known as a medicinal plant and as a plant hallucinogen all over the world. Pre-historic uses of *Datura* in medicinal and ceremonial rituals could be observed in aboriginal in the Indian sub-continent. The therapeutic activities of most plants are due to the presence of one or more of such components as alkaloids, tannins, saponins, and cardiac glycosides [25]. The phytochemical screening revealed the presence of saponins, tannins, steroids, alkaloids, flavonoids, phenols, and glycosides. Atropine and

scopolamine are competitive antagonists of muscarinic cholinergic receptors and are central nervous system depressants. All parts of the plant are toxic, but the highest amount of alkaloids is contained in the ripe seeds. Many cases of accidental poisoning by *D. stramonium* have been reported when these plants were eaten accidentally.

Ethanomedical uses of *D. Stramonium*

Plant-derived drugs come into use in modern medicine through the use of plant material as indigenous cures in folklore or traditional systems of medicine [26]. The leaves of *D. stramonium* are used for the relief of headaches and vapors of leaf infusion are used to relieve the pain of rheumatism and gout. The smoke from the burning leaf is inhaled for the relief of asthma and bronchitis. European remedy of *D. stramonium* for hemorrhoid is to steam the part over boiling water containing leaf. The fruit juice is applied to the scalp for the treatment of falling hair and dandruff. It is also applied to smooth painful wounds and sores. Seeds and leaves of the plant were used to sedate hysterical and psychotic patients, and also to treat insomnia. The plant was used as a hallucinogenic drug [27].

Datura stramonium is also used to relax the smooth muscles of the bronchial tube and asthmatic bronchial spasm. It was reported that it was used internally to treat madness, epilepsy, and depression. Externally it forms the basis of ointment for burns and rheumatism. It is also used in the treatment of Parkinson's disease and hemorrhoids. Its leaves, applied after roasting, are useful in relieving pain. The bitter narcotic plant relieves pain and encourages the healing process. The seeds of the plant are medicinally the most active. Externally, the plant is also used as a poultice in treating fistulas, abscesses wounds, and severe neuralgia. Scopolamine is also found in the plant, which makes it a potent cholinergic-blocki hallucinogen that has been used to calm schizoid patients [28]. Its leaves, containing hyoscyamine and atropine, can be used as an immensely powerful mind-altering drug.

The seeds of *Datura* are analgesic, anthelmintic, and anti-inflammatory and as such, they are used in the treatment of stomach and intestinal pain that results from worm infestation, toothache, and fever from inflammation [29]. The juice of its fruit is applied to the scalp, to treat dandruff and falling hair. The growing plant works as an insect repellent, which protects neighboring plants from insects. *Datura stramonium* is mostly used as anthelmintics and antiparasitic in Marche, Abruzzo, and Latium. Records of continued use of the plant in these sectors were collected from farmers and shepherds (mostly old people).

Traditional uses of *Carica Papaya*

The whole *C. papaya* has unique medicinal uses. Every part of the plant can be used to cure disease. The plant is divided into leaves, fruit, seeds, peel, roots, and latex [30].

Leaves: This has numerous benefits. It can be used to cure many fatal diseases. In some parts of Asia the leaves of papaya are steamed and eaten like spinach. The leaves of *C. papaya* can be used for the treatment of fever.

Dengue Fever: The juice from the leaves helps to increase the count of white blood cells and platelets, it also helps to normalize clotting and repairs the liver [31]. The extract of papaya juice was given to patients with dengue fever within 24 hours the platelet count and white blood cell count raise to normal level. The secondary metabolite of this plant makes up a vast repository compound. The aqueous extract exhibits potential activity against dengue fever.

Cancer Cell Growth Inhibition: *C. papaya* leaf extract has demonstrated the inhibition of cancer cell growth [32]. It boosts the production of key signaling molecules called Th1-type cytokines, these cytokines help to regulate the immune system. Additional benefits of papaya leaves are [32]:

i. It can act as an acne medicine
ii. It increases appetite in patients with low appetite
iii. It helps to ease menstrual pain.
iv. It can help to relieve nausea

Fruits: It is a rich source of nutrients such as vitamins, minerals, and dietary fiber. Danielone is a phytoalexin found in papaya. This compound shows high anti-fungal activity. The fruit can be used as:

i. Laxative
ii. As cure for indigestion
iii. Helps to prevent heart attack and stroke [33].

Fresh ripe papaya should be taken every morning to prevent indigestion and constipation, and it also helps to improve appetite [33]. The fruit of *C. papaya* can be used to treat mouth ulcers, gum disease, and toothache.

Seeds: They are black with a very sharp and spicy taste. They can sometimes replace black pepper. Papaya seeds are very pungent and have more medicinal value compared to other parts of the tree. Papaya seeds are antibacterial and very effective against Staphylococcus infections. The seeds help

to protect the kidneys from toxins and prevent kidney failure, also helping in the removal of piles and typhoid. Dried papaya seeds have more nutritional value. Grinding these seeds and adding it to meals will help add enzymes to the diet.

Peel: Peel from papaya is often used as cosmetic agents and it can be used as home remedies [34]. Papaya peel can act as sunscreen and a soothing agent, it helps fight dandruff and it can be used as a muscle relaxant.

Roots: The juice from the root is used to ease urine problems in some Asian countries. A decoction formed by boiling the roots of the papaya can be used to cure dyspepsia.

Pharmalogical Properties

Pharmacological properties of D. stramonium

Antiasthmatic activity

Datura stramonium in asthma treatment and possible effects on prenatal development were studied. Exposure of the foetus to *D. stramonium* when a mother uses it for asthma, will cause a continuous release of acetylcholine, resulting in the desensitization of nicotinic receptors, this could ultimately result in permanent damage to the foetus [35]. Therefore, we conclude that this African herbal remedy should be used with caution during pregnancy.

Anticholinergic activity

The alkaloids found in *D. stramonium,* are organic esters used clinically as anticholinergic agents [29]. Jimson weed has been reported as a drug of abuse and has been involved in the accidental poisoning of humans and animals. Symptoms of acute jimson weed poisoning included dryness of the mouth and extreme thirst, dryness of the skin, pupil dilation and impaired vision, urinary retention, rapid heartbeat, confusion, restlessness, hallucinations, and loss of consciousness. The anticholinergic syndrome results from the inhibition of central and peripheral muscarinic neurotransmission [36].

Acaricidal, repellent, and oviposition deterrent properties

The ethanol extracts obtained from both leaf and seed in *D. stramonium (Solanaceae)* were investigated for acaricidal, repellent, and oviposition deterrent properties against adult two-spotted spider mites (T. *urticae* Koch) (*Acari: Tetranychidae*) under laboratory conditions. Leaf and seed extracts, which were applied in 167.25 and 145.75 g/l concentrations, respectively (using a Petri leaf disc-spray tower method), caused 98% and 25% mortality among spider mite adults after 48 hours. These results suggest that *D. stramonium* extracts could be used to manage the two-spotted spider mite.

Antimicrobial activity

The methanol extract of *D. stramonium* showed activity against Gram-positive bacteria in a dose-dependent manner [37]. Little or no antimicrobial activity was found against *Escherichia coli* and *Psuedomonas aeruginosa* [22]. The antimicrobial activity of the combined crude ethanolic extract of *D. stramonium, Terminalia arjuna,* and *Withania somnifera* was evaluated using the cup plate diffusion method to assess its antibacterial and antifungal properties. The results demonstrated significant inhibition against various bacterial strains, including *Staphylococcus aureus, Bacillus subtilis, E. coli,* and *Klebsiella pneumoniae*, as well as antifungal activity against *Candida albicans*. The extracts were subjected to screening to detect potential antimicrobial activity against *S. aureus*, *B. subtilis*, *E. coli, K. pneumoniae, Micrococcus luteus*, and *C. albicans*, and their efficacy was compared to the standard antibiotic Ciprofloxacin. The results revealed that the extracts exhibited significant antimicrobial activity, particularly against *S. aureus* and *B. subtilis*, with inhibition zones comparable to Ciprofloxacin. However, the extracts showed moderate activity against *E. coli* and *K. pneumoniae*, while *M. luteus* and *C. albicans* displayed lower susceptibility, suggesting a varying degree of effectiveness depending on the microbial strain [23].

Anticancer activity

An integrated approach is needed to manage cancer using the growing body of knowledge gained through scientific developments. Thousands of herbal and traditional compounds are being screened worldwide to validate their uses as anti-cancerous drugs [38]. *Datura stramonium* in a therapeutic dose of 0.05–0.10 g was used to cure cancer. It is likely unsafe, as it may cause vomiting, hypertension, and loss of consciousness, potentially leading to coma. Additionally, it may interact with anticholinergic drugs, enhancing their effects and increasing the risk of severe adverse reactions [38].

Anti-inflammatory activity

Coriandrum sativum (C. sativum), D. stramonium, and Azadirachta indica (A. indica) are traditionally

used in the treatment of inflammation [39]. Ethanolic extracts of fruits of *C. sativum*, and leaves of *D. stramonium*. Ethanolic extracts of fruits of *C. sativum*, leaves of *D. stramonium,* and *A. indica* were subjected to preliminary screening for anti-inflammatory activity in albino rats. All ethanolic extracts exhibited significant anti-inflammatory activity comparable to the standard drug diclofenac sodium against the carrageenan-induced rat paw edema method [40]. Among these plants, *A. indica* showed maximum anti-inflammatory activity per hour.

Larvicidal and mosquito-repellent activities: Ethanolic extracts of leaves of *D. stramonium* were evaluated for larvicidal and mosquito-repellent activities against *Aedes aegypti*, *Anopheles stephensi,* and *Culex quinquefasciatus* [41]. The LD50 values for larvicidal activity were found to be 86.25, 16.07, and 6.25 mg/l against *A. aegypti*, *A. stephensi,* and *C. quinquefasciatus,* respectively. The ethanolic leaves extract of *D. stramonium* provided complete protection time (mosquito repellance) of 2.7, 71.7, and 117.7 minutes against *A. aegypti*, *A. stephensi,* and *C. quinquefasciatus* at higher concentration (1%).

Pesticide toxicity: Extract of *D. stramonium* was effective in countering the toxicity of the cypermethrin pesticide toxicity.

Antifungal activity

Antifungal activity of a concoction brewed from *D. stramonium, Calotropis gigantea, A. indica* (neem), and cow manure (T1) followed by methanol-water (70/30 v/v) extracts of *D. stramonium, C. gigantea* and *A. indica* [28], T2 against *Fusarium mangiferae*. The study proved that the concoction-brewed compost T1 is effective, inexpensive, easy to prepare, and constitutes a sustainable and eco-friendly approach to control floral malformation in mango when it is sprayed at the bud break stage and again at the fruit set stage.

Vibriocidal activity: A simple *in vitro* screening assay was employed for the standard strain of *Vibrio cholerae*, 12 isolates of *V. cholerae* non-O1, and *Vibrio parahaemolyticus* [42]. Aqueous and organic solvent extracts of different parts of the plants were investigated by using the disk diffusion method. Extracts from 16 medicinal plants were selected on account of the reported traditional uses for the treatment of cholera and gastrointestinal diseases, and they were assayed for vibriocidal activities [43]. The results indicated that *Lawsonia inermis, Saraca indica, Syzygium cumini, Terminalia belerica, Allium sativum,* and *D. stramonium* served as broad-spectrum vibriocidal agents.

Biopesticide with antifungal activity: Leaf extracts obtained from eight plants (*Vitex negundo, Polyathia longifolia, Vinca rosea, W. somnifera, L. inermis, Adhotoda zylanica, D. stramonium,* and *Hyptis suaveolens*) showed antifungal activities against the fungal pathogen (*Fusarium oxysporum*) of wilt of pigeon pea (C*ajanus cajan L.*) [44]. Both *in vivo* and *in vitro* higher concentrations of ethanoic leaf extracts of all eight plants showed complete inhibition in linear growth and sporulation in test fungi.

Protective agent in severe OP toxicity: Treatment of patients following an OP exposure can deplete a hospital's entire supply of atropine [45]. Given the possibility of multiple severe exposures after a terrorist attack using OP nerve agents, there exists a need for either greater atropine stores or the development of alternative antidotes. Jimsonweed (*D. stramonium*) contains atropine and other anticholinergic compounds and is common and readily available [46]. It is used recreationally for its central anticholinergic effects and is easy to be made into an extract by boiling the crushed seeds. The extract has a rapid onset of effects and may be useful for the treatment of OP poisoning. Pre-treatment with *D. stramonium* extracts significantly increases survival following severe dichlorvos exposure.

Pharmaceutical activities of Carica papaya Linn.

Antioxidant activity

The important and major group of the phytochemicals present in papaya can be considered as a natural source of antioxidants [47]. These antioxidants when present in low concentrations compared to the oxidizable substrate are significantly said to delay or prevent the process of oxidation caused by free radicals. Phenols, carotenoids, and traditional antioxidant vitamins C and E also contribute to antioxidant activity, which plays an important role in total antioxidant activity. Antioxidants also aid in decreasing DNA damage and diminishing lipid peroxidation, and finally, it boosts up our body's immune system and also function in inhibiting the malignant transformation of cells for further damage [48].

Antibacterial activity

Carica papaya has shown to exhibit antibacterial activity, i.e. papaya has a positive effect against bacterial infection. It was reported that the use of

C. Papaya had benefited in treating the wounds hence it improved the efficient action of phagocytic cells in destroying bacteria [49]. The extracts of *C. papaya* from the skin, pulp, and seeds of both ripen and unripened had potential antibacterial activity against the various bacteria including *E. coli, Enterobacter cloacace, B. subtilis, Bacillus cereus, Proteus vulgaris, Salmonella typhi, P. aeruginosa,* and *Shigella flaexner* [50].

Anti-helminthic activity

Helminthiasis is a disease that is caused by worms such as pinworm, roundworm, or tapeworm [51]. These worms reside in the gastrointestinal tract and also burrow and spread into the liver, producing harmful effects on the host and causing blood loss while secreting toxins that result in severely damaging the organs.

The extracts of papaya plants including the seed extract have been used traditionally for the treatment of helminthiasis, the important and major proteolytic enzyme that is considered to digest nematode cuticles [52]. The enzymes because of their lowest toxicity have been traditionally used as medicine to treat gastrointestinal discomforts caused by nematodes. The Aqueous extracts of the seeds from papaya significantly showed anti-helminthic activity against helminths such as *Ascaris lumbricoides* and *Ascaris diagalli*.

Anti-inflammatory activity

The major proteolytic enzymes such as papain and chymopapain and also antioxidant nutrients from papaya with Vitamin C, E, and Beta carotene have significantly reduced the severity conditions of asthma, osteoarthritis, and rheumatoid arthritis [53]. The reaction of living cells or tissue to injury or infection/irritation/infiltration is said to be process Inflammation [54].

Anticancer activity

The unique structure of the enzyme papain which is a good source of *C. papaya* has proved effective properties against cancerous cells. Cancerous cells possess a protective coating of fibrin which remains undetected for about a long period [55]. The papain, which is an endolytic enzyme, isolated from papaya cleaves peptide bonds and helps in breaking down the fiber coated over cancerous cell walls and helps against recognizing the cancer cell.

Papaya is referred to as a storehouse of cancer-fighting lycopene and lycopene is a member of the carotenoid family, that helps in fighting cancerous cells [56]. Lycopene is an unsaturated open straight hydrogen compound that contains 11 conjugated and 2 unconjugated double bonds. Hence, it enhances cell-to-cell communication by increasing Gap junctions.

Toxicity

Carpain, the major macrocyclic lactone alkaloid of *C. papaya* leaf, was observed to form hydrophilic interactions and hydrogen binding with the interface of choline (both acetyl- and butyryl-) acyl pocket domains and binding site, with Trp 82 of the choline forming hydrophobic interaction with carpain lactone (2.5 Å) and Val 288 of the acyl pocket-forming hydrogen bonding with the carpain carbonyl group (3.3 and 4.6 Å) [57]. This mechanism was observed to inhibit cholinesterase activities. Adedayo *et al.* (2020) also observed that Voacangine and Undulatine are potent inhibitors of cholinesterase. Therefore, at higher doses of exposure, as observed by *Fasakin et al*. (2021), cholinesterase will be over inhibited, leading to excessive choline accumulation at the synaptic cleft and, finally, neurodegeneration.

Exposure to smoked *C. papaya* has also been shown to cause lesions at the fimbria-formix, a process that has been shown to result in hippocampus dysfunction [57]. This indicates that the observed elevated lipid peroxidation in the brain of experimental animals exposed to alkaloid extracts of *C. papaya ex vivo* by Fasakin *et al.* (*2021*) may be the ordeal behind the dysfunction observed. More so, exposure to the plant's alkaloids has been implicated in the onset of necrosis by causing enlargement of the perinuclear space of neural cells' nucleus. Furthermore, the study noted that exposure to the *C. papaya* leaves caused the hippocampus cells to be less active and deplete their neurotransmitter production rate. Nissl substances reduction, magnocellular layer disruption, and vacuolations were also observed during exposure to *C. papaya* leaves to smoke.

The studies of Oyewole and Owoyele (2012, 2014) further confirmed these observations, that exposure to smoked *C. papaya* leaves altered anxiolytic effects and long-term spatial memory and induced ultimate changes in experimental animals' hippocampus morphology. The studies further noted that smoking *C. papaya* leaves could cause neurons to be less active and deplete their neurotransmitter production rate, indicating that ingestion of high doses

of *C. papaya* leaves will mediate the exact mechanism of action.

Mechanism of Action of *C. Papaya* and *D. stramonium* with Their Psychoactive Properties

Carica papaya: Mechanism of action

The mechanism of action of *C. papaya* leaves is mediated by their diverse bioactive compounds, including alkaloids, flavonoids, phenolic acids, and enzymes. These constituents act synergistically to produce various therapeutic effects. One significant mechanism involves the immunomodulatory activity of alkaloids such as carpaine, which enhances the production of pro-inflammatory cytokines like IL-6 and TNF-α, boosting the immune response against pathogens. Additionally, flavonoids stimulate the synthesis of interferons, crucial for antiviral defences, particularly in conditions such as dengue fever [57].

Antioxidant activity is another critical mechanism through which *C. papaya* leaves exert therapeutic effects. Flavonoids such as quercetin and phenolic compounds like gallic acid neutralize ROS, reducing oxidative stress and lipid peroxidation. These compounds also upregulate endogenous antioxidant enzymes, including superoxide dismutase and catalase, which further mitigate cellular damage caused by oxidative stress [58].

The leaves also exhibit a remarkable ability to increase platelet count, a mechanism particularly relevant in managing thrombocytopenia associated with dengue fever. Alkaloids such as pseudocarpaine stimulate bone marrow megakaryocytes, enhancing platelet production and mitigating platelet destruction. This action is believed to restore hemostasis and prevent complications like hemorrhage in patients with dengue fever [59].

In terms of anti-inflammatory activity, flavonoids in *C. papaya* leaves inhibit the cyclooxygenase-2 enzyme, reducing the production of pro-inflammatory prostaglandins. Furthermore, these compounds suppress the nuclear factor-kappa B signaling pathway, which regulates the expression of inflammatory mediators. This dual action makes the leaves effective in reducing inflammation in conditions such as arthritis and colitis [60].

The antiviral effects of *C. papaya* leaves are linked to their ability to inhibit viral replication. Bioactive compounds like flavonoids and phenolic acids interfere with the viral replication cycle by targeting viral proteases and RNA polymerases, thereby suppressing the production of essential viral proteins. These properties have been demonstrated in studies on the dengue virus, where the extracts were shown to significantly reduce viral load [61].

The anticancer activity of *C. papaya* leaves is mediated through the induction of apoptosis in cancer cells. This occurs via the activation of caspases, which cleave cellular proteins and lead to programmed cell death. Additionally, phenolic acids in the leaves inhibit angiogenesis, the process of new blood vessel formation, effectively limiting tumor growth and metastasis. These compounds also suppress oncogenic signaling pathways such as Phosphoinositide 3-Kinase/Protein Kinase B (Akt) (PI3K/Akt) and Mitogen-Activated Protein Kinase (MAPK), which are critical for cancer cell proliferation and survival [62].

Finally, *C. papaya* leaves exhibit antimicrobial properties by disrupting the structural integrity of microbial cell membranes and interfering with nucleic acid synthesis. Alkaloids, tannins, and phenolic compounds collectively act against bacteria, fungi, and parasites, demonstrating broad-spectrum antimicrobial activity [63].

Datura stramonium: Mechanism of action

Datura stramonium belongs to the family Solanaceae. Over seventy (70) alkaloids have been identified in the plant, with the different seasons, climate, and location of cultivation posing different alkaloid patterns. The alkaloids in *D. stramonium* implicated for its neuromodulatory effects are hyoscyamine, scopolamine, and atropine [64]. These alkaloids are anticholinergic compounds as they cross the blood–brain barrier to bind with muscarinic acetylcholine receptors and act as competitive antagonists at these receptors. The muscarinic acetylcholine receptor subtypes antagonized during *D. stramonium* exposure are the M2, M4, and M5 receptors [65]. These alkaloids alter the imbalance between adrenergic and cholinergic regulation of brain function. Atropine has been observed to stimulate the central nervous system. In contrast, scopolamine depresses the central nervous system.

Datura stramonium anticholinergic properties have potentiated its use as a substitute for atropine in managing muscarinic symptoms during OP toxicity. The plant has varying therapeutic potentials, such as treatment of inflammation, swellings and bruising, wounds, gout and rheumatism, sciatica, and toothache, in folklore medicine [66]. Still, they have all been eclipsed by the toxicity and hazards of plant ingestion. It was observed that chronic

exposure to *D. stramonium* aathigh doses for four (4) weeks significantly elevated cAMP response element-binding protein (CREB) expression in male animals but depleted CREB expression in female animals. This result agrees with earlier observations that the mechanism of action of *D. stramonium* is sex and age-dependent, with the female species being observed to respond more and sometimes differently than the male species [66]. The alteration of CREB protein expression at the molecular level has been implicated as the paradigm underlining *D. stramonium* addiction despite its adverse effects [66].

Only a few psychoactive substances have been reported for severe negative recreational experiences (including comas and deaths) as *D. stramonium*. Symptoms of severe toxicity appear within 30 to 60 minutes of ingestion and could last for days as a result of the plant's ability to delay gastric absorption and to empty by inhibiting gastric motility via its anticholinergic effect, thereby increasing the transit time of the plant in the victim's gastrointestinal tract, resulting in extension of toxidromes duration. Children and teenagers have shown more susceptibility to *D*. *stramonium* toxicity, with very low doses resulting in very profound central and peripheral nervous system effects [67].

Despite the scarceness of death associated with exposure to *D. stramonium*, ingestion of about 125 seeds has been reported to cause death via heart failure. The first recorded poisoning was in 1,676 when soldiers under the command of Captain John Smith during the Bacon Rebellion prepared a salad comprising of *D. stramonium* and immediately began hallucinating. The plant has also been shown to contain gamma – 1 – glutamyl – aspartate, a compound that has been implicated in permanent short-term memory loss and impaired learning [68]. Ingestion of the plant at high doses has been observed to cause insanity in humans.

All the plant parts have been observed to contain lethal levels of tropane alkaloids scopolamine, hyoscyamine, and atropine which block the neurovegetative cholinergic system through competitive antagonistic actions on the central and peripheral muscarinic cholinergic receptors They are therefore grouped under anticholinergics or deliriants [69], which when ingested causes mydriasis, dry skin, tachycardia, and other fatal consequences. During the first few weeks of sprouting, *D. stramonium* mainly contains scopolamine, but as they mature, hyoscyamine begins to predominate. Uncontrolled inhibition of cholinesterases results in excessive choline accumulation at the synaptic cleft, thereby resulting in overstimulation of cholinergic neurons [70]. Excessive stimulation of the cholinergic neurons has been implicated in neurodegeneration syndromes such as hallucination, psychosis, tachycardia, severe mydriasis, delirium, hyperthermia, bizarre behavior, and in extreme cases, the organism's death [71].

Another system implicated in the neurotoxicity of *D. stramonium* is the monoaminergic system of neurotransmission. Exposure to the plant can cause excessive inhibition of the two isoforms (A and B) of monoamine oxidase6 (MAO), which are responsible for the oxidative deamination of biogenic amines (noradrenaline, serotonin, dopamine, tyramine, etc.). Although MAO inhibitors are therapeutic, the excessive inhibition of MAO by *D. stramonium* leads to neurotoxicological complications such as hypertensive crisis and serotonin toxicity [72]. Another mechanism of *D. stramonium* neurotoxicity is via impairment of the purinergic system of neurotransmission [72].

Enzymes involved in the purinergic system of neurotransmission are the ecto-nucleotide pyrophosphatase/phosphodiesterase, ecto-nucleoside triphosphate diphosphohydrolase, ecto-5'-nucleotidase, alkaline phosphatase, and Na+/K+ATPase. Dysfunction of the Na+/K+ATPase enzyme, as exhibited by the plant, has been implicated in the distortion of Na+/K+ equilibrium. This mechanism has been shown to result in nerve endings depolarization coupled with Ca2+ influx into brain cells, leading to excess neurotransmitter release and swelling of the neurons. Inhibition of ecto-nucleoside triphosphate diphosphohydrolase by *D*. *stramonium* impairs neuronal adenosine triphosphate (ATP) hydrolysis. A mechanism that has been shown to result in excessive extracellular ATP accumulation, P2 purinergic receptors overstimulation, and consequently, impairment of the purinergic neurotransmission system. Furthermore, ecto-5'-nucleotidase inhibition by *D. stramonium* has been implicated in extracellular adenosine level depletion, resulting in adrenergic neurotransmission and memory impairment [73].

Interestingly, *D. stramonium* also significantly elevates the activity of tissue non-specific alkaline phosphatase, the enzyme involved in enhancing the toxicity of extracellular tau protein, resulting in the progression of Alzheimer's disease. Furthermore, *D. stramonium* has been shown to cause neurotoxicity via excessive generation of free radicals and impairment of the antioxidant system.

This excessive generation of free radicals is marked by a high level of lipid peroxidation, Na+K+ATPase impaired function, activation of glial cells, misfolded proteins, membrane configuration derangement, cellular apoptosis, and dysfunction of cellular mitochondria [74]. The activities and levels of antioxidants were depleted, resulting in the depletion of neuronal integrity, loss of cognitive functions, and neuronal cell deaths [75].

Neurotoxicity of *D. stramonium* has also been established via alteration of the CREB gene expression. Elevated CREB gene expression observed in male rats was suggested to be due to excessive expression of the inactive form of CREB protein or the CREB-2 isoform [76]. This process has been implicated in the neurodegeneration of the frontal cortex and hippocampal neurons. At the same time, the depleted CREB gene expression observed in female rats was associated with neurodegeneration via excessive inhibition of CREB function and expression in pyramidal neurons, which results in excessive loss of cornu ammomis 1 subfield neurons. Similar neurodegeneration was observed in the frontal cortex of female rats, where depletion in CREB expression and its integrative role was observed during *D. stramonium* exposure [77].

Datura stramonium toxicity has also been observed to mediate cerebellar dysfunctions in granular cell parallel fibers and Purkinje cells of the cerebellum, resulting in degeneration and atrophy of the granule cells' parallel fibers, which are usually marked by hypoplasia, dyssynergia, and disequilibrium. This dysfunction was also implicated in learning, memory, and motor impairments observed during the study [78,79].

Conclusion and future remarks

Summary of key findings

This study investigated Nigerian plants with psychoactive properties, examining their medicinal uses, prevalence, and mechanisms of action. We identified several prominent plants, including *D. stramonium* and *C. papaya*, which are known for their psychoactive effects. These plants have been traditionally utilized for various medicinal purposes, such as antioxidant, anti-inflammatory, and anti-diabetic properties, and are integral to addressing a range of health conditions. Through extensive literature review and analysis, we found that the prevalence of these plants in Nigerian traditional medicine is significant, reflecting their cultural and historical importance.

In terms of the mechanism of action, our research revealed that the psychoactive properties of these plants can be attributed to some phytochemical compounds, leading to effects on the central nervous system. The interaction of these compounds with neurotransmitters and receptors influences mood, cognition, and behavior. Our findings shed light on the potential therapeutic applications of these plants in addressing mental health conditions or providing alternative treatments for certain ailments. Overall, our study contributes to the understanding of the rich botanical resources of Nigeria and their potential benefits. Further research is needed to explore the full range of psychoactive compounds in these plants and their potential as sources of novel therapies."

Implications for practice and policy

The findings of our research have significant implications for both practice and policy in the realm of healthcare and botanical resource management. In terms of practice, the identified Nigerian plants with psychoactive properties offer a potential avenue for integrating traditional medicine into modern healthcare. Healthcare practitioners could explore the therapeutic applications of these plants in treating mental health disorders and other related conditions. However, caution, proper regulation, and consistent dosage administration are crucial to ensure patient efficacy and safety. Collaboration between traditional healers and modern medical professionals could help bridge the gap between traditional knowledge and evidence-based healthcare practices.

From a policy perspective, it is important for regulatory bodies and government agencies to acknowledge the cultural and historical significance of these plants within Nigerian traditional medicine. This recognition could lead to the establishment of guidelines for their sustainable harvest, cultivation, and utilization thus ensuring their preservation for future generations. Additionally, clear regulations would help prevent misuse, illegal trade, and potential harm.

Furthermore, policies should facilitate research into the chemical constituents and potential therapeutic applications of these plants, while also promoting safety protocols for their use. Integrating traditional knowledge holders and indigenous communities into policy discussions will be crucial to ensuring a holistic and culturally sensitive approach. In summary, our research underscores the need for a balance that integrates the traditional

medicine approach into modern healthcare while upholding safety and preservation through well-informed policies and regulations.

Conclusion

This study has provided a comprehensive examination of Nigerian plants with psychoactive properties, highlighting their medicinal significance, pharmacological mechanisms, and potential risks. By analyzing the traditional uses and modern biomedical perspectives of *D. stramonium* and *C. papaya*, this review underscores their relevance to both ethnobotanical practices and contemporary medicine.

Our findings reveal that while these plants possess valuable bioactive compounds with therapeutic potential—ranging from anti-inflammatory and antimicrobial effects to neuroactive properties—their use must be approached with caution. *Datura stramonium,* rich in tropane alkaloids such as atropine and scopolamine, exhibits potent anticholinergic effects that can be both medicinal and toxic, depending on the dosage and method of use. Its psychoactive properties, historically exploited in both healing and ritualistic contexts, pose significant risks, including neurotoxicity and substance abuse potential. On the other hand, *C. papaya* is widely regarded as safe, with broad applications in traditional medicine for its antimicrobial, antioxidant, and anti-inflammatory properties. However, inconsistencies in traditional dosing and potential interactions with other drugs necessitate further clinical evaluation.

Furthermore, this review highlights the gap between traditional knowledge and modern pharmacological validation. Despite their extensive use in Nigerian traditional medicine, standardized scientific research on their safety, efficacy, and mechanisms of action remains limited. Addressing this gap requires interdisciplinary collaboration between ethnobotanists, pharmacologists, and healthcare professionals to ensure these plants are utilized safely and effectively.

Future research should focus on isolating and characterizing the active compounds of these plants, conducting rigorous clinical trials, and developing regulatory frameworks to integrate their use into modern healthcare. Additionally, public health awareness campaigns are necessary to educate communities on the potential risks of unregulated use, particularly in the case of *D. stramonium*.

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