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ETHNO-MEDICINAL AND PHYTOCHEMICAL PROPERTIES OF GENUS *ALLIUM*: A REVIEW OF RECENT ADVANCES

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Abstract

Allium is one of the largest genera of monocotyledons with 900 species distributed all over the world. It is also one of the most important genera containing several medicinal and edible plants. Various species of *Allium* are known since ancient times and are used as spices, vegetables and, as medical plants. *Allium cepa* (common onion) and *Allium sativum* (common garlic) are the two main species that have widely been used for therapeutic properties. Studies have revealed many members of the genus *Allium* as rich source of secondary metabolites which contributes to its biological activities. A wide variety of phytochemicals including the flavonoids, alkaloids, sulfides, saponins, polysaccharides, polyphenols, and several compounds of the sulfur containing amino acids cysteine have been identified as main constituents of these plants. The antioxidant and anti-carcinogenic properties of many *Allium* species have been authenticated worldwide. The antifungal and antimicrobial activities of bulbs and aerial parts of species have been reported. In addition, species from this genus have a wide array of biological activities like antibacterial, antiviral, antifungal, anti-diabetic potentials as well as beneficial effects on the cardiovascular and immune systems. The present article reviews recent advances in ethno-medicinal uses and active phytochemicals found in the various species of the genus *Allium*.

Key words: Antioxidants, Phytochemistry, Flavonoids, Secondary metabolites, Antitumor.

Introduction

Herbs have been used as food, spices, and medicinal purposes for centuries in widespread areas of the world. Since ancient times, traditional medical practices have been known in various parts of the world. However, it is observed that these practices may vary from country to country or place to place. Approximately 80% population of the world depends on these medicinal plants for controlling different ailments and most of these therapies include use of plant extracts and their active components. All over Pakistan numerous plants and herbs were used by traditional medical practitioners. Traditional systems like "Greco-Islamic medicines", "Greek medicines" or "YunaniTibb" are widely practiced in Pakistan. In addition, "Prophetic medicines" which represent a kind of herbal medicine has also been used in different countries in the Orient (Onyeagba *et al*., 2005; Khalil *et al*., 2014; Craig, 1999). A vast proportion of the plants are yet to be explored for its medicinal values. Because of little or no side effects on human health: plants and plant derived active ingredients remain a popular choice for disease cure. Over the time the global market and sales of the herbal medicines have significantly increased (Khan *et al.,* 2019; Ali *et al*., 2018; Adnan *et al*., 2018; Shinwari *et al*.,2018; Khalil *et al*., 2014; Yousaf *et al*., 2004).

Medicinal plants play key role in modern medicine (Ikram *et al*., 2015; Jan e*t al*., 2015; Khalil *et al*., 2014; Hussain *et al*., 2014; Gillani, 2010; Shinwari *et al*., 2009). The medicinal plant plays a key role in controlling of many lethal disease (Begum *et al*., 2017; Zahra *et al*., 2016; Tariq *et al*., 2016; Shinwari & Qaiser, 2011; Shinwari *et al*., 2013). *Allium* is one of the largest genera of monocots consisting of about more than 900 accepted species naturally occurring on the north hemisphere. The genus *Allium* is economically important containing several medicinal and edible species used as food and medicine in early days. Worldwide, about 50 *Alium* species are cultivated for different purposes. Most of the wild species are collected by the local population and is used as spices, vegetables, medicinal plant and also for ornamental purposes. Wild species possess vast capacity as a valuable part of the daily human diet. Members of the genus *Allium* have been recognized as rich source of secondary metabolites with biological activities (yousaf *et al.*,2004). The economically important *Allium* crop species like common garlic and onion play a significant role in daily diet which is used as vegetables, and for medicinal purposes. Compounds from *Allium* species provide broad range of health benefits like antiviral, antibacterial, antifungal, anti-diabetic, anti-carcinogenic, anti-platelet, antispasmodic, antiseptic, anti-helminthic, anti-thrombotic, anti-asthmatic, anti-carminative, anti-oxidant, anti-inflammatory, anti-hypertensive, hypoglycemic, hypotensive, lithontripic and hypo-cholesterolemic properties. *Allium cepa* (onion) is the richest source of a lot number of compounds and commonly grown vegetable type and used for different purpose. Garlic (*Allium sativum*) also known as Russian penicillin, has even been reported as clinically used in countries like USA and Russia. Epidemiological studies have suggested that garlic and onion show broad range of anti-cancer and chemo-therapeutic activities (Kratchanova *et al.*, 2010; yousaf *et al.*, 2010; Harris *et al.*, 2001).

Today the world faces a major problem of the antibiotic resistance especially *Staphylococcus aurous* and *Mycobacterium tuberculosis* are particularly challenging the current antibacterial therapies. It has been reported that *Allium sativum* and *Allium cepa* are important because of presence of flavonoids and organo-sulfor compounds which offer protection against malignancy by alteration in carcinogen metabolizing enzymes, arrests cell cycle, induce apoptosis in the affected cells, suppress the oncogenic signal transduction pathways and inhibition of neoangiogenesis (Amri, 2014). It has been reported that *Allium chinense* and *Allium ascolanicum* can be used as vegetable, condiments and also remedy for fever and stomach problems (Singh *et al.*, 2015). *Allium sativum* has been reported to be used as remedy for malaria, ring worm, wound, evil eyes and gastritis (Araya *et al.*, 2015). It hasalso been reported to be effective in controlling blood glucose levels in diabetes diseases (Goyal, 2015). There are several reports on the medicinal uses of many important plant species revealing excellent activities against broad range of diseases (Khan *et al*., 2017; Rehman *et al*., 2017; Riaz *et al*., 2017; Hayat *et al*., 2016; Qasim *et al*., 2016; Habiba *et al*., 2016; Qasim *et al*., 2010). In this review the ethno medicinal uses, photochemistry, biological and pharmacological activities of the genus *Allium* are presented.

Ethno medicinal uses of the genus *Allium*: A number of *Allium* species are edible and are mainly used as flavors in foods. These plants are the rich source of bioactive natural product and phyto-nutrients which are important elements of daily life. Studies revealed that vegetables from genus *Allium* have tumor inhibitory properties. It has been reported that increased consumption of these vegetable decreases the risk of incidence of carcinoma. Their consumption has been shown to treat different types of cancer including the prostate, colorectal, stomach and breast types of cancer. These vegetables are also effective against free radicals mediated cardiovascular diseases and aging (Kratchanova *et al.*, 2010). The ethnomedicinal uses of the reported *Allium* species with their common names, parts used, and medicinal uses are indicated in Table 1 and Figs. 1 and 2.

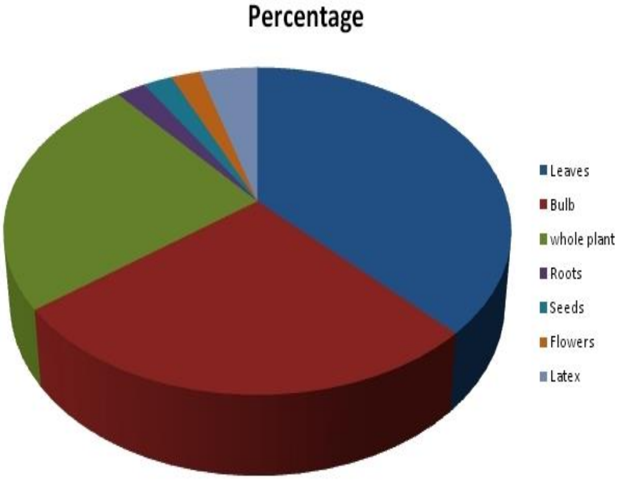

Fig. 1. Parts of plants used as Ethno-medicine.

Phytochemistry: The genus *Allium* is a rich source of compounds that display many bioactivities both *in vivo* and *in vitro*. It contained a lot of different metabolites. Both wild and cultivated species have many key metabolites and other sulfur-rich substances like allicin isolated from *Allium sativum* (common garlic) (O'Donnell *et al.*, 2008). *Allium cepa* is full of many important secondary metabolites. Flavonoids, fructans, and oraganosulfur compounds have been isolated from *Allium cepa* (common onion). Both its wild and cultivated species are full of key sulfur-containing compounds. Up to 60 compounds isolated from this genus are tabulated along with their biological activates in Table 2.

Alkaloids: There are number of alkaloids reported from the genus *Allium*. Three pyridine-N-oxide alkaloids having disulfide functional groups have been isolated from the *Allium stiptatum,* such as 2-(methyldithio) pyridine-N-oxide, 2- (methylthiomethyl) dithio] pyridine-N-oxide and 2,2′-dithio-bis-pyridine-N-oxide. These compounds possess antimicrobial activities against several bacterial species. A thiosulfinate natural products allicin that widely occurred in genus *Allium* was resolved by the synthesis of compound 2-(methyldithio) pyridine-N-oxide by simple method of kitson and loomes. These compounds were isolated as yellow and orange oils from the chloroform extracts with the different molecular formulas (O'Donnell *et al*., 2008).

Flavonoids: Flavonoids and their derivatives are isolated from many different species of the genus *Allium*, like from *Allium sativum, Allium cepa, Allium schoenoprasum* and also from wild species like *Allium filidens, Allium griffithianum, Allium rosenbachianum*. They have anti-oxidant, anti-tumor, anti-inflammatory and anti-mutagenic activities (Borlinghaus *et al.*, 2014). A variety of flavonoids like flavone, flavonol, flavenone have been found in various *Allium* species (Table 2).

Carbohydrates: *Allium sativum* has been reported to contain the highest amounts of carbohydrates. It is also found in considerable amounts in other species like in *Allium porrum* and *Allium cepa*. *Allium cepa* contain fructo-oligosaccahrides, *Allium porrun*contain active polysaccharides like glucuronic acid, galactose, rhamnose. The polysaccharides were separated by water and extraction procedure; the extracts were found to have higher polyuronic and protein amount and low sugar value. *Allium sativum* mainly contain reducing sugar such as glucose, fructose, sucrose and maltose. They have high biological activities to stimulate the immune system of the human body (Kratchanova *et al.*, 2010).

Sulfur compounds: Considerable number of sulfur compounds have been isolated and reported from the genus *Allium*. Oraganosulfur compounds such as di-allylsulfide, sulfinate, allylpropylsulfide and S-methyl-L-cysteine sulphoxide were isolated from *Allium cepa*. Allicin (diallylthiosulfinate), a defense molecule was isolated from *Allium sativum* which had broad range of biological activities. These compounds have been used for prevention of cancer, diabetes, and cardiovascular problems (Borlinghaus *et al*., 2014). Cysteine sulphoxides (alliin) were isolated from number of species such as *Allium filidens, Allium griffithianum*, *Allium rosenbachianum*, *Allium barsczewskii* and *Allium sativum*. Twenty seven volatile sulfur rich compounds were extracted from *Allium tuberosum* including sulfide, disulfides, trisulfides, and tetrasulfides with ethyl, butyl, and pentyl groups (Borlinghaus *et al*., 2014; Krest *et al*., 2000. Thioethyl and thiopentyl compounds were also reported from *Allium schoenoprasum*. These sulfur containing compounds have maximum antioxidant and antitumor activities (Block, 2013).

Table 1 Ethno-medicinal uses of different species from genus *Allium*.

S. No.	Botanical name	English/ Common name	Folk name*	Habit	Part used										Ethno medicinal uses	Literature Cited
					R	Se	L	F	St	D	B	W	Fr	La		
1.	*Allium cepa*	Onion/shalloot	Pyaz	Herb	-	-	+	-	-	-	+	-	-	-	Antioxidant, anti-carcinogenic, anti-platelet, anti-thrombotic, anti-asthmatic, anti-diabetic, fibrinolytic, anti-helminthic, anti-inflammatory, antiseptic, antispasmodic, carminative, diuretic, expectorant, febrifuge, hypoglycemic, hypotensive, treatment of dysentery	(Keusgen *et al.*, 2002; Ndukwu *et al.*, 2005)
2.	*Allium sativum*	Garlic	Ooga/Weza	Herb	-	-	-	-	-	-	+	+	-	-	Fevers, cough, constipation, asthma, nervous disorders, hypertension, ulcers skin diseases, antihelminthic, carminative, anti-diabetics, aromatic	(Ndukwu *et al.*, 2005)
3.	*Allium filidens*		oogakai				+								Stomach ache, gastrointestinal disorder	(Haq *et al.*, 2011)
4.	*Allium griffithianum*		Zangalipyaz	Herb	-	-	-	-	-	-	-	+	-	-	Use in dyspepsia, carminative, flatulence and colic	(Ajmal *et al.*, 2012)
5.	*Allium humile*		Da ghraouga	Herb	-	-	+	-	-	-	+	-	-	-	Indigestion, condiment	(Kala, 2006)
6.	*Allium jacquemontii*		Jangalithoom /pyazakay	Herb	-	-	-	-	-	-	+	-	-	+	Applied on unequal mammary gland of livestock	(Abbasi *et al.*, 2013)
7.	*Allium porrum*	Leek	Ooga	Herb	-	-	+	-	-	-	+	-	-	-	Immuno stimulating activity, flavonoid, polysaccharide, tumor inhibitor, antioxidant, anticarcinogenic, vitamin	(Kratchanova *et al.*, 2010)
8.	*Allium stipitatum*			Herb	-	-	+	-	-	-	+	-	-	-	pyridine-N-oxide alkaloids (1 -3) possessing disulfide functional groups having antibacterial activity of mycobacterium, methicillin resistant *staphylococcus aurous*, multidrug resistant variant of *Staphylococcus aurous*, inhibitor of fatty acid biosynthesis, up regulating the production of expression various heat shock protei	(O'Donnell *et al.*, 2008)
9.	*Allium tuberosum*	Garlic chives			-	-	+	-	-	-	+	+	-	-	Antibacterial, cardiac, digestive, stimulant, Aphrodisiac agent, stomachic, tonic	(Pino *et al.*, 2001)
10.	*Allium barszczewskii*			Herb	-	+	+	-	-	-	+	-	-	-	Colds and flu, headache, fever, toothache, seeds increase appetite	(Keusgen *et al.*, 2006
11.	*Allium chitralicum*			Herb	-	-	-	-	-	-	+	+	-	-	Against sense of fear, appetizer and general tonic	(Keusgen *et al.*, 2006)
12.	*Allium fedtschenkoanum*			Herb	-	-	-	-	-	-	-	+	-	-	Used against cold	(Keusgen *et al.*, 2006)
13.	*Allium neapolitanum*	Daffodil Garlic		Herb	-	-	+	-	-	-	+	-	-	-	Reduce blood cholesterol level, tonic to digestive syste tonify the circulatory system, chloroform	(Della *et al.*, 2006)
14.	*Allium oreoprasum*			Herb	-	-	+	-	-	-	-	+	-	-	Ailment of gastritis, cough and cold, edema, stomach ache, diarrhea, dysentery, rheumatism, jaundice, numbness of limbs	(Bhattarai *et al.*, 2006)
15.	*Allium rosenbachianum*			Herb	-	-	+	-	-	-	-	-	-	-	Condiment for soaps	(Keusgen *et al.*, 2006)
16.	*Allium schoenoprasum*	Chives		Herb	-	-	+	-	-	-	-	+	-	+	Carminative, digestive, diuretic, blood building, antiseptic,	(Duarte *et al.*, 2007)
17.	*Allium umbilicatum*			Herb	-	-	+	-	-	-	-	+	-	-	Anticytotoxic, prevent prostate cancer, condiment	(Sadeghi *et al.*, 2015)
18.	*Allium victorialis*			Herb	-	-	+	-	-	-	+	+	-	-	Antitumor, anticytotoxic	(Lee *et al.*, 2001)

*Folk name in local language (Pakistan); Legend: Se (Seed), R(Roots), F(Flower), L(Leaves), St(Stem), D(Decoction), W(Whole plant), Fr(Fruit), L(Latex), B(Bulb)

Table 2. Active ingredients isolated from the genus*Allium* and their biological activities.

S. No.	S. No.	Compounds	Species	Effects /activities	References
1.	1.	Pyridine-N-oxide alkaloids such as 2-(methyldithio)pyridine-N-oxide (1), 2 -[(methylthiomethyl)dithio]pyridine-N-oxide (2), and 2, 2′-dithio-bis-pyridine-N-oxide (3)	*Allium stiptatum*	Antibacterial activity against Mycobacterium, methicillin-resistant *Staphylococcus aurous*, multidrug-resistant (MDR) variants of *Staphylococcus aurous*, antifungal	(O'Donnell *et al.*, 2008; Krest *et al.*, 2000)
	2.	Cysteine sulfoxides			
	3.	Pyrithoine			
	4.	Allyl Propyl Disulfide,			
	5.	3-mercapto-2-methyl pentan-1-ol			
	6.	Gamma-L-glutamyl-trans-S-1-propenyl-L-cysteine sulfoxide			
	7.	Cartechol			
	8.	Protocatechnic acid			
	9.	Thiopropiono aldehyde			
	10.	Thiocyanate			
	11.	Minerals and Vitamins			
	12.	Flavonoids,			
	13.	Organosulfur compounds			
2.	14.	Selenoamino acids	*Allium cepa*	Diabetes, peroxynitrite induced diseases, osteoporosis, anticancer, Anti- inflammatory, Anti-oxidant, Cardio vascular problems, Tooth disorders, Piles, Urinary infections, Sexual Disability, Cough, Haemostatic effects,	(Cai *et al.*, 1995)
	15.	S-methyl-L-cysteine sulphoxide			
	16.	Vitamin C			
	17.	Vitamin B			
	18.	Potassium			
	19.	Sodium			
	20.	Magnesium			
	21.	Calcium			
	22.	Phosphorus			
	23.	Selenium			
	24.	Chromium			
3.	25.	3-Keto umbilicagenin A and B	*Allium umbilicatum*	Cytotoxic against tumor cells	(Sadeghi *et al.*, 2015)
	26.	S-allyl-L-cysteine sulfoxide			
	27.	Organosulfuricflavours			
4.	28.	Gitogenin 3-O-lycotetroside	*Allium vectorialis*	Cytotoxicity against cancerous cells	(Lee *et al.*,2001)
	29.	2-vinyl-4H-1			
	30.	3-dithiin			
	31.	Essential oils,			
	32.	Flavonoids			
5.	33.	Carotenoids	*Allium shcoenoprasum*	Antiseptive, promote digestive process, Antioxidant	(Duarte *et al.*, 2007; Stajner *et al.*, 2008)
	34.	Vitamin C			
	35.	Glutathione			

Table 2. (Cont'd.).

S. No.	S. No.	Compounds	Species	Effects /activities	References
	37.	Fatty acids			
	38.	Tocopherols			
	39.	Sapogenins,			
	40.	Saponins			
	41.	Ascorbic acid			
	42.	Flavonoids			
	43.	Selenoamino acids			
	44.	Allysulfides			
	45.	Flavonoids			
	46.	Phenols			
	47.	Polysaccharides			
6.	48.	Alliin (S-allyl-L-cysteine)	*Allium sativam*	Antioxidant, antitumor, enhance immune system, anticarcinogenic	(Block, 2013; Stajner *et al.*, 2008; Cai *et al.*, 1995)
	49.	Allicin			
	50.	Essential oil			
	51.	Thiosulfinates			
	52.	Vitamin C			
	53.	Glutathione			
	54.	Carotenoids			
	55.	Terpenes			
	56.	Sulfide with ethyl			
7.	57.	Disulfides with butyl	*Allium tuberosum*	Antioxidant, antitumor	(Pino *et al.*, 2001)
	58.	Trisulfides, Tetrasulfides with pentyl groups			
	59.	Oxygenated compounds			
	60.	Cysteine sulphoxides (alliin)			
8.	61.	S-methyl-L-cysteine sulphoxides (methiin)	*Allium barsczewskii*	Antioxidant	(Borlinghaus *et al.*, 2014; Krest *et al.*, 2000)
	62.	Cysteine sulphoxides (alliin)			
	63.	S-methyl-L-cysteine sulphoxides (methiin)			
9.	64.	flavonoids	*Allium filidens*	Antioxidant	(Borlinghaus *et al.*, 2014; Krest *et al.*, 2000)
	65.	Carbohydrates			
	66.	Cysteine sulphoxides (alliin)			
	67.	Flavonoids			
10.	68.	S-methyl-L-cysteine sulphoxides (methiin)	*Allium griffithianum*	Antioxidant	(Borlinghaus *et al.*, 2014; Krest *et al.*, 2000
	69.	Carbohydrates			
	70.	Cysteine sulphoxides (alliin)			
	71.	Carbohydrates			
11.	72.	S-methyl-L-cysteine sulphoxides (methiin)	*Allium rosenbachianum*	Antioxidant	(Borlinghaus *et al.*, 2014; Krest *et al.*, 2000)
	73	Flavonoids			

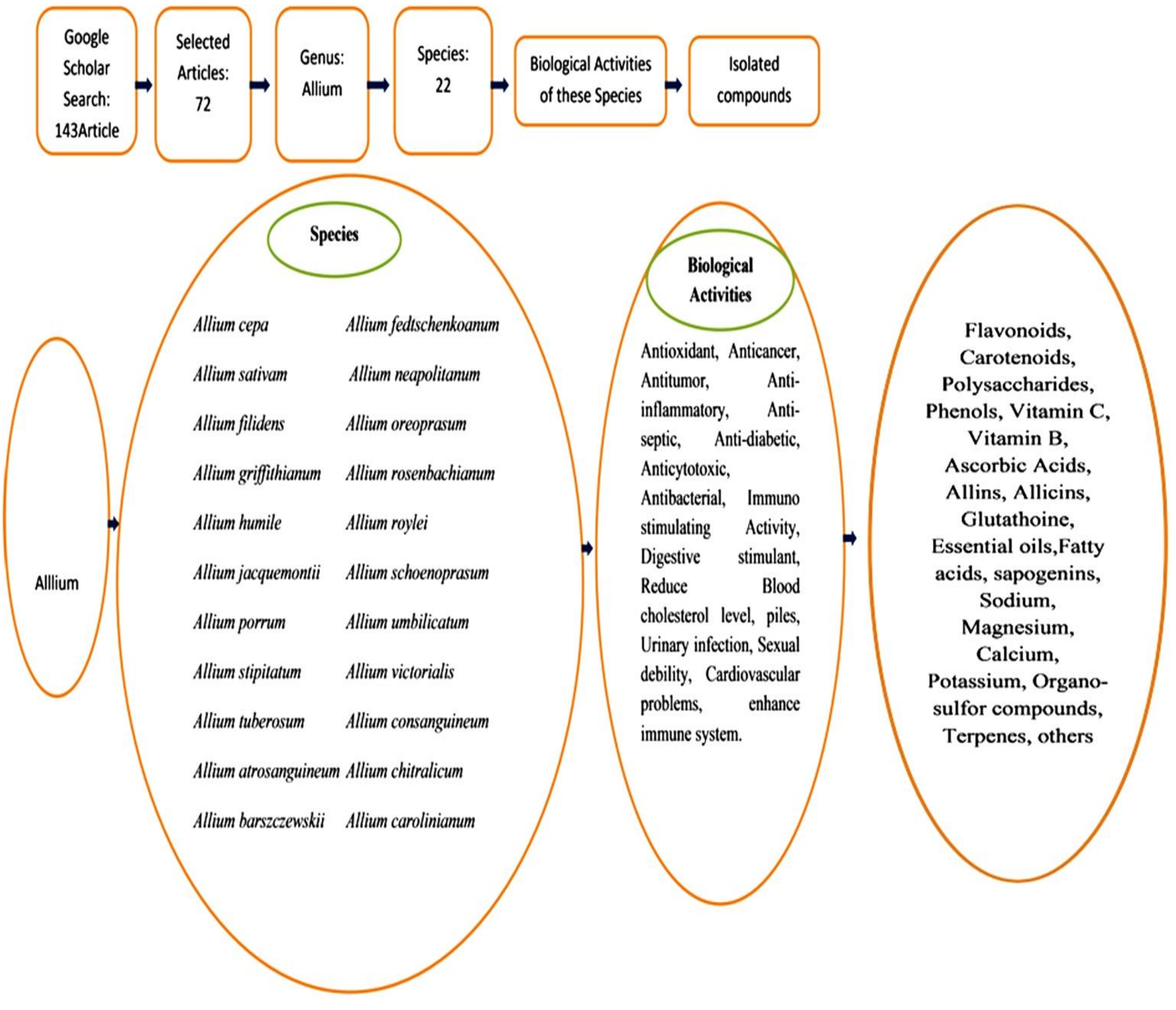

Fig. 2. Graphical abstract

Essential oil: Essential oils are derived from *Allium* species such as *Allium schoenoprasum* and *Allium sativum*. These oils have been reported to exhibit antibacterial, antifungal, and antiviral activities. All these oils were initially isolated using water distillation; and their serial dilutions were used to experimentally determine their minimum inhibitory concentration (MIC) in bacterial culture. These oils possess significant antimicrobial activities (Duarte *et al*., 2007).

Other compounds: A broad range of other compounds has also been isolated from the genus *Allium* (Table 2). *Allium cepa*has been reported to contain carotene, vitamin B, calcium and traces of vitamin C, *Allium sativum* (phenol, vitamin C, carotenoid), and *Allium tuberosum* (terpenes, oxygenated compounds). Other compounds reported from this genus include sapogenins, saponins, cartechol, terpenes, seleno amino acids, potassium, sodium, magnesium, ascorbic acid. The biological activities of these compounds are given in Table 1.

Biological activities: The genus *Allium* possesses wide range of biological activities (Table 1). Compounds from *Allium* genus typically have broad range of applications in health field such as anti-inflammatory, anti-spasmodic, anti-carcinogenic, anti-septic, lithontripic and hypo-cholesterolemic properties. The plant bulb is used in food and culinary preparation that can act as effective remedy for several infections, inflammation, respiratory and digestion problems (Stajner *et al*., 2008). Investigations carried out on *Allium* species show that the active components are cysteine sulphoxideallicin, alliin, flavone, tannins and phenol or their derivatives (Kyo *et al*., 2001). Table 2 illustrates an overview of current pharmacological applications of different Alium species.

Antibacterial activity: Allicin (diallylthiosulfinate) a defense molecule from the *Allium sativum* is produced upon tissue damage from the amino acid alliin (S-allylcysteinesulfoxide) by the enzyme allinase. Allicin is reactive sulfur and undergo a redox reaction which is essential for their biological activity. It can inhibit the proliferation of bacteria and/or induces bacterial cell death depending on the dose. It has also been reported to inhibit the methicillin-resistant *Staphylococcus aureus* (MRSA). The minimum concentration of organosulfor compounds to inhibit the growth of staphylococcus aurous and *Escherichia coli* was about 35× more than DADS (diallyl disulfide) (6.15 mM). Allicin-derived DADS has been reported with low antibacterial activity than thiosulfinates. Many strain of gram positive and gram negative bacteria i.e. *Bacillus* spp, *Streptococcus* spp, *Salmonella typhimurium*, *Agrobacterium tumefaciens*, *Pseudomonas syringae* and *Vibrio cholera* have been reported to be sensitive to allicin (Borlinghaus *et al.*, 2014; Fujisawa *et al.*, 2009). Compounds from *Allium stiptatum* like 2-(methyldithio) pyridine-N-oxide, 2-[(methylthiomethyl) dithio] pyridine-N-oxide, and 2,2′-dithio-bis-pyridine-N-oxide have been proved for its antibacterial activity against multidrug resistant(MDR)-*Staphylococcus aurous*, methicillin-resistant *staphylococcus aurous*, and fast growing strain of *Mycobacterium*. These compounds exhibited minimum inhibitory concentration (MIC) of 0.5-8μg/mL against the above mentioned bacterial strains (O'Donnell *et al.*, 2008). The crude extracts of garlic (*Allium sativum*) in combination with lime (*Citrus aurantifolia*) inhibit *Bacillus* spp., *Staphylococcus* spp. and *Escherichia coli*; however *Salmonella* spp., has been reported to be resistant to these extracts. The highest zone of inhibition was 19mm for *staphylococcus aureus* (Onyeagba *et al.*, 2005). Nanoparticles (size 33.6 nm) of onion (*Allium cepa*) extracts have been used as a reducing agent that have been found effective against *E. coli* and *Salmonella typhimurium* (Saxena *et al.*, 2010).

Antioxidant activity: *Allium* species possess effective antioxidant abilities in all organs mainly in leaves and bulbs. They could prevent tumor promotion and process be involved with free radicals, like cardiovascular diseases and aging. In many *Allium* species (both wild and cultivated) the superoxide dismutase (SOD) and catalase (CAT) activities were detected in bulbs. *Allium sativum* which is a cultivated species show high SOD activity as compared to other wild species like *Allium schoenoprasum*. This high antioxidant activity is because of antioxidant enzyme activities like SOD, CAT and non-enzymatic antioxidants like glutathione (GSH) and flavonoids (Stagner *et al.*, 2008). Antioxidant SOD activity was reported in many species especially in the leaves of these plants. *Allium sativum* possess high antioxidant contents such as phenols and flavonoids. The antioxidant activities of common garlic (Allium sativum) were evaluated under controlled humidity and temperature (70-80ºC) condition. This condition resulted in increased antioxidant component and the color of garlic was changed to black (called black garlic) which have been associated with high antioxidant ability (Choi *et al.*, 2014; Wang *et al.*, 2010). *Allium cepa* a cultivated species was assessed for total phenol contents, antioxidant activity and free radical scavenging activities. Four varieties of *Allium cepa* (common onion) red, violet, green and white have been investigated. The total phenols contents varied from 4.6-74.1mg/g and thus the antioxidant activities also varied from 13.6%-84.1%. The red and violet varieties showed more antioxidant activities than the green and violet (Prakash *et al.,* 2007).

Antitumor activity: Two sapogenins compounds from *Allium umbilicatum* and *Allium porrum* were investigated for cytotoxic activity against J-774 (murine macrophage) and WEHI-164 (murine fibrosarcoma). These compounds possess weak cytotoxic activities because of their chemical structure which has hydroxyl or keto group; because hydroxylation at C6 position has negative effect on cytotoxic activity. Saponin a compound isolated from *Allium* species especially from *Allium porrum,* has cytotoxic activity against tumor cells. It was investigated that cytotoxicity of steroidal saponin was due to the detergent effects on cell membranes. Sadeghi *et al.*, (2015) reported that saponin induce cell death by apoptosis *in vitro*. *Allium sativum* and *Allium cepa* possessed antitumor activities because they were rich in S-allyl-l-cysteine (SAC); an important water soluble substance. SAC having chemo-preventive effect on carcinogenesis in a rat experiment in which aged garlic rich in SAC reduced the outbreak of aberrant crypt foci and colon tumor through suppression of tumor cell proliferation. Processed *Allium sativum* were rich in SAC and possessed more anti-tumor activity, because during the processing such as temperature treatment and humidity controlled room maintenance the amount of SAC increased. The extracts of garlic have inhibitory activities against broad range of cancer with 50% cure frequency mouse fibro sarcoma. Furthermore, garlic extracts also increased the generation of cytokines (IFN-α, IFN-γ, IL-2, NO) from T helper lymphocytes and macrophages. These cytokines enhance the activity of natural killer cells (Choi *et al.*, 2014; Wang *et al.*, 2010) and could be associated with anticancer as well as immune-enhancing effects of these plants.

Antifungal activity: *Allium* species possess antifungal properties against many strains of fungi. Onion and garlic show great potential in treatment of fungal diseases from important pathogenic genera like *Candida*, *Malassezia* and *dermatophytes*. The aqueous extract of garlic and onion were used against *Malassezia furfur*, *Candida albicans*, dermatophyte species and compared with the activity of a known antifungal drug, ketoconazole (KTZ). The aqueous extract of *A. sativum* and *A. cepa* inhibit the growth of all tested fungi with a maximum of 100% at defined concentration in a dose dependent manner. Depending on genera and species tested, MIC (minimum inhibitory concentration) value showed susceptibility of all fungi. The *in-vitro* efficacy of onion and garlic extract against these fungus strain suggest a potential therapeutic efficacy in the treatment fungal disorder (Shams-Ghahfarokhi *et al.*, 2006). Saponins and sapogenins are secondary metabolites isolated from species of *Allium* such as from *A. porrum* has been used to cure many fungal diseases. The antifungal activity of saponins was evaluated against soil borne pathogens *Fusarium oxysporum*, *Fusarium solani*, *Rhizoctoniasolani*, air-borne pathogens *Botrytis cinerea*, *Alternaria alternata*. It was concluded that the bulb extract showed high antifungal activity against these strains (Barile *et al.*, 2007). *In vitro* effect of aqueous extract of garlic (*A. sativum*) on the growth of *Cryptococcus neoformans* showed that low concentration garlic extract were both inhibitory and lethal to many strains of *Crytococcus* *neoformans*. Garlic extract was found more effective against pseudohyphal variant strains of *Cryptococcus neoformans*than the yeast like strains and the lethal effect of garlic was independent of capsule presence (Romtling& Bulmer, 1978). These Chitinases isolated from *A. tuberosum* have been reported to be active ingredient for anti-fungal activity against *Rhizoctonia solani*, *Gusarium oxysporum*, *Coprinuscomatus*, *Mycosphaerella arachidicola* and *Botytis cinerea*. However, these chitinases did not show antibacterial activity. Moreover, the antifungal activity was acid and alkali-stable, protease-resistant and fairly thermostable (Lam *et al.*, 2000). Allicin an essential metabolite of *Allium,* has been reported to have antifungal effects, and its removal during solvent extraction resulted in decreased antifungal activity. Studies revealed that old garlic extract with no allicin or allicin derived constituents showed no *In vitro* antimicrobial activity. Essential oils isolated from *A. sativum* also exhibit antifungal activity (Harris *et al.*, 2001).

Antiviral activity: Few studies have reported antiviral action of *Allium* genus. These few studies include the *In-vitro* antiviral activity of garlic against influenza A and B, rhinovirus, HIV, herpes simplex virus 1 and 2, cytomegalovirus, viral pneumonia and rotavirus (Harris *et al.*, 2001). Allicin, diallyltrisulfide, alcohol and diallyl disulfide have shown to be active constituent involved in antiviral activity (Harris *et al.*, 2001). Essential oil from *A. sativum* also possesses antiviral activity. Fructan isolate from onion has been reported for its antiviral activity against influenza A virus (Lee *et al.*, 2012). Further research based on *In vitro* viral culturing is needed to explain the mechanism of antiviral effects of these plant species.

Anti-diabetic activity: S-methyl cysteine sulfoxide (SMCS) isolated from *A. cepa* (common onion) has been proved for antidiabetic effects. It was investigated in experiments on rats, maintaining their body weight and control of blood sugars. The mechanism of action could be partly dependent on the stimulation of insulin secretion (Kumari & Augusti, 2002). The hypoglycaemic and hypolipidaemic effects of aqueous extract of *Allium cepa* was investigated on rat experiments using control and experimental groups. Depending on dose of aqueous extract of *A. cepa*, reduction in blood glucose levels, total serum lipids and cholesterol was recorded in the study population. Most effective percent blood glucose reduction was observed at dosage of 300mg/kg. This represents a protective mechanism against diabetes mellitus. Another report reveals that garlic (*A. sativum*) is insulin otropic rather than hypoglycemic (Ozougwu, 2011, Islam & Choi, 2008). In another report revealed, it was proved that the aqueous extract of *A. sativum* extract possessed antidiabetic effect and was proved effective in another experiment on rats (Mostofa *et al.*, 2007). Dosage dependent decrease in blood glucose level and increase in body weight was observed as compared to control group (Mostofa *et al.*, 2007). The garlic ethanolic extract of *A. sativum* was investigated for antidiabetic effects in normal and streptozotocin-induced diabetic rats. In the subjected rats, significant decrease in the levels of serum glucose, cholesterol, urea, uric acid and creatinine was found (Eidi *et al.*, 2006).

Anticancer activities of *Allium* species: The genus *Allium* consisted of many phytochemicals having cancer chemo-protective abilities. Many species of this genus possess cancer-preventive properties. Diallyl sulfides, disulfides and trisulfides from *A. cepa*, *A. sativum*, *A. schoenoprasum* and *A. tuberosum* are cancer chemo-protective phytochemicals. In addition, *Allium* species also contain flavonoids, saponins and carotenoids which are cancer chemo-protective. These substances act as antioxidant and electrophile scavengers and stimulate the immune system. Garlic is known to have anti-tumor properties by stimulating lymphocytes and macrophages to destroy cancer cells as well as to disrupt the metabolism of tumor cells. Various studies revealed that garlic can reduce the development of colon, skin, and stomach and bladder cancer. It can inhibit the formation nitrosamines and DNA adducts (Craig,1999). *Allium* derivatives from garlic have extensive anti-proliferative effect on human cancers. These garlic derivatives have been found effective for both hormone responsive and unresponsive cell lines by inducing apoptosis, regulation of cell cycle progression/ proliferation, modification of pathways of signal transduction and regulate nuclear factors involved in immune function and inflammation. *Allium* derivatives can inhibit the proliferation of human breast and prostate cell lines although the mechanism of this anti-proliferative effect is not clear (Pinto & Rivlin, 2009). Pyridine N-oxide alkaloids isolated from *A. stiptatum* such as 2-[(methylthiomethyl)dithio] pyridine-N-oxide and 2-(methyldithio) pyridine-N-oxide have been demonstrated for its anti-proliferative effects on human cancer cell lines (O'Donnel l *et al*., 2008).

Effects of *Allium* species on lipid and cholesterol levels: S-methyl cysteine sulfoxide (SMCS) a precursor of onion oil, isolated from *Allium cepa*have been reported to reduce the level of cholesterol, triglyceride and phospholipids indicating that it have hypolipidemic effects and reducing the cholesterol levels (Kumari *et al.*, 2007). Garlic can be used for treating hypercholesterolemia. Both garlic and its preparations have widely been recognized as agents for treatment and prevention of heart diseases like atherosclerosis, thrombosis, hypertension, hyperlipidemia. Clinical experiments of garlic showed significant positive activities against cardiovascular diseases. *In vivo* studies on animal models are in agreement with this notion (Banerjee & Maulik, 2002).

Conclusions

Phytochemical and pharmacological studies of the genus *Allium* have received more interest in recent years. Modern *in vivo* and *in vitro* pharmacological studies have confirmed the traditional use of *Allium* species. The crude extracts and compounds from the plant bulbs, aerial parts possess many different kinds of biological effects. Thus, these plants have attracted more attention from the scientific community for the isolation of active ingredients and their potential therapeutic uses. Phenols, saponins, polysaccharides, flavonoids, have been identified as the main chemical constituents of the *Allium* species. As a result of these efforts, about 30 out of approximately 700 species have been studied exclusively. However, further research is needed to fully explore the bioactive compounds in the species of the genus *Allium* with special focus on the development of new drugs and therapeutics especially against carcinogenesis, immune, and cardiovascular diseases.

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