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AONLA (*EMBLICA OFFICINALIS*): ROLE IN HEALTH MANAGEMENT VIA CONTROLLING VARIOUS BIOLOGICAL ACTIVITIES

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ABSTRACT

Since ancient times, Amla, also known as Indian gooseberry trees, *Phyllanthus emblica* (also known as *Emblica officinalis*), has been utilised extensively in the treatment and prevention of disease. Almost every part of the tree root, bark, leaf, flower, fruit, and seed is used in Ayurvedic and Unani medicine to improve the digestive system, reduce fever, cleanse the blood, relieve asthma and coughing, fortify the heart, and more. In addition to having significant secondary metabolites including emblicanin-A and emblicanin-B, this tree is a strong source of vitamin C. Other secondary metabolites such as pectin, gallic acid, pyrogallol, and tannins are also found in significant amounts. Among its many constituents include tannins, alkaloids, gallic acid, fibre, carbs, vitamin C, and an abundance of antioxidants. Amla fruits are commonly used to treat a range of ailments due to their potential as antioxidants. Both in vitro and in vivo studies have shown that amla is important in reducing oxidative stress, reactive oxygen species, and lipid peroxidation. It also increases the levels of various antioxidants, which in turn helps to avoid pathogenesis. Health management has been shown to benefit from the antioxidative, anti-inflammatory, hepatoprotective, gastroprotective, anti-diabetic, antibacterial, neuroprotective, cardioprotective, and immunomodulatory qualities. Additionally, it has been shown in multiple trials to be beneficial in the treatment of cancer. In light of these discoveries, the goal of this review is to fully examine *P. emblica's* pharmacological activities and the intricate composition of its phytochemical constituents. This article systematically summarises the role of Amla (*Emblica officinalis*) in the management and treatment of illnesses by looking at the in vitro and in vivo research.

Keywords **:** *Phyllanthus emblica*, Disease's cure, Health management, Antioxidant, Anticancer, anti-inflammatory, neuroprotective

Introduction

In addition to India, Aonla trees can be found in the natural forests of Cuba, the United States, Pakistan, Sri Lanka, Malayasia, China, Java, and the West Indies. Aonla fruit or its powder is used to make traditional specific formulations of ayurvedic

medicines like ashokarishta, chavanprash, triphalamasin, and triphala. Aonla (*Emblica officinalis* Gaertn), also known as Indian gooseberry, is a significant fruit crop of Indian origin that is grown in all regions of the country under a variety of agroclimatic conditions. In ancient literature, it was referred to as Amritphal and was revered as a sacred tree (Singh *et al.,* 2019, Jat *et al.*, 2020).

The fruit is useful for many ailments and can be made into a number of things with added value. Fruit is also used to make Aonla powder, which is superior to synthetic vitamin C in correcting deficiencies. On an estimated 50,000 hectares of land, it generates 1.5 lakh tonnes annually (Pathak *et al.,* 2003). It is cultivated for commercial reasons in the following states: Uttar Pradesh, Uttarakhand, Gujarat, Maharashtra, Rajasthan, Tamil Nadu, Andhra Pradesh, Karnataka, Bihar, Haryana, Madhya Pradesh, Rajasthan, and West Bengal (Pathak *et al.,* 2003). 92,000 hectares of land are used to grow aonla nationwide, with an annual production of 1046 thousand MT (millions of tonnes) [NHB, 2024]. In Uttar Pradesh, it is most commonly grown in Pratapgarh, Varanasi, Sultanpur, Azamgarh, Jaunpur, Rai Bareily, Agra, and Bareilly. According to Pathak *et al.* (1993), Pratapgarh is among the best districts in the country for commercial aonla farming.

Tree height, tree habit, tree form, leaf size, leaf form, leaf width, leaf apex, foliage, and inflorescence colour have all been described, along with the morphological characteristics of a number of aonla cultivars, including Chakaiya, Banarasi, Francis, Kanchan, Krishna, Anand2, Anand-1, NA-10, and NA-7. Different cultivars had different heights and habits; Anand-2 and Anand-1 had tall upright trees, whereas NA-7 had tall spreading trees, Francis had tall drooping trees, and Kanchan had tall semi-spreading trees (Kumar *et al.,* 2016). Recent in vitro research has demonstrated that *E. officinalis* (amla) plays a significant role in preventing the growth of colorectal cells and, in rodent models induced by carcinogens, a number of cancers, such as skin, stomach, and liver cancers (Chen *et al.,* 2011; Krishnaveni and Mirunalini, 2012; Ngamkitidechakul *et al.,* 2010). For every 100 g of *P. emblica* fruit, there are an incredible 600–1,300 mg of vitamin C. Glutamic acid (29.6%), proline (14.6%), aspartate (8.1%), alanine (5.4%), and lysine (5.3%) are the most abundant amino acids in the mixture (Saini *et al.,* 2022).

In Ayurveda, it is highly prized for its healing qualities. Aonla is an important component of ayurvedic treatments like triphala and chavanprash. Fresh or dried fruit can be used to treat jaundice, diarrhoea, diabetes, and inflammation. It also possesses potent antimicrobial properties (Kumari and Khatkar, 2016). Natural products have existed since the dawn of human civilisation. Today, there is widespread recognition of the value of traditional medical systems and certain of its methods. Select medications with botanical origins now need to be evaluated using a clever and useful approach.

All components of *Phyllanthus emblica*, including the fruits, flowers, seeds, leaves, and bark, have been used extensively in traditional medicine. Pharmacological research indicates that *P. emblica* has anti-inflammatory (Wang *et al.,* 2019), anti-cancer (Ngamkitidechakul *et al.,* 2010; Mahata *et al.,* 2013; Gaire and Subedi, 2014; Zhao *et al.,* 2015; Chekdaengphanao *et al.,* 2022; Naik and David, 2023), cytoprotective (Zhang *et al.,* 2016), anti-viral (Lv *et al.,* 2014; Lv *et al.,* 2015), anti-aging (Wu *et al.,* 2022), anti-apoptotic (Chekdaengphanao *et al.,* 2022), anti-inflammatory (Wang *et al.,* 2019), hepatoprotective (Pramyothin *et al.,* 2006), and antioxidant qualities (Chaphalkar *et al.,* 2017; Sheoran *et al.,* 2019). Different parts of Phyllanthus emblica have been used to manufacture a variety of herbal and patent medicines (Dinesh *et al.,* 2017). Amla has also been used in formulations or in combination with other natural products because of its health-promoting qualities. Health management has been shown to benefit from the antioxidative, anti-inflammatory, hepatoprotective, gastroprotective, anti-diabetic, antibacterial, neuroprotective, cardioprotective, and immunomodulatory qualities. Additionally, it has been shown in multiple trials to be beneficial in the treatment of cancer.

The effect of *E. officinalis* extracts on cellular oxidative state was tested using hepatocyte cell lines. Following incubation with *E. officinalis*, levels of lipid hydroperoxide and reactive oxygen species (ROS) dramatically dropped. Furthermore, *E. officinalis* enhanced glutathione levels, antioxidant capacities, and enzyme activities (Shivananjappa and Joshi, 2012). When compared to cisplatin-control rats, *E. officinalis* markedly enhanced antioxidant status, apoptosis, inflammation, and renal function (Malik *et al.,* 2016a). *Emblica officinalis* fruit extract is used medicinally to treat diarrhoea because of its spasmolytic and antidiarrheal qualities, which may be mediated via dual blockage of muscarinic receptors and Ca^{2+} channels (Mehmood *et al.,* 2011). Furthermore, it was shown that the aqueous extract of E. officinalis had antidepressant-like properties, possibly as a result of antioxidant activity and GABA and MAO-A blocking (Dhingra *et al.,* 2012). According to current in vitro research, *E. officinalis* (amla) plays a significant role in

preventing the formation of colorectal cells and a number of malignancies, such as skin, stomach, and liver cancers in rodent models brought on by carcinogens (K.H. Chen *et al.,* 2011; Ngamkitidechakul *et al.,* 2010; Krishnaveni and Mirunalini, 2012). We carried out a comprehensive investigation to look into the function of *E. officinalis* in the treatment of the illness using both in-vitro and in-vivo research.

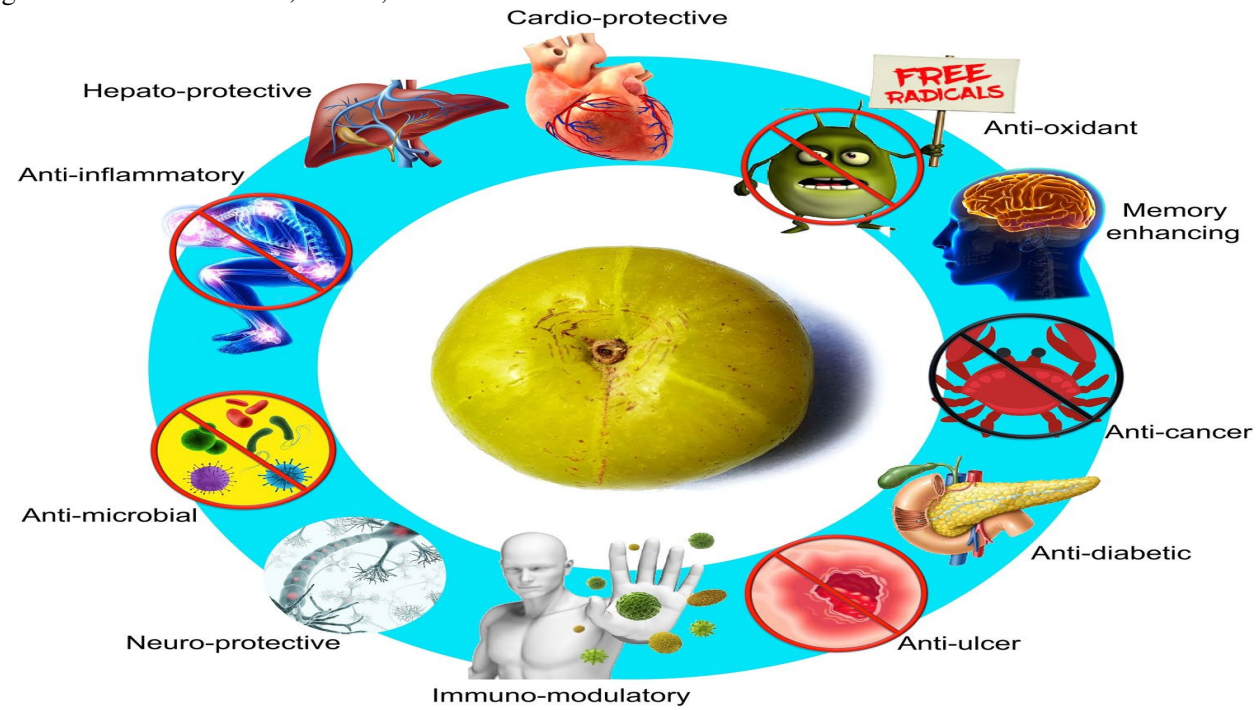

Fig. 1 : Diagrammatic presentation of selected pharmacological properties of *Emblica officinalis* Gaertn. syn. *Phyllanthus emblica* L. (Source: Gantait *et al.,* 2021)

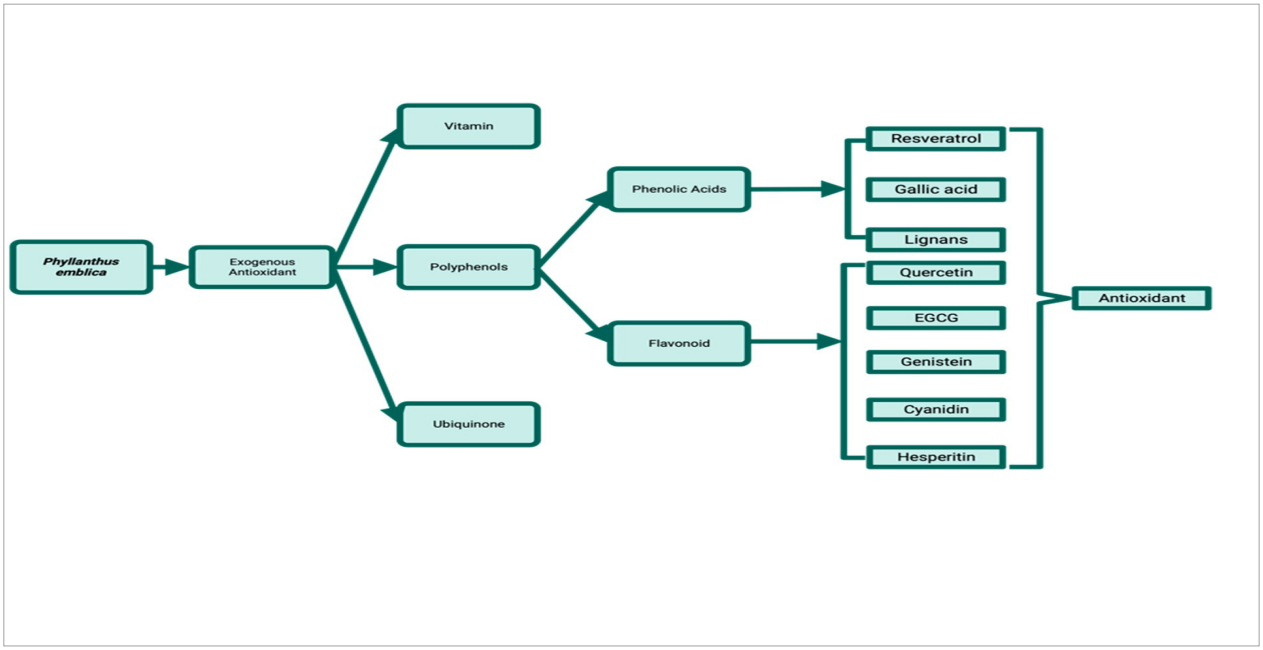

Fig. 2 : Antioxidant of *Phyllanthus emblica* (Prananda *et al.,* 2023).

These days, researchers' primary focus is on examining and screening plants for the presence of chemicals with therapeutic qualities. Secondary metabolites produced in higher plants have a variety of therapeutic possibilities in addition to antimutagenic and anticarcinogenic qualities. Phenolic chemicals can

be found in fruits and vegetables (Singh *et al*., 2016). Aonla is processed into a variety of products because of its exceptional nutritional profile and physico-chemical characteristics. Aonla fruit is typically used raw, boiled, or pickled because of its sour and astringent flavor. Due to their high antioxidant and vitamin C content, consumers appreciate the various varieties of aonla goods that are readily accessible on the market, including murrabas, juice, jam, cheese, sweets, powder, beverages, and chutney. Many ayurvedic remedies, such as Triphla and Chyawanprash, contain aonla as a primary ingredient (Pant *et al.,* 2004; Goyal *et al.,* 2007; Mishra *et al.,* 2009).

Table 1 : Origin of severel phytochemicals from *Emblica officinalis* Gaertn. syn. *Phyllanthus emblica* L

S.N.	Plant part	Phytochemical	References
	Bark	β-sitosterol, Leucodelphinidin, Lupeol, Tannin	Srikumar *et al.,* (2007), Khan (2009)
1.	Fruit	Di-O-galloyl-glucose (3–6), β-carotene, arginine, aspartic acid, ascorbic acid, and alanine Calcium, Boron, carbohydrates, The compounds chembulagic acid, chibulinic acid, chembulaginic acid, and chembic acid Chloride Cystine, copper, corilagin, corilagic acid, D-glucose, d-fructose, and Ellagic acid Emblicol, Emblicanin-A, -B, Gallic acid, gallic acid ethyl ester, ethyl gallate (also known as Phyllemblin), The compounds gibberellin A1, A3, A4, A7, A9, and A3 (syn. gibberellic acid), Glucogallin Glucose Glutamic acid l-malic acid, glycine, histidine, iron, isoleucine, leucine, and lysine 2. O-gallate Magnesium, manganese, myristic acid, methionine, and myo-inositol Nitrogen, Nitrogen, phyllemblinic acid, phosphorus, pectin, phenylalanine, polysaccharide, Potassium, Proline, Quercetin, ribofavin, rutin, selenium, serine, silica, sodium, starch, sucrose, sulphur, tannin, terchebin, thiamin, threonine, trigalloyl glucose, tryptophan, tyrosine, zinc, zeatin, zeatin riboside, zeatin nucleotide, phyllantidine, and phyllantine protein	Ghosal *et al.* (1996), Jagetia *et al.* (2004), Srikumar *et al.* (2007), Singh *et al.* (2011), Srinivasan *et al.* (2018)
2.	Leaf	Phyllantidine, Phyllantine, Gallo-tannin, Kaempferol, Kaempferol-3-O-glucoside, Amlaic acid, Astragalin, Ellagic acid, and Tannin	Srikumar *et al.* (2007), Khan (2009
3.	Root	Ellagic acid, Lupeol	
4.	Seed	β-sitosterol, Flavonoid, Linoleic acid, Linolenic acid, Myristic acid, Oleic acid, Palmitic acid, Stearic acid, Tannin	Srikumar *et al.* (2007), Khan (2009), Sriwatcharakul (2020)
5.	Shoot	3–6-di-O-galloyl-glucose, β-sitosterol, Chebulagic acid, Chibulinic acid, Ellagic acid, Gallic acid, Glucogallin, Lupeol	Srikumar et al. (2007)
6.	Twig	Tannin	
7.	Whole plant	Ascorbic acid, Lupenone	

1. Antioxidant activity

Oxidative stress is associated with either a decrease in antioxidant content or an increase in the generation of free radicals. The observed event implies that there has been an imbalance between pro-oxidant and antioxidant molecules. Because they have several unpaired electrons, pro-oxidants and free radicals are unstable and highly reactive with other substances. According to a prior study, *Phyllanthus emblica* possesses antixoidant properties. For lipid peroxidation (IC50 = 84,10 ± 3.04 µg/mL), nitric dioxide (IC50 = 39.14 ± 2.31 µg/mL), and DPPH radical scavenging (IC50 = 39.73 ± 2.12 µg/mL), the methanol extract of *P. emblica* exhibited moderate antioxidant activity.

Additionally, *Phyllanthus emblica* demonstrated that the rats could recover from CCl_4 therapy by raising the levels of catalase, superoxide dismutase, glutathione peroxidase, and glutathione in their lungs. The pharmacological characteristics of *P. emblica* may be attributed to active phyto-constituents such rutin, kaempferol, gallic acid, and caffeic acid (Tahir *et al.,* 2016). According to another study, the IC50 values of *P. emblica* branches, leaves, and barks in aqueous extract were 6.92 ± 0.22 µg/mL, 7.72 ± 0.25 µg/mL,

and 6.54 ± 0.27 µg/mL, respectively.

These results fell just short of the IC50 of ascorbic acid (8.06 ± 0.01) µg/mL (Iamsaard *et al.,* 2014). The antioxidant capacity of *P. emblica* was addressed by phytochemical components such as reseveratrol, gallic acid, lignans, quercetin, EGCG, genistein, cyanidin, and hesperitin (Figure 2). The antioxidant qualities of *Emblica officinalis* tannoid, which contains punigluconin, pedunculagin emblicanin A, and emblicanin B, were examined. The results were compared to the effects of the well-known antioxidant deprenyl. Doses of 10 and 5 mg/kg of active tannoids with deprenyl were found to improve the activity of glutathione peroxidase, catalase, and superoxide dismutase in the striatal and frontal cortex, respectively, and to decrease lipid peroxidation. The effects of acutely administered deprenyl and *Emblica officinalis* tanninoids were insignificant.

Additionally, according to the study, *E. officinalis's* tannoids, which resemble vitamin C, might have antioxidant properties (Bhattacharya *et al.,* 1999). The aqueous extract of *Emblica officinalis* was discovered to be a strong inhibitor of lipid peroxide formation and a scavenger of hydroxyl and superoxide radicals based on an in vitro study that examined the antioxidant activity. Additionally, an ancient medicine made and utilized as a health tonic in India contained *Emblica officinalis* and shown potent antioxidant properties. According to Jose and Kuttan (1995), the antioxidants found in *Emblica officinalis* are partially extractable with ether but are heat stable and aqueously soluble. Extracts from *E. officinalis* demonstrated their effect on the oxidative status of hepatocyte cell lines by reducing lipid hydroperoxide and reactive oxygen species. The outcome clearly demonstrates that aqueous extracts of *E. officinalis* can boost hepatocytes' natural antioxidant defences (Shivananjappa and Joshi, 2012). It was investigated whether fruit extract from *Emblica officinalis* could improve the plasma biochemical profile in rats that had oxidative alterations brought on by alcohol. When alcohol was administered, there was an increase in plasma nitrite/nitrate, lipids, lipoproteins, creatinine, and total bilirubin.

Mice administered 250 mg/kg body weight of alcohol-supplemented extract daily also demonstrated a considerable reduction in creatinine and nitrite/nitrate levels, as well as control over lipoprotein profiles and plasma lipids. Additionally, rats administered the extract exhibited markedly elevated levels of total plasma protein, uric acid, and the A/G ratio (Reddy *et al.,* 2010). The antioxidant properties of amla (*Emblica officinalis*) and the free and bound phenolics were investigated in a study. By scavenging free radicals and lowering power tests, *emblica officinalis* free and bound phenolics demonstrated 4–10 times higher levels of antioxidant activity than curcumin free and bound phenolics. Higher levels of antioxidant activity have been linked to *E. officinalis's* phenolic content.

2. Anti-inflammatory activity

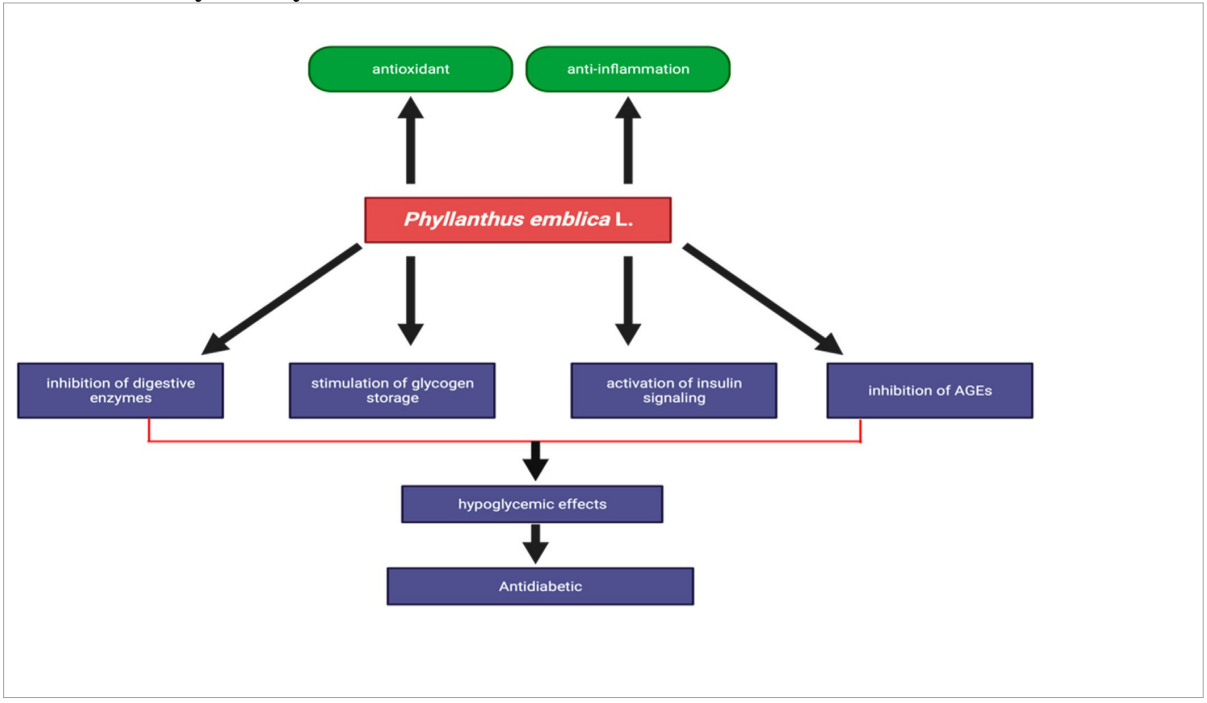

Fig. 3 : Antiinflammatory of *Phyllanthus emblica* (Prananda *et al.,* 2023).

An essential innate immune response to outside stimuli, such as pathogen-induced damage or infection, is inflammation (Jubaidi *et al.,* 2021). Inflammation is an important immunological response that aids the body in surviving and recovering from damage. It is recognised as a good pathological process due to its significant role in restorative, healing, and aggressive mechanisms, especially in defending against stress brought on by pathogens and dangerous situations (Rakha *et al.,* 2022). Inflammation is a complex process that involves numerous biological reactions, mainly classified as acute and chronic inflammation.

Acute inflammation is a defence mechanism that the body uses to help heal wounds and protect against microbial invasion. Conversely, chronic inflammation damages essential cells, molecules, and organs, resulting in the onset and progression of numerous chronic illnesses, such as cancer, neurological conditions, diabetes, inflammatory bowel disease, cardiovascular disease, and disorders of the skeletal muscles (Ferraz *et al.,* 2020). Therefore, chronic inflammation exacerbates ageing as well.

The fruit preparations of *Phyllanthus emblica* significantly and dose-dependently suppressed COX-2 and nitric oxide (NO). The molecule NO is necessary for immune-signaling pathways. An excess of NO can lead to a variety of clinical diseases and abnormalities, such as oxidative stress, cardiovascular-related damage, and severe inflammation. *Phyllanthus emblica* extracts demonstrated dose-dependent NO suppression in LPS-stimulated RAW264.7. The 95% ethanolic extract showed significantly greater NO inhibition (49.1%) at 50 and 100 µg/mL concentrations compared to hot water and commercial extract. The *P. emblica* extracts demonstrated a notably higher level of COX-2 inhibition in comparison to both hot water and commercial extract.

The highest COX-2 inhibition was recorded at a dose of 10 µg/mL (46.4%). COX-2 inhibition may control inflammation in inflammatory diseases and abnormalities. *Phyllanthus emblica* showed its anti-inflammatory qualities by inhibiting the COX-2 enzyme and excessive NO production in macrophage cells (Li *et al.,* 2022). Research on *Emblica officinalis* extracts revealed that the water component of the methanolic extract of the leaves exhibited anti-inflammatory qualities. The effects of several inflammatory mediators were examined, including platelet-activating factor, thromboxane B2, leukotriene B4, LTB4, and migration of human polymorphonuclear leucocytes generated by N-formyl-L-methionyl-Lleucyl-L-phenylalanine. The water component of the methanolic extract inhibited human PMN migration at very low doses (Asmawi *et al.,* 1993). Compared to all phlogistic treatments, intraperitoneal injections of hydroalcoholic extract from *Emblica officinalis* at 700, 500, and 300 mg/kg significantly decreased rat paw oedema and decreased the formation of granulomas.

However, at a higher dose of 700 mg/kg, the extract demonstrated robust anti-inflammatory responses in experimental animals and demonstrated effects that were comparable to those of traditional anti-inflammatory drugs (Golechha *et al.,* 2014). A second investigation was carried out utilising an animal model of acute and chronic inflammation brought on by cotton pellets and carrageenan in order to evaluate the anti-inflammatory qualities of *Emblica officinalis* phenolic components. According to the results, inflammation was decreased by the *E. officinalis* fractions containing free (FPEO) and bounded (BPEO) its ability to modulate free radicals (Muthuraman *et al.,* phenolic compounds. Nevertheless, compared to the diclofenac-treated group, significant effects were only observed at high doses of both fractions. Overall, research indicates that phenolic compounds from *Emblica officinalis* may be a potential herbal candidate for reducing acute and chronic inflammation through its ability to modulate free radicals (Muthuraman *et al.,* 2011). When *Emblica officinalis* extract was given to bronchial epithelial cells (IB3-1 CF) exposed to Pseudomonas aeruginosa strain PAO1, it significantly decreased the expression of pro-inflammatory cytokines, GRO-alpha and GRO gamma of ICAM-1 adhesion molecule, and IL-8 neutrophil chemokines that are dependent on PAO1. Pyrogallol, like the entire EO extract, suppressed the expression of pro-inflammatory genes dependent on *Pseudomonas aeruginosa.* However, 5-hydroxy-isoquinoline, a different molecule that was extracted from EO, showed no impact (Nicolis *et al.,* 2008). The nephroprotective effects of *E. officinalis* dried fruit extract were tested in rats with cisplatin-induced nephrotoxicity, as evidenced by increased oxidative stress, apoptosis, and inflammation; however, *E. officinalis* at 600 mg/kg significantly restored renal function, increased antioxidant status, and significantly reduced inflammation and apoptosis in comparison to rats given controlled cisplatin (Malik *et al.,* 2016a).

3. Hepatoprotective effect

Phyllanthus emblica contains rich amounts of gallic acid and many other well-known medicinal phytochemicals and acids, and fruit from the plant has been shown to have in vitro inhibitory effects on liver fibrosis and hepatic steatosis. NAFLD (non-alcoholic fatty liver disease), one of the most prevalent chronic

liver illnesses, is closely associated with metabolic syndrome and is defined as the accumulation of hepatic steatosis that is not brought on by excessive alcohol consumption (Paik *et al.,* 2020). Additionally, it has been demonstrated that gallic acid content reduces oxidative stress, hepatosteatosis, and dyslipidaemia caused by a high-fat diet (HFD) in vivo. Huang et al. initiated a study to evaluate the hepatoprotective effect of *P. emblica* L. fruit aqueous extract (WEPE) on NAFLD in an animal model. WEPE was reported to improve steatosis, increase antioxidant enzyme activities, and significantly reduce body weight, peritoneal fat, and epididymal fat in rats given an HFD by increasing adiponectin in adipocytes, PPAR-α in the liver, and decreasing SREBP-1c in the liver. This could be the reason why WEPE can reduce the buildup of hepatic fat. These findings suggest that WEPE may be useful in treating steatosis caused by an HFD (Tung *et al.,* 2018).

In order to test the hepatoprotective qualities of extracts from *Emblica officinalis* and Chyavanaprash, carbon tetrachloride was used to cause liver damage in rats. The results showed that both extracts prevented the hepatotoxicity caused by the administration of carbon tetrachloride, as demonstrated by the reductions in serum levels of liver lipid peroxides (LPO), glutamate-pyruvate transaminase, and alkaline phosphatase. Furthermore, each extract was shown to considerably lower these high levels, suggesting that the extract prevented rats from developing fibrosis (Jose and Kuttan, 2000). Furthermore, univacuolated hepatocytes demonstrated a potent pathogenic defence against liver cells induced by pretreatment with *Emblica officinalis*. Blood enzyme and peroxide levels drop after pretreatment with 100 and 200 mg/kg body weight of *E. officinalis* in a model of carbon tetrachloride intoxication (Sultana *et al.,* 2005). 50% of the hydroalcoholic extract of *Emblica officinalis* fruit showed hepatoprotective qualities against liver damage caused by antituberculosis drugs, per the results of a ground-breaking study. The extract's antioxidative, CYP 2E1 inhibitory, and membrane stabilising qualities were evidence of its hepatoprotective effect (Tasduq *et al.,* 2005). In vitro studies revealed that *Emblica officinalis* fruit extract had nitric oxide scavenging and antioxidant qualities in rats with alcohol-induced liver damage. Furthermore, in vivo alcohol dose increased levels of protein carbonyl, nitrate, nitrile, and liver lipid peroxidation. Alkaline phosphatase, gamma-glutamyl transferase, and plasma transaminases were also shown to have significantly increased. The injection of alcohol to rats significantly lowers the activity of hepatic mitochondrial antioxidant enzymes in comparison to control rats. When alcoholic rats are given 250 mg/kg body weight of fruits, the levels of enzymatic and non-enzymatic antioxidants are restored, lipid peroxidation and protein carbonyl levels are decreased, and plasma enzyme levels are considerably brought closer to normal (Damodara Reddy *et al.,* 2010). Consequently, it was found that *Emblica officinalis* had a protective impact on the liver mitochondria of rats that were fed ethanol (Reddy *et al.,* 2009).

4. Gastroprotective effect

Two models were used to evaluate the effect of *Emblica officinalis* methanol extract on acute stomach ulcers in rats (S.A. Almatroodi *et al.,* 2020). Extract given orally at doses between 10 and 50 mg/kg showed dose-dependent ulcer prevention qualities in models of acute ulcers. Finally, the extract's notable healing and ulcer-preventive qualities might have been influenced by its effects on mucosal components (Sairam *et al.,* 2002). Another study claims that the fruit extract of *Emblica officinalis* possesses antidiarrheal and spasmolytic qualities. This may be due to the fact that it blocks both muscarinic receptors and calcium channels (Mehmood *et al.,* 2011). A 100 mg/kg oral pretreatment of the water portion of *Emblica officinalis* fruit extract was administered to rats with indomethacin-induced ulcers, improving their hexosamine and stomach mucus discharges.

5. Anti-diabetic effect

Due to its microvascular effects (retinopathy, neuropathy, and nephropathy) and macrovascular complications (heart attack, stroke, and peripheral vascular disease), diabetes mellitus is a common endocrine metabolic disease that has resulted in significant morbidity and mortality (Hussain *et al.,* 2021). The human body has both enzymatic and non-enzymatic antioxidant systems that lower reactive oxygen species production, which has been connected to the development of several degenerative disorders, including diabetes. The prevalence of the disease is rising quickly worldwide and is affecting many regions (Shamsudi *et al.,* 2022).

Blood glucose levels are greater in diabetics because of a lack of insulin. Type 2 diabetes, also known as non-insulin-dependent diabetic mellitus, is the most prevalent type of the disease and affects 90–95% of patients due to insufficient insulin synthesis or utilisation (Bitew *et al.,* 2021). According to the World Health Organisation, there will likely be 300 million or more diabetics by 2025, a huge rise from the current level (Ansari *et al.,* 2022). Insulin and a range of oral antidiabetic medications, including glinides,

biguanides, and sulfonylureas, are now accessible treatments for diabetes (Kalaitzoglou *et al.,* 2019). The ethanolic extract of *P. emblica* is a potent treatment to lower blood glucose levels, according to Bashir et al. (2018). After treatment with 80 mg/kg *P. emblica*, the glucose level in diabetic rats dropped dramatically (to 166 ± 0.7 mg/dL) in comparison to the untreated diabetic rats (to 380 ± 0.7 mg/dL). Tannin, an effective drug that increases insulin sensitivity towards peripheral tissues and prevents adipogenesis, is a component of the ethanolic extract of *P. emblica* (Gul *et al.,* 2022). Activation of insulin signalling, suppression of AGEs, stimulation of glycogen storage, and inhibition of digestive enzymes are some of the mechanisms by which *Phyllanthus emblica* produces hypoglycemia.

Amla's efficacy was examined in mice whose hyperglycemia was caused by arsenic. The results showed that exposure to arsenic alters glucose homeostasis and significantly reduces the hepatic glucose regulating enzyme and pancreatic inflammatory markers such as TNF-α and IL1β. Furthermore, compared to controls, arsenic exposure markedly reduced blood insulin and c-peptide protein. Blood sugar levels and hepatic glucose regulatory enzymes were balanced when arsenic and amla (500 mg/kg b.w.) were administered together. Additionally, pancreatic inflammatory markers such phosphoenolpyruvate carboxykinase, glucose-6 phosphatase, and IL-1β were dramatically decreased. Furthermore, compared to individuals treated with arsenic alone, it significantly increases serum insulin and c-peptide protein levels (Singh *et al.,* 2020). Diabetic rats were used in a follow-up study to examine *Emblica officinalis's* antidiabetic qualities.

The results showed that the groups treated with plant extracts had significantly lower blood glucose levels than the group treated with metformin. Furthermore, extract doses of 200 and 400 mg/kg significantly reduced serum glucose and lipid levels, respectively, similar to the group treated with metformin (Elobeid and Ahmed, 2015). The current study sought to determine how *Emblica officinalis* aqueous extract affected oxidative stress-mediated nerve injury in diabetics. In the von-Frey hair test and Randall-Selitt, rats with diabetes demonstrated a significantly reduced paw withdrawal threshold together with a decrease in tail-flick latency. A dose-dependent reduction in biochemical, molecular, and behavioural alterations occurred after treatment with the *Emblica officinalis* aqueous extract. *Emblica officinalis* extract and oxidative-nitrosative stress modulation, however, decreased reversed neuropathic pain and the diabetic condition in diabetic rats (Tiwari *et al.,* 2011). Thirteen uremic diabetic patients were treated with amla extract and epigallocatechin gallate for three months before several plasma biomarkers were evaluated. Oral administration of a 1:1 blend of Amla extract and epigallocatechin gallate dramatically improved antioxidant activity and showed promise as a safe and effective treatment for diabetic uremic patients (Chen *et al.,* 2011).

6. Anti-microbial activity

According to a study, aonla had antimicrobial activity against *Bacillus subtilis, Candida albicans, Micrococcus varians, Staphylococcus aureus, S. haemolyticus,* and *S. saprophyticus.* Bioactive substances such flavonoids, phenols, saponins, and tannins are responsible for the potent antibacterial qualities of aonla fruit extract (Javale and Sabnis 2010). Jahan and Akter (2015) conducted research to evaluate the antibacterial qualities of *Phyllanthus emblica*. In this work, the disc diffusion method was applied. A standard kanamycin disc was used to test the methanolic extract of *P. emblica* at a concentration of 500 µg/disc against gram-positive, gram-negative, and multidrug-resistant bacteria. The results demonstrated that Shigella dysenteriae (17 mm), Staphylococcus aureus (20 mm), and *Bacillus subtilis* (25 mm) were among the pathogens that were strongly inhibited by the ethanolic extract of PE. The aqueous and ethanolic extracts of *P. emblica* were shown to be effective against Pseudomonas aeruginosa using the disc diffusion method (Farhana *et al.,* 2022). At doses of 50 mg/mL and 25 mg/mL, respectively, the methanolic extract of *P. emblica* totally bactericidalized AMR (antimicrobial-resistant) S. Typhi and S. Enteritidis (Nair *et al.,* 2020). Aqueous and successive extracts of Ocimum sanctum leaves and stems, as well as the fruit pulp of *Emblica officinalis*, were tested for antimicrobial activity. Amoxicillin and amphotericin B, two common drugs, were linked to the outcomes. In terms of defence against all pathogenic bacteria, it was found that the methanolic extract of *Emblica officinalis* was superior to the leaf and stem extracts of Ocimum sanctum (Vijayalakshmi *et al.,* 2007). Using the solvent-solvent partitioning method, alkaloids were separated from the methanolic extract of *Emblica officinalis* fruit, and their antibacterial and cytotoxic properties were evaluated.

A significant degree of cytotoxicity and antibacterial activity against both Gram-positive and Gram-negative pathogenic bacteria was shown by the chloroform soluble fraction of the methanolic extract (Rahman *et al.,* 2009). Aqueous infusions and decoctions of *Emblica officinalis* demonstrated potent

antibacterial activity against bacterial isolates, such as Salmonella typhi, *Pseudomonas aeruginosa, Klebsiella pneumoniae, K. ozaenae, Escherichia coli, Proteus mirabilis, S. paratyphi* A), S, and paratyphi B (Saeed and Tariq 2007). Long-term feeding of experimental mice was used to examine the impact of E. officinalis on respiratory tract infections caused by Klebsiella pneumonia. The findings showed that amla supplementation through food prevents bacterial colonisation of the lungs (Saini and Sharma, 2008).

The impact of *Emblica officinalis* ethanolic extract on denaturing Candida albicans' adhesion to epithelial cells on human buccal and acrylic surfaces was evaluated. Overall, less yeast strains adhere to buccal epithelial cells, and acrylic strips were seen after exposure to 75–300 mg/ml of plant extract as opposed to NSS, according to the study's findings. The ethanolic extract of *Emblica officinalis* denatured acrylic surfaces and postponed Candida albicans' attachment to buccal epithelial cells, per in vitro findings (Thaweboon & Thaweboon, 2011). Aqueous and methanolic extracts of *Emblica officinalis* were tested for their capacity to suppress pathogenic microbes. The aqueous amla extract infusion showed strong antibacterial activity against *E. cloacae* and *E. coli*, which explained the result. The highest MIC against *K. pneumoniae* is seen in the *Emblica officinalis* aqueous extract. However, its methanolic extract MIC demonstrates the highest efficacy against *E. coli* (Kumar *et al.,* 2011).

7. Neuroprotective effect

To increase cognition in humans and animals, flavonoid-rich plant or dietary extracts may strengthen neuronal function, protect vulnerable neurons, or promote neuronal regeneration (Hwang *et al.,* 2012). Their neuroprotective properties have been demonstrated in models of oxidative stress and Aβ-induced neuronal death. Extracts from ginkgo biloba that are high in flavonoids have been shown to improve and change the brain, especially in cases of Alzheimer's disease and age-related dementia (Calderaro *et al.,* 2022). Individual flavonoids, such as the citrus flavanone tangeren, have been shown to maintain nigrostriatal integrity and functionality following 6-hydroxydopamine lesioning, suggesting that they may provide protection against the pathogenesis of Parkinson's disease (Vauzour *et al.,* 2008).

The findings of a recent study by Rajalakshmi *et al.* (2019) on the Indian gooseberry, *Phyllanthus emblica*, shed light on the plant's potential neuroprotective and antioxidant properties as well as its historical medical uses. This study assessed *P. emblica's* ability to scavenge radicals using a range of assays and its impact on neuroprotection using human brain cell lines (PC12) subjected to glutamate-induced cellular inhibition.

The remarkable antioxidant activity of the *P. emblica* extract was one of the investigation's key findings. The hydroxyl radical scavenging and DPPH assays had respective IC50 values of 0.426 mg/mL and 73.21 µg/mL. This illustrates how effectively it gets rid of free radicals, which are connected to oxidative stress and a host of health issues. The study also revealed significant lipid peroxidation activity (IC50: 73.21 µg/mL), highlighting *P. emblica's* capacity to prevent oxidative damage to cellular membranes, which is crucial for maintaining cellular integrity. Investigations on *P. emblica's* neuroprotective qualities revealed that it may shield PC12 cells from glutamate-induced cytotoxicity.

This was confirmed by cell viability experiments, which showed that *P. emblica* extract protected neuronal cells. Its neuroprotective properties were further demonstrated by monitoring the activities of ROS, GSH, and LDH. According to Li *et al.* (2011), PC12 cells were shielded from H_2O_2-induced cell death by *P. emblica* extracts.

All *P. emblica*-derived samples showed a dose-dependent and consistent protective activity against H_2O_2-induced PC12 cell death. The results showed that the ethanol and hot water extracts had better percentages of PC12 cell protection than the commercial extracts. Hydroalcoholic extracts from *P. emblica* showed neuroprotective properties in rat models of kainic acid-induced seizures, according to Li *et al.* (2022). These outcomes may be due to the extracts' antioxidant and anti-inflammatory properties.

An investigation into the effects of *Emblica officinalis* on memory and brain cholinesterase activity was carried out using a mouse model. Different mouse groups were given oral doses of anwala churna ranging from 200 to 50 mg/kg for a period of fifteen days. The findings show that *Emblica officinalis* enhances brain cholinesterase activity and memory scores while lowering total cholesterol levels in a dose-dependent manner. Anwala churna has been shown to be a helpful medication in the treatment of Alzheimer's disease or in improving memory in addition to its cholesterol-lowering and anticholinesterase qualities (Vasudevan and Parle, 2007). The effects of the fruit hydroalcoholic extract of *E. officinalis* were compared to the markers of oxidative stress, kainic acid-induced seizures, and

cognitive deficits. The study's findings demonstrated that, in comparison to the vehicle-treated kainic acid group, pretreatment with hydroalcoholic *E. officinalis* fruit extract at doses of 500 and 700 mg/kg markedly enhanced the latency of seizures. A hydroalcoholic extract of the fruit of E. officinalis greatly reduced the cognitive decline caused by KA (Golechha *et al.,* 2011).

According to a study, much or all of *E. officinalis'* antistress effectiveness may be explained by its capacity to normalise stress-induced disturbances in free radical foraging activity. Many stress-related diseases are believed to be influenced by age-related increases in free radicals in different tissues (Bhattacharya *et al.,* 2000). The antidepressant qualities of *Emblica officinalis* fruits were examined using a mouse model. The extract dramatically shortened the immobility duration, demonstrating strong antidepressant-like effects. At a dosage of 200 mg/kg, the extract demonstrated improved antidepressant efficacy and was comparable to phenelzine, imipramine, and fluoxetine. The study's overall results showed that the aqueous extract of *E. officinalis* had antidepressant-like effects, possibly by inhibiting MAO-A and GABA and exhibiting antioxidant activity (Dhingra *et al.,* 2012).

8. Cardioprotective effects

The potential of *Emblica officinalis'* ethanolic extract to lower cholesterol and safeguard the heart was examined. Rats given a high-fat diet displayed altered lipid profiles, but these changes were undone when extract was introduced. In rats given a high-dietary-fat diet, supplementing with *Emblica officinalis* alleviated cardiac autonomic dysfunctions, and electrophysiological analysis revealed altered heart rate and sympathovagal balance (Kanthe S.A. Almatroodi, *et al.* Gene Reports 21 (2020) *et al.,* 2017). It was examined how *Emblica officinalis* ethanolic extract affected the changes in vascular chemistry and cardiovascular system histology caused by a high-fat diet (HFD).

It has been demonstrated that rats fed a high-fat diet have considerably greater MDA and lower NO levels. Furthermore, the oxidative stress brought on by a high-fat diet was lessened by supplementing with extracts. Research indicates that rats given a high-fat diet benefit from the cardioprotective effects of *Emblica officinalis* extract (Patil *et al.,* 2019). Rats with isoproterenol-induced cardiotoxicity were used to test the preventive effect of *E. officinalis*. The findings demonstrated that isoproterenol markedly reduced the heart's myocyte-injury-specific marker enzymes, lactate dehydrogenase and creatine phosphokinase-MB, as well as the antioxidant enzymes catalase, glutathione peroxidase, and superoxide dismutase. Lipid peroxidation, haemodynamic repair, and antioxidant preservation have all significantly decreased, nevertheless. Damage to myocytes, marker enzymes, and left ventricular function was caused by *E. officinalis* prior to treatment. Improvements in haemodynamic results demonstrate that *E. officinalis* has a potent antioxidant and free radical scavenging activity in addition to its cardioprotective capabilities (Ojha *et al.,* 2012). A study found that diabetic rats given *Emblica officinalis* fruit juice might help from treatment for the heart damage linked to type 1 diabetes. The lipid profile was disturbed, serum glucose levels increased, food and water intake increased, cardiomyopathy and heart hypertrophy increased, and weight reduction via STZ was prevented (Patel and Goyal, 2011).

9. Nephroprotective effect

In models of oxidative stress and Aβ-induced neuronal death, their neuroprotective qualities have been proven. Flavonoid-rich ginkgo biloba extracts have been demonstrated to improve and alter the brain, particularly in cases of age-related dementia and Alzheimer's disease (Calderaro *et al.,* 2022). According to the findings, the PC12 cell protection percentages of the hot water and ethanol extracts were higher than those of the commercial extracts. Li *et al.* (2022) reported that hydroalcoholic extracts from *P. emblica* demonstrated neuroprotective effects in rat models of seizures produced by kainic acid. These effects could be ascribed to the extracts' anti-inflammatory and antioxidant qualities. The dried fruit extract of *E. officinalis* of doze 600 mg/kg was tested for its protective effect on cisplatin-induced nephrotoxicity in rats, and the results showed that it significantly restored antioxidant status, normalized renal function, and improved histological alterations. Additionally, the study found that *E. officinalis* reduced nephrotoxicity in rats subjected to cisplatin through apoptosis and MAPK-induced suppression of inflammation (Malik *et al.,* 2016b). The ethanolic extract from the leaves of *Emblica officinalis* significantly lowers blood urea nitrogen and serum creatinine, preventing renal damage. It also increases the activity of antioxidant enzymes and lowers the level of renal MDA. Additionally, red blood cell alterations, histological damage, and morphological modifications are recovered by oral administration of Amla leaf extract (Purena *et al.,* 2018).

10. Role as skin protector/UV protection

Human skin fibroblasts were used to measure procollagen production and matrix metalloproteinases (MMPs), and the effects of amla extract were investigated in vitro. The results can be explained by the extract's concentration-dependent promotion of fibroblast proliferation and time- and concentration-dependent promotion of procollagen production. It is useful for cosmetic, pharmacological, and therapeutic purposes and dramatically increases TIMP-1 by controlling collagen metabolism (Fujii *et al.,* 2008). According to another study, cells treated with 0.5 mg/ml of *emblica* extract were 9.5 ± 0.28 times more resistant to UVB-induced collagen damage than cells that were not treated. However, at 0.5 mg/ml of ascorbic acid, 3.7 ± 0.07 times protection was shown (Majeed *et al.,* 2011). In human skin fibroblasts, fruit from *Emblica officinalis* has been demonstrated to effectively prevent UVB-induced photoaging by preserving pro-collagen 1 and increasing cellular proliferation, both of which UVB inhibited. Adil *et al.* (2010) reported that *Emblica officinalis* generated hyaluronidase inhibitory activity and prevented the disrupted cell cycle that produced UVB from returning to its normal phase.

11. Lipid lowering effect

Amla's effectiveness in treating type II hyperlipidemia was investigated, and its hypolipidemic qualities were compared to those of simvastatin. Results showed that as compared to simvastatin treatment, amla medication significantly reduced VLDL, LDL, triglyceride, and TC levels while increasing HDL levels. Overall, the results indicate that Amla significantly lowers blood pressure in addition to having a hypolipidemic impact (Gopa *et al.,* 2012). The anti-hyperlipidemic effects of gallic acid and *E. officinalis* fruit juice were studied in an animal model by giving rats high-fat food additives, tyloxapol, and poloxamer-407 to induce hyperlipidaemia. After receiving gallic acid and *E. officinalis* fruit juice, the rats' liver and aorta showed decreased oil infiltration and plasma cholesterol. Variya *et al.* (2018) claim that *E. officinalis* mechanically lowers the activity of lipogenic enzymes in the liver, increases the expression of peroxisome proliferator-activated receptors-α (PPARα), and encourages lipid oxidation through carnitine palmitoyl transferase.

In rabbits given cholesterol, the effects of fresh *Emblica officinalis* juice on lipid reduction and antiatherosclerosis were examined. Lipid levels in tissues and aortic plaques were observed to have decreased after consuming fruit juice. Juice from *E. officinalis* changes how rabbits absorb nutrients by increasing their excretion of phospholipids and cholesterol (Mathur et al., 1996). TAG and cholesterol levels in the blood and liver were significantly greater in the group of old rats under control, but they sharply decreased after amla was administered. On the other hand, oral amla therapy markedly increased the liver's PPARα protein levels. Furthermore, the liver and serum of elderly rats have reduced levels of thiobarbituric acid-reactive material. These results suggest that amla may reduce oxidative stress and hence prevent age-related hyperlipidaemia (Yokozawa *et al.,* 2007).

12. Role on respiratory system

The mitochondrial function of the C2C12 myotube treated with Amla was investigated in a murine model of skeletal muscle cells that are rich in mitochondria. Treatment with amla fruit extract increases mitochondrial spare respiratory capacity, which helps cells survive stress. Amla was said to promote Nrf2 and AMPK activation. Furthermore, it was shown that Amla administration enhanced the cytoprotective effects and decreased ROS levels in cells with t-BHP-induced oxidative stress (Yamamoto *et al.,* 2016). Reproductive reconstruction was found to benefit from the ameliorative effects of *Emblica officinalis* Garten. When mature male rats are exposed to organophosphate insecticide, their reproductive systems experience oxidative stress. In one trial, participants received treatment with *Emblica officinalis* Garten both by itself and in combination with chlorpyrifos. The extract of *Emblica officinalis* in conjugation with chlorpyrifos showed recovery as compared to the treatment with *Emblica officinalis* Garten alone, which had parameters that were somewhat close to the untreated group (Dutta and Sahu, 2013).

13. Immunomodulatory effects

Amla's ability to shield mouse thymocytes from arsenic-induced oxidative stress and apoptosis was evaluated. Arsenic treatment increased ROS production and lipid peroxidation in the mouse thymus while decreasing antioxidant activity, cell survival, and mitochondrial membrane potential in comparison to controls. The effects of arsenic exposure alone were reversed when amla extract and arsenic were combined. It decreased the levels of lipid peroxidation and ROS generation, as well as the levels of antioxidant enzymes, cytochrome c oxidase, caspase-3activity, and mitochondrial membrane potential, when compared to mice treated alone with arsenic (Singh *et al.,* 2013). The study's goal was to determine amla's

immunomodulatory and antioxidant properties. Chromium treatment breaks DNA and stops lymphocytes stimulated by lipopolysaccharide and concanavalin-A from proliferating. Amla extract reduces the immunosuppressive effects of chromium on lymphocyte proliferation (Sai Ram *et al.,* 2002) and suppresses apoptosis and DNA fragmentation brought on by chromium. It also recovers the production of IL-2 S.A. Almatroodi, *et al.* (2020) and IFN-gamma. Additionally, it promotes the synthesis of interferon gamma and IL-2.

14. Role in bone diseases

The usefulness of fruit extracts from *Emblica officinalis* in the treatment of osteoporosis and rheumatoid arthritis was investigated. Extracts from *Emblica officinalis* have been shown to contribute to the induction of programmed cell death in mature cells. According to Penolazzi *et al.* (2008), it may be an essential strategy to prevent and reduce osteoporosis, joint deterioration, and skeletal issues caused by arthritis. In a rat model, treatment with aqueous extracts of *Emblica officinalis* and Cissus quadrangularis petroleum ether extract considerably increased blood levels of ALP while significantly restoring hydroxyproline and TRAP levels to normal. *Emblica officinalis* and Cissus quadrangularis treatments were reported to considerably prevent the loss of bone mass and strength caused by osteoporosis (Sirasanagandla *et al.,* 2013).

15. Anti-cancer effects

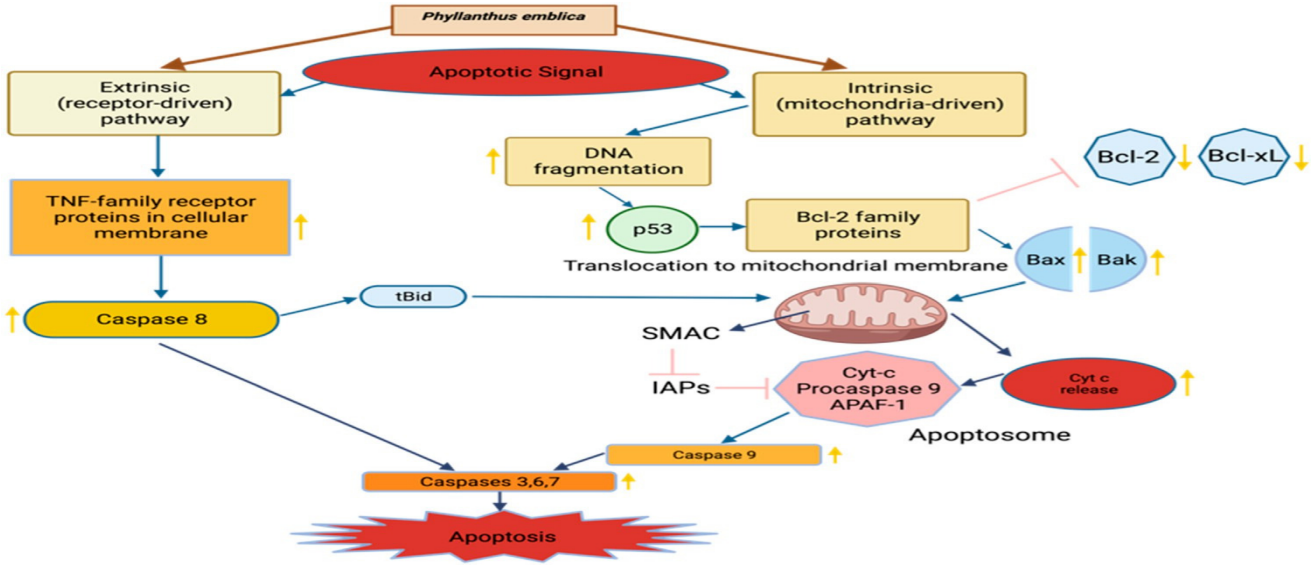

Fig. 4: Anticancer of *Phyllanthus emblica* (Prananda *et al.,* 2023)

Scientists are looking into new medications and treatments that lower cancer cell survival, block angiogenesis, restrict proliferation, and limit metastasis because cancer is still a big global health concern. A number of flavonoids and phytochemical compounds have emerged as promising cancer therapeutic alternatives in the past ten years. *Phyllanthus emblica* fruit extract's mode of action was thoroughly examined in a study conducted by Mahata *et al.* (2013). Its impact on activator protein-1 (AP-1) activity and its relationship to HPV-driven cervical cancer cells were the main focus of the investigation. The data revealed a startling pattern: constitutively active AP-1 HPV16-positive (SiHa) and HPV18-positive (HeLa) cervical cancer cells responded to the *Phyllanthus emblica* fruit extract by reducing DNA binding in a dose- and time-dependent manner.

This AP-1 suppression and the decrease in viral transcription prevented the growth of cervical cancer cells. Furthermore, the induction of apoptotic cell death was mostly attributed to *Phyllanthus emblica's* growth-inhibitory effect. These findings suggest that *Phyllanthus emblica* may be helpful in treating HPV-induced cervical cancer cells because it simultaneously blocks AP-1 and targets the transcription of viral oncogenes that cause cervical cancer (Mahata *et al.,* 2013; Quranayati *et al.,* 2022). In a separate study, Samatiwat *et al.* (2021) assessed the anti-proliferative qualities of *Phyllanthus emblica* bark ethanolic extract in connection to cholangiocarcinoma.

On the KKU-452 CCA cell line, the extract's cytotoxic potential was demonstrated by a significant induction of apoptosis and an IC50 value of 52.2 µg/mL. Furthermore, at concentrations of 25 and 50

μg/mL, the ethanolic extract of Phyllanthus emblica bark considerably decreased cell migration, with reductions of 425% and 32.9%, respectively, in comparison to untreated cells. These anticancer effects were believed to be caused by the phenolic acid and flavonoid content of *Phyllanthus emblica* bark extract (Samatiwat *et al.,* 2021). Numerous medicinal plants or their active ingredients may aid in the treatment of cancer by changing the activity of certain genes (Almatroudi *et al.,* 2019; Rahmani, 2015; Rahmani *et al.,* 2014a; Rahmani *et al.,* 2014b; Rahmani *et al.,* 2014c; Rahmani *et al.,* 2015; Almatroodi *et al.,* 2019).

On high-grade serous epithelial ovarian cancer cells with p53 and BRCA1/2 mutations that were resistant to taxol and carboplatinum, a ground-breaking study was carried out to examine the function of extract's anti-metastatic, anti-proliferative, and anti-angiogenic qualities. The results of the study demonstrated that amla extract significantly reduced the migratory and invasiveness features of all tested high-grade serous epithelial ovarian cancer cell morphologies, significantly increased the expression of E-cadherin, and significantly decreased the expression of IGF1R, SNAIL1, and HIF-1α. Additionally, mouse xenografts made from OV4855 cells showed tumour shrinkage with oral administration of amla extract (De *et al*., 2020). An important study on ovarian cancer found that amla extract inhibits the synthesis of E-cadherin, targeting SNAIL1 and miR-375, and lowers the expression of the IGF1R gene and protein.

Furthermore, the extract raised the miR-375 levels in the medium's exosomes. Lastly, in xenograft tumour attenuation produced from SKOV3, extract greatly decreased the expression of IGF1R and SNAIL1 proteins (De *et al*., 2016). A human colon cancer cell line was used in a follow-up study to assess the impact of *Emblica officinalis* fruit aqueous extract on cell death and genomic damage. The results demonstrated a significant and sleep-dependent decrease in necrosis and the nuclear division index with time. Furthermore, PE significantly increased apoptosis and showed a substantial correlation between apoptosis and CIN (Guo *et al.,* 2013). The extract from *Emblica officinalis* contains antimetastatic qualities that can decrease cancer cell invasion, adhesion, migration, and proliferation in both time-dependent and doze-dependent ways, per the findings of another study. In this case, the anti-metastasis cellular mechanism demonstrated a reduction in MMP2 and MMP9 expression. Yahayo & colleagues (2013). Both in vitro and in vivo, amla extract (AE) demonstrated anti-proliferative qualities in ovarian cancer cells. Amla extract dramatically increases the expression of the autophagic proteins beclin1 and LC3B-II in vitro. Additionally, it reduces cell proliferation by working in concert with cisplatin (De *et al.,* 2013).

16. Anti-diarrheal activity

P. emblica extract shown a strong anti-diarrheal action (Afrin *et al.,* 2016). These researchers tested the anti-diarrheal effects of a 2 mL/mouse dosage on mice with diarrhea caused by castor oil. A dose of 500 mg/kg BW of *P. emblica* extracts was administered to the mice one hour prior to their oral induction with castor oil. When compared to the control group that received a normal antidiarrheal medication, the results demonstrated that *P. emblica* considerably suppressed the defecation mean number. *P. emblica's* methanolic extract demonstrated 42.86% inhibition at a 25% dose and 64.29% inhibition at a 500 mg/kg BW dose. At a dose of 5 mg/kg, the anti-diarrheal standard medication, loperamide, showed 71.43% inhibition. *P. emblica* may have demonstrated its antidiarrheal activity by blocking prostaglandin production through an antisecretory mechanism, as it successfully prevented castor oil-induced diarrhea (Afrin *et al.,* 2016).

Future perspective and challaenges

Researchers have developed a way to create medications using the secondary metabolites present in medicinal plants within the last 200 years. The Indian medicinal system makes extensive use of the herb *Phyllanthus emblica.* Antioxidant, anti-cancer, hepatoprotective, neuroprotective, immunomodulatory, anti-inflammatory, anti-diabetic, and anti-hyperlipidemic effects are just a few of the well-established positive health effects and pharmacological activities that have been linked to *P. emblica's* therapeutic qualities in a number of studies employing different extracts and herbal preparations. *Phyllanthus emblica* has long been used to cure a wide range of ailments in addition to food products. Even though a number of contemporary research methods have been developed to support the traditional medicinal uses of *P. emblica*, many elements, such as its contents and applications, still require more scientific investigation. For example, just a few studies mentioned *P. emblica's* antimalarial, antiviral, anti-venom, and insecticidal properties. Several of its traits were also described, along with other divisions of *P. emblica*. Finding the substances, agents, or constituents that mediate its therapeutic action is therefore crucial. Moreover, more comprehensive research is needed to examine *P. emblica's* possible medical benefits, such as extensive evidence-based trials.

Conclusion

In conclusion, our in-depth examination of *P. emblica*, often known as Indian gooseberry or Amla, has shed light on its remarkable phytochemical composition and extensive array of pharmacological properties. With a lengthy history in traditional medicine, this indigenous fruit has shown to be a priceless source of bioactive compounds with great potential for a variety of therapeutic applications. The phytochemical analysis of *Phyllanthus emblica* revealed a large number of secondary metabolites, including as flavonoids, tannins, polyphenols, and ascorbic acid. When combined, these compounds enhance the plant's antibacterial, anti-inflammatory, and antioxidant qualities, making it a promising candidate for use in the production of both natural and pharmaceutical medications. It has been shown to have anti-inflammatory, hepatoprotective, gastroprotective, anti-diabetic, antibacterial, neuroprotective, cardioprotetive, and immunomodulatory properties, all of which are important for managing health. Its function in preventing cancer has been established by changing the activity of many genes. Several studies in this area have shown how versatile this botanical treasure is, leading to new lines of inquiry and possible applications in the medical and healthcare domains. It's crucial to acknowledge the limitations of our review, though.

There is a lot of potential for *Phyllanthus emblica* to provide bioactive substances with a variety of pharmacological characteristics. Even though this review is a useful tool for comprehending its possible advantages, more study and clinical trials are necessary to fully realize this amazing botanical species' therapeutic potential. Notwithstanding its drawbacks, the strong evidence in this study highlights the importance of *Phyllanthus emblica* in the field of natural medicine and encourages more research in the quest for better medical treatments. First of all, although we have compiled a comprehensive overview of the existing literature, research on *P. emblica* is always evolving, and new information may have emerged after the completion of this review. Since most studies have been conducted in vitro or in animal models, more clinical trials are necessary to ascertain the safety and efficacy of *Phyllanthus emblica*-based medicines in humans. Furthermore, the phytochemical composition of *P. emblica* varies by geography and habitat, making it challenging to standardise its medical benefits.

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