

Study of the Biology, Medicinal and Therapeutic Properties of *Amanita muscaria* (L) Lam. (Basidiomycota: Agaricales: Amanitaceae)

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| <p>Abstract: <i>Amanita muscaria</i> (L.) Lam, 1783 (Agaricales: Amanitaceae), commonly known as the fly agaric, is one of the most iconic and visually distinctive mushroom species, recognized for its striking red cap with white spots. This species has significant biological, ecological, medicinal, and ethnomycological relevance. Its bioactive compounds, mainly muscimol, ibotenic acid, and muscarine, exhibit notable psychoactive, neuroactive, and therapeutic properties. Recent studies have highlighted its potential role in neurodegenerative conditions such as Parkinson’s disease, Alzheimer’s disease, epilepsy, and depression, due to its interaction with GABAergic and glutamatergic neurotransmission. Additionally, its ethnobotanical use in traditional healing practices, spiritual ceremonies, and as an insecticidal agent further emphasizes its relevance. However, toxicity remains a limiting factor regarding its clinical application, demanding careful assessment of dosage, preparation method, and administration routes. Despite these limitations, laboratory findings suggest possible anti-inflammatory, neuroprotective, hepatoprotective, and antioxidant properties, making it a promising candidate for future pharmacological research. This review discusses the biology, morphology, distribution, toxicology, medicinal potential, and therapeutic applications of <i>A. muscaria</i>, providing a comprehensive look into its scientific significance.</p> <p>Keywords: Ethnomycology, Medicinal Mushrooms, Neuroactive Compounds, Therapeutic Properties.</p> <p>Copyright © 2026 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC 4.0) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.</p> | <p style="text-align: center;">Research Paper</p> <p>*Corresponding Author: <i>Carlos Henrique Marchiori</i> Marco Santana Institute, Goiânia, Goiás, Brazil</p> <p>How to cite this paper: Marco Vinícios de Oliveira Santana <i>et al</i> (2026). Study of the Biology, Medicinal and Therapeutic Properties of <i>Amanita muscaria</i> (L) Lam. (Basidiomycota: Agaricales: Amanitaceae). <i>Middle East Res J. Med. Sci.</i> 6(1): 1-11.</p> <p>Article History: Submit: 30.11.2025 Accepted: 26.12.2025 Published: 02.01.2026 </p> |
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1. INTRODUCTION

Fungi are essential biological organisms responsible for decomposition, nutrient cycling, and ecological balance. They are eukaryotic and heterotrophic organisms, with cell walls composed mainly of chitin, chitosan, or polysaccharides. Their reproductive process occurs through spores, and their mycelial structure allows environmental adaptability and

diverse ecological interactions. They also possess important biochemical substances studied for medicinal, agricultural, and industrial purposes. These microorganisms represent an important source of new biologically active compounds and metabolic pathways for research and innovation. Table 1 presents the general characteristics of fungi (Michelot and Meléndez-Howell, 2003; Li and Oberlies, 2005; Alves, 2012; Carboué and Lopez, 2021; Biderman, 2023).

Table 1: General characteristics of fungi, describing their main structural, physiological, and ecological features in nature, highlighting their roles as decomposers, symbionts, and pathogens in terrestrial ecosystems

| Characteristic | Description |
|---------------------|--|
| Cell type | Eukaryotic, heterotrophic organisms with membrane-bound organelles |
| Structure | Unicellular yeasts or filamentous hyphae forming extensive mycelium |
| Reproduction | Asexual and sexual reproduction through the formation and dispersion of spores |
| Cell wall | Rigid wall composed mainly of chitin, chitosan, and polysaccharides |
| Nutrition | Absorptive nutrition using extracellular enzymes to decompose organic matter |
| Ecological role | Key decomposers, mutualistic symbionts, plant pathogens and food producers |
| Economic importance | Source of antibiotics, enzymes, fermented foods and bioactive metabolites |

Among the various fungal species, *A. muscaria* is one of the most widely recognized due to its characteristic red cap with white spots, historical symbolism, toxicological properties, and medicinal potential. It has been described in folklore, shamanic rituals, ethnomedicine, and modern scientific investigations. Historically, it was considered toxic, but studies revealed the presence of neuroactive and

pharmacologically relevant compounds. These compounds have renewed scientific interest in this species, expanding investigations into its therapeutic potential in neuroscience and pharmacology. Morphology of the *A. muscaria* Figure 1 (Michelot and Meléndez-Howell, 2003; Li and Oberlies, 2005; Alves, 2012; Carboué and Lopez, 2021; Costa, 2024).

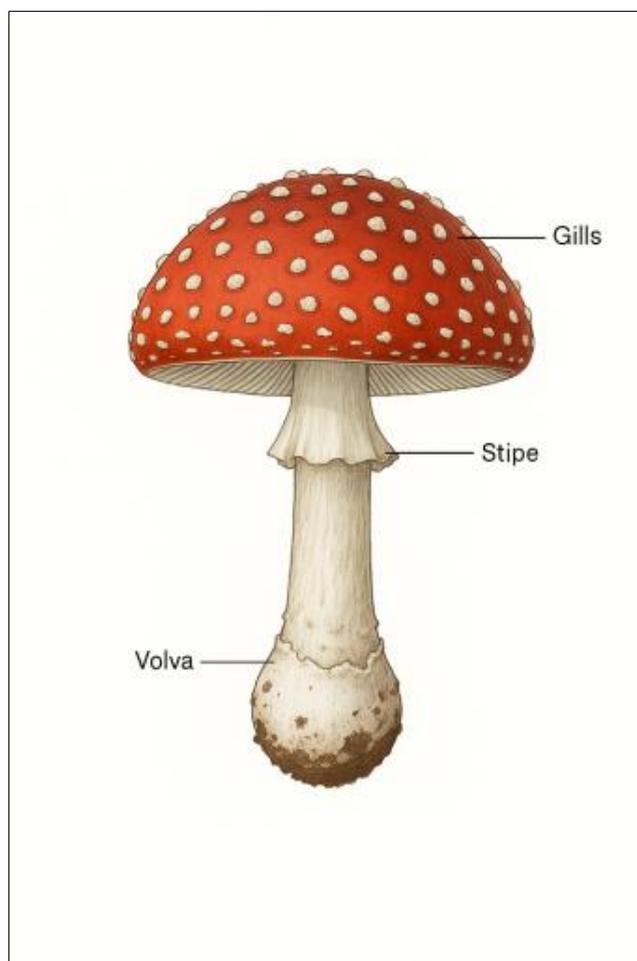


Figure 1: Macroscopic morphology of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae), showing the red cap with white warts, a cylindrical stipe with an annulus and a volva at the base, and illustrating typical identification features. The white, free, and crowded gills are responsible for spore production and support taxonomic classification within Basidiomycota. This visual representation highlights diagnostic structures frequently used in biological, ecological, and toxicological studies

Amanita muscaria belongs to the phylum Basidiomycota, order Agaricales, and family Amanitaceae. It is commonly found in temperate and boreal forests, forming ectomycorrhizal associations with trees such as pine, birch, and spruce. In this symbiotic interaction, the fungus facilitates the absorption of mineral nutrients by the plant, while receiving carbohydrates from root exudates. This mutualism improves soil quality, enhances plant

development, and contributes to the ecological stability of forest environments. The species adapts to different altitudinal ranges and soil types, favoring its geographical distribution. Figures 2A and 2B demonstrate the life cycle of *A. muscaria* (Michelot and Meléndez-Howell, 2003; Li and Oberlies, 2005; Alves, 2012; Carapeto *et al.*, 2017; Carboué and Lopez, 2021; Biderman, 2023; Costa, 2024).

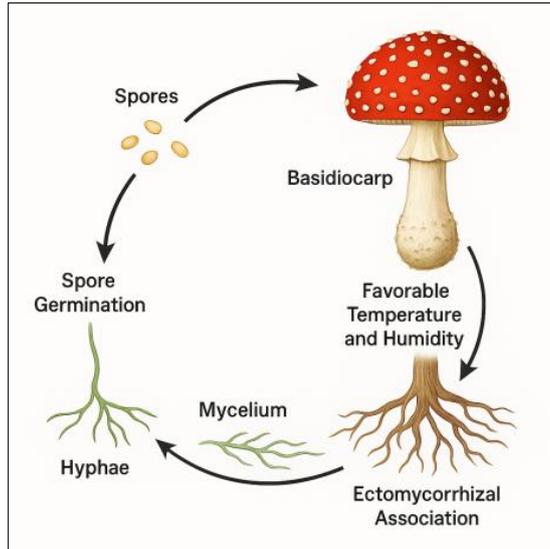


Figure 2A: Life cycle of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae), showing spore germination, hyphal growth, formation of mycelial network, and establishment of ectomycorrhizal association with host tree roots. The basidiocarp emerges from the soil under favorable temperature and humidity conditions, completing the reproductive stage. This diagram illustrates key developmental stages used to understand ecological adaptation and propagation mechanisms

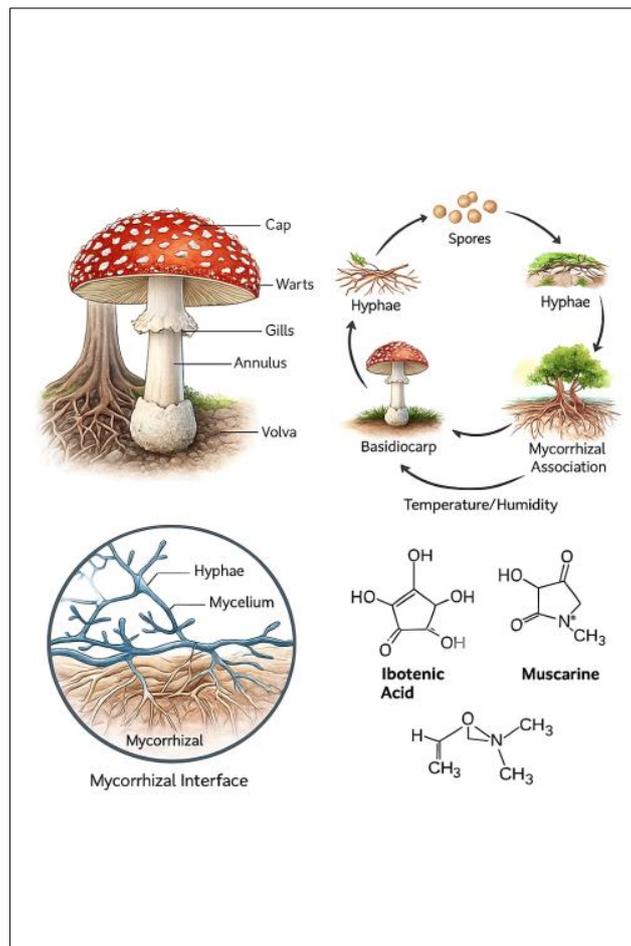


Figure 2B: Microscopic structure of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae) showing hyphal organization, presence of septate hyphae, and development of mycorrhizal mantle around host root tips. The Hartig net facilitates nutrient exchange between fungal structures and plant tissues. This representation highlights the functional role of mycorrhiza in nutrient uptake, symbiosis, and ecological resilience

Biochemically, *Amanita muscaria* produces several compounds of pharmacological relevance, such as muscimol, ibotenic acid, and muscarine. Muscimol is identified as a potent GABA receptor agonist, while ibotenic acid acts on glutamatergic receptors, producing neuroexcitatory effects. These substances have attracted interest in studies on cognitive modulation, neurodegeneration, and psychopharmacology. Research

demonstrates possible applications in conditions such as epilepsy, Alzheimer’s disease, and movement disorders, although risks related to toxicity and dosage persist. Table 2, presents the morphological and taxonomic characteristics of *A. muscaria* (Michelot and Meléndez-Howell, 2003; Li and Oberlies, 2005; Alves, 2012; Carapeto *et al.*, 2017; Carboué and Lopez, 2021; Biderman, 2023).

Table 2: Morphological and taxonomic features of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae), including its systematic position, macroscopic structures, and typical habitat associations in temperate forest environments

| Feature | Description |
|-----------------|---|
| Kingdom | Fungi |
| Phylum | Basidiomycota |
| Order | Agaricales |
| Family | Amanitaceae |
| Cap (pileus) | Bright red to orange with persistent white warts; becomes smoother with age |
| Gills | White, crowded, free to slightly adnexed beneath the cap |
| Volva and stipe | White, sac-like volva at the base and cylindrical stipe with annulus |
| Habitat | Ectomycorrhizal under conifers and birch in temperate and boreal forests |

Additionally, *A. muscaria* has shown potential insecticidal, anti-inflammatory, antioxidant, and neuroprotective properties in experimental studies. Extracts of this fungus demonstrated effectiveness against *Musca domestica* L., 1758 (Diptera: Muscidae) and *Culex quinquefasciatus* Say, 1823 (Diptera: Culicidae), indicating insecticidal properties. However, due to its high toxicity, clinical use requires careful evaluation, standardized preparation methods, and strict dosage control. Despite these limitations, its bioactive components make it a promising candidate for pharmacological investigations and therapeutic applications (Michelot and Meléndez-Howell, 2003; Li and Oberlies, 2005; Alves, 2012; Carboué and Lopez, 2021; Biderman, 2023; Costa, 2024).

2.0. METHOD

This study was conducted through a structured literature investigation across reliable scientific sources available on the internet. The search focused on content published in recent years that addressed topics such as biological characteristics, chemical composition, pharmacological substances, medicinal applications, ecological importance, toxicity, and therapeutic potential of the species *A. muscaria*. Relevant documents were selected according to previously defined parameters, ensuring coherence with the main objective of this research.

The selection criteria considered the clarity of the content, scientific approach, presence of verified data, and contribution to the understanding of the medicinal and biological properties of the species. Only complete texts written in English or Portuguese were considered, with a priority given to those containing

updated information and objective findings. The data were organized and examined to identify relevant aspects and similarities among different studies.

The collected material was categorized according to thematic relevance, allowing a better understanding of specific topics, such as pharmacological activity, toxicological effects, ecological distribution, and potential therapeutic applications. From the collected information, the main concepts were synthesized and associated with related scientific and biological principles. Tables and figures were planned to illustrate the biological, ecological, and biochemical aspects of the species.

No experimental procedures involving laboratory or field analysis were performed for this study. Instead, an interpretative and descriptive approach was applied, aiming to gather, organize, compare, and discuss information available in scientific and academic sources about *A. muscaria*, focusing on its biological, medicinal, and therapeutic relevance.

3.0. RESULTS

The biological analysis of *A. muscaria* revealed structural and ecological features that demonstrate its relevance in natural environments, including its eukaryotic organization, decomposer role, and ability to form symbiotic associations, as shown in Figure 3, the illustrated macroscopic morphology of *A. muscaria*. These aspects highlight the importance of fungi in nutrient cycling, environmental balance, and mutualistic relationships in forest ecosystems (Carboué and Lopez, 2021; Biderman, 2023; Costa, 2024).

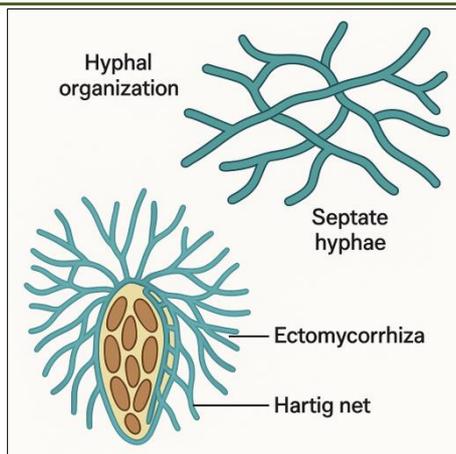


Figure 3: Microscopic structures of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae) showing septate hyphae, basidiospores, clamp connections, and ectomycorrhizal mantle formation around host root tissues. These adaptations facilitate nutrient absorption, symbiotic interactions, and efficient communication between fungal and plant cells. This organization supports ecological resilience, forest productivity, and classification of the species within Basidiomycota

Morphological examination confirmed the identification of *A. muscaria* based on macroscopic structures such as red cap, white warts, lamellae, and volva, allowing differentiation from similar species in the Amanitaceae family. The internal hyphal network and clamp connections are essential for fungal classification (Li and Oberlies, 2005; Figueiredo *et al.*, 2006; Geml *et al.*, 2008; Alves, 2012; Carboué and Lopez, 2021; Biderman, 2023; Costa, 2024).

Ecological observations revealed that *A. muscaria* can be found in temperate and boreal forests,

forming associations with pine, birch, oak, and spruce trees. Its distribution across continents is predominantly linked to acidic and sandy soil conditions, and forest interaction of *A. muscaria*. These findings support the species' adaptability and ecological relevance in the forest. Table 3 shows the distribution and habitat of *A. muscaria* ecosystems. Table 3, shows a study of the distribution and habitat of *A. muscaria* (Alves, 2012; Almeida, 2014; Cárcamo *et al.*, 2016; Carapeto *et al.*, 2017; Carboué and Lopez, 2021; Biderman, 2024).

Table 3: Distribution and habitat of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae) across different geographic regions, showing typical host plants, seasonal occurrence, soil preferences, and ecological notes related to its expansion

| Region | Typical host plants | Season | Soil type | Ecological notes |
|---------------|--------------------------|---------------|--------------|--|
| Eurasia | Birch, pine, spruce | Summer–Autumn | Acidic | Abundant in boreal and mixed temperate forests |
| North America | Coniferous forests | July–October | Acidic | Common in mountainous and coastal regions |
| South America | <i>Pinus</i> spp. | Autumn | Sandy | Introduced through pine plantations |
| Brazil | <i>Pinus</i> plantations | Winter–Spring | Acidic | Recorded mainly in reforested areas |
| Scandinavia | Birch, oak | June–August | Moist acidic | Linked to traditional ethnomycological use |
| Japan | Oak, beech | Autumn | Humus-rich | Occurs in humid temperate forests |
| Russia | Spruce, fir | Summer–Autumn | Acidic | High frequency in taiga ecosystems |

Toxicological studies demonstrated that *A. muscaria* extracts can affect insects such as *M. domestica*, *C. quinquefasciatus*, and *Aedes aegypti* (Linnaeus, 1762) (Diptera: Culicidae), producing paralysis, larvicidal action, and egg viability reduction. These compounds, including muscimol and muscazone, are structurally represented in Table 4, the insecticidal

evidence of *A. muscaria*, and Figure 4, Chemical structures of muscimol, ibotenic acid, and muscarine, showing their potential biological applications (Li and Oberlies, 2005; Figueiredo *et al.*, 2006; Geml *et al.*, 2008; Alves, 2012; Carapeto *et al.*, 2017; Carboué and Lopez, 2021; Biderman, 2023; Maestrovirtuale, 2024).

Table 4: Insecticidal evidence of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae) extracts, summarizing experimental studies that report toxic effects of its compounds on different target species and potential applications in vector control

| Target species | Compound | Effect | Notes |
|-------------------------------|------------------|-----------------------|--|
| <i>Musca domestica</i> | Muscimol | Paralysis and death | Effective at relatively low concentrations |
| <i>Culex quinquefasciatus</i> | Ibotenic acid | Larvicidal activity | Affects larval development and survival |
| Synanthropic flies | Muscazone | Neurotoxic disruption | Interferes with neuromuscular function |
| <i>Aedes aegypti</i> | Crude extract | Increased mortality | Potential for integrated pest management |
| Houseflies | Amanita tincture | Reduced egg viability | Impacts reproductive capacity |

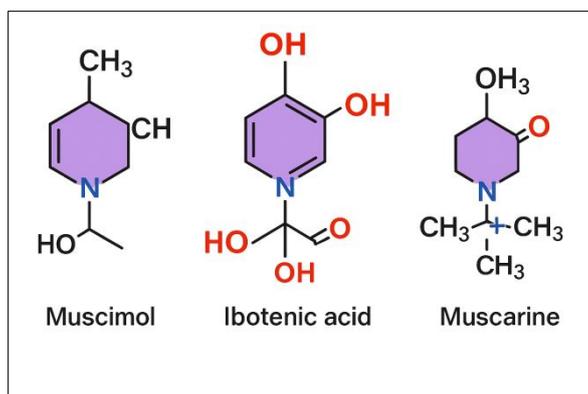


Figure 4: Chemical structures of muscimol, ibotenic acid, and muscarine, showing their molecular configurations, functional groups, and relation to neuroactive properties. These compounds act on GABAergic and glutamatergic receptors, influencing central nervous system responses. Their structural differences explain variations in toxicity, psych activity, and therapeutic potential

It was observed that *A. muscaria* establishes ectomycorrhizal relationships with several tree species, contributing to nutrient absorption, root protection, and improved environmental resilience. These symbiotic mechanisms are visually described in, demonstrating nutrient exchange and soil enhancement. Table 5 shows a mycorrhizal association between *A. muscaria* (Figueiredo *et al.*, 2006; Geml *et al.*, 2008; Alves, 2012; Carboué and Lopez, 2021; Biderman, 2023; Costa, 2024).

Pharmacological evaluation indicated that consumption of *A. muscaria* produces dose-dependent psychoactive effects, including sensory alteration, hallucinations, and neurological impairment. These neurochemical processes are illustrated in Figure 5, the interaction of muscimol and ibotenic acid with GABA-A receptors, highlighting their potential pharmacological implications. Table 6, shows the hallucinogenic profile and adverse effects of consuming *A. muscaria* (Geml *et al.*, 2008; Alves, 2012; Cárcamo *et al.*, 2016; Carapeto *et al.*, 2017; Carboué and Lopez, 2021).

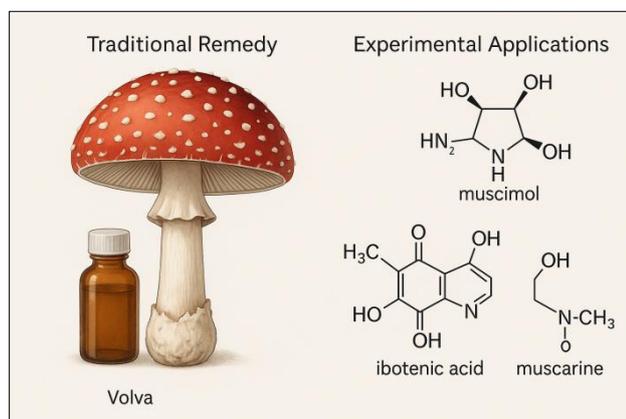


Figure 5: Traditional and modern representations of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae), highlighting external morphology, red cap with white warts, stipe with annulus and volva, and its use in ethnomycology, medicinal research, and experimental applications. The visual comparison illustrates both cultural symbolism and scientific relevance, showing its transition from ritualistic contexts to pharmacological studies. This image supports biological interpretation and contextual understanding of the species

Table 6: Hallucinogenic profile and adverse effects of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae) consumption, relating dose levels to psychoactive intensity, duration of effects, and potential toxic reactions observed in human reports

| Dose level | Effect | Duration | Possible adverse effects | Comments |
|--------------|--|-----------|------------------------------------|--|
| Low | Relaxation, mild euphoria, sensory enhancement | 2–4 h | Occasional nausea or dizziness | Usually associated with small experimental doses |
| Moderate | Euphoria, visual distortion, and altered time perception | 5–8 h | Vomiting, sweating, disorientation | Higher variability between individuals |
| High | Hallucinations, dissociation, dream-like states | 6–10 h | Confusion, agitation, tremors | Medical supervision may be required |
| Very high | Profound delirium, loss of coordination | 8–12 h | Convulsions, coma risk | Represents toxic exposure level |
| Microdose | Subtle mood and perception changes | 1–3 h | Mild discomfort | Explored in anecdotal self-experiments |
| Repeated use | Accumulated psychological effects | Variable | Fatigue, emotional instability | Not recommended without monitoring |
| Intoxication | Severe CNS disturbance | Prolonged | Potential respiratory compromise | Emergency treatment indicated |

Experimental evidence demonstrated that compounds such as muscimol and ibotenic acid have potential effects in neurological disorders, chronic pain, hepatic inflammation, and emotional instability. These biological applications are illustrated in Figure 6, traditional and experimental medicinal uses of *A.*

muscaria, supporting interest in pharmacological and ethnomedical research. Table 7, therapeutic and clinical evidence related to muscimol (Figueiredo *et al.*, 2006; Cárcamo *et al.*, 2016; Carboué and Lopez, 2021; Dyshko *et al.*, 2024).

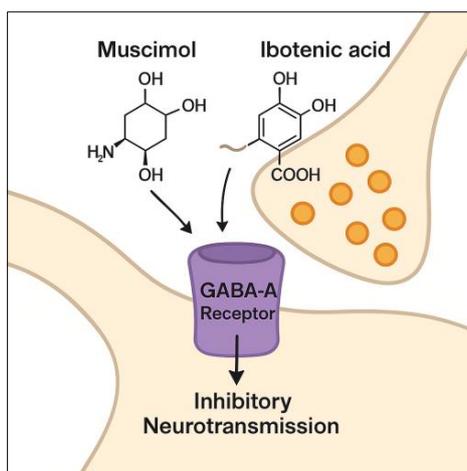


Figure 6: Neurochemical interaction of muscimol and ibotenic acid with GABA-A receptors, demonstrating inhibitory signaling pathways and synaptic modulation in the central nervous system. The diagram highlights the binding process, neural response reduction, and effects on perception, cognition, and sensory processes. This representation supports an understanding of pharmacological action and the biological relevance of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae) compounds

Table 7: Therapeutic and clinical evidence related to muscimol and *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae) preparations, summarizing observed effects in experimental and clinical contexts for neurological and systemic conditions

| Condition | Compound | Observed effect | Study model |
|---------------------|------------------------------|---|----------------------|
| Alzheimer’s disease | Muscimol | Neuroprotection and reduced neuronal loss | Animal model |
| Parkinson’s disease | Muscimol + mandrake tincture | Improved motor symptoms | Clinical observation |
| Liver inflammation | Muscimol | Hepatoprotective action with improved markers | Experimental study |

| Condition | Compound | Observed effect | Study model |
|---------------------|------------------|-------------------------------------|-----------------------|
| Cardiovascular risk | Muscimol | Reduction of risk indicators by 25% | Animal study |
| Depression | Muscimol | Stabilization of CNS activity | Preclinical data |
| Alcohol dependence | Amanita extract | Decreased alcohol craving | Human reports |
| Chronic pain | Topical tincture | Analgesic relief in neuralgia | Ethnomedical evidence |

4.0. DISCUSSION

The biological relevance of *A. muscaria* is confirmed by its ecological versatility and capacity to establish ectomycorrhizal associations with different forest tree species. These mutualistic interactions improve nutrient cycling, soil structure, and water retention, contributing to forest stability and resilience in temperate and boreal ecosystems. Ecological interaction of *A. muscaria* with forest trees, which illustrates nutrient exchange between fungal hyphae and roots and highlights its importance in ecosystem functioning (Negri *et al.*, 2022; Okhovat *et al.*, 2023; Maciejczyk, 2024).

Toxicological observations reveal that ingestion of *A. muscaria* may lead to a wide spectrum of dose-dependent physiological and neurological manifestations. Symptoms vary from mild gastrointestinal discomfort and sensory alteration to severe confusion, hallucinations, and central nervous

system depression when higher amounts are consumed. Traditional and experimental medicinal uses of *A. muscaria* are summarized in Figure 7. Dose-dependent toxicological responses of *A. muscaria*, demonstrating the relationship between dose, exposure, and clinical outcome and reinforcing the need for strict safety evaluation (Michelot and Melendez-Howell, 2003; Patocka and Kocandrova, 2017; Negri *et al.*, 2022; Okhovat *et al.*, 2023; Maciejczyk, 2024). Morphological and taxonomic characterization remains essential for safe identification of *A. muscaria* in ecological, toxicological, and clinical contexts. Its red cap with white warts, white crowded gills, cylindrical stipe with annulus, and the presence of a volva at the base allow differentiation from other potentially toxic or edible mushrooms that share the same habitat. These diagnostic features are clearly presented in Figure 7. Morphological representation of *A. muscaria*, supporting reliable recognition in field surveys and laboratory analyses Li and Oberlies, 2005; Cárcamo *et al.*, 2016; Carapeto *et al.*, 2017; Carboué and Lopez, 2021).

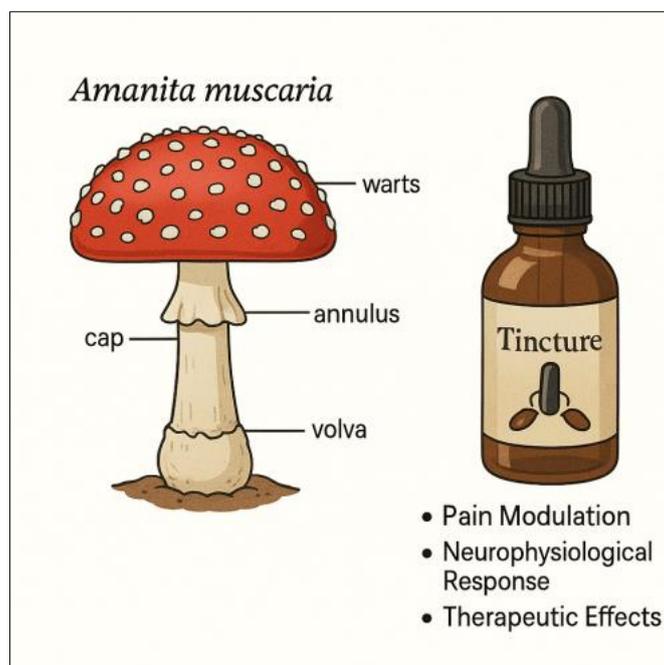


Figure 7: Traditional and experimental medicinal uses of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae), showing topical applications, tincture preparations, and potential roles in pain modulation and neurophysiological balance. The representation illustrates therapeutic perspectives based on the pharmacological properties of muscimol and ibotenic acid, without promoting recreational use. This visual context supports academic interpretation of biological, ethnomedical, and clinical relevance

In parallel with its toxicological profile, pharmacological data indicate that bioactive compounds such as muscimol and ibotenic acid interact with inhibitory and excitatory neurotransmitter systems. These substances may modulate neuronal excitability and synaptic transmission, suggesting potential applications in experimental models of neurodegeneration, pain, and psychiatric disorders.

However, their narrow safety margin and variable content in natural specimens demand careful standardization, controlled dosing, and rigorous preclinical assessment before any clinical use is considered. Figure 8, dose-dependent toxicological responses of *A. muscaria* (Li and Oberlies, 2005; Geml *et al.*, 2008; Carapeto *et al.*, 2017; Ordak *et al.*, 2023; Costa, 2024).

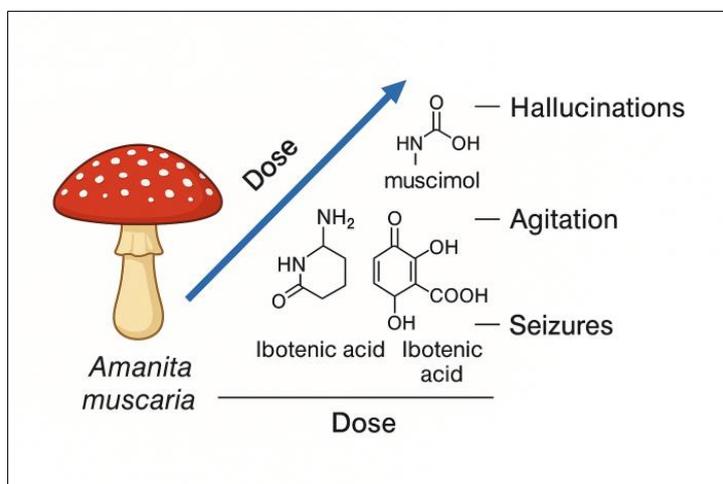


Figure 8: Dose-dependent toxicological responses of *Amanita muscaria* (L.) Lam, 1783 (Agaricales: Amanitaceae), showing stages from mild physiological effects to severe neurotoxic manifestations associated with muscimol and ibotenic acid exposure. The progression illustrates neurological symptoms, organ involvement, and potential risks related to ingestion, reinforcing the importance of dosage control and scientific regulation. This representation supports toxicological interpretation and safety assessment for pharmacological research

Ethnopharmacological records and experimental studies suggest that preparations derived from *A. muscaria* could present analgesic, neuroprotective, and psychotropic actions under controlled conditions. Nevertheless, the same properties that generate interest also impose significant risks when used without scientific supervision. For this reason, further investigations are required to define extraction protocols, determine pharmacokinetics, evaluate long-term safety, and establish regulatory criteria that differentiate experimental, therapeutic, and toxicological contexts (Li and Oberlies, 2005; Figueiredo *et al.*, 2006; Carboué and Lopez, 2021; Biderman, 2023; Ordak *et al.*, 2023; Costa, 2024).

5.0. CONCLUSION

Amanita muscaria presents biological, ecological, and chemical characteristics that make it a relevant species for scientific investigation. Its bioactive compounds show promising effects in neuropharmacology, toxicology, and potential medicinal applications. However, toxicity variability, dosage sensitivity, and preparation methods represent significant limitations for clinical use. While experimental research demonstrates potential therapeutic effects, controlled studies and standardized extraction protocols are necessary. Future research should focus on

safety, regulation, and pharmacological validation to enable its possible biomedical application.

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