Review Article

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The exploitation of sunflower (*Helianthus annuus* L.) seed and other parts for human nutrition, medicine and the industry

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Abstract: Sunflower is cultivated around the globe to meet various nutritional, medicinal and industrial needs. The seed is a rich source of edible oil, protein, vitamins, antioxidants and other micronutrients. It is considered a source of healthy diets and has been recommended to improve the human immune system as well as to cure various chronic diseases. Sunflower seed oil contained poly-unsaturated fatty acids (linoleic acid), tocopherols and phytosterols, which tends to lower low-density lipid and improve immunity against various human diseases. Its seed and plants parts have been directly exploited as a source of herbal medicine. Methanolic extract of seed and other parts contained diterpene, carboxylic acid, aldehyde, steroid, polyphenol, vanillic acid, ferulic acid, trans-caffeic acid, coumaric acid, nicotinic acid, allelochemical and other aromatic compounds, which may help to cure several chronic human diseases without side effects as mentioned in this review. Future research should be carried out to fully exploit the usefulness of this plant against epidemic outbreaks.

Keywords: anti-inflammatory; antioxidant; antiviral; fatty acids; human medicine.

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Introduction

Sunflower is grown on a global scale for its edible oil, confectionary use, roasting and as bird food. It is the 14th largest edible oil in human diets with total oil production of 15.85 million metric tons (MT) after oil palm, soybean and rapeseed (FAO 2014). Oil is used for cooking, biofuel soap and paints as well as by the nutraceutical industry. Sunflower seed contributes about 10% to the total edible oil production of the world (FAO 2014). Ukraine had the world highest seed production (12.24 million MT) followed by the Russian Federation (10.48 million MT). Its seed contains about 30–50% oil, 20–30% protein, tocopherols, phytosterols and significant amounts of micronutrients such as calcium, zinc, selenium, phosphorus and iron (Aishwarya and Anisha 2014). Sunflower's oil is a rich source of polyunsaturated and mono-unsaturated fatty acid, tocopherols and sterols (Rauf et al. 2017). The seeds are directly consumed in the human diet and bird food (Rauf 2019).

The sunflower plant is also known for its remarkable beauty and show peculiar heliotropic movements to track sunlight. Archaeobotanical records showed that it was domesticated about 4000–4500 year ago by native North American people (Harter et al. 2004). The earliest domesticated remains of the sunflower were identified in San Andrés, in the Mexican state of Tabasco. However, recent genetic research demonstrated that sunflower was domesticated from wild species indigenous to eastern North America (Blackman et al. 2011). Blackman et al. (2011) also provide evidence to reject the hypothesis of a secondary centre of domestication. According to their theory, the eastern United States of America was the independent centre of diversity and all observed plant samples show this common area of origin (Blackman et al. 2011).

The sunflower was a plant of common use among the North American native tribes, who used this plant and its seed in many different ways. The seed flour was used as food and in making of cakes, bread and or mixed with other vegetables and corn. The seed was also a favourite snack of the North American natives. It was also used in making purple dye and was used in body painting and decoration. The plant was brought to Europe by a Spanish traveller during the 15th Century. The sunflower plant has great aesthetic value, resultantly it occupied as an ornamental plant in the gardens of Europe and also had small scale use for medicinal purpose. Sunflower started to gain its popularity for commercial-scale cultivation during the 18th Century in Europe. A breeding program was initiated at Krasnodar, Russia for genetic improvement of sunflower to improve oil content. Selection led to the increase in oil content, which helped to grow sunflower on a commercial scale and its reintroduction in native lands of Argentina, Brazil and USA. Breeding programs

aimed for improving its oil contents in the sunflower seed. Two kinds of sunflower were developed through selection; i.e., small, black seed sunflower with high oil content (40–50%), and large seed striped sunflower with low oil content. The former was used in confectionery, as snacks and bird food due to its high protein and fibre contents (Rauf 2019).

Sunflower has been historically used as an ethnomedicinal plant since time by native Indians in the American continent. Seed and other parts of the plants may be used, *inter alia*, to cure heart diseases, malaria, viral infection, bronchial, pulmonary infection, coughs, or whooping cough (Pal 2011). Seed, receptacles, roots and leaf foliage contained allelopathic chemicals, antioxidant, anti-inflammatory, anti-hypersensitive, antibacterial, anti-hyperglycemic compounds that make this crop a valuable source for ethnomedicine worldwide (Pal 2011). Sunflower's extracts contain complex compounds such as diterpene, carboxylic acid, aldehyde, steroid, polyphenol, vanillic acid, ferulic acid, trans-caffeic acid, coumaric acid, nicotinic acid and other aromatic types (Fei et al. 2014; Liang et al. 2006).

Recent research published during the ongoing COVID-19 pandemics demonstrated the importance of healthy diets comprising of vitamins, macro and micronutrients to boost immunity under an epidemic and thereafter (Jayawardena et al. 2020; Muscogiuri et al. 2020). Various publications mentioned sunflower seed as a source for healthy diets. Sunflower oil is a rich source of tocopherols and sterols having strong antioxidant property (Rauf et al. 2017), while its whole seed contains micronutrients such as zinc, selenium and iron that may also help to improve human immunity (Rauf 2019). Moreover, its seed, leaf and root extract have medicinal characteristics that are useful to cure various human diseases. In wake of an epidemics, improved human immunity, better health, and continued search of plant material for their medicinal value remain the best option for recovering against any kind of infection (Jayawardena et al. 2020). The medicinal value of sunflower may help to prevent various human diseases with lesser side effects and calls for further research on sunflower extracts to prevent chronic diseases. Hence, this review article was written with a focus on the utilization of sunflower to obtain various nutritional, medicinal and sanitation benefits for human beings.

Sunflower related species

Genus *Helianthus* comprises more than 51 species. However, there are only two cultivated species from this genus (Warburton et al. 2017). The medicinal and industrial value of various species belonging to genus *Helianthus* does not seem to be well understood. The wild species have been exploited to improve the

agronomic performance of the sunflower breeding lines and cultivars (Warburton et al. 2017). Several species contained novel fatty acids such as linolenic acid in their seed and thus may be exploited in a breeding program (Warburton et al. 2017).

Helianthus tuberosus a cultivated species from genus *Helianthus* had a high concentration of protein (6.36%), insulin (10.13%) and essential amino acids such as methionine (73), lysine (287), valine (210), isoleucine (181), phenylalanine (174) threonine (183) mg 100 g^{-1} in its tuber than potato and chicory. Edible tubers of *H. tuberosus* also contained fructans as a functional food, which play an important role in various processes and improve the immunity against various diseases (Cieślik et al. 2011). *H. tuberosus* contained an adequate concentration of all essential elements (N, K, Zn, Ca, Mg, Fe, Mn, Cu) except P and thus a good source of nutrition for ruminants as well (Terzić et al. 2012). *H. tuberosus* donated its edible tuber forming character to cultivated sunflower, which was known to be a rich source of protein (Seiler et al. 2010). Intergeneric crosses were attempted between the *Helianthus annuus* × *Echinacea purpurea* to increase genetic diversity within sunflower species and to introduce some characteristics of *E. purpurea* in cultivated species (Vassilevska-Ivanova et al. 2014). Viable hybrids were generated, and intergeneric hybrids had characteristics with average trait values of both species (Vassilevska-Ivanova et al. 2014). *E. purpurea* species had high medicinal value and used to cure respiratory diseases. The species contained bioactive compounds which may help to improve the immunity and cure of various diseases (Kumar and Ramaiah 2011).

Industrial value: sunflower as a source of cheap and safe raw material

Animal residues are considered as a source of various infection and diseases during handling and processing in the industry. In contrast, plants have been considered a safe and cheap source of raw material. Sunflower oil is not only used as salad dresser and medium for cooking, but the industry also uses its raw material in making soap, paint and varnishes (Rauf et al. 2017). Sunflower oil is rich in polyunsaturated fatty acid which is known to reduce blood cholesterol and low-density lipids. Presence of polyunsaturated fatty acid in sunflower oil reduces oxidative stability of sunflower oil for cooking. Deep frying or cooking of oils rich in polyunsaturated fatty acid caused rancidity and production of oxygen radicals which has been decreased by genetic modification in sunflower fatty acid production pathways (Rauf et al. 2017). Oleic acid is a mono-unsaturated fatty acid and has higher oxidative stability than poly-unsaturated fatty acid which also reduces the LDL density lipid in blood profile and increases high-density lipids. High oleic (80%) and stearic acid (35%) lines have been developed to improve sunflower oil

utilization in cooking and margarine production (Alberio et al. 2016). "Pervenets" mutant line was obtained by treating mutagen ethyl-methane sulfonate had oleic acid contents greater than 80% while CAS-29 and CAS-30 had stearic acid contents of 34.5% (Fernández-Moya et al. 2005). High oleic acid contents in oil tend to reduce the risk of heart attack and breast cancer. It suppressed the expression of gene related to breast cancer (Menendez et al. 2005). These lines may be exploited to develop speciality oils. Stearic acid is saturated fatty acid but has a neutral impact over the bloodstream cholesterol level. Traditionally sunflower oil contained about 2–4% of stearic acid but mutation breeding resulted in the development of lines having new alleles that expressed to produce stearic acid contents up to 35% in sunflower oil. Increase in oleic acid occurred at the expense of linoleic acid while the increase in stearic acid occurred at the expense of the oleic and linoleic acid. Mid oleic (50–60%) and stearic acid (20%) lines have also been developed which may be cultivated for the extraction of cooking oil and margarine production (Anushree et al. 2017; Bootello et al. 2012). Increase stearic acid production may help to eliminate the trans-esterification process in sunflower, which is hazardous for human health. Sunflower butter is a new food product, introduced in the market with trademark as "SunButter®". It has been considered as highly nutritional, tasty and healthy butter, which may be alternative for those people who had allergic problems with peanut butter (Seiler and Gulya 2016).

The saponification value of sunflower oil (0.1358) was lower than other crops such as palm and coconut oil. This may be due to high polyunsaturated fatty acid percentage present in traditional sunflower oil. The current pandemic situation requires increased production of the soap for sanitation purpose, which may increase the demand for sunflower oil as raw material. Sunflower breeding lines have been developed with high palmitic acid that may be used in a hybrid development program to increase palmitic acid for the soap industry. CAS-5 line contained about 25% palmitic acid in comparison to conventional level (8%) in sunflower oil (Pérez-Vich et al. 2016) 3-keto-acyl-ACP synthase II locus was shown to be associated with the high palmitic acid in sunflower (Pérez-Vich et al. 2016). Leaves of sunflower also contained latex for the production of natural rubber. The high percentage (95%) of the rubber had low molecular weight ranging between 65,000 and 74,000 g mol^{-1} while a small proportion (5%) had large molecular weight about 600,000 g mol^{-1}. Sunflower seems to be a good substitute for the production of latex. Various breeding and genetic engineering methods may be pursued for the enhancement of rubber yield and quality (Pearson et al. 2010). Likewise, *H. tuberosus* appears as a good source of fructans. contents which depend upon the cultivars, growth condition and maturity of its tubers (Bach et al. 2015).

Immunity booster

Sunflower seed is rich sources of tocopherols, sterols, vitamin B and microelements such as zinc, folate, and selenium, which play an important role as immunity booster against various chronic diseases by scavenging the oxygen radical and protecting the cellular membranes (Caretto et al. 2002). Tocopherol and sterol provide strong wound healing property. There were several derivatives of tocopherols in sunflower oil (α, β, γ, δ), which differ in their power as an antioxidant (Velasco et al. 2004). Sunflower oil had tocopherol range of 314.5–1024.5 mg kg^{-1} seed and from 562.8 to 1872.8 mg kg^{-1} in oil (Velasco et al. 2002). The oil contained about 96% of α-tocopherol (Velasco et al. 2002). However, mutation breeding and selection led to modify the tocopherol contents in sunflowers to increase the concentration of other derivatives of tocopherols which improved the anti-oxidative properties of sunflower oil (Velasco et al. 2004). Sunflower oil enriched with γ-tocopherol had higher oxidative stability at 180 °C than oil with α-tocopherol (Marmesat et al. 2008). Sunflower oil rich in α-tocopherol has the highest anti-inflammatory properties (79.5%) vis-à-vis other vegetable oil (corn and olive) against paw oedema without causing any gastric damage in rats (Odabasoglu et al. 2008).

Phytosterol lowers the blood cholesterol level and inflammation thus preventing various heart diseases and have also been considered to suppress tumour growth (Jones and AbuMweis 2009; Ostlund 2007). Phytosterol is similar to the cholesterol in their chemical structure but greatly reduce the absorption of cholesterol within the bloodstream (Jones and AbuMweis 2009). A daily intake of 0.4–2 g of phytosterols is recommended to reduce the LDL cholesterol (Cabral and Klein 2017) and generally concluded as safe for human health (Brufau et al. 2008). Sunflower oil contained phytosterols such as brassicasterol, campesterol, stigmasterol and β-sitosterol (Vlahakis and Hazebroek 2000). Total phytosterol contents ranged from 2100 to 4540 μg g^{-1}, which was lesser than canola or oilseed rape and similar to that of soybean (Vlahakis and Hazebroek 2000). Phytosterol contents also differed among various germplasm collections. Seed phytosterol contents of 985 sunflower accessions ranged between 1319 and 5119 mg kg^{-1}, campesterol (32–197 g kg^{-1} phytosterols), stigmasterol (41–128 g kg^{-1}), β-sitosterol (448–755 g kg^{-1}), and Δ7-stigmasterol (8–274 g kg^{-1}) (Fernández-Cuesta et al. 2014).

Anti-inflammatory and analgesic activity

Inflammation is an immunological response against various types of disease condition and unchecked inflammation causes several pathological conditions

such as fever, pain, swelling, redness and even loss of tissue/organ function. Sunflower extract has been known for anti-inflammation and analgesic activity. A treatment of sunflower seed extract (300 mg kg^{-1}) caused a 33% reduction in inflammation in comparison to the control (Onoja et al. 2019). Egg-albumin induced paw oedema model was used to determine the anti-inflammation reaction of sunflower treatment (Onoja et al. 2019). The acetic acid writhing showed inhibition (50 and 58%) of analgesic potential with methanol seed extract treatments of 100 and 200 mg kg^{-1}, respectively (Islam et al. 2016a,b).

Fractionation of petroleum ether extract from sunflower seed led to the isolation of diterpene acid, grandiflorolic, kaurenoic and trachylobanoic acids. These anti-inflammatory compounds reduced the production of various inflammatory compounds such as nitric oxide, prostaglandin $E_2$and tumour necrosis factor (TNF-α) production, as well as expression of inducible nitric oxide synthase and cyclooxygenase-2 (Díaz-Viciedo et al. 2008). Sunflower seed water extract had an inhibitory effect on the expression of interleukin (IL)-4/IL-13, and immunoglobulin E, thus causing allergic inflammation in ovalbumin-induced rats (Heo et al. 2008).

Sunflower aqueous seed extract had high antioxidative properties and daily intake of sunflower seed may prevent the cellular oxidative reactions that induce damage to the DNA and cellular organelles preventing from various diseases including cancer (Giada and Mancini-Filho 2009). Sunflower seed contained various types of antioxidant enzymes (catalase, peroxidase, glutathione dehydrogenase, superoxide dismutase), which act as a scavenger for various reactive oxygen species (ROS). ROS can damage cellular membranes, proteins and DNA. The concentration of ROS scavengers increased when sunflower cultivars were subjected to various stress environments. These antioxidant enzymes when ingested protect against various diseases including cancer. In a study, when sunflower seed extract (83.5 and 166.4 μg ml^{-1}) was applied to cancer line (RD) inhibited its growth (Al-Jumaily et al. 2013). However, inhibitory effects were not apparent in the normal cell line. Non-enzymatic antioxidants include peptide, saponin, carotenoid, flavonoid and phenolic compounds. Phenolic compounds such as chlorogenic and caffeic acid bounded with protein also showed antioxidant properties (Salgado et al. 2012). Sunflower antioxidants had been known for protecting against low-density lipoprotein and act as a scavenger for radicals (Ojo et al. 2017). Sunflower root extract containing a high concentration of saponin reduced the blood sugar, low-density lipoprotein and increased the level of various antioxidant enzymes (Ojo et al. 2017). Sunflower seed extract had high flavonoid and phenolic activity which may have induced cytotoxicity and antioxidative value of sunflower seed extract in caco-2 colon cancer cells (Smith et al. 2016). Flavonoid (100 μg ml^{-1}) obtained from leaves of Jerusalem artichoke (*H. tuberosus*)

had high scavenging activity and reduced the peroxide value in lard (Yang et al. 2011). Ethyl acetate leaf extract of Jerusalem artichoke, a close relative of sunflower had a high concentration of phenolic compound which had strong antioxidative properties. Among these phenolic compound, three compounds; i.e., 3-*O*-caffeoylquinic acid and 1,5-dicaffeoylquinic acid were identified (Yuan et al. 2012). They had a dominant role in radical scavenging. Heat-treated sunflower pectin induced apoptosis of CT26 colon cancer cells and inhibited tumour growth in cancer cells (Guan et al. 2018). Sunflower treatment showed similar results when compared with 5-fluorouracil, however, sunflower treatment did not cause any damage to spleen and thymus (Guan et al. 2018). Chloroform leaf extracts of *H. tuberosus* L. contained active compound as sesquiterpene lactones, diterpenes which were evaluated against the breast cancer for cytotoxicity (Pan et al. 2008).

Curing of diseases

Sunflower methanol root extract showed high efficiency against the inhibition (64%) of *Plasmodium berghei* - which causes malaria in some rodents – at a dose of 100 mg kg^{-1}. Ethanol extract of roots showed inhibition of 79.2% at a dose of 400 mg kg^{-1} in the prophylactic assay. Moreover, root extracts were considered safe when compared with positive (chloroquine) control (Ekasari et al. 2019). There was no difference between ethyl-acetate and methanol seed extract for the treatment of malarial *Plasmodium falciparum* parasites 3D7 strain (Mutiah et al. 2017). Antimalarial activity of ethyl-acetate leaf extract of sunflower had IC50 17 mg L^{-1} (Mutiah et al. 2017). Another study showed IC50 (160 µg ml^{-1}) of sunflower leaf extract as compared to the betel leaf extract IC50 (179 µg ml^{-1}) against *Plasmodium* spp. (Tjitraresmi et al. 2020). Sunflower extracts had fractions of artemisinin, heliangolide, linoleic acid eupalinolide C (Mutiah et al. 2017). Artemisinin has been found highly effective in comparison to malarial drug-resistant strains of *P. falciparium* (causing malaria in humans). However, a shortage of this compound made its unavailability for the malarial patient (Ro et al. 2006). Sunflower could also be an alternative source for artemisinin, and concentration of this chemical may be increased through selection.

The sunflower was known as traditional folkloric medicine effective against diabetes (or hyperglycemia). Methanolic seed extract (600 mg kg^{-1}) showed a significant decrease in blood glucose level (66.74%) after 6 h when compared with control glibenclamide (2 mg kg^{-1}) of alloxan-induced diabetic rats (Onoja and Anaga 2014). In another study, oral administration of methanolic seed extract (200 and 500 mg kg^{-1}) significantly reduced the blood sugar level in Type II streptozotocin-nicotinamide induced diabetic rats (Saini and Sharma 2013). In comparison with other species, sunflower methanolic extract of 150 mg kg^{-1} was effective in reducing the blood sugar level of alloxan-induced diabetic rats

(Luka et al. 2013). However, the order of effectiveness for particular treatment was *Vernonia amygdalina* better than *Moringa oleifera*, which was above *H. annuus* (Luka et al. 2013). Methanolic leaf extract (300 mg kg^{-1}) showed a reduction in fasting blood sugar, glycosylated haemoglobin, and degeneration of pancreas and liver when alloxan-induced rats were treated over 21 days (Onoja et al. 2018). Treatments effects were apparent after seven days and statistically similar to a drug after 21 days (Onoja et al. 2018). Sunflower root extract (300 mg kg^{-1}) comprising of high concentration of saponins significantly reduced the blood sugar after 14 days of treatment in allaxan induced rats (Ojo et al. 2017). Advanced glycation end-products (AGEs) are produced in hyperglycemia that further causes various chronic diseases. Sunflower sprout had the strongest inhibitory effects (83.29%) over the AGES at a concentration of 1.0 mg/mL when compared aminoguanidine (1 mM). It also had the strongest antioxidant properties among all compared sprouts available in Chinese markets (Sun et al. 2012). The process of extraction of caffeoylquinic acids from sunflower, which is under a patent, has shown promise against disease such as hypertension, hyperglycemia and type 2 diabetes (Bombardelli and Corti 2015). The tubers of Jerusalem artichoke are a rich source of inulin polysaccharide (8–13%) (Pan et al. 2008). Tubers are sweeter due to fructose which is 1.5 time sweeter than sucrose. Tuber powder has been successfully used as a sweetener in bakery product (Celik et al. 2013).

Anti-microbial activity

Sunflower seed has broad-spectrum anti-viral, anti-bacterial and anti-fungal activity. Its seed is rich in protein, approximately 20–30%, depending upon the sunflower hybrid type. Seed storage proteins are considered to play a significant role in various metabiological processes of humans. Seed storage protein comprised of 11S globulin and 2S albumins. 2S albumin makes 60% of the total seed storage protein. Albumin proteins had bactericidal, viricidal and fungicidal properties which may help to reduces infections against various pathogens (Guo et al. 2017). Sunflower flower and seed water extract have been found effective against various gram-negative and positive bacteria within a range of 0–20 mm inhibition zone (Al-Shukaili and Hossain 2019).

Anti-bacterial activity of sunflower extract

Several reports listed in Table 1 indicate the efficacy of the various sunflower extract and oil against various bacterial strains. Therefore, sunflower extract may

Table 1: Exploitation of various species of *Helianthus* for nutrition, medicinal and industrial purposes.

Species	Edible	Utility	Extracted compounds	References
H. annuus	Oilseed	Food, paint soaps and varnishes	Bioactive compounds such as anti-inflammatory, anti-oxidant, fatty acid, anti-fungal, antibacterial and antivirus proteins	
H. tuberosus	Tubers	Food, nutraceutical, and bioethanol	Insulin, polyphenol, antioxidant and phenol	Ma et al. 2011
H. radula	Wild	Industrial	Rubber	
H. petiolaris	Wild	Medicinal-musculoskeletal system disorders	Anti-inflammatory and antioxidant	Blanco and Thiagarajan 2017
H. grosseserratus	Wild	Industrial and medicinal	Foliage protein (20%)	Adams et al. 2018
H. nuttallii	Wild	Industrial	Hydrocarbon (7.78%)	Adams et al. 2018

help to reduce the infection and may help to reduce the inbuilt resistance within bacterial strains due to various antibiotics (Akpor et al. 2019). Sunflower extract was obtained using various solvents; i.e., methanol, n-hexane and ethyl-acetate. These extracts differed in their chemical composition. N-hexane solvent had the least number of dissolved chemical whereas methanol had the highest number of extracted phytochemicals (Akpor et al. 2019). Methanol extract had sunflower phytochemicals such as terpene, glycoside, phenols, flavonoids, saponins and tannins (Akpor et al. 2019). A methanol seed extract has a promising impact on various pathogens due to its peroxidation inhibition properties (Subashini and Rakshitha 2012). Several reports mentioned that methanolic extract had an inhibiting effect on various races of salmonella typhi (Islam et al. 2016a,b; Subashini and Rakshitha 2012), whereas petroleum ether extract show sensitivity to the *P. aeuregenosa* (Islam et al. 2016a). The cytotoxic (LC50) effects of sunflower methanol extract were 1.2 $\mu g\ ml^{-1}$ while petroleum ether had LC50 1.1 $\mu g\ ml^{-1}$ (Islam et al. 2016a). Hydrolysate sunflower protein treated with pepsin had antimicrobial activity against several bacterial strains (Zhao et al. 2017).

Anti-fungal activity of sunflower seed

Two compounds obtained from sunflower receptacles such as demethoxyencecalin and demethylencecalin inhibited the growth of *Pyricularia oryzae*. The

calculated inhibitory dosage of both chemicals was 100 and 50 μg $disk^{-1}$ (Satoh et al. 1996). Moreover, both compounds inhibited the growth of *Cladosporium herbarium* at 20 and 2 μg per 20 mm^2 (Satoh et al. 1996). Antifungal lipid transfer protein named as Ha-AP10 having a molecular mass of 10 KDA was extracted from the sunflower seed. It completely inhibited the growth of *Fusarium solani* f. sp. *eumartii* at a concentration of 40 μg ml^{-1} (Regente and Canal 2000). The essential oil of *H. annuus* and *Helianthus strumosus* contained various types of monoterpene hydrocarbons (*α*-pinene, sabinene and *β*-pinene). Extracted essential oil predominantly comprise of *α*-pinene (50%). *Cryptococcus neoformans* showed sensitivity toward the application of essential oil (Lawson et al. 2019). The sensitivity of the *C. neoformans* was linked with α-pinene, sabinene and *β*-pinene (Lawson et al. 2019). Ozonoid sunflower oil (Bioperoxoil®) showed significant anti-inflammatory, and antimicrobial (MIC value = 3.5 mg ml^{-1}) properties against several fungal strains and showed better wound healing properties than control (neomycin–clostebol) (Rodrigues et al. 2004). Sunflower ozonized oil Oleozón had MIC_{90} 9.5 mg ml^{-1} against fungal strains such as *Staphylococcus aureus* and *Staphylococcus epidermidis* (Lezcano et al. 2000). Trypsin inhibitor (TI) isolated from sunflower seed had antifungal properties against the *S. sclerotiorum* at a concentration of 14 μg ml^{-1} and completely inhibited the germination of spores on sunflower. Anti-oxidant properties of TI may also be used to check against other fungal diseases in other organisms (Mendieta et al. 2004). Lectin protein (Helja) of 16 KDA was extracted from the sunflower, which has carbohydrate-binding property and high specificity for gluco-conjugate sugar motif. A concentration of 200 μg ml^{-1} has shown an inhibitory effect on all types of human yeast. It induced pseudohyphae formation on *Candida tropicalis* and changed the membrane permeability and produced ROS species in targeted yeast cells (Regente et al. 2014) (see Tables 2 and 3).

Anti-viral activity

The replication of viral particle depends on the proteases, which cleave the viral surface glycoprotein to initiate the activation of infection in the host cell. Therefore, these proteases are the target of virucidal drugs (Steinmetzer and Hardes 2018). Sunflower trypsin inhibitor (SFT1) has been used to design the various type II transmembrane protease inhibitors such as serine-protease, peptide-based inhibitors which may prove helpful to inhibit the viral infections (Fitler et al. 2014; Li et al. 2007; Long et al. 2001).

Crude, fraction and antimicrobial peptides were extracted from sunflower to check their antiviral activity against the HSV-1 virus. It was shown that there was

Table 2: Efficacy of sunflower extracts against various bacterial strains.

Bacterial strain	Seed extract		Check		Reference
	Concentration	Inhibition (cm)	Concentration	Inhibition (cm)	
Salmonella typhi	50 µg ml^{-1}	1.5	50 µg ml^{-1} ampicillin	1.6	Subashini et al. 2012
Salmonella paratyphi	Methanol extract (100 µg/disc)	11	Standard 30 µg/disc	50	Islam et al. 2016a,b
Escherichia coli	50% oil	18			Al-Shama et al. 2010
Staphylococcus aureus	50% oil	15			Al-Shama et al. 2010
Bacillus subtilis	Ethyl acetate 1000 mg L^{-1}	25 mm			Akpor et al. 2019
Escherichia coli	Ethanol 10 mg L^{-1}	0 (OD)	0	1.34(OD)	Chandramoorthy 2016
Staphylococcus aureus	Ethanol 10 mg L^{-1}	0 (OD)	0	1.8 (OD)	Chandramoorthy 2016
Pseudomonas aeruginosa	Ethanol 10 mg L^{-1}	0.45(OD)	0	0.94(OD)	Chandramoorthy 2016
Klebsiella pneumoniae	Ethanol 10 mg L^{-1}	0.45 (OD)	0	0.79(OD)	Chandramoorthy 2016

Table 3: Antifungal activity of various concentration of sunflower extracts.

Fungal strain	Seed extract		Check		Reference
	Concentration	Inhibition (cm)	Concentration	Inhibition (cm)	
Fuserium oxisporium	50 μg ml^{-1}	0.5	Amphotercin (control) (25 μg ml^{-1})	0.6	Subashini et al. 2012
Aspergillus fumigatus	50 μg ml^{-1}	1.3	Amphotercin (control) (25 μg ml^{-1})	1.7	Subashini et al. 2012
Cryptococcus neoformans	78 μg ml^{-1}		Amphotericin B (1.56 μg ml^{-1})		Lawson et al. 2019

dosage dependent EC_{50} against the viral infection (Oliveira et al. 2009). EC_{50} of crude extract, fraction and the isolated peptide was 21.5, 15.9, 4.8 μg ml^{-1}, respectively. The concentration of 78.6 μg ml^{-1} of isolated peptides had a direct viricidal effect against HCV-1 (Oliveira et al. 2009). Diethyl ether pollen extract from sunflower had inhibitory (91–100%) effect on the Epstein-Barr virus early antigen induction (EPV-EA) (Ukiya et al. 2003). Diethyl ether solvent led to the extraction of various diterpenes, fatty acid esters, and tocopherols, and out of which 21 compounds of di- or poly-cyclic ring molecule had strong inhibitory effects over the induction of EPV-EA (Ukiya et al. 2003).

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