A Comprehensive Review on the Pharmacognostic, Phytochemical, and Pharmacological Aspects of Myristica fragrans (Nutmeg): Bridging Traditional Knowledge with Modern Therapeutic Perspectives

Suhani .S. Solapure[1], Supriya Kore[2], Aman Bagwan[3] , Komal Avatade[4], Arati Patil[5], Sneha Chougule[6], Sneha Lohar[7]
Y. D Mane Institute of Pharmacy Kagal-416216, Kolhapur, Maharashtra

***Abstract*—The prized fragrant spice known as nutmeg (Myristica fragrans) is well-known for its significant therapeutic properties as well as its rich flavor and scent. Myristicin, eugenol, trimyristin, myristic acid, lignans, terpenoids, alkaloids, and flavonoids are among the many bioactive substances that give it its many pharmacological effects. Strong antioxidant, antibacterial, analgesic, anti-inflammatory, and anticancer properties are displayed by nutmeg. Cells are shielded from oxidative damage by its phytoconstituents, which efficiently scavenge free radicals, prevent lipid peroxidation, and strengthen enzymatic antioxidant defense. Strong antibacterial and antibiofilm characteristics are demonstrated by M. fragrans extracts against a variety of oral and pathogenic pathogens. It has long been used in Ayurveda to treat neurological conditions, inflammation, discomfort, and digestive problems. Nutmeg's potential as a natural, safe, and beneficial ingredient for pharmaceutical, nutraceutical, and cosmetic formulations is highlighted by recent research that scientifically substantiate these therapeutic claims. Myristica fragrans is a significant herbal source for the development of contemporary phytotherapy, and this review emphasizes the pharmacognostic, phytochemical, and pharmacological features of nutmeg.**

***Index Terms*—Myristica fragrans; Nutmeg; Pharmacognosy; Phytochemical constituents; Antioxidant activity; Antimicrobial activity; Anti-inflammatory; Analgesic; Anticancer; Herbal medicine; Traditional uses; Phytotherapy.**

I. INTRODUCTION

The plant Myristica fragrans, sometimes referred to as "nutmeg," yields both mace and nutmeg. The mace is the red lacy coating (aril) on the seed kernel, which is nutmeg, which is the seed kernel inside the fruit.

In addition to being a popular spice, nutmeg has a number of medicinal uses. Nutmeg has a mildly warming flavor and a distinctively pleasant scent. Many types of baked goods, sweets, puddings, meats, sausages, and sauces, drinks and vegetables are flavored with it [1].

Myristica fragrans' chemical components have antimicrobial, antidepressant, aphrodisiac, memory-boosting, hypolipidemic, and hypocholesterolemic properties. hepatoprotective and antioxidant qualities. The nutmeg seed kernel is used extensively in traditional medicine as an astringent, hypolipidemic, antithrombotic, and carminative. antifungal, antiplatelet aggregation, aphrodisiac, and for the treatment of nausea, dyspepsia, and flatulence. Mace is frequently used as a folk remedy, hair colorant, and flavoring. Additionally, it has anti-inflammatory, anticarcinogenic, and antipapillomagenic properties [2].

Due to its medicinal qualities, nutmeg seed has also been utilized in traditional treatments for conditions like stomach pain, aches,Abortifacient and aphrodisiacal [3].

Figure 1. Dried nutmeg seeds (Myristica fragrans) used as spice and medicinal material.

Synonym:

1. Myristica officinalis L. f.
2. Myristica moschata Thunb.

Taxonamical Information:

Kingdom	Plantae
Subkingdom	Tracheobionta
Phylum	Tracheophyta
Super division	Spermatophyta – Seeds
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Magnoliidae
Order	Magnoliales
Family	Myristicaceae
Genus	Myristica Gronov
Species	Myristica fragrans Houtt

Vernacular Name: -

Sanskrit	Jatiphala / Jatipatri
Hindi	Jaiphal
Marathi	Jaiphal
Gujarati	Jathiphal
Tamil	Jathikai
Telugu	Jajikaya
Kannada	Jajikai
Bengali	Jayphal
Malayalam	Jathikka
Urdu	Jaiphal
English	Nutmeg

Historical Cultivation and Usage :-

The Myristica fragrance fruit's seed, the nutmeg, has a It grows from the Myristica fragrans tree and has a yellow, peach-like shape. The tree Is a fragrant, dioecious, evergreen tree that is frequently grown in tropical Areas, especially those in tropical America, Southeast Asia, and The islands of the Pacific. Its birthplace was Indonesia's Banda Island. Which is referred to as the Spice Islands or Maluku. In the past, the Arab Introduced the nutmeg to Europe prior to its discovery. Trees on Banda Island by the Portuguese in the fifteenth century [4].When the Dutch colonized the area later in the 17th century, Spice Islands, and they continued to have authority over the spice trade, and Until the British acquired nutmeg at the end of the 18th century. Banda Island seedlings [5]. Lately, there has Nutmeg seeds have been in high demand in developed nations. Germany Among the leading nutmeg seed countries are Japan, the US, and Europe. Importers. A number of nations, such as Sri Lanka, India, Indonesia, and Nutmeg exports from Grenada are well-known [6]. The Portuguese found nutmeg in 1512, and it originated in Indonesia's Banda Islands. The Dutch were responsible for spreading the word about the significance of nutmeg seeds. Nux muscatus, which translates to "musky nut," is the Latin root of the name nutmeg. Jaiphal is the Indian name for nutmeg. The ethno-medical literature claims that the Indians used nutmeg seed oil to treat digestive ailments, the Egyptians used it for embalming, and the Italians used it to treat plague. Nutmeg seeds have long been used in medicine as a narcotic, an aphrodisiac, an abortifacient, an anti-flatulent, and a way to start menstruation. Early in the 19th century, it was discovered that nutmeg seeds had an impact on the central nervous system. Hemorrhoids, persistent vomiting, rheumatism, cholera, psychosis, stomach pains, nausea, and anxiety are among the traditional ailments that nutmeg seeds are said to treat. Additionally, nutmeg seed oil has analgesic, antirheumatic, and antiseptic qualities [7].

Botanical Description :

Myristica fragrans is an evergreen tree with spreading branches and soft, greyish-brown bark that can reach a height of 20 to 25 feet. The plant thrives in a warm, humid climate with 150–250 cm of rainfall and an elevation of 1,000 m above sea level.The leaves are oblong, glabrous, acuminate, aromatic, dark green, and glossy above. Typically, flowers are dioecious, but they can also be monoecious, small axillary, sub-umbellate racemes, compound, or occasionally forked, with variable sex expression.The pedicels and peduncles have a glabrous appearance.The fruit hasna fleshy pericarp and is spherical; the fruit skin is yellowish and splits into two longitudinal valves.

The nutmeg belongs to the Myristicaceae family and the Magnoliales order. The fruit is used to make two significant spices: mace and nutmeg. The tree's seed is nutmeg, which is ovoid, dark brown, 2-3 cm long, and weighs 5-10 g. Among flowering plants, nutmeg seeds are thought to be the most primitive because they contain ruminate endosperm.

The dried, lacy, reddish seed covering, or aril, is called mace. The first harvest can occur seven to nine years after planting, but it takes a nutmeg tree about 20 years to reach its full potential. Mace production is estimated to be between 1500 and 2000 tonnes annually, while nutmeg production is estimated to be between 10,000 and 12,000 tonnes, with an estimated yearly global demand of 9000 tonnes. Although the tree produces fruit throughout the year, April through November is the ideal time to harvest it.

Indonesia and Grenada are the primary producers and exporters; other significant producers include India, Malaysia, Papua New Guinea, Sri Lanka, and the Caribbean Islands [7] [8].

Figure 1. Nutmeg tree (Myristica fragrans) showing mature fruiting branches.

Figure 2. Glossy green leaves of Myristica fragrans

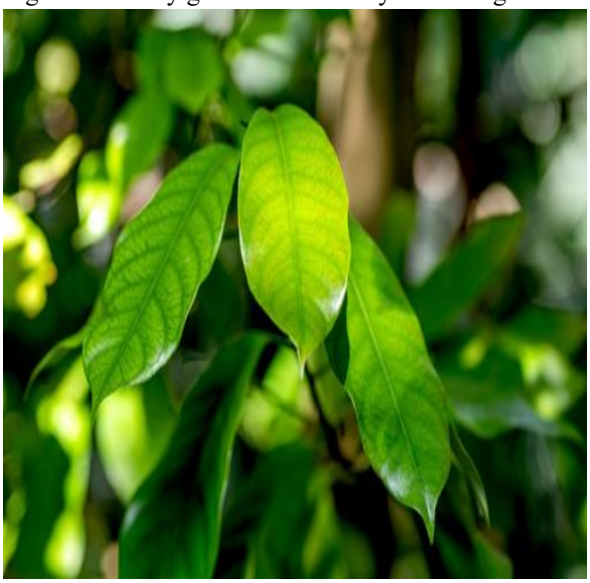


Figure 3. Unripe fruits of nutmeg attached to twigs.

Figure 4. Split fruit revealing red aril (mace) covering the brown seed.

Figure 5. Dried mace separated from the nutmeg seed.

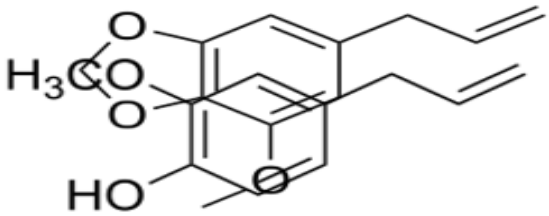
Figure 6. Ground nutmeg powder used as spice and medicinal ingredient.

Chemical composition: -

Knowing an oil's composition provides valuable insight into its potential uses in a variety of fields. It also gives a clearer picture of its function in health and how it can be used to treat a wide range of illnesses. Thirty to fifty-five percent of raw nutmeg seeds are oily, while forty to sixty percent are solid, including cellulose. Nutmeg oil is composed of several oleoresins, an essential oil that makes up 8% to 15%, and a crude fixed oil called nutmeg butter that makes up 20% to 40%. An aromatic group gives this nutmeg butter its strong aroma [9].

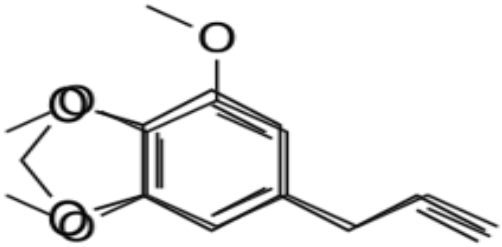
Volatile chemicals, terpenoids, phenolics, lignin compounds, protein, mucilage, and starch are among the phytochemical compounds of M. fragrans that are most widely recognized. The aqueous extract of M. fragrans also contained flavonoids, phlobatanins, anthraquinones, alkaloids, saponins, and cardiac glycosides. Terpenes and alkenylbenzene derivatives make up the volatile oil of nutmeg. About 80% of the alkenylbenzene compounds are made up of myristicin, safrole, and elimicin [1]. The primary components of M.fragrans seed essential oil were found to be bioactive chemicals such as camphene, elemicin, eugenol, isoelemicin, isoeuglenol, methoxyeugenol, and elimicin [10].About 10% of nutmeg contains volatile oil, primarily pinene and camphene. Myristicin, safrole, elemicin, terpinol, cymene, eugenol, isoeugenol, and methyl eugenol are among the minor constituents. The plant also produces elimicin and safrole [11].

Myristicin.



Eugenol

Elemicin



Safrole

Pharmacological Action :-

Nutmeg has a variety of bioactive compounds that are important in traditional medicine and have been proposed as treatments for a wide range of chronic and non-chronic illnesses [12]. Significant pharmacological properties, including anti-inflammatory, antioxidant, antibacterial, antidiabetic, and anticancer properties, make plants promising natural products. Because of its natural antioxidant, secondary metabolites, flavonoids, terpenes, alkaloid, phenol, and fatty acid, it plays a significant role in both treating and preventing a variety of ailments. As a

result, there is increasing interest in mixing pharmaceutical drugs with natural therapies in an effort to cure a variety of ailments. Nutmeg seed has a variety of pharmacological qualities that are relevant to both commercial and pharmacological activities. The fraction thought to contain the pharmacologically active ingredients is the nutmeg seed extract. Thus, more research is necessary to fully understand the potential therapeutic and pharmacological effects of nutmeg. The possible medicinal benefits of nutmeg seeds are described in the material that follows[3].

Nutmeg Part	Major Constituents	Pharmacological Activities
Seed (Nutmeg)	Myristicin, Elemicin, Eugenol, Trimyristin, Myristic acid, Lignans	Antioxidant, Antimicrobial, Anti-inflammatory, Analgesic, Anticancer, Hepatoprotective, Neuroprotective
Aril (Mace)	Myristicin, Safrole, Essential oils, Terpenoids	Antimicrobial, Antioxidant, Anti-inflammatory, Aphrodisiac, Digestive stimulant
Fruit Pericarp	Phenolics, Volatile oils	Antioxidant, Antimicrobial, Antidiabetic, Anti-diarrhoeal
Leaves	Essential oils (eugenol, caryophyllene), Phenolics	Antimicrobial, Anti-inflammatory, Antioxidant, Insecticidal
Bark	Fixed oils, Phenolics	Antimicrobial, Anti-inflammatory, Astringent
Oil (Nutmeg essential oil)	Myristicin, Elemicin, Sabinene, Pinene, Terpineol	Antimicrobial, Analgesic, Anti-inflammatory, CNS stimulant, Carminative
Kernel Fat (Nutmeg butter)	Trimyristin, Fatty acids	Emollient, Anti-inflammatory, Antioxidant, Used in topical preparations

Antioxidant Activity: -

Free radicals and other reactive oxygen species (ROS) are produced spontaneously in the human body by a variety of exogenous and endogenous sources, including hydrogen peroxide (H2O2), superoxide anions ($O2), and hydroxyl radicals ($OH). These ROS can have a variety of effects on lipids, proteins, and nucleic acids, and as a result, are crucial in the development and/or progression of a number of diseases . Oxidative stress is caused by an imbalance between the production of ROS and the host antioxidant system's ability to quench them in pathological situations in immune-compromised hosts. To combat oxidative stress, an external supply of antioxidants may be highly beneficial. Nutmeg is one of many spices that have been shown to have strong antioxidant properties [7].

The primary antioxidants found in nutmeg are lignans, carvacrol, α- and β-pinene, p-cymene, β-caryophyllene, methoxy-eugenol, eugenol, and isoeugenol [12].Numerous active phytochemicals, such as vitamins, carotenoids, terpenoids, alkaloids, flavonoids, lignans, simple phenols, phenolic acids, etc., contribute to antioxidant qualities. Antioxidant activity and total phenolic content have been shown to significantly and favorably correlate. Secondary metabolism is the primary source of phenolic antioxidants in plants, and their redox characteristics and chemical structure—that is, the quantity and location of the hydroxyl group—play a major role in their antioxidant capacity [7]. These antioxidants reduce oxidation of LDL or inhibit lipid peroxidation, scavenge nitric oxide (NO), quench singlet oxygen, limit the generation of nitric acid, and metal chelate. It is estimated that nutmeg has a 462 uM BHT and 656 uM α-tocopherol free radical scavenging activity. Considered a natural source of antioxidants, nutmeg may lower the chance of acquiring harmful bacteria [12].

Antimicrobial Activity:-

Both nutmeg and mace, M. fragrans, are known to have potent antimicrobial activity against bacteria that cause food poisoning, animal and plant diseases, Helicobacter pylori, Bacillus subtilis, E. coli, Saccharomyces cerevisiae, and multidrug-resistant Salmonella typhi .Excellent antibacterial activity against endodontic microorganisms of the main tooth root canal was demonstrated by M. fragrans. Extracts from M.fragrans have demonstrated remarkable efficacy against oral microbes including S. mutans. It effectively inhibited the growth of P. gingivalis and is a natural antibiofilm agent that works against Streptococcus sanguinis and A. viscosus, the two main oral colonizers. Myristicin, trimyristin, and myristic acid, among other chemicals found in M. fragrans essential oil, demonstrated varying degrees of effectiveness against distinct bacteria. It has been proposed that functional groups like -COOH, -COOR, -NH2, or -SH are in charge of the antibacterial activity. Thus, the fact that myristic acid and trimyristin both contain these groups implies that they might function similarly, which could account for their antibacterial properties[13].

Anti-inflammatory Activity:-

Despite the development of numerous anti-inflammatory medications in recent years, researchers and the medical community continue to place greater emphasis on natural sources of anti-inflammatory compounds because of the numerous negative effects of chemical medications. Mace and nutmeg essential oils have long been used to treat rheumatism, paralysis, and sprains. The properties of M. fragrance's petroleum ether extract are comparable to those of non-steroidal anti-inflammatory medications. Rats' edema caused by carrageenan can be prevented by nutmeg chloroform extract. In addition, nutmeg and mace methanol extracts have long-lasting anti-inflammatory properties. These characteristics may result from myristicin found in nutmeg essential oils[14]. Myristicin's anti-inflammatory impact resulted from its suppression of growth factors, chemokines, cytokines, and nitrous oxide in macrophages triggered by double-stranded RNA (dsRNA) through the calcium pathway . According to a different study, nutmeg seed ethanolic extract has strong anti-inflammatory properties by preventing the synthesis of nitric oxide and inflammatory cytokines[12].

Antidiabetic Activity :-

One naturally occurring substance that was separated from M. fragrans is macelignan. By activating the peroxisome proliferator receptor (PPAR, á/ã) and reducing endoplasmic reticulum stress, it alleviated lipid metabolic abnormalities and increased insulin sensitivity, indicating that it is an antidiabetic drug for the treatment of type 2 diabetes[15]. Blood glucose levels in all groups of rats were found to drop when petrolium ether extract of M.fragrans was administered to normal, glucose-fed, and alloxan-induced diabetic rats. This effect on blood sugar levels may be caused by the beta-cells' induced release of insulin. Rats given the extract orally displayed a lowering of their blood glucose levels. The body weight of the diabetic rats who received the extract orally increased. This may be because insulin secretion is increased and glycemic control is improved[16]. The suppression of glucose levels after external glucose loading may result from increased absorption of glucose, decreased absorption of glucose, or increased secretion of pancreatic secretions. After three to seven hours of therapy, a moderate drop in blood glucose levels was seen in streptozotocin-induced diabetic rats given an ethanolic extract of M.fragrans fruits. The greatest decrease was observed seven hours after therapy. These findings demonstrate that M.fragrans extracts have anti-diabetic effects[14].

Hepatoprotective Activity :-

Nutmeg can prevent hepatotoxicity because it contains myrislignan, a particular bioactive ingredient that shields the liver from harm. A powerful hepatoprotective effect has been observed for myristicin, an active component of nutmeg, which also suppresses the release of tumor necrosis factor (TNF)-alpha from macrophages . Nutmeg may protect against liver damage by helping to return mice to more healthy levels of various acylcarnitines and lipids, according to metabolomics analyses that examined the mechanism underlying the spice's protective effects in the mouse animal model of liver toxicity. Additionally, studies of gene expression revealed that nutmeg altered peroxisome proliferator-activated receptor alpha (PPARα)[12].

Cardioprotective Activity: -

In many nations, the main causes of disability and mortality are chronic illnesses such as diabetes, cancer, heart disease, high blood pressure, chronic kidney disease, and arthritis. Seven out of ten fatalities worldwide are caused by chronic illnesses. Chronic diseases are long-term conditions that are typically treatable but incurable. Numerous illnesses have been treated using natural treatments found in natural goods and functional foods. They are crucial in controlling basic pathophysiological processes such fibrosis, hypoxia, inflammatory responses, and oxidative damage. A unique chemical composition found in nutmeg seeds can lower lipid oxidation, prevent diabetes, hyperlipidemia, and heart disease. Traditional medicine has long utilized nutmeg seed as a natural remedy for a wide range of illnesses, including heart issues. According to recent research, nutmeg seed extract has strong bioactive chemicals with notable cardioprotective qualities, making it a promising new therapy option for cardiac conditions. The several bioactive substances in the extract, including myristicin, safrole, and eugenol, are thought to be responsible for these qualities. Because of its anti-inflammatory and antioxidant qualities, myristicin, the primary active ingredient in nutmeg, can fight against hyperlipidemia, brain damage, hyperglycemia, cardiac tissue damage, and hepatotoxicity [3].

According to ancient reports, nutmeg has cardio-tonic properties and guards against oxidative stress. Myristica fragrans seed extract was given to hypercholesterolemic rabbits, and the results indicated a considerable decrease in serum cholesterol and low-density lipoproteins (LDL). Additionally, nutmeg extract promotes the elimination of cholesterol and phospholipids through feces and stops the buildup of triglycerides, cholesterol, and phospholipids in the liver, heart, and aorta by stopping atheromatous plaque in the aorta [17]. Myristica fragrans' anti-aggregatory and hypolipidemic properties in albino rats' platelets were investigated. For 60 days, albino rats were administered an oral dose of 500 mg/kg of ethanolic nutmeg extract. Low-density lipoproteins (LDL), very-low-density lipoproteins (VLDL), and total cholesterol were found to have significantly decreased, while high-density lipoprotein (HDL) cholesterol increased. Toxicity investigations revealed no negative effects on various hematological and biochemical markers [18].

Antidepressant Activity:-

Depression, which is generally characterized by melancholy, mood fluctuations, disinterest in one's environment, and psychomotor slowness, affects about 5% of the population. The World Health Organization states that depression ranks as the fourth most common cause of disability globally. For ages, nutmeg has been used to treat psychoactive effects like hallucinations and anxiety because it can alter the central nervous system's physiology. The n-hexane extracts of M. fragrans seeds were tested for their antidepressant properties in mice utilizing the forced swim test (FST) and tail suspension test (TST)[12].It is well known that nutmeg has anxiogenic and antidepressant effects. Nutmeg extract was found to have a significant impact on the neurological system in a recent study and may be used to treat behavioral agitation, anxiety, and insomnia. This is because nutmeg's constituents have the ability to increase serotonin secretion, which promotes drowsiness or relaxation. The interaction of nutmeg with the brain's endogenous cannabinoid system initiates this mechanism. Immune function, appetite, temperament, and sleep are among the physiological activities that the endocannabinoid system (ECS) regulates[3].

Anticonvulsant Activity:-

Hexane extract from M. fragrans exhibits anticonvulsant properties against Grand Mal, Petit Mal, and Status Epilepticus animal models. Its anti-convulsant action could be partially attributed to decreased dopaminergic transmission. It was also shown that nutmeg essential oil had strong anticonvulsant properties against tonic extension of the hind limbs brought on by electroshock. It demonstrated dose-dependent anticonvulsant action against tonic seizures brought on by pentylenetetrazole. It postponed the start of strychnine-induced tonic extensor jerks in the hind limbs. Additionally, it was anticonvulsant at lower dosages while weak proconvulsant at larger dosages prevented clonic seizures caused by pentylenetetrazole and bicuculline [1].

Memory Enhancing Activity:-

The impact of M. fragrans seeds on mice's capacity for learning and memory. The elevated plus-maze and passive-avoidance devices were used to evaluate the learning and memory parameters. The learning and memory levels of both young and old mice were markedly enhanced when the n-hexane extract of M. fragrans was administered for three days in a row at the lowest dose of 5 mg/kg body weight. Additionally, the extract corrected the learning and memory deficits caused by scopolamine and diazepam in young mice. Numerous characteristics of M. fragrans, either alone or in combination, including procholinergic, anti-inflammatory, and antioxidant activity, may be responsible for the observed memory-enhancing effect [19].

Insecticidal Activity :-

When it comes to the stored product insects, Sitophilus zeamis and Tribolium castaneum, nutmeg oil has potent antifeedant activity, fumigant toxicity, and contact toxicity [9].Revealed that the chemicals found in M. fragrans seeds have insecticidal effects on adult female Blattella germanica (Dictyoptera: Blattellidae). The kernel's myristicin can be added to pyrethrum to increase its toxicity to houseflies, even if myristicin is inactive for itself. Cockroaches have been shown to be poisoned by M. fragrans aqueous decoctions. M. fragrans essential oil exhibits insecticidal properties against Callosobruchus chinensis and Lycoriella ingenua larvae [15].

Anticancer Activity:-

Numerous studies involving animals have demonstrated the exceptional anticarcinogenic effect of nutmeg essential oil. The host enzymes involved in the activation and detoxication of xenobiotic substances, such as chemical carcinogens and muta-gens, are disrupted by the essential oil. Nutmeg essential oil on the actions of hepatic carcinogen-metab-olizing enzymes in Swiss albino mice, specifically cytochrome P-450, aryl hydrocarbon hydroxylase, glutathione-S-transferase, and acid-soluble sulfhydryl level.The cytochrome P450 level was markedly elevated by nutmeg oil ($p < 0.05$). The activity of aryl hydrocarbon hydroxylase was considerably decreased. When compared to controls, glutathione-S-transferase activity was noticeably higher ($p < 0.1–0.001$). The nutmeg essential oils significantly increased the acid-soluble sulfhydryl ($p < 0.05$) [9].

Nutmeg is among the many seeds and spices that contain a wide range of bioactive chemicals. Modzelewska et al. (2005) reported that sesquiterpenes, one of the components of nutmeg, exhibited exceptional pharmacological activity against cancer. the proof that myristicin acts as a preventative mediator by preventing lung tumor development in mice. Additionally, myristicin from nutmeg caused human leukemia K562 cells to undergo apoptosis by suppressing the activation of genes linked to the mitochondrial pathways and DNA damage response. Phytosterols are also present in nutmeg. Numerous physiological mechanisms, such as angiogenesis, cancer-cell inhibition, and the stimulation of death in cancer cells, are associated with phytosterols.For several cancer types, nutmeg extract can be utilized as a chemopreventive and therapeutic treatment. Additionally, nutmeg seeds contain substances that can be added to current chemotherapeutic treatments or used alone to increase their efficacy while reducing any related harm [3].

Toxicological Properties:-

It is well known that nutmeg seeds have a negative reputation for being poisonous and having narcotic qualities . There have been few documented cases of nutmeg intoxication. A 23-year-old college student was reported to have become intoxicated after consuming nutmeg seeds . Additionally, nutmeg poisoning in a 16-year-old student was documented following ingestion of the ground uncooked seeds. A instance of a 17-year-old male who was disoriented and walked back and forth while clearly talking to himself because of a nutmeg overdose was described. But eating nutmeg by itself is unlikely to be fatal, as the symptoms go away in a day. Although 5–30 g of nutmeg powder is considered dangerous, no fatalities have been reported. However, no life-threatening condition was noted even when nutmeg seeds (20–80 g of powder) were consumed in greater dosages. These investigations, however, focused on eating raw nutmeg seeds rather than their extract or oil. Numerous extraction techniques have been shown to be effective in creating extracts that are safe and free of toxins. One of the best methods for creating safe and hygienic products is supercritical extraction. Varying fractions with varying compositions and

lower toxicity can be produced by adjusting the supercritical extraction settings. Furthermore, myrislignan, a bioactive component of supercritical nutmeg extract, demonstrated strong in vivo protective qualities against thioacetamide-induced liver damage. Therefore, nutmeg extract can be used as a powerful ingredient in the food and pharmaceutical industries to create a safe, toxin-free product. To determine the safety and effectiveness of nutmeg seeds as well as the best dosages and therapy formulations, further thorough research is required[3].

II. CONCLUSION

One of the most useful and adaptable medicinal spices is nutmeg (Myristica fragrans Houtt.), which connects the advances of contemporary pharmacological science with the rich history of traditional medicine. Nutmeg's diverse biological actions are mostly attributed to its rich phytochemical composition, which includes myristicin, eugenol, trimyristin, myristic acid, lignans, terpenoids, flavonoids, and phenolic chemicals. Its important antioxidant, antibacterial, anti-inflammatory, analgesic, anticancer, and neuroprotective properties have been shown in studies, supporting its traditional applications in Ayurveda, Unani, and folk medicine.

By scavenging free radicals, boosting enzymatic defense, and stopping lipid peroxidation, its powerful antioxidant capability allows resistance against oxidative stress. Nutmeg's antibacterial and antibiofilm qualities provide natural substitutes for resistant bacterial strains, including oral infections like Porphyromonas gingivalis and Streptococcus mutans. Its capacity to block pro-inflammatory mediators and alter pain signaling pathways is responsible for its anti-inflammatory and analgesic properties, and its phenolic components, which trigger apoptosis and stop tumor growth, are linked to its anticancer potential.

There are also issues with standardization, dosage optimization, bioavailability, and toxicity assessment despite these encouraging pharmacological characteristics. Due to substances like myristicin, excessive nutmeg use might have harmful effects; therefore, careful preparation and dosage are crucial. To improve efficacy and safety, future research should concentrate on identifying particular bioactive compounds, investigating their molecular mechanisms, and creating innovative delivery methods including liposomes, phytosomes, and nanoemulsions.

Additionally, the disciplines of pharmaceuticals, nutraceuticals, and cosmeceuticals can develop novel nutmeg-based formulations by combining contemporary analytical methods with traditional expertise. Standardized extraction techniques, appropriate quality control, and sustainable farming methods are also essential for guaranteeing reliable medicinal outcomes.

To sum up, Myristica fragrans is a valuable herbal resource with significant industrial and medicinal potential. Nutmeg could become a powerful natural cure in contemporary phytotherapy and drug discovery, as well as a culinary spice, with further study and development unlocking its full medicinal potential.

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