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Pharmacological and Phytochemical Insights into *Helianthus annuus* L.*:* A Comprehensive Review of Its Therapeutic Potential

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ABSTRACT

Helianthus annuus L. or sunflower, is a widely cultivated oilseed crop known for its nutritional, medicinal, and economic importance, sunflower is highlighted for its bioactive constituents, including flavonoids, phenolic acids, glycosides, and alkaloids. This plant possesses various therapeutic benefits such as anti-inflammatory, antioxidant, anti-diabetic, anti-cancer, anti-ulcer, cardiovascular, and wound-healing properties. It discusses sunflower's role in managing chronic diseases like diabetes and cardiovascular conditions, focusing on its potential to regulate oxidative stress, inflammation, and glycemic control. Recent findings on its cytotoxic effects against cancer cells, antimicrobial activity, and hepatoprotective effects further emphasize its medicinal relevance. Emerging trends like sunflower-based biofuel production and biotechnological advancements for enhancing drought resistance and oil quality are also discussed. The paper emphasizes the importance of continuous research to address agricultural constraints, improve productivity, and enhance the crop's environmental resilience. The review positions sunflower as a key crop for both economic and ecological sustainability. Ultimately, *Helianthus annuus* L. emerges as a promising botanical resource with broad applications in both food and pharmaceutical industries.

1. INTRODUCTION

The majority of people on the planet, particularly in poor nations, rely significantly on traditional healers and medicinal plants to meet their basic medical needs. The connection to traditional medications causes a number of issues. Because of this, researchers have recently revalued a large number of medicinal plant species based on differences in their species and therapeutic potential. In order to update the present state of knowledge, it is therefore vital to review the earlier literature that has been published on certain species. One of them is *Helianthus annuus* L. *Helianthus annuus* L. also known to as the sunflower, is a plant species of significant economic importance, a member of the family Asteraceae, furthermore called as the daisy family. The sunflower (*Helianthus annuus* L.) ranks among the foremost sources of high-quality edible oil and is recognized for its substantial nutritional, culinary, and medicinal properties [1]. Primarily, sunflowers are

cultivated for their oil-rich seeds, which find applications in various food products and industrial uses. While the seeds represent the principal portion of the sunflower utilized for food and oil extraction, other components—such as leaves, flowers, and stems—have more limited roles, primarily in medicinal, ornamental, or industrial applications [2].

Fig.1: Whole plant and various parts of *Helianthus annuus*

The seeds and flowers Fig.1 of *Helianthus annuus* L. possess febrifuge properties, are classified as stomachic, and serve as an excellent source of nutrition [3]. Furthermore, they have been documented to assist in the treatment of numerous pulmonary disorders. The flower heads are rich in antioxidant compounds, including flavonoids and phenolic acids, and have been employed in traditional medicine to alleviate inflammation, fevers, and respiratory conditions [4]. In addition, a warm wash made from a decoction of *Helianthus annuus* L.roots has been used to treat rheumatic pain. Extensive investigations into the seeds of *Helianthus annuus* L. have identified various chemical constituents and biological activities, with a particular emphasis on their antioxidant, antimicrobial, cytotoxic, and thrombolytic properties [5]. In the field of ethnomedicine, sunflower seeds are traditionally prescribed to address several ailments, such as whooping cough, colds, coughs, and infections of the lungs, larynx, and bronchi, in addition to heart illness [6]. The methanolic extract derived from the seeds of *Helianthus annuus* L. has demonstrated hepatoprotective and antioxidant effects[7]. Additionally, the petroleum ether extract of *Helianthus annuus* shows potential as a natural remedy for hyperlipidemia, which may contribute to its antihyperlipidemic activity.[8] Sunflower traditional extraction methods, such as Soxhlet extraction, along with emerging alternatives like pressurized liquid extraction (PLE), are widely employed to isolate vegetable oils and plant-derived compounds. Conventional techniques often rely on hazardous organic solvents—such as methanol, hexane, and chloroform—which can leave toxic

residues in the final product and pose risks to both human health and the environment. Knez et al.,reported that in contrast, pressurized liquid extraction is viewed as a more sustainable and efficient approach, progressively replacing traditional methods[9]. Environmentally friendly extraction strategies frequently involve subcritical or supercritical conditions, which offer several benefits including high selectivity, minimal exposure to oxygen and light, and the use of low temperatures that help preserve heat-sensitive constituents. Moreover, these advanced techniques enable rapid processing and facilitate easy solvent removal, ultimately resulting in superior-quality extracts[10].This study aims to assess the phytochemical makeup of *Helianthus annuus* L. leaf, stem, and seed extracts.

2. DETAILED CHARACTERIZATION OF THE PLANT

2.1. TAXONOMICAL CHARACTERIZATION

- Kingdom- Plantae
- Sub-kingdom-Viridiplantae
- Infrakingdom- Streptophyta
- Superdivision-Spermatophyta (Seed plants)
- Subdivision- Angiospermae (Flowering plants)
- Division- Magnoliophyta (Dicotyledons)
- Superphylum- Ombrophyte
- Phylum- Tracheophyta
- Subphylum-Spermatophytina
- Class- Magnoliopsida
- Superorder-Asteranae
- Order-Asterales
- Family- Asteraceae
- Genus -Helianthus
- Species- *Helianthus annuus*

2.2. BOTANICAL CHARACTERIZATION

Helianthus annuus, widely recognized as the sunflower, is an extraordinary plant with a range of compelling botanical traits. Here's a structured breakdown of its characteristics:

Growth Habit:

- Annual: This plant completes its life cycle in a single year, showcasing its remarkable ability to thrive quickly.

- Herbaceous: With a non-woody stem, sunflowers exemplify robust growth and vitality.

- Erect: Sunflowers grow upright and can reach impressive heights of 1-3 meters, with certain varieties soaring even higher.

Stem:

- Stout: The thick, sturdy stem is designed to support the substantial flower head, demonstrating strength and resilience.

- Hairy: The coarse hairs covering the stem add texture and contribute to its firm nature.

- Single or branched: Typically, sunflowers feature a single main stem; however, they can also branch out, creating an appealing silhouette.

Leaves:

- Heart-shaped to ovate: The broad leaves, characterized by heart-shaped bases and pointed tips, make a striking visual statement.

- Alternate arrangement: Leaves are strategically positioned along the stem in an alternate pattern, maximizing light exposure for optimal photosynthesis.

- Hairy: The rough texture of the leaves, thanks to their coarse hairs, adds to their visual appeal.

- Serrated margins: The edges of the leaves feature small, tooth-like projections, emphasizing their distinctiveness.

- Large: With the potential to grow up to 40 cm long and wide, these leaves create a bold presence.

Inflorescence (Flower Head):

- Capitulum: The sunflower's flower head is a captivating composite structure made up of numerous individual flowers clustered together.

- Large and showy: This vibrant flower can reach diameters of up to 30 cm, making it a focal point in any garden or landscape.

- Disc florets: The central portion of the flower, filled with tiny, tubular disc florets, is key to seed production and the plant's reproduction.

- Ray florets: The outer "petals," which are actually individual ray florets, play a crucial role in attracting pollinators, enhancing the sunflower's role in the ecosystem. [12]

2.3. IMPORTANT PHYTOCONSTITUENTS

Table 1 shows *Helianthus annuus* L. is a rich source of bioactive phytoconstituents, including glycosides, flavonoids, phenols, and alkaloids. These compounds exhibit anti-inflammatory, antioxidant, antimicrobial, and cardioprotective properties, making the plant valuable in traditional and modern medicine.

Flavonoids with anti-inflammatory, antioxidant, and cardioprotective qualities include luteolin, kaempferol, quercetin, and apigenin Fig.2. Quercetin and kaempferol both lessen oxidative stress and the chance of developing chronic illnesses like cancer and heart disease. Apigenin has neuroprotective and anti-cancer effects, while Luteolin supports immune function and reduces inflammation. Phenolic compounds such as Caffeic acids, coumaric acid, protocatechuic acid, gallic acid, sinapic acid, and chlorogenic acid Fig.2 have potent antioxidant and antimicrobial properties. Sinapic and Gallic acids protect against oxidative damage, while Chlorogenic acid aids in weight management and blood sugar regulation. Caffeic and Coumaric acids contribute to anti-inflammatory and hepatoprotective effects, whereas Protocatechuic acid is linked to anti-cancer and neuroprotective benefits.

Table 1: Various phyto-constituents existing in the *Helianthus annuus* L.

Phytochemical Class	Compound	Plant Part	Detection Technique
Flavonoids	Kaempferol [42]	Leaves, Flowers	LC-MS/MS, HPLC
	Quercetin [42]	Leaves, Petals	HPLC, LC-MS
	Apigenin [43]	Flower, Leaves	LC-MS/MS
	Luteolin [43]	Leaves	LC-MS
Phenols	Sinapic acid [44]	Seeds, Leaves	HPLC, GC-MS

	Gallic acid [45]	Leaves, Flowers	HPLC
	Chlorogenic acid(polyphenolic tannin)[43]	Leaves, Flowers, Seeds	HPLC, LC-MS/MS
	Caffeic acids[45]	Leaves, Flower	UPLC-MS
	Coumaric acid [43]	Leaves	HPLC
	Protocatechuic [44]	Leaves, Seeds	HPTLC, HPLC
Glycosides	Helianthosides (Triterpene glycosides) [45]	Whole plant (mainly leaves)	LC-MS/MS
	Quercetin 3-glucoside (Flavonol glycosides) [43]	Leaves, Flower	LC-MS
Alkaloids	2-naphthylalanine [44]	Seeds	GC-MS
	Medroxalol [44]	Seeds	LC-MS, GC-MS

Glycosides, such as Helianthosides and Quercetin 3-glucoside, exhibit antiviral, anti-inflammatory, and cardioprotective properties. They enhance bioavailability and prolong the effects of their active aglycone forms, supporting overall health and disease prevention. Alkaloids are bioactive compounds with pharmacological effects. 2-Naphthylalanine has potential antimicrobial properties, while Medroxalol is known for its beta-blocking and antihypertensive effects. Fenspiride is commonly used to treat respiratory conditions due to its anti-inflammatory and bronchodilatory properties.

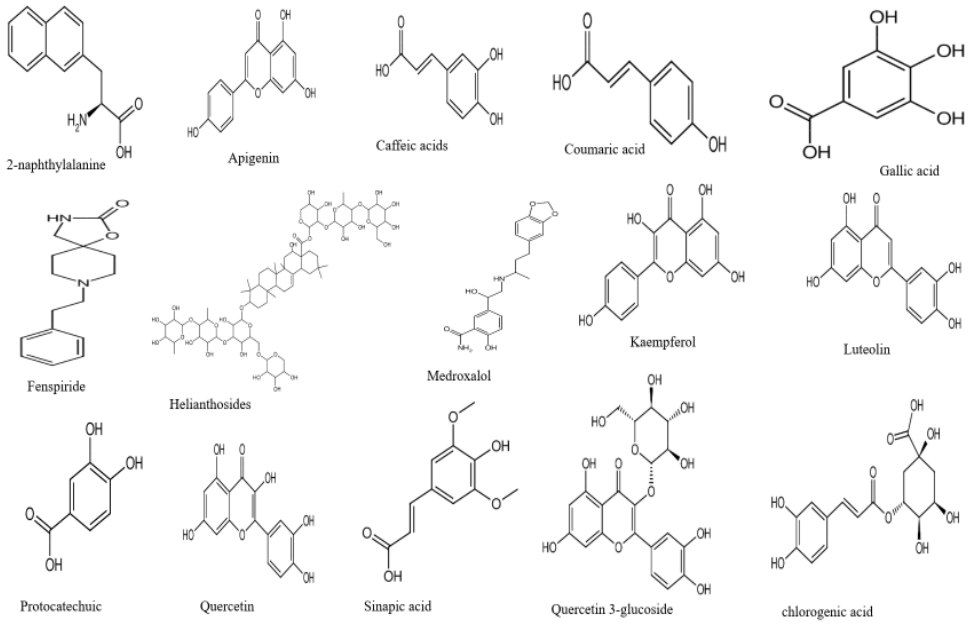

Fig.2: Structure of various phyto-constituents existing in the *Helianthus annuus* L.

3. PHARMACOLOGICAL ACTIVITIES

Helianthus annuus exhibits several pharmacological activities due to its bioactive compounds found in its seeds, leaves, and roots, described in Table 2 [13]. Key pharmacological activities include:

Table 2: Pharmacological activities and Biological compounds of sunflower (*Helianthus annuus* L.) [11]

Pharmacological Activities	Biological Compounds
Antioxidant activity	L-ascorbic acid, tocopherols antioxidant enzymes catalase, glutathione dehydrogenase, guaiacol peroxidase, glutathione reductase, carotenoids
Antimicrobial activity	Alkaloids, saponins, tannins, glycosides,phenolic compounds
Antidiabetic activity	Chlorogenic acid, glycosides, phytosterols, caffeic acid, quinic acid
Cardiovascular activity	11S globulin peptides
Anti-inflammatory activity	Alpha-tocopherol, triterpene glycosides, helianthosides
Anti ulcer activity	Flavonoids, tannins, alkaloids, saponins.

Anti cancer activity	Chlorogenic acid,Scopoletin,β-sitosterol,Caffeic acid
Wounds healing	Linoleic acid, arachidonic acid

3.1. ANTI-INFLAMMATORY ACTIVITY

Odabasoglu F et al. [14] established a recent investigation has demonstrated the efficacy of a methanol extract's n-butanol-soluble fraction is used to treat inflammation brought on by TPA (12-O-tetradecanoylphorbol-13-acetate) in murine models. Moreover, sunflower extracts exhibit significant anti-inflammatory properties, attributable to their diverse array of bioactive compounds, including flavonoids, phenolic acids, vitamin E, and magnesium. These compounds function collectively to neutralize free radicals, inhibit pro-inflammatory cytokines, and modulate inflammatory enzymes. Notably, the high linoleic acid concentration in sunflower oil is instrumental in decreasing TNF-alpha levels, a critical factor in the pathogenesis of psoriasis. while the oil has been shown to produce no adverse reactions on the skin. Additionally, saponins present in sunflower leaves contribute to the reduction of inflammation.

In a separate study, the gastrointestinal and anti-inflammatory effects of sunflower oil were assessed in rats subjected to treatment with indomethacin. Furthermore, the anti-inflammatory properties of LPS-stimulated macrophages were used to test mung bean ethanol extracts. The abundance of gallic acid, vitexin, isovitexin, and polyphenols within these extracts was found to significantly diminish macrophage activity by preventing the expression of pro-inflammatory genes, all without inducing toxicity.[15]

3.2. ANTI- DIABETIC EFFECT

Natural antioxidants and antiglycatives have a major impact on diabetes prevention and therapy by focusing on reactive oxygen species (ROS), which set off a number of metabolic processes connected to problems from diabetes. Among these remedies, sunflower sprouts are particularly noteworthy, demonstrating powerful DPPH radical scavenging capabilities, as well as impressive suppression of β-carotene oxidation and iron reduction in comparison to sunflower seeds.[16]

Xi M et al.[17] showed that a specific phenolic compound found In these sprouts, cynarin, has proven effective in lowering cholesterol and triglyceride levels, potentially benefiting individuals with hyperglycemia or hyperlipidemia. Additionally, secondary metabolites in *helianthus annus* L.seed extract are instrumental in regulating glucose levels. These extracts contain alpha-glycosidase inhibitors that hinder the function of intestinal brush border enzymes, ultimately leading to a reduction in carbohydrate digestion and absorption. This process significantly alleviates postprandial hyperglycemia. [18] Sunflower seeds' abundance of bioactive substances, such as quinic acid, chlorogenic acid, caffeic acid, glycosides, and phytosterols, is responsible for their anti-diabetic qualities. Both sunflower and flax seeds are particularly recognized for their effectiveness in lowering glucose levels, making them valuable dietary components for managing type 2 diabetes [19] various studies involving human and animal subjects have demonstrated that the consumption of these seed extracts results in improved glycemic control.

Furthermore, these extracts may contribute to reducing reducing the risk of type 2 diabetes by reducing insulin resistance, particularly in people who are already pre-diabetic. About 70% of the Chlogenic acid and caffeic acid are the sources of the polyphenols present in sunflower seeds. The enzyme that converts glucose-6-phosphate is interesting into glucose, glucose-6-phosphatase translocase, is inhibited by chlorogenic acid. By inhibiting this process, chlorogenic acid helps decrease glucose production, thereby alleviating the severity of diabetes and providing both anti-diabetic and antioxidant effects.[20]

Overall, the Under hyperglycemic circumstances, advanced glycation end products (AGEs) are formed and accumulate significantly contribute to the pathogenesis of diabetes, making the antioxidant properties of these natural compounds even more vital for those affected by the condition.

3.3. ANTIOXIDANTS EFFECT

Antioxidants are poised to take center stage in our understanding of cellular protection and the prevention of chronic diseases. As we look ahead, the exploration of natural antioxidants is expected to reveal even more about their roles such as peptides (like reduced glutathione), carotenoids, enzymes (like catalase, glutathione dehydrogenase, guaiacol peroxidase, and other phenolic substances (such as flavonoids, phenolic acids, and tocopherols).[21] The future promises exciting discoveries regarding sunflower seeds and sprouts, which are anticipated to demonstrate substantial due to their high levels of vitamins, flavonoids, polyunsaturated fatty acids, and phenolic compounds, they have been demonstrated to have anti-inflammatory,antibacterial, antihypertensive, wound-healing, and cardiovascular effects.Researchers will likely delve deeper into how various factors influence the antioxidant activity in sunflower seedlings, particularly as they react to UV-B radiation that is absorbed by the cotyledons of sunflowers.[22]

We expect the upcoming studies to highlight sunflower oil's richness in natural antioxidants, particularly phenolic compounds. With ongoing research, it's exciting to predict that we will uncover more about the significant antioxidant activity of compounds such as lignans in sunflower seeds. These compounds are anticipated to play a crucial role in reducing the risk of cardiovascular diseases and certain cancers by scavenging free radicals [23]. The spotlight will also be on the intriguing influence of UV-B rays' effects on sunflower cotyledon antioxidant defences. It is expected that future findings will reveal the remarkable enhancements in antioxidant enzyme activity (such as catalase, glutathione dehydrogenase, and guaiacol peroxidase) and soluble antioxidant defence (such as reduced glutathione) when exposed to specific levels of UV-B, showcasing values such as 32.0 nmol/g, 0.36 pmol/mg, 4.6, and 18.7 U/mg respectively [24].

As these discoveries unfold, we can anticipate a broader understanding of how these natural compounds operate within our bodies and their potential to enhance health and well-being.

3.4. ANTI MICROBIAL ACTIVITY

Ha-AP10 is a 10 kDa basic polypeptide homologous to many plant Lipid transfer proteins (LTPs), which indicates effective antimicrobial activity against a model fungus. As in other seeds, in sunflower seeds, (*Helianthus annuus* L.) Ha-AP10 exhibits high antimicrobial activity [25]. This protein is present for the first 5 days (and possibly longer) of sunflower germination. Another report

revealed that Ha-AP10 exhibits a weak inhibitory effect on the growth of the fungus Alternaria alternata, which naturally attacks sunflower seeds[26]. Parekh and Chanda[27] investigated that some secondary leaf and root metabolites inhibit the growth of some microorganisms isolated from sexually transmitted infections. The antimicrobial mechanism varies among different phytochemicals. For example, tannins form irreversible complexes with proline-rich proteins, thereby inhibiting microbial cell protein synthesis. The antibacterial and antifungal activity of sunflower seed extract was studied by determining the barrier zone formed around the disk which revealed varying degrees of potency to inhibit Salmonella typhi, Staphylococcus aureus, Bacillus subtilis, Vibrio cholerae, Aspergillus fumigatus, Rhizopus stolonifer, Candida albicans and Fusarium oxysporum[28]. The antibacterial and antifungal activity may be due to the extracted flavonoids, alkaloids, saponins and tannins which have been shown to inactivate microbial adhesion, enzymes and cell envelope transport proteins [29]. The findings suggest that H. annuus seed extract has antimycobacterial activity (MIC = 500 µg/ml) [30]and is in agreement with previous work by Cantrell et al. [31] who reported that I. hele-nium, another species of the sunflower family, exceeded the 80% barrier against M. tuberculosis H37Rv (100 µg/ml methanolic extract) using the radiorespirometric BACTEC assay.Also, Ibrahim TA et al.[32] Table 3 reported that the bactericidal effect of aqueous and ethanolic leaf extracts of *Helianthus annuus* was evaluated using the disk diffusion method and the agar well diffusion method.

Table 3: Antibacterial Activity of Aqueous and Ethanol Extract by Disk and Agar Well Diffusion Methods [29]

	Disk Diffusion (mm)		**Agar Well Diffusion (mm)**	
Bacterial Strain	Aqueous Extract	Ethanol Extract	Aqueous Extract	Ethanol Extract
Staphylococcus aureus	1.1±0.5	6.1 ± 0.2	1.9 ± 0.5	5.8 ± 0.1
Klebsiella pneumoniae	1.2 ± 0.1	5.88 ± 0.7	1.3 ± 0.2	-
Pseudomonas aeruginosa	1.6 ± 0.3	6.1 ± 0.3	1.67 ± 0.2	5.71 ± 0.5
Bacillus subtilis	1.7 ± 0.5	7.1 ± 0.5	2.1 ± 0.1	5.7 ± 0.1
Salmonella typhi	1.1 ± 0.2	5.5 ± 0.1	1.1 ± 0.5	5.2 ± 0.1
Escherichia coli	1.3 ± 0.5	5.5 ± 0.1	1.3 ± 0.1	5.8 ± 0.2
Micrococcus luteus	1.1 ± 0.3	5.3 ± 0.2	1.7 ± 0.1	5.5 ± 0.3

3.5. ANTI CANCER ACTIVITY

Decoctions made from the pith of sunflower stalks (*Helianthus annuus* L. HAL) have been used in the treatment of advanced cancer,,and one of the main ingredients in these decoctions consist of polysaccharides derived from sunflower stalk pith (HSPP). To investigate the mechanisms behind the anticancer properties of a specially formulated HSPP with anti-tumor effects, a syngeneic mouse model of lung carcinoma metastasis was established. According to the findings, long-chain fatty acids were present in the HSPP. The metastasis of the tumor cells was inhibited by the HSPP. The polysaccharide is believed to finally stop tumor growth and metastasis by lowering macrophage-derived TNF-α [33]. Using varying doses of sunflower seed oil (1.3, 2.6, 5.2, 10.4, 20.8, 41.6, 83.2, and 166.4 μg/ml) and exposure times (24, 48, and 72 hours), the cytotoxic effects of sunflower (*Helianthus annuns* L.) seed extracts were investigated against two cell lines (RD and L20B). The results demonstrated that sunflower seed oil had a clear cytotoxic effect on the RD cancer cell line's growth. and that this effect depended on concentration. Furthermore, compared to the growth of the L20B transform cell line, the RD cell line's growth was more susceptible to sunflower seed oil.[34]

3.6. ANTI-ULCER ACTIVITY

Helianthus annuus L. has been studied for its potential antiulcer effects due to its rich phytochemical composition, which includes flavonoids, tannins, alkaloids, and saponins. Sunflower contains flavonoids and phenolic compounds that help reduce oxidative stress, which plays a key role in ulcer formation and the plant's extracts may reduce inflammation in the gastric mucosa, preventing ulcer formation. Also, some studies suggest that *Helianthus annuus* L. promotes mucus production in the stomach, which helps protect the gastric lining from acid and pepsin. Sunflower extracts may enhance the healing of gastric lesions by stimulating tissue repair. Venkateswarlu K et al.[35] established that albino Wistar rats were used to assess the ability of hydroalcoholic extracts of A. indicum, H. annuus, and a combination of the two to prevent ulcers caused by ethanol and pyloric ligation stomach ulcers.

3.7. CARDIOVASCULAR ACTIVITY

Helianthus annuus L. has various cardiovascular effects due to its bioactive compounds, including flavonoids, phenolic acids, unsaturated fatty acids, and antioxidants. Sunflower seeds and oil are rich in unsaturated fatty acids, particularly linoleic acid, which aids in lowering LDL (bad cholesterol) levels while boosting HDL (good cholesterol), thereby reducing the risk of atherosclerosis. Additionally, they are a source of magnesium and potassium, which help relax blood vessels and regulate blood pressure. The presence of bioactive peptides in sunflower seeds may also contribute to antihypertensive effects by inhibiting angiotensin-converting enzyme (ACE). Sunflower seeds and oil contain, flavonoids, vitamin E and polyphenols, which reduce oxidative stress and inflammation—two key factors in cardiovascular disease [36].

3.8. WOUNDS HEALING

In young male lambs, A therapeutic substitute for the microscopical and clinical wound healing processes may be sunflower seed oil with a high linoleic acid content. The areas of the wounds are decreased by 300% after three days of treatment, and the wounds show improvement both macroscopically and in comparison, to control wounds after seven days. These findings corroborate Baie and Sheikh's findings that amino

acids and essential fatty acids aid in wound healing [37]. As a precursor to prostaglandins, linoleic and arachidonic acids are essential for preserving the epidermal barrier against water loss, regulating cell division, regulating epidermis differentiation, and ultimately controlling scales on the skin. According to Van Dorp and Prottey et al. [38], a high linoleic acid concentration in sunflower oil has the potential to reverse and heal dermatosis as well as scaly lesions.

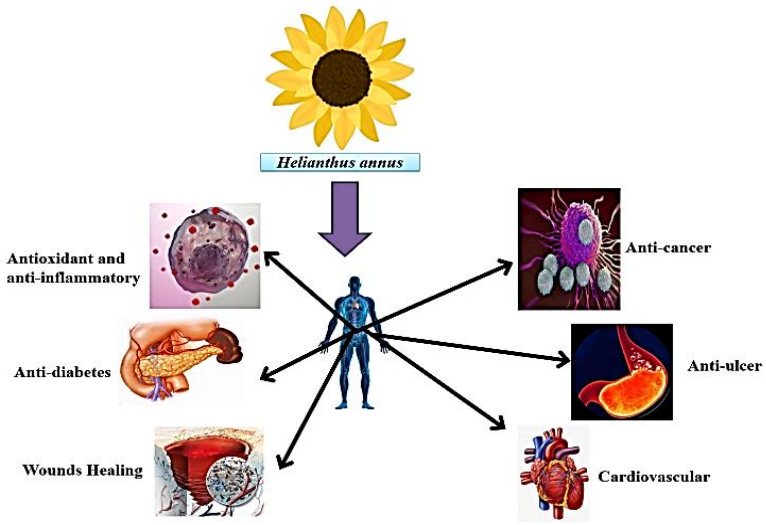

Fig.3: Various therapeutic potential of *Helianthus annuus* L.

4. CONCLUSION

Helianthus annuus L., also known as the sunflower, is a plant of significant economic and medicinal value. This review highlights its diverse phytochemical composition and bioactive properties, which contribute to its broad spectrum of pharmacological effects. Ali Esmailet al., reported [39] that the sunflower exhibits potent anti-inflammatory, antioxidant, anti-diabetic, anti-cancer, anti-ulcer, cardiovascular and wounds healing activities, primarily due to its rich content of flavonoids, phenolic acids, tocopherols, and essential fatty acids. Studies have demonstrated its potential in managing chronic diseases, including diabetes and cardiovascular conditions, by regulating oxidative stress and inflammation. Sunflower plants are used in phytoremediation to absorb heavy metals like lead and arsenic from contaminated soils [40]. The plant's bioactive compounds also show promising cytotoxic effects against cancer cells, suggesting possible applications in oncological treatments.Compounds derived from sunflower extracts are used in cosmetics, skincare, and biodegradable plastics due to their emollient and antioxidant properties[41]. Moreover, sunflower extracts have been explored for their antimicrobial and hepatoprotective properties, further expanding their medicinal significance. As research progresses, there is a growing need for clinical studies to validate these findings and establish standardized formulations for therapeutic use. Future investigations should focus on optimizing extraction methods, identifying novel bioactive compounds, and exploring potential synergies with existing pharmaceuticals. Overall,

Helianthus annuus L. remains a valuable botanical resource with immense potential in both the food and pharmaceutical industries.

Authors contribution:

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Moumita Ray: Primary editing, design, figure preparation.

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GRAPHICAL ABSTRACT