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Review Article

Ananas comosus (Pineapple): A Comprehensive Review of Its Medicinal Properties, Phytochemical Composition, and Pharmacological Activities

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Abstract

Herbal medicine, also known as phytomedicine, utilizes various plant parts like leaves, fruits, roots, bark, or flowers for their health benefits, standing as an alternative healthcare approach to conventional medicine. Traditional herbal remedies, integral to medical systems worldwide, notably in China and India, are gaining global recognition for their efficacy and fewer side effects. Approximately 80% of the world's population relies on traditional herbal medicine for primary healthcare, as per the World Health Organization. Ananas comosus (L.) Merril, commonly known as pineapple, belongs to the Bromeliaceae family, encompassing about 50 genera and 200 species. Pineapple, a perennial herbaceous plant, exhibits unique physical attributes, with its main parts including the stem, leaves, peduncle, multiple fruit, crown, shoots, and roots. Pineapple contains various amino acids, including tyrosine and tryptophan, along with bromelain, an enzyme aiding digestion by breaking down proteins. This review outlines previous research on the phytochemical and pharmacological characteristics of Ananas comosus, highlighting its diverse medicinal properties. From antimicrobial and anticancer activities to antioxidant, anti-inflammatory, and hepatoprotective effects, pineapple demonstrates significant therapeutic potential across multiple health domains. Additionally, its nutritional value and traditional uses further underscore its importance as a versatile herbal remedy.

Keywords: Ananas comosus, pineapple, phytochemicals, pharmacological activities, medicinal properties, bromelain.

1) Introduction:

Herbal medicine, also known as phytomedicine, utilizes various plant components like leaves, fruits, roots, bark, or flowers for their health-enhancing qualities. It's often seen as an alternative form of healthcare separate from conventional medicine[1]. Globally, traditional herbal medicines, integral to medical traditions such as those in China and India, are gaining increased recognition for effectively treating various health issues. This acknowledgment stems from their diverse functional attributes and notable effectiveness, often accompanied by minimal side effects[2]. As per the World Health Organization (WHO), around 4 billion individuals, constituting 80% of the global population, depend on traditional herbal medicine as their primary form of healthcare. Historically, herbal remedies were often uncovered through trial and experimentation. The knowledge transmitted across generations serves as the cornerstone of contemporary traditional medicine. Nevertheless, relying solely on historical usage as evidence of safety and efficacy may not always be dependable[3]. That being noted, Ananas comosus, commonly referred to as pineapple, is among the extensively studied plants worldwide, aimed at comprehending and uncovering its potential benefits[4]. Ananas comosus (L.) Merr., belongs to the Bromeliaceae family, which comprises roughly 50 genera and 200 species[5]. The pineapple, a perennial herbaceous plant, typically reaches heights and widths of 1–2 meters, resembling a spinning top in its shape. Its primary components consist of the stem, leaves, peduncle, multiple fruit, crown, shoots, and roots. The multiple fruit forms through the fusion of individual fruitlets on a single stalk, with numerous flowers arranged helically along the axis. Each flower yields a fleshy fruitlet that merges with those of adjacent flowers, giving the impression of a unified fleshy fruit[6]. Pineapple predominantly contains tyrosine and tryptophan as its primary amino acids, in addition to asparagine, proline, aspartic acid, serine, glutamic acid, α-alanine, aminobutyric acid, valine, and isoleucine. Furthermore, pineapple is rich in bromelain, an enzyme that aids digestion by breaking down proteins[7] The pineapple possesses distinctive attributes, and its sweetness makes only the fruits suitable for consumption. Typically, the remaining parts of the plant are discarded, yet the byproducts from pineapple can be transformed into value-added goods[4]. This review delves into the phytochemical and pharmacological traits of Ananas comosus, offering insights gleaned from prior research.

Taxonomical Classification:

Kingdom: Plantae

Phylum: Tracheophyta

Class: Lilopsida

Order: Bromeliales

Family: Bromeliaceae

Genus: Ananas

Species: A. comosus

Common names:

Table 1: Various common names of Ananas comosus:

Spanish	Piña
Brazil	Abacaxi
Egypt	Ananas
French	Ananas
English	Pineapple
Indonesian	Nanas
Ethiopia	Freit
Mexico	Piña
Thailand	Sabparot
USA	Pineapple
Chinese	Bōluó
Russian	Ананас
German	Ananas
Hindi	Ananas

Parts Used:

Fruit, Stem, Leaves, Bromelain extract, Peel, Crown, Roots, Shoots.

Figure 1: Pineapple

Synonyms(s):

Pineapple, Ananas, Ananas sativus, Bromelia comosa

2) Botanical Description:

Ananas comosus (L.) Merr. is a perennial herbaceous plant typically reaching heights and widths of 1–2 meters. It belongs to the Bromeliaceae family and is categorized under the Bromelioideae subfamily. Within the Bromeliaceae family, which comprises Tillandsioideae, Bromelioideae, and Pitcarniodeae subfamilies, Ananas stands out for its unique characteristics, earning its recognition as a distinct genus[6].

3) Morphological Description of Ananas comosus:

The pineapple is a perennial herb with a height ranging from 90-100cm. It possesses two types of roots: one cluster around the stem in a hemispherical mass, with some emerging from the axils, while the other type consists of slender roots that extend into the soil up to 1.2 meters deep. The stems are stout and thick, measuring 20-50cm in height and 7-11cm in thickness, often concealed by leaves. The leaves are typically densely clustered and rigid, resembling swords. When unripe, the pineapple's outer shell appears dark green, turning to a dark orange-yellow hue with mottling as it ripens[8].

4) Cultivation:

Pineapple cultivation primarily occurs in the high rainfall and humid coastal regions of peninsular India, as well as in the hilly northeastern areas of the country. However, commercial growth is feasible in interior plains with moderate rainfall, provided supplementary protective irrigation is available[9]. The ideal temperature range for successful cultivation is between 22°C and 32°C. Growth halts below 20°C and above 36°C. Pineapple thrives in well-drained loamy soil and exhibits resilience during dry periods[10]. Pineapple cultivation can extend up to 1,100 meters above sea level in frost-free areas. It thrives in various soil types, excluding very hard clay soil. Sandy loam is particularly favourable, with an ideal soil depth of 45-60 cm and absence of hard pan or stones. Avoidance of low-lying areas with high water tables is recommended. A soil pH range of 5.0-6.0 is optimal. Pineapple propagation primarily relies on vegetative methods such as crown cuttings and suckers to ensure genetic consistency and accelerate fruit production. Planting season varies based on climate and region. In tropical regions with consistent temperatures, planting can occur year-round, while in areas with distinct wet and dry seasons, it's advisable to plant at the onset of the rainy season to ensure ample water supply during crop establishment. Timing may also consider avoiding extreme temperatures or frost, which can harm pineapple plants[9].

5) Phytochemical Constituents:

Phytochemicals are plant chemicals that are non-nutritive and possess properties that protect against diseases or prevent them. Plants produce these chemicals primarily for self-protection, but recent research has shown that they can also provide protection against diseases in humans[11].

Previous research on the stem of A. comosus has indicated the presence of bromelain and tacorin, respectively[12,13]. Moreover, the stem also contains saponin, flavonoids, phytosterol, carbohydrates, alkaloids, cardiac glycosides, amino acids, and proteins [14].

In the research study, the peel of A. comosus is found to contain numerous natural antioxidants, including flavonoids, phenolic compounds, terpenoids, carotenoids, coumarins, saponin, lignin, plant sterols, and ascorbic acid. The predominant polyphenols identified in the A. comosus peel include catechin,

epicatechin, gallic acid, myricetin, salicylic acid, p-coumaric acid, trans-cinnamic acid, tannic acid, and ferulic acid[15]. Flavonoids tested positive in extracts prepared using ethanol, methanol, and acetone, whereas phenolic compounds were only detected in the ethanolic extract. Terpenoids exhibited positive results in both ethanolic and methanolic extracts[16]. Additionally, the presence of bromelain has been demonstrated[17].

A qualitative phytochemical analysis of pineapple crown revealed the presence of alkaloids, flavonoids, saponins, steroids, triterpenoids, phenolic hydroquinone, and tannins[18]. Bromelain was also detected in the pineapple crown[19].

The phytochemical screening of leaf extract from Ananas comosus revealed the presence of carbohydrates, alkaloids, saponins, flavonoids, tannins, phenolic compounds, as well as proteins and amino acids[20,21]. The presence of triterpenoids, steroids, alkaloids, saponins, glycosides, and carbohydrates was documented in extracts obtained using petroleum ether, chloroform, and methanol[22]. Additionally, it has been demonstrated that bromelain is also present in the leaves[23].

The phytochemical constituents of Ananas comosus fruits were also examined. Extraction using seven different solvents—ethanol, methanol, ethyl acetate, acetone, n-hexane, chloroform, and distilled water—yielded saponins, tannins, steroids, flavonoids, terpenoids, naphthoquinone, inulin, alkaloids, phenols, and amino acids as phytochemical compounds[24]. Additionally, the fruit also contains terpenoids, flavonoids, phytosterols, alkaloids, cardiac glycosides, amino acids, proteins, polyphenols, and saponins[14]. Bromelain was also identified in the fruit of Ananas comosus[25].

Table 2: Summary of Phytoconstituents present in Ananas comosus

Phytoconstituents	Fruit	Stem	Leaf	Crown	Peel
Alkaloid	+	+	+	+	-
Amino acids	+	+	+	-	-
Bromelain	+	+	+	+	+
Carbohydrate	-	+	+	-	-
Cardiac glycoside	+	+	-	-	-
Coumarins	-	-	-	-	+
Flavonoids	+	+	+	+	+
Glycoside	-	-	+	-	-
Inulin	+	-	-	-	-
Naphthoquinones	+	-	-	-	-
Phenols	+	-	+	-	+
Phenolic hydroquinone	-	-	-	+	-
Phytosterols	+	+	-	-	-
Polyphenols	+	-	-	-	-
Protein	+	+	+	-	-
Saponin	+	+	+	+	+
Steroids	+	-	+	+	-
Sterols	-	-	-	-	+
Tacorin	-	+	-	-	-
Tannins	+	-	+	+	-
Terpenoids	+	-	+	+	+

Present: (+); Not Present: (-)

6) Nutritional Value:

Pineapple is a delightful tropical fruit known for its abundant juiciness, lively tropical taste, and extensive health advantages. It boasts significant levels of calcium, potassium, vitamin C, carbohydrates, dietary fibre, water, and various minerals, which promote digestive health and aid in achieving optimal weight and balanced nutrition[26]. Pineapple fruit includes an enzyme called bromelain, which aids in digestion and offers therapeutic benefits. Bromelain shows promise as an anti-inflammatory, antioxidant, anti-cancer, and heart-protective agent[27]. Pineapple is a widely consumed fruit in Bangladesh, known for its low fat and sodium content. It typically contains 10-25 mg of vitamin C. Pineapple composition has primarily been studied in its edible portion. It comprises 81.2 to 86.2% moisture and 13-19% total solids, with sucrose, glucose, and fructose being the main components. Carbohydrates make up to 85% of total solids, while fibre accounts for 2-3%. Among organic acids, citric acid is the most abundant. The pulp has minimal ash content, nitrogenous compounds, and lipids (0.1%). Approximately 25-30% of nitrogenous compounds are true proteins. Fresh pineapple also provides minerals such as calcium, chlorine, potassium, phosphorus, and sodium[26]. The composition of pineapple varies significantly based on factors like ripening process and cultivar type. A study assessing antioxidant activity using a β-carotene-linoleate acid antioxidant assay at a concentration of 100 ppm found pineapple to be a substantial source of antioxidants. This suggests a high phenolic content in the fruit, highlighting its antioxidant properties[27].

Pineapple juice is rich in ascorbic acid, making it a valuable source of Vitamin C. Ascorbic acid, also known as Vitamin C, serves as an effective antioxidant, combating bacterial and viral infections while aiding the body in iron absorption. Consuming half a cup of pineapple juice provides 50 percent of an adult's daily recommended intake of Vitamin C. Pineapples contain various essential minerals, including manganese, a trace mineral crucial for bone formation and the activation of certain enzymes. Additionally, pineapples contain copper, another trace mineral that facilitates iron absorption and regulates blood pressure and heart rate[26].

Table 3: Primary components of pineapple per 100 grams[27].

Constituents	Pineapple pulp	Pineapple juice
Proximate composition		
Carbohydrate	11.7	12.1
Total sugars	10.5	12.1
Ash	0.3	0.4
Protein	0.5	0.4
Fat	0.5	0.1
Fibre	1.2	0.2
Vitamins		
Folate	19.6	23.0
Thiamine	0.1	0.1
Ascorbic acid	46.1	14.0
Riboflavin	0.03	0.02
Niacin	0.3	0.3
Minerals		
Calcium	8.0	8.1
Magnesium	15.0	13.6
Potassium	140.0	134.0
Iron	0.17	0.2
Manganese	0.8	1.2
Sodium	5.0	5.2
Copper	0.06	0.04
Phosphorus	8.1	9.8
Zinc	0.08	0.08

Table 4: The natural and chemical components found in pineapple pulp and waste[26].

Parameters	Pineapple pulp	Pineapple waste
Moisture (%)	87.3	91.35
Total sugars (%)	8.66	9.75
Ascorbic acid (mg/100g)	21.5	26.5
Reducing sugars (%)	10.5	8.2
Crude fibre (g/100g-fw)	0.41	0.60
Ash content (mg/100g)	1.8	0.04
Titratable acidity (%)	2.03	1.86
Non-reducing sugars (%)	7.4	8.8
Total soluble solids (%)	13.3	10.2

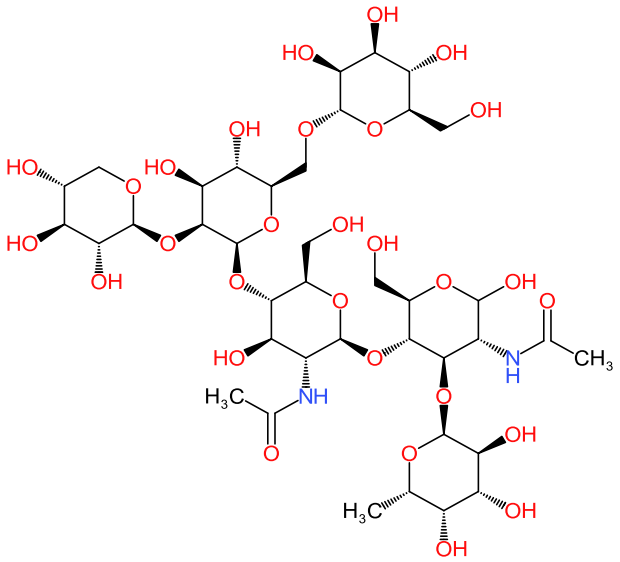

Figure 2: Chemical Structure of Bromelain[28]

7) Extraction of Pineapple Different Parts:

a) **Ananas Comosus Peel Extract:** Ananas comosus fruit was washed thoroughly with tap water and then peeled using a sterile knife. The moist peel was chopped into pieces and dried in an oven at 40°C for 72 hours. The dried peels were subsequently ground into a powder using a mechanical grinder. Two hundred grams (200 g) of the powder was soaked in 1 L of 80% methanol for 48 hours, filtered through a muslin cloth, and then evaporated to dryness using a rotary evaporator. The resulting Ananas Comosus Peel Extract appeared as a brownish, syrupy extract, which was stored at 4°C and later dissolved in distilled water for experimentation[29].

b) **Ananas comosus Crown Extract:** The pineapple crowns of the N36 variety, index 2, were acquired. These crowns were then cut into small pieces and blended using a fruit juice processor, with a ratio of pineapple crown to purified water of 1:1. The resulting extract was filtered through a muslin cloth. Subsequently, the pineapple crown extract was centrifuged at 360 x g for 10 minutes at 4°C. The clear supernatant was collected and utilized for analysis[30].

c) **Ananas comosus Leaf Extract:** Pineapple leaves were gathered and subsequently dried in the shade before being finely powdered. Following this, 50 grams of the leaf powder underwent extraction with 300 ml of methanol for 48 hours using a Soxhlet apparatus. The resulting leaf extract was then concentrated to dryness utilizing a rotary evaporator[31].

d) **Ultrasonic Extraction of Ananas comosus Stem:** Pineapple stems were subjected to drying in an oven set at 50°C. Once dried, the sample was pulverized into a powder and then dissolved in 96% ethanol at a ratio of 1:10 in an Erlenmeyer flask. This mixture underwent exposure to ultrasonic waves with parameters set at 1.5 m amplitude, 50 kHz frequency, and 360 W power for a duration of 40 minutes at 25°C. The residual ethanol was evaporated at ambient temperature until a concentrated extract was achieved[32].

e) **Ananas comosus Fruit Extract:** The process began with cleaning and cutting the pineapples, which were then mashed and dried using a cabinet dryer set at 50°C. From this process, a total of 200 g of dried and mashed pineapple material was obtained. Subsequently, this material

underwent extraction with two litres of 96% ethanol for a duration of 120 hours. Following extraction, the product was filtered, and the ethanol was subsequently removed using a rotary evaporator and a water bath over a period of three days[33].

8) Other Applications of Ananas comosus (Pineapple):

In folk medicine practices, pineapple juice is consumed as a diuretic and to facilitate labour. It is also utilized as a gargle for sore throats and as a remedy for sea sickness. In certain cases, the flesh of very young, potentially toxic fruits is intentionally ingested to induce abortion, typically taken with honey over three consecutive mornings. Additionally, it is used to expel intestinal worms and as a potent treatment for venereal diseases. In Africa, the dried and powdered root serves as a remedy for oedema. The crushed rind is applied topically to fractures, and a decoction of the rind with rosemary is applied to treat haemorrhoids. Indigenous people in Panama use the juice extracted from the leaves as a purgative, emmenagogue, and vermifuge.

Since 1963, thousands of potted pineapple plants treated with ethylene and bearing fruit, along with their intact crowns, have been annually shipped from southern Florida to northern cities as indoor decorations.

Pineapple leaves yield a robust, white, silky fibre that was extracted by Filipinos prior to 1591. In India, shoemakers highly value this thread, while it was historically utilized in the Celebes. In West Africa, it has served as material for stringing jewels and crafting capes and caps worn by tribal chiefs.

Unused pineapple crowns are occasionally given to horses when they are not required for planting. The residual waste from pineapple processing factories can be dehydrated and utilized as "bran," suitable for feeding cattle, pigs, and chickens[34].

9) Pharmacological Activities of Ananas comosus:

a) Antimicrobial Activity: According to research conducted on pineapple (Ananas comosus) fruit extract, it demonstrated antimicrobial properties, particularly exhibiting antibacterial effects against Staphylococcus aureus. This was attributed to bromelain as the active compound, alongside phytochemical factors like Vitamin C and flavonoids[35]. Another study focusing on the peel of Ananas comosus demonstrated its antimicrobial properties, suggesting its potential use in treating and preventing infectious diseases. The methanolic extract of A. comosus peel showed no activity against B. subtilis and E. coli at a concentration of 50 mg/ml (50,000 µg/ml), but exhibited activity against S. typhi at a concentration of 100 mg/ml (100,000 µg/ml). Additionally, chloroform extracts of A. comosus peels displayed activity against Staphylococcus aureus[36]. The aqueous extract derived from the crown leaves of pineapple contained proteins exhibiting various enzymatic activities, including nonspecific proteolytic, gelatinolytic, collagenase, fibrinolytic, acid and alkaline phosphatase, nuclease, and peroxidase. Additionally, it displayed significant antibacterial and antifungal properties. Taken together, these characteristics suggest its potential application in the treatment of microbial infections[37].

b) Antibacterial Activity: An in vitro assessment of the antibacterial efficacy of pineapple extract (bromelain) on periodontal pathogens revealed that bromelain effectively inhibits the growth of potent periodontal pathogens. Consequently, it has the potential to serve as an antibacterial agent[38]. Additionally, research indicated that the antibacterial properties of pineapple peel extract are attributed to the presence of flavonoids and saponins within it[39].

c) Anticancer Activity: A literature review on the cytotoxic activity of pineapple revealed its potential as an anticancer agent, primarily due to secondary metabolites such as flavonoids and bromelain enzymes present in the fruit. Bromelain and flavonoids within pineapple exhibit anticancer effects by triggering apoptosis in cancer cells through various mechanisms. These include inducing p53 expression, upregulating the anti-apoptotic protein Bcl-2, increasing the expression of the pro-apoptotic protein Bax, activating caspases, reducing COX2 expression, and modulating the MAPK and Akt/PKB pathways to inhibit the NF-kB pathway[40].

d) Antioxidant Activity: Polyphenols, recognized as secondary plant metabolites, demonstrate established antioxidant properties. The considerable presence of polyphenols in pineapple fruit extracts and juice underscores their potent antioxidant activity. Consequently, these extracts and juice hold promise for application in the prevention and treatment of various diseases within the realm of medicine[41]. Another study demonstrated that crude bromelain exhibits moderate antioxidant activity[42]. Significant antioxidant activity was noted in the hydro-alcoholic extract of pineapple leaves. The results indicated the highest inhibition with the hydro-alcoholic solution (56.40), while the lowest inhibition was observed with the ethanolic extract (42.86)[37].

e) Anti-inflammatory Activity: A study conducted on pineapple leaf extract validated its anti-inflammatory properties in reducing carrageenan-induced paw edema in rats[31]. Rhizome bromelain extract demonstrates inhibitory effects against lipopolysaccharide (LPS)-stimulated inflammatory responses in RAW264.7 macrophage cells. Pure bromelain exhibits stronger anti-inflammatory effects compared to crude bromelain[43]. Bromelain extract can be derived from both the fruit and stems of pineapple. Healthcare practitioners have observed enhanced digestion in patients who incorporate pineapple as their preferred fruit within their meal plans. Despite the lack of published studies documenting specific digestion changes following the consumption of the fruit compared to supplementation with purified extract, it is anticipated that the whole fruit may eventually reveal distinct health-supportive properties, potentially including benefits related to digestion and anti-inflammatory effects[36].

f) Antidepressant Activity: The methanolic extract from Ananas comosus peel demonstrates a significant antidepressant effect in mice, as evidenced by its efficacy in both the Forced Swim Test and Tail Suspension Test models of depression, even at very low doses[44]. In another study, it was found that pineapple juice exerted potent and consistent antidepressant effects across various experimental models, including the tail suspension test, forced swim test, and reserpine-induced hypothermia. Notably, pineapple juice contains significant levels of the neurotransmitter serotonin and moderate levels of noradrenaline, both of which are pivotal in depression pathology. Additionally, the MAO inhibitory property and antioxidant activity exhibited by pineapple may contribute positively to its antidepressant potential[45].

g) Hepatoprotective Activity: Research conducted on Pineapple (Ananas comosus) Juice demonstrated hepatoprotective activity in rats induced with isoniazid, following oral administration of 2 mL for 4 weeks. However,

its effectiveness was found to be less than that of silymarin at a dosage of 25 mg per kg of body weight[46]. In a separate study conducted on the ethanolic Fruit Extract of Ananas comosus in rats with Paracetamol Induced Liver Toxicity, it was found to possess notable hepatoprotective properties. Detailed biochemical analysis showed significant alterations in serum biochemical parameters, suggesting the potential role of secondary metabolites present in the extract in conferring its hepatoprotective effects[47].

h) Anti-rheumatic Activity: According to the study, the peel extract of Ananas comosus fruit demonstrated anti-rheumatic activity by elevating the levels of SOD, CAT, and GPx in the liver, kidney, and spleen, while reducing the levels of CRP and PGE2 prostaglandin in the serum of arthritic rats. Histopathological examination of the paw also showed a decrease in necrosis following treatment with the extract. It was concluded that the presence of flavonoids and tannins in the crude extract may be responsible for the observed anti-arthritic activity in this investigation[48].

i) Anti-ageing Activity: The methanol fruit extract from Ananas sativa, obtained from pineapple fruit and pulp, demonstrated anti-aging effects in the model organism Drosophila melanogaster. This extract prolonged lifespan, boosted the activity of natural antioxidant enzymes, improved reproductive capabilities, heightened the organism's response to cellular oxidative stress, and enhanced resistance to heat and dietary stress as the organism aged[49].

j) Anti acetylcholinesterase Activity: A study conducted on Bromelain revealed its potential for neuroprotection by reducing oxidative stress and increasing cholinesterase levels in the brains of mice. This research underscores Bromelain's ability to defend against oxidative damage and cholinergic deficiencies in the brain[50]. Yet another study, this time on the peel extract of Ananas comosus in rats, demonstrated that administering the peel extract to rats fed a High Fat Diet resulted in reduced acetylcholinesterase activity in the brain[51].

k) Cardioprotective Property: As per a study investigating the effects of Pineapple on reducing cardiac oxidative stress and inflammation in rats fed a high cholesterol diet, it was found that Pineapple exhibits antioxidant and lipid-lowering properties. Consequently, regular consumption of Pineapple can decrease hypercholesterolemia-induced cardiac lipid peroxidation and inflammation in a live model. This study suggests that Pineapple could be a promising candidate for protecting the heart against hypercholesterolemia[52]. In a separate study aimed at identifying the cardioprotective potential of the hydro-alcoholic fruit extract of Ananas comosus against isoproterenol-induced myocardial infarction in Wistar Albino rats, it was found that administering the extract led to decreased levels of cholesterol, low-density lipoprotein, very low-density lipoprotein, triglycerides, alanine aminotransferase, and aspartate aminotransferase. Simultaneously, it increased high-density lipoprotein and total protein levels. Pretreatment with the extract safeguarded against the cardiotoxicity induced by isoproterenol. The study concluded that the hydroalcoholic extract of Ananas comosus exhibits cardioprotective properties[53]. In another study that explored pineapple and losartan's combined cardioprotective effects against acute and chronic myocardial damage induced by isoproterenol in rats. Pre-treatment with these agents led to improved biomarker activities in heart tissue and decreased serum levels, along with enhanced antioxidant activities and histological improvements. The highest pineapple dose (500 mg/kg) with losartan showed the most significant cardioprotective effects[54].

l) Anti-coagulant Activity: According to the study on pineapple extract, it exhibited anticoagulant properties when compared to ethylenediamine tetra acetic acid (EDTA). Notably, among the four extraction methods employed, 95% ethanol and Expression yielded significant volumes of extract. Expression with spiral twist yielded an extract comparable to EDTA in preventing blood coagulation and maintaining red blood cell integrity. Despite minor variations in extract volumes, a 300ul dosage showed results akin to EDTA in preventing cell crenation and clumping, as well as preserving cell staining reactions. Overall, the study suggests that pineapple extract holds promise as an anticoagulant agent[55]. Bromelain, containing several proteolytic enzymes, exhibits anticancer and thrombotic properties. The anticoagulant effect of bromelain, either alone or in combination with N-acetylcysteine, was assessed using human blood and showed thrombolytic activity when combined with N-acetylcysteine[56].

m) Anthelmintic Activity: The research conducted on Pineapple Fruit Peeling Juice against Ascaridia galli and Heterakis gallinarum in naturally infected semi-scavenging Philippine native chickens revealed that chickens treated with pineapple exhibited the lowest infection levels of Ascaridia galli and experienced significantly improved weight gain compared to those given a placebo. This suggests the potential of pineapple fruit peeling juice as a viable alternative anthelmintic[57]. An in vitro study on pineapple peel juice conducted against Paramphistomum sp. demonstrated that a 25% w/v concentration of pineapple peel juice was effective in combating Paramphistomum sp., with survival index and relative motility values comparable to those of Albendazole at 10% w/v ($p < 0.05$)[58].

n) Anti-diabetic Activity: An investigation into the antidiabetic effects of Ananas comosus leaves in STZ-induced diabetic rats revealed promising results. Oral administration of Ananas comosus leaves extract at 300mg/kg b.w. significantly restored altered biochemical parameters in diabetic rats to near-normal levels. The extract improved glycogen content and the activities of glycogen metabolizing enzymes, while reducing elevated serum aminotransferase and alkaline phosphatase activities. Additionally, it normalized increased lipid peroxide levels in plasma and pancreatic tissues, and enhanced pancreatic enzymatic activities and plasma non-enzymatic antioxidant levels. These findings suggest that Ananas comosus leaves extract possesses significant antidiabetic activity, likely attributed to its antioxidant properties and bioactive components[59].

o) Wound Healing: A study investigating the impact of pineapple juice on perineal wounds revealed a significant difference between the experimental and control groups. The observed significance value of 0.02 ($p < 0.05$) indicates that pineapple juice has an influence on the healing process of perineal wounds in women[60].

Table 5: Summary of Pharmacological Activities of Ananas comosus

Pharmacological Activities	Fruit	Stem	Leaf	Crown	Peel	Bromelain
Antimicrobial Activity	+	-	+	+	+	+
Antibacterial Activity	+	-	-	-	+	+
Anticancer Activity	+	-	-	-	-	+
Antioxidant Activity	+	-	+	-	-	+
Anti-inflammatory Activity	+	+	+	-	-	+
Antidepressant Activity	+	-	-	-	+	+
Hepatoprotective Activity	+	-	-	-	-	-
Anti-rheumatic Activity		-	-	-	+	-
Anti-ageing Activity	+	-	-	-	-	-
Anti acetylcholinesterase Activity		-	-	-	+	+
Cardioprotective Property	+	-	-	-	-	+
Anti-coagulant Activity	+	-	-	-	-	+
Anthelmintic Activity	+	-	-	-	+	-
Anti-diabetic Activity	-	-	+	-	-	-
Wound Healing	+	-	-	-	-	-

Present: (+); Not Present: (-)

Table 6: Summary of studies done on Ananas comosus for various Pharmacological Activity

Sr. No.	Study Design	Name of Study	Pharmacological Activity
1	In Vitro	Antibacterial effect of pineapple (Ananas comosus) extract towards Staphylococcus aureus	Antimicrobial
		Enzymatic, antimicrobial and toxicity studies of the aqueous extract of Ananas comosus (pineapple) crown leaf	
2	In Vivo	Antidepressant activity on methanolic extract of ananas comosus linn peel (meacp) by using forced swim and tail suspension apparatus in mice	Antidepressant
		Eat Pineapple A Day To Keep Depression At Bay	
3	In Vitro	In vitro Evaluation of Antibacterial Efficacy of Pineapple Extract (Bromelain) on Periodontal Pathogens	Antibacterial
		Antibacterial Activity Test of Ethanol Extract Pineapple (Ananas comosus (L.) Merr.) Peel against Growth of Propionibacterium acnes	
4	In Vivo	Hepatoprotective Activity of Ethanolic Fruit Extract of A. comosus in Paracetamol Induced Liver Toxicity in Rats	Hepatoprotective
		Hepatoprotective Activity of Pineapple (Ananas comosus) Juice on Isoniazid-induced Rats	
5	In Vitro	Antioxidant capacity of pineapple (Ananas comosus (L.) Merr.) extracts and juice	Antioxidant
		Antioxidant Activity of Crude Bromelain of Pineapple (Ananas comosus (L.) Merr) Crown from Subang District, Indonesia	
		Enzymatic, antimicrobial and toxicity studies of the aqueous extract of Ananas comosus (pineapple) crown leaf	
6	In Vivo	Anti-rheumatic activity of Ananas comosus fruit peel extract in a complete Freund's adjuvant rat model	Anti-rheumatic
7	In Vitro	Anti-inflammatory evaluation and characterization of leaf extract of Ananas comosus	Anti-Inflammatory
		Anti-Inflammatory Effect of Pineapple Rhizome Bromelain through Downregulation of the NF-κB- and MAPKs-Signaling Pathways in Lipopolysaccharide (LPS)-Stimulated RAW264.7 Cells	Anti-Inflammatory
8	In Vivo	Pineapple Fruit Extract Prolonged Lifespan and Endogenous Antioxidant Response in Drosophila melanogaster Exposed to Stress	Anti-ageing
9	In Vivo	Invulnerability of bromelain against oxidative degeneration and cholinergic deficits imposed by dichlorvos in mice brains	Anti-acetylcholinesterase
		High-fat diet-induced memory impairment and anxiety-like behavior in rats attenuated by peel extract of Ananas comosus fruit via atheroprotective, antioxidant and anti-inflammatory actions	
10	In Vivo	Pineapple consumption reduced cardiac oxidative stress and inflammation in high cholesterol diet-fed rats	Cardioprotective
		Cardioprotective potential of hydro-alcoholic fruit extract of Ananas comosus against isoproterenol induced myocardial infraction in Wistar Albino rats	

		Potency Evaluation Of Combined Therapy Of Losartan And Ananas Comosus During Isoprenaline Mediated Cardiac Dysfucntion In Rats	
12	In Vitro	Anticoagulant Activity of Pineapple (Ananas comosus) Extract on Human Blood Samples	Anticoagulant
		Comparison of proteolytic, cytotoxic and anticoagulant properties of chromatographically fractionated bromelain to un-fractionated bromelain	
13	In Vivo	In vivo anthelmintic activity of pineapple (Ananas comosus Merr.) fruit peeling juice in semi-scavenging Philippine native chicken naturally co-infected with Ascaridia galli and Heterakis gallinarum	Anthelmintic
	In Vitro	In vitro anthelmintic activity of pineapple peel juice (Ananas comosus (L.) Merr.) against Paramphistomum sp.	
14	In Vivo	Studies on the antidiabetic activity of Ananas comosus leaves in STZ induced diabetic rats	Anti-diabetic
15	In Vivo	The Effect of Pineapple Juice on Perineal Wound Healing Among Post Partum Women	Wound Healing

10) Conclusion:

In conclusion, Ananas comosus (pineapple) emerges as a multifaceted medicinal plant with a wide array of pharmacological properties. Its rich phytochemical composition, including bromelain, flavonoids, polyphenols, and other bioactive compounds, contributes to its diverse therapeutic effects. From its antimicrobial and anticancer activities to its antioxidant, anti-inflammatory, and hepatoprotective properties, pineapple demonstrates promising potential for addressing various health conditions. Moreover, its nutritional value and traditional uses further enhance its significance as a natural remedy. Continued research into the therapeutic mechanisms and clinical applications of pineapple could uncover new avenues for its utilization in healthcare. Overall, the findings underscore the importance of Ananas comosus as a valuable resource in herbal medicine and highlight its potential contribution to global health and well-being.

11) Future perspectives:

Looking ahead, the future of pineapple research presents a landscape ripe with potential for innovation and discovery. One avenue of exploration lies in maximizing the utilization of pineapple byproducts, transforming waste into valuable resources through sustainable practices. Advancements in extraction methods offer another frontier, with the potential to yield higher quantities of bioactive compounds while minimizing environmental impact. Additionally, the development of pineapple-based functional foods holds promise for addressing specific health needs and preferences. Biotechnological approaches may further enhance pineapple's nutritional content and therapeutic properties, paving the way for novel varieties with tailored health benefits. Clinical studies are crucial for validating pineapple's pharmacological activities and establishing its efficacy and safety in human applications. Moreover, continued research into pineapple's nutritional composition and traditional uses promises to uncover new insights into its health-promoting potential. As interdisciplinary efforts converge, the future of pineapple research shines bright with opportunities to harness its benefits for the betterment of human health and well-being.

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