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A Review on Phytochemical Activityof Acacia Catechu

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Abstract: *Acacia catechu, commonly known as catechu or khair, is a deciduous tree native to Southeast Asia and the Indian subcontinent. This plant species has been utilized extensively in traditional medicine for centuries due to its diverse pharmacological properties. The bioactive constituents extracted from various parts of Acacia catechu, primarily catechins, flavonoids, and polyphenolic compounds, exhibit significant therapeutic potential.*

This review aims to comprehensively summarize the pharmacological attributes and therapeutic applications of Acacia catechu. Pharmacological investigations have revealed its antiinflammatory, antioxidant, antimicrobial, antidiabetic, and anti-cancer properties. The presence of bioactive compounds, such as catechin derivatives and flavonoids, contributes to its remarkable antioxidant and free radical scavenging activities.

Furthermore, Acacia catechu extracts have demonstrated promising effects in managing various health conditions. Its anti-inflammatory potential has been explored in the treatment of inflammatory disorders, while its antimicrobial properties showcase efficacy against a spectrum of pathogens. Additionally, the plant's antidiabetic attributes have sparked interest in potential applications for glycemic control.

This review consolidates current scientific knowledge on Acacia catechu, emphasizing its pharmacological properties and therapeutic potential. Nevertheless, further research, including clinical trials, is imperative to elucidate its mechanisms of action and validate its efficacy and safety for widespread therapeutic use. .

Keywords: Acacia catechu, catechin, flavonoids, pharmacological properties, therapeutic potential, traditional medicine

I. INTRODUCTION

Acacia catechu (L.f.) Willd. is a deciduous tree belonging to the family Fabaceae and has been widely used in Ayurveda for many years for the treatment and prevention of various diseases and/or disorders. It is called Cutch tree in English, Kahir in Hindi and Khadira in Sanskrit [1,2]. It is native to the Indian subcontinent and Southeast Asia and is well-known for its various uses in traditional medicine, woodworking, and various industrial applications. Here is a detailed introduction to Acacia catechu:

Taxonomy:
Kingdom: Plantae
Phylum: Angiosperms
Class: Eudicots
Order: Fabales
Family: Fabaceae
Genus: Acacia

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Species: Acacia catechu
Appearance: Acacia catechu is a deciduous tree that can grow up to 15-20 meters in height. It has a straight, slender trunk with dark gray to brownish-black bark. The leaves are bipinnately compound, consisting of numerous small leaflets.
Distribution: This tree species is native to the Indian subcontinent, particularly found in India, Bangladesh, Sri Lanka, and parts of Southeast Asia. It thrives in a range of ecosystems, from dry, arid regions to more humid environments.
Uses and Significance: Acacia catechu is highly valued for its various applications:
Medicinal Uses: The heartwood of Acacia catechu is rich in tannins and has been used for centuries in traditional medicine. It is known for its astringent and anti-inflammatory properties. It is used to treat various health issues, such as diarrhea, dental problems, sore throat, and skin conditions.
Ayurvedic Medicine: In Ayurveda, the traditional Indian system of medicine, it is known as "Khadira." It is used in various formulations to treat digestive disorders, respiratory issues, and to improve oral health.
Natural Dye: The heartwood contains catechins, which are used to produce a natural brown dye known as "catechu" or "katha." This dye has been used to color fabrics, leather, and as a coloring agent for betel leaves in paan (a traditional preparation in South Asia).
Woodworking: The timber of Acacia catechu is valued for its hardness and durability. It is used in woodworking, particularly for making furniture, tool handles, and agricultural implements.
Environmental Significance: The tree helps combat soil erosion and desertification due to its deep-rooted nature and adaptability to arid conditions.
Conservation Status: Acacia catechu is not listed as a globally threatened species, but like many tree species, it may face threats from deforestation and habitat loss in various regions.
In a research investigation, it was determined that both aqueous and methanolic extracts possess significant oxidative stress-modulating activity (using, 2,2-Diphenyl-1-Picrylhydrazyl (DPPH), ferric reducing antioxidant power (FRAP), 2,2′-Azinobis-(3-Ethylbenzothiazoline-6-Sulfonic Acid) (ABTS) and Superoxide Radical Scavenging Assay), and have the potential to be used as an antioxidant agent [3]. In an antimicrobial study, an *A. catechu* extract (ethanolic and aqueous) was found to be effective against *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhi*, *Klebsiella pneumonia*, *Shigella sonnei* [4,5], and *Streptococcus mutans* [6].

1.1 Phytochemical Constituents of *Acacia catechu*

In the heartwood of *A. catechu*, catechin content was 3.30% [7], 66.9% [8], and 3.580% [8,9]. Camphor (methanol extract), phytol (methanol extract), vitamin E acetate, 2-ethyl-3methyl1butene, butylphosphonic acid, di(4-methoxybenzene (hydroethanolic extract), ellagic acid, quercetin, rutin, and kaempferol are present in the leaves [10], and the bark shows the presence of catechin (methanol extract), quercetin, kaempferol (ethyl acetate), kaempferol (methanol extract) ascorbic acid, riboflavin, thiamine, niacin, and carotenoids [11]. Gayathari et al. [7] and Bhardwaj et al. [8] showed the presence of catechin, rutin, isorhamnetin, and epicatechin in heartwood. Saha et al. [12] identified 41 compounds in ethanolic leaf extracts through the GC/MS technique. Li et al. [13] identified two new phenolic compounds viz. 5-hydroxy-2-[2-(4hydroxyphenyl) acetyl]3methoxylbenzoic acid and (2S,3S)-3,7,8,30,40-pentahydroxyflavane in aqueous catechu extract through HPLC. Various pharmaceutical studies have shown that phytochemicals are beneficial to the prevention of illnesses [8]. The flavonoid class and subclass flavan-3-ols/flavonol are both referred to as catechin [14]. It is usually prominent in plants that have good antioxidant properties [15]. It has been found that *A. catechu* (heartwood portion) extract contains 23.1% epicatechin and 66.9% catechin [16]. *Acacia catechu* contains catechu tannic acid, catechuic acid (25% to 33%), catechu red, acacatechin, quercetin (10% to 12%), catechin (2% to 12%), epicatechin (25–33%), quercitrin, fisetin, gummy matter, phlebotannin, quercetin, tannins, cyanodol, polyphenols, and moisture [17,18]. Steroids, alkaloids, saponins, flavones, carbohydrates, glycosides, tannins, and phenolic compounds were found in the leaves of *A. catechu* [19]. Flavonoids are the most abundant class of naturally occurring phenolic chemicals, and they are found in a large variety of plant components, both free and as

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glycosides [20].. Anti-arthritic, antiangiogenic, antibacterial, anticancer, antiulcer, mitochondrial adhesion inhibition, protein kinase inhibition, and other biological actions have been demonstrated. In animal models, plant flavonoids inhibit tumour development [21].

II. MEDICINAL USES OF *ACACIA CATECHU*: TRADITIONAL KNOWLEDGE AND AYURVEDA

Acacia catechu is extremely valuable due to its therapeutic properties. This plant has long been used in traditional medicine, especially in Asia for its valuable nutritional properties [21]. This plant has the potential to produce functional foods and medications [11]. The *Acacia catechu* plant has been used traditionally to treat asthma, bronchitis, cancer, chest pain, diarrhea, mouth sores, sore, throats, ulceration, vitiligo, and wound healing and possesses antifungal, antiviral, spasmolytic, and hypoglycemic properties [22]. In Ayurveda, there are many references to prove that *A. catechu* is a beneficial plant with numerous curative properties [23] including for skin disease. Khadirarishta is a popular ayurvedic skin tonic made from the bark and heartwood of *A. catechu*. Additionally, heartwood extract has been utilized in many pharmaceutical products, including Lavangadi Vati [24]. “Ercha” a traditional Chinese drug used to treat coughs, diarrhea, skin ulcers, and blemishes [25] is prepared from this plant. The benefits of khoyer, according to folk medicine practitioners in Bangladesh, is used for pain relief and blood sugar control in diabetics [26]. This plant is widely used as chew sticks in different parts of the world because of its potential antibacterial properties [27,28].

2.1 Biological Activities of Acacia catechu

Numerous studies have been conducted in recent years to examine the pharmacological activities of A. catechu extract. In this review, we have discussed the in vivo and in vitro studies that included the immunomodulatory, antihyperglycemic, hepatoprotective, antidiarrheal, antinociceptive, antihyperlipidemic, antiulcer, antioxidant, antidiabetic, antiproliferative, antibacterial, antifungal, haemolytic, and anti-inflammatory properties of A. Catechu.

Immunomodulatory Activities

Anti-Inflammatory Effects: Acacia catechu contains bioactive compounds, including catechins and flavonoids, which have demonstrated anti-inflammatory properties. By reducing inflammation, it can help prevent excessive immune responses that can lead to tissue damage.

Antioxidant Activity: The plant's bioactive compounds also possess antioxidant properties, which can help neutralize harmful free radicals in the body. Oxidative stress can weaken the immune system, and antioxidants help maintain its optimal function.

Enhanced Immune Response: Some studies suggest that Acacia catechu extracts may enhance the body's immune response by stimulating the production and activity of immune cells like macrophages and lymphocytes. This can improve the body's ability to defend against infections.

Allergy Management: Immunomodulation can also be useful in managing allergies. Acacia catechu may help regulate the immune response to allergens, reducing the severity of allergic reactions.

Antiviral Potential: Acacia catechu has shown antiviral properties in some studies. By modulating the immune system, it may help the body better fight off viral infections.

Protection Against Autoimmune Disorders: In some cases, an overactive immune system can lead to autoimmune disorders where the body mistakenly attacks its tissues. Immunomodulatory agents like Acacia catechu may help in managing and regulating the immune response in such conditions.

Cancer Support: Some research suggests that Acacia catechu may have potential in supporting the immune response against cancer cells. It is often used as an adjuvant therapy in cancer treatment.

Wound Healing: By regulating the immune response, Acacia catechu may aid in wound healing. It can help reduce inflammation at the wound site while supporting the immune cells involved in the healing process.

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2.2 Antihyperglycemic Activities

Diabetes mellitus is a grouping of metabolic conditions indicated by elevated blood glucose levels caused by insulin secretion abnormalities. Insulin is a hormone generated by the pancreas and regulates blood glucose levels in most people. Plant-based drugs are used to cure diabetic diseases and are of great interest as they have proven their hypoglycemic efficacy to varying degrees. The effect was explored in *A. catechu* by administering hydroethanolic leaf extracts orally for 30 days at doses of 200 mg/kg and 400 mg/kg concentrations in diabetic rats. The results indicate that the extract lowered blood glucose levels significantly. The activity of Aspartate aminotransferase, Alanine aminotransferase, and alkaline phosphatase in group III and group IV was found to be considerably decreased in rats as compared with the control group[29]. In diabetic rats, *A. ataxacantha* root extracts considerably reduced the activities of AST, ALT, and ALP [30].

2.3 Antihyperlipidemic Activity

Cholesterol is a necessary component of the cell membrane, as it ensures the adequate permeability and fluidity of the membrane. A higher total cholesterol level increases the risk of heart disease and stroke. Triglycerides are neutral fats that serve as an energy source and dietary fat transporter in the body. HDL is a high-density lipoprotein that reduces the risk of heart disease and stroke. Because it transports cholesterol from peripheral tissues to the liver, it is considered beneficial. While it deposits in blood vessel walls, (LDL) low-density lipoprotein is considered harmful cholesterol. LDL cholesterol is a strong analyst of coronary artery disease and atherosclerosis. The liver produces lipoprotein that is VLDL, and it serves as the internal lipid transport mechanism in the body. An A. catechu hydroethanolic leaf extract was given to the diabetic rat for 30 days at concentrations of 200 mg/kg and 400 mg/kg. Triglyceride, LDL, serum total cholesterol, and VLDL cholesterol were observed to be considerably higher in diabetic rats. Upon comparison of the diabetic to the normal rats, the amount of HDL serum was considerably lower. The flavonoids in the plant extract are responsible for boosting HDL levels [29]. The root extract of A. ataxacantha improved serum HDL levels and effectively reduced triglyceride serum, total cholesterol, VLDL, and LDL [30].

2.4 Antiulcer Activity

The most frequent type of ulcer in humans is peptic ulcer. It is also known as Ulcus pepticum, a peptic ulcer disease in the gastrointestinal region that is typically acidic and really painful. Helicobacter pylori are spiral-shaped bacteria that dwell in the acidic and are responsible for around 80% of ulcers. A. catechu root extract was investigated in wistar albino rats utilized in 95% ethanolic and aqueous extract by measuring values in three tests, i.e., acute toxicity studies, NSAIDs-induced ulcer model, and Aspirin + Pylorus ligation-induced. For this, the animals fasted for 24 h before the experiment and were given free access to drinking water. The ulcer model generated by NSAIDs had the inhibitor effect. Animals were placed in ten groups containing six animals: group I and II had given 150 mg/kg ranitidine and 1 mL vehicles; groups III and IV were given a complete ethanolic root extract at 200 and 400 mg/kg doses; groups V and VI were given aqueous root extract at 200-400 mg/kg doses orally. The A. catechu ethanolic extract significantly shows the inhibition of 31.33% and 55.35% at 200 and 400 mg/kg, respectively. Additionally, an aqueous extract shows an inhibition equal to 54.54% and 71.14% at 200 and 400 mg/kg, respectively. The aqueous extract of A. catechu provided considerable protection against ethanolinduced ulcers and decreased the ulcer index [31]. Acacia senegal (Arabic gum) in adult male rat animal model showed effective protection against peptic ulcers. The results show that Arabic gum significantly reduces peptic ulcers [32].

2.5 Antinociceptive Activity

In this activity, an A. catechu methanolic wood extract (at doses: 50, 100, 200, and 400 mg per kg b.w.) in Swiss albino mice was investigated for its antinociceptive effect. By intraperitoneal acetic acid administration in a dose-dependent and substantial method, the extract reduced writhing in mice. The percentages of writhing reduction were 51.5, 57.6, 63.6, and 69.6% in all four doses. The results show that 200 and 400 mg/kg b.w. of extract relieved pain better than

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aspirin. The current study reviled that the extract used for pain alleviation was also validated [32]. An Acacia nilotica aqueous extract, at a dose of 50 mg/kg of bark, caused a significant reduction in pain [33].

2.6 Antidiabetic Activities

Hyperglycemia is a significant cause of diabetes mellitus (DM) and inhibitors namely carbohydratehydrolase such as α-glucosidase and α-amylase which provide an efficient technique for lowering postprandial hyperglycemia by controlling dietary carbs and glycogen breakdown. To know the effective values of A. catechu, Aryal et al. [33] investigated the antidiabetic potential of ethanolic bark extract, via α-glucosidase and α-amylase inhibition assays. Both assays demonstrated a good anti-diabetic impact; however, the α-amylase inhibition assay demonstrated the greatest inhibitory effect. As a consequence, the crude ethanol extract demonstrated antidiabetic efficacy in αamylase assays, with an IC_{50} of 67.8 µg/mL compared to acarbose (IC_{50} = 6.1 µg/mL). In a similar study, both α-glucosidase and α-amylase inhibition assay against the ethanolic seed extract of A. catechu was evaluated. Both assays demonstrated a good anti-diabetic effect, although the αglucosidase assay had the greatest inhibitory impact. At a dosage of 500 µg/mL, the inhibitory effect of A. catechu ethanolic extract of α-glucosidase was 53.77%. Furthermore, the IC_{50} value for inhibiting α-glucosidase activity was 187.80 µg/mL. α-glucosidase activity is higher than that of α-amylase. Because of the number of flavonoids and polyphenols in A. catechu, it has a high potential for blocking carbohydrate hydrolases [34].

2.7 Antiproliferative Activities

In a study, bark extracts/fractions of *A. catechu* were investigated for their antiproliferative effect against six human cancer cell lines, i.e., A549 lung, PC-3 prostate, MCF-7 breast, Hep-G2 liver, HeLa cervix, and IMR32 cell line [2]. From the results, it was determined that the ethyl alcohol bark fraction (EAFB) was found to be effective against the growth of the MCF-7 cell line; the IC_{50} values of various cell lines were 137.5 µg/mL (MCF-7), 153.23 µg/mL (A549), 186.19 µg/mL (PC3), 204.67 µg/mL (HepG2), 163.97 µg/mL (HeLa), and 251.33 µg/mL (IMR32). In methanolic fraction (MEB), the A549 cell line was determined to be the most effective with an IC_{50} value of 184.52 µg/mL. In *n*-butanol (NBFB) and aqueous bark fraction (AFB), the HeLa cell line was determined to be the most effective, having an IC_{50} value equal to 186.51 µg/mL and 241.30 µg/mL, respectively. In another study, an *A. catechu* heartwood methanolic extract (70%) (ACME) was tested against the breast carcinoma MCF-7 cell line. . The cell viability percentage of the *A. catechu* heartwood extract at different concentrations (1 ng, 10 ng, 100 ng, 1 µg, 10 µg, and 100 µg) was (13.63879%, 16.88865%, 22.69579%, 32.92488%, 39.21151%, and 47.46937%) was observed. Furthermore, the MTT assay clearly demonstrates that ACME has a potent antiproliferative effect on breast cancer cells line with an IC_{50} value equal to 105.35 µg/mL [35]. Diab et al. [36]

2.8 Antioxidant Activities

A. catechu plant extracts have significant antioxidant potential, evaluated by a DPPH test [2]. It was observed that ethyl acetate bark fraction (EAFB) exhibited the highest scavenging ability, whereas the aqueous fraction of bark (AFB) had the lowest. In the ABTS assay, EAFB had the highest ABTS radical, followed by bark methanol extract (MEB), n-butanol bark fraction (NBFB), and AFB. In terms of ferric ion reduction potential, EAFB was the most effective, followed by MEB, NBFB, and AFB. In the CUPRAC test, EAFB had the highest reducing activity while AFB had the lowest. In the superoxide radical scavenging (SRS) experiment, , EAFB exhibited the highest scavenging potential, whereas AFB had the lowest, and MEB and NBFB exhibited no significant differences. In the peroxyl radical scavenging (PRS) experiment, EAFB showed the lowest IC_{50} value, followed by MEB, NBFB, and AFB. The difference between MEB and NBFB was indistinguishable. In a study, methanolic extract showed a considerable scavenging activity as compared to the aqueous extract.In another study, the DPPH assay was used to study the scavenging activity. The concentration of DPPH was 0.2 mM in the reaction mixture and the test sample concentration

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was (5–100 µg/mL). Discolorations were measured spectrophotometrically at 517 nm. The IC_{50} value was found to be 7.11 µg/mL in the DPPH assay [34]. In a similar study,
Aryal et al. [33]

2.9 Antimicrobial Activities

Acacia catechu confirmed good to excellent antimicrobial activities, depending on the organisms. In a study, A. catechu extracts were used against Escherichia coli, Staphylococcus aureus, Salmonella typhi, Klebsiella pneumonia, and Shigella sonnei through the agar well diffusion method [3]. The MIC and MBC of an A. catechu aqueous fraction of bark were 6.25 and 12.5 mg/mL, while the drug MIC and MBC were 0.0625 and 0.25 mg/mL. In another study by Joshi et al. [37], there was no activity against S. paratyphi, E. coli, S. typhi, and Proteus mirabilis

2.10 Antifungal Activities

Acacia catechu ethanolic extract was tested in vitro for antifungal activity against three human pathogenic fungi: Epidermophyton floccosum, Trichophyton rubrum, and Microsporum gypseum [4]. For the study, the agar well diffusion method was used. The extract had no antidermatophytic activity, showing that it was ineffective. In another study, an A. catechu extract was assessed for its antifungal activity against Fusarium oxysporium [38]. The highest ZOI (17 mm) was calculated in the ethyl acetate fraction. Only F. oxysporium was shown to be active in the hexane fraction. Hexane had little activity against fungal organisms. Ethyl acetate and diethyl ether fraction showed high antifungal activity, and methanol and chloroform showed moderate activity. These results show that ethyl acetate extract has a strong antifungal activity while hexane extract has a negligible antifungal activity.
Due to the exceptional health-promoting activities of A. catechu, they have applications in the food industry as ingredients and in the beverage industry.
in any of the extracts. Diethyl ether extract was used to assess the highest zone of inhibition (ZOI) against the Pseudomonas bacterial strain. Diethyl ether, methanol, and ethyl acetate extract demonstrated better inhibition whereas hexane and chloroform showed modest action. Shigella sp. and Bacillus subtilis showed good inhibitory effects in the ethyl acetate extract with a minimum bactericidal concentration (MBC) of 50 mg/mL and at 100 mg/mL (MBC). Another test performed by Geetha et al. [4]

III. UTILIZATION OF *A. CATECHU* AS FOOD AND BEVERAGE AS SUPPLEMENT DUE TO THEIR BIOACTIVE COMPOUNDS

Natural Food: Catechu is often used as a natural food coloring agent, particularly in
Coloring: traditional Indian and Southeast Asian cuisine. It imparts a brown or reddish-brown color to various dishes and sweets, such as betel leaves, paan, and certain traditional desserts.
Flavoring Agent: A. catechu is sometimes used as a flavoring agent in culinary preparations. It can add a subtle earthy and woody flavor to foods and beverages.
Digestive Aid: In traditional medicine, catechu has been used as a digestive aid. It is believed to help alleviate digestive discomfort and promote overall gastrointestinal health when consumed in moderation.
Anti-inflammatory Properties: Some bioactive compounds in A. catechu, such as catechins and tannins, possess anti-inflammatory properties. These compounds can be used in the formulation of functional beverages or dietary supplements intended to support a healthy inflammatory response in the body.
Antioxidant Benefits: Catechins found in A. catechu are known for their antioxidant properties. Antioxidants can help protect cells from oxidative stress and may be incorporated into beverages or foods aimed at promoting overall health and well-being.
Functional Teas and Infusions: Catechu can be used in the preparation of herbal teas and infusions. These beverages are often consumed for their potential health benefits, such as antioxidant and anti-inflammatory effects.

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Supplement Capsules or Extracts: A. catechu extracts, often in the form of capsules or tinctures, can be consumed as dietary supplements. These supplements are typically standardized to contain specific levels of bioactive compounds, making it easier to quantify their intake.

Oral Health Products: Some oral health products, such as toothpaste or mouthwash, may incorporate catechu due to its astringent properties, which can help reduce gum inflammation and promote oral hygiene.

Traditional Medicine: In some traditional systems of medicine, A. catechu is used to prepare herbal remedies and tonics. These preparations are believed to have various health benefits, including supporting the respiratory and digestive systems.

It's important to note that while A. catechu has been used traditionally for various purposes, more research is needed to fully understand its potential health benefits and safety. Before incorporating it into your diet or as a supplement, it's advisable to consult with a healthcare professional, especially if you have any underlying health conditions or are taking medications. Additionally, the regulatory status of A. catechu may vary by region, so it's essential to be aware of local regulations regarding its use in food and beverages.

IV. CONCLUSIONS

The use of herbal medicines has become a global subject with medical and economic ramifications over the past few decades. *Acacia catechu* is a medicinal plant used for the treatment of various diseases in traditional and modern medicinal systems. The outcome of this study showed that *A. catechu* shows the presence of many bioactive compounds and displays polyphenolic and flavonoid contents, i.e., catechin, epicatechin, quercetin, lupeol, kaempferol, etc., in different parts (involving heartwood, leaves, bark, seed). The plant has been extensively studied for its pharmacological activities, and the results show that it has potent immunomodulatory, hypoglycaemic, hepatoprotective, antidiarrheal, antipyretic, antinociceptive, antihyperlipidemic, antiulcer, antioxidant, antimicrobial, antidiabetic, antiproliferative, antibacterial, antifungal, haemolytic, and anti-inflammatory properties that make this plant very valuable. However, this plant is helpful in curing various ailments. These data prove that *A. catechu* is a potential medicinal plant and could be used in the discovery or production of novel drugs. Although *A. catechu* has a high nutritional and phytochemical value, there is still a lack of research on its molecular mechanism and a need for chemical investigations and clinical trials to ensure the plant's safety in the food and pharmaceutical industries.

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