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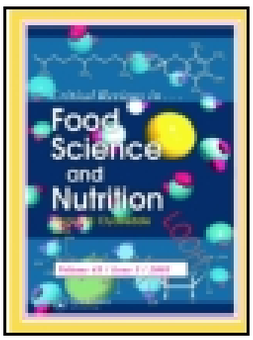

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REVIEW

Traditional and modern uses of onion bulb (*Allium cepa* L.): a systematic review

Joaheer D. Teshika[a,*], Aumeeruddy M. Zakariyyah[a,*], Toorabally Zaynab[a], Gokhan Zengin[b], Kannan RR Rengasamy[c], Shunmugiah Karutha Pandian[c], and Mahomoodally M. Fawzi[a,*]

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ABSTRACT

Onion, (*Allium cepa* L.), is one of the most consumed and grown vegetable crops in the world. Onion bulb, with its characteristic flavor, is the third most essential horticultural spice with a substantial commercial value. Apart from its culinary virtues, *A. cepa* is also used traditionally for its medicinal virtues in a plethora of indigenous cultures. Several publications have been produced in an endeavor to validate such traditional claims. Nonetheless, there is still a dearth of up-to-date, detailed compilation, and critical analysis of the traditional and ethnopharmacological propensities of *A. cepa*. The present review, therefore, aims to systematically review published literature on the traditional uses, pharmacological properties, and phytochemical composition of *A. cepa*. *A. cepa* was found to possess a panoply of bioactive compounds and numerous pharmacological properties, including antimicrobial, antioxidant, analgesic, anti-inflammatory, anti-diabetic, hypolipidemic, anti-hypertensive, and immunoprotective effects. Although a large number of *in vitro* and *in vivo* studies have been conducted, several limitations and research gaps have been identified which need to be addressed in future studies.

KEYWORDS

Allium cepa; onion bulb; medicinal; traditional; pharmacological; ethnopharmacology

Introduction

The diversified genus Allium encompasses around 918 species among which *Allium cepa* L., commonly known as onion, is botanically classified under the Amaryllidaceae family (theplantlist.org). The word "onion" is derived from the Latin word 'unio' which means 'single' or 'one' because the onion plant produces only single bulb (Corzo-Martínez et al. 2007). *Allium cepa* was commonly known by many other conventional or alternative names such as Egyptian onion, common onion, shallot and many more. Onion is an essential spice as well as commercial vegetable. Its edible portion stem, also known as a bulb, consists of an inner fleshy and outer dry membranous scaly leaves, and it is the primary organ of interest (Fig. 1). The shape of the bulb can be a globe, a flattened globe, sometimes with a flat top, spindle-like or almost cylindrical (Brewster 2008). Usually, they exist in various colors such as white, yellow, purple, red, green, and can also be classified according to its pungency (Slimestad et al. 2007). When bulbing begins, photosynthate produced by the leaf blades is transported to the leaf bases. This causes the core to swell resulting in the formation of a bulb. When the bulb ripens, the outer scales develop into a dry and impermeable skin, which help in preventing desiccation. Eventually, the bulb reaches maturity, and the leaf blade ceases to form on the inner bulb resulting in a hollow pseudostem. As the leaf sheath weakens, the pseudostem detaches from the leaf blades and the foliage falls (Rubatzky and Yamaguchi 1997).

Onion is considered to be one among the oldest vegetables and was mentioned in several ancient scriptures (Singh 2008). By the middle ages, it became one of the fundamentals in many cuisines in most parts of the world and therefore is always on demand throughout the year. In fact, onion is the third most essential horticultural crop after potato and tomato, with more than 170 countries commercially cultivating it globally. The current worldwide onion production is estimated to be 78.31 million tons with the average productivity of 19.79 t/ha (FAO 2015). India ranks first with regards to the total area under onion cultivation, which is expected to be 1.09 million hectares and is the second largest onion producer with 15.88 million tons, followed by China (22.46 million tons) (FAO 2015). In general, onion is cultivated and traded for its versatility, namely as fresh shoots for green salad onion and a bulb for consumption (cooked and raw), pickling, use in processed food, dehydration, and seed production (Brewster 2008). In fact, its use depends highly on its pungency; for instance, slightly mild onions can be used in salad preparation while the highly pungent varieties are suitable for sauces and gravies (Wiczkowski 2011).

With regards to its global consumption, Libyans are the one who consumes the highest amount of onion, which accounts for an average of 30 kg annually per capita followed by the Americans (16 kg) (FAO 2015). Apart from its culinary uses, onion has been reputed in the indigenous knowledge of medicine for ages. Ancient Egyptians used to

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Figure 1. An onion bulb dissected to show the dry outer protective skin layer (SK); the fleshy, swollen sheaths derived from bladed leaf bases (SH); the swollen bulb scales without leaf blades (SC); and, towards the center, the sprout leaves (SP) with successively increasing proportions of leaf blade, which will elongate and emerge when the bulb sprouts.

worship the bulb, as they believed in its spherical shape and concentric rings which represented eternity while the Greek and Phoenicians sailors consumed it to prevent scurvy and other diseases (Swenson 2008).

Various studies have explored the biological profile of this plant, and a profusion of literature has revealed and published on onion dealing with chemical analysis, flavor and discoloration precursors (Corzo-Martínez et al. 2007; Dong et al. 2010; Jones et al. 2004; Kato et al. 2013; Lanzotti 2006; Rose et al. 2005; Wiczkowski 2011). A wide range of phytocompounds including phenolic acids, flavonoids (quercetin, kaempferol), anthocyanins, and organosulfur compounds have been identified in onion. However, there is currently a lack of updated compilation of available data on its traditional uses, chemical profile, and pharmacological properties. In this context, we aimed to review the pharmacological benefits as mentioned above in an attempt to preserve and promote its medicinal uses. A literature search was performed using articles published from 1990 to 2018 using databases such as PubMed, Science Direct and Google Scholar. Other sources such as books, dissertations, and online materials were also taken into consideration. The scientific name of the plant was identified according to the International Plant Name Index (www.ipni.org) and The Plant List database (theplantlist.org). The major chemicals were identified using the PubChem database.

Traditional uses of *Allium cepa*

Allium cepa has been traditionally used for its remedial characteristics in the management of various ailments. The essence of *A. cepa* proliferated into ancient Greece where it was used as a blood purifier for athletes. During the invasion of Rome, gladiators used to rub down onion juice to firm up the muscles. The Greek and Phoenicians sailors consumed it to prevent scurvy. Moreover, the Greek physician Hippocrates, used to prescribe onion as a wound healer, diuretic and pneumonia fighters. In the 6th century, onion was described as one of the indispensable vegetable or spice and medicine in India (Kabrah 2010).

In the present review, we found that the Asian nations, viz., India and Pakistan were among the majority to use onion for the treatment of various diseases. Overall, it was observed that *A. cepa* was most regularly used in low-developed countries. This could be probably due to the lack of medical facilities and the easy availability of traditional remedies including onion. As shown in Table 1, it can be noted that *A. cepa* is commonly taken raw or as a decoction for treating infectious diseases. It is also used in a wide variety of preparations for internal and external use to relieve several ailments including digestive problems, skin diseases, metabolic disease, insect bites and others (Silambarasan and Ayyanar 2015; Sharma et al. 2014; Hayta et al. 2014; Jaradat et al. 2016).

Phytochemistry of *Allium cepa*

Several phytochemical studies have been performed on *A. cepa*, and it was found to harbor myriad of compounds responsible for its peculiar flavor and medicinal properties. Among the different classes of phytochemicals, phenolic compounds have received much attention due to their contribution to the biological properties of medicinal plants. A study (Prakash et al. 2007) was conducted on four varieties of *A. cepa* (red, violet, white, green) for their respective phenolic composition through high performance liquid chromatography (HPLC). Ferulic acid, gallic acid, protocatechuic acid, quercetin, and kaempferol were identified. There were significant variations in the number of phenolic compounds in each variety, ferulic acid (13.5–116 µg/g), gallic acid (9.3–354 µg/g), protocatechuic acid (3.1–138 µg/g), quercetin (14.5–5110 µg/g), and kaempferol (3.2–481 µg/g).

Table 1. Traditional uses of *Allium cepa* for medicinal purpose.

Continent	Region	Mode of preparation/dosage	Ailments	References
ASIA				
	India	Raw	Cardiovascular diseases Ingestion Adjuvants	(Silambarasan and Ayyanar 2015)
		NI	Hemorrhoids and lower gastrointestinal bleeding	(Pandikumar et al. 2011)
		The juice of its bulb is given 3 times a day for a month	Stone disease (antilithic)	(Agarwal and Varma 2015)
		NI	Cut wounds Rheumatism, headache	(Ayyanar and Ignacimuthu 2011)
		Bulb extracts mixed with Mentha leaves extract is taken orally for a week Inhalation	Epilepsy	(Semwal et al. 2010)
		Paste is applied externally on skin allergy.	Skin allergy	(Sharma et al. 2014)
		NI	Stomach pain, blocked nose, sinusitis, phinitis	(Deb et al. 2015)
		Half teaspoon of bulb extract is taken orally with honey early morning on an empty stomach for two weeks	Menstrual disorders (Oligomenorrhea)	(Bhatia et al. 2015)
		Rhizome juice of *Allium cepa* is applied on the eyes to get relief from eye diseases (three drops-thrice a day for 24 days)	Eye diseases	(Ayyanar and Ignacimuthu 2005) (Kala 2005)
		Eat raw bulbs	Fever	(Pradhan and Badola 2008)
		NI	Alopecia (Hair loss)	(Hajare 2015)
	Palestine	Bulbs juice and oil	Hypoglycemic, hypolipidemic, stomachic, bacteriostatic, anthelmintic, rubefacient, Anti-inflammatory, antiseptic. For pulmonary infection, For urinary retention, Abscesses, Cough & aphrodisiac, ear infection, demulcent, mouth ulcers.	(Jaradat 2005)
		About 20–30 ml of the bulb juice are to be given five times a day	Diarrhea	(Jaradat et al. 2016)
	Pakistan	NI	Stimulant, diuretic, aphrodisiac, expectorant	(Aziz and Sharma 2016)
		NI	Anti-bacterial, dysentery cure, stung cure, bruise and pimples	(Ishtiaq et al. 2015)
		Decoction, Juice, Infusion, Vegetable, Paste	Carminative, cough, fever, flu, constipation, jaundice	(Ahmed et al. 2014)
		One tea spoon of bulb juice thrice a day.	High blood sugar	(Mushtaq et al. 2009)
	Turkey	Infusion Crushed + salt	Cicatrizant, rheumatism, asthma, cancer, diuretic, fungal infection, headache, hypertension, rheumatism, Sprain, edema, bruise Gastrointestinal diseases, renal colic, menstrual pain, analgesic, bronchitis	(Hayta et al. 2014) (Sargın et al. 2013) (Dogan and Ugulu 2013)
	Jordan	Fresh bulbs or bulb juice are taken orally	Diabetes, loss of appetite, coughing, liver diseases and prostate cancer	(Alzweiri et al., 2011)
	Russia and Central Asia	Galenical	Skin diseases	(Mamedov et al. 2005)
AFRICA				
	Mauritius	Decoction	Type 1 diabetes Type 2 diabetes High level of cholesterol Renal failure Hearing loss Erectile dysfunction Cataract	(Mootoosamy and Mahomoodally 2014)
	Nigeria	Maceration Decoction	Hypertension Reduce flatulence	(Gbolade 2012)
	Rwanda	Decoction	Liver disease	(Mukazayire et al. 2011)
	Uganda	Chewing, cooking, oral in water and in food	Sexual Impotence and Erectile Dysfunction	(Kamatenesi-Mugisha and Oryem-Origa 2005)
	Kenya	Bulb pounded and sap applied.	Snake bites (Antivenin)	(Owuor and Kisangau 2006)
EUROPE				
	Serbia	Decoction Cataplasm	Tonic, colds, coughs Injuries, swelling, hematomas, cuts, toothache, draining pus from infected areas. Inflammations and infections of the urogenital tract, cystitis	(Jarić et al. 2015)
	Italy	Decoction or eaten raw Eaten raw Topic use by rubbing	Stimulating milk production, antispasmodic antiseptic, blood purifying, diuretic, hypotensive, wounds, cold, insect bites, greasy skin, warts, sting nephritis, ear pain, urinary diseases	(Menale et al. 2016; Menale and Muoio 2014)

(*continued*)

Table 1. Continued.

Continent	Region	Mode of preparation/dosage	Ailments	References
	Spain	Infusion decoction raw crushed	Skin diseases, sinusitis, flu, cold, bronchitis, pneumonia, asthma, sore throat, teeth disorders, high blood pressure. Anti-catarrhal	(Menendez-Baceta et al. 2014) (González et al. 2010)
	Middle Navarra	NI	Whitlows, pimples, wounds and grazes, to healing skin infections, boils	(Cavero et al. 2011)
	Balkan Peninsula	Heated and externally applied as a poultice	Wound healing	(Jarić et al. 2018)
	France	Decoction	Flu syndrome	(Boulogne et al. 2011)
SOUTH AMERICA				
	Brazil	Maceration, infusion	Diabetes, asthma, bronchitis, expectorant, flu, cough, cough with catarrh	(Ribeiro et al. 2017)
	Colombia	Maceration,	Snake bite	(Vásquez et al. 2015)
NORTH AMERICA				
	Mexico	Infusion/oral	Diabetes, cough, epilepsy, vermifuge, sore throat, toothache, flu, rash, body pain cramps	(Josabad Alonso-Castro et al. 2012)

Abbreviation: NI- Not indicated.

Moreover, a number of flavonoids were also detected in different onion varieties: quercetin aglycon, quercetin-3, 4′-diglucoside, quercetin-4′-monoglucoside, quercetin-3-monoglucoside (Zill-e et al. 2011), quercetin 3-glycosides, delphinidin 3,5-diglycosides (Zhang et al. 2016), quercetin 3,7,4′-triglucoside, quercetin 7,4′-diglucoside, quercetin 3,4′-diglucoside, isorhamnetin 3,4′-diglucoside (Pérez-Gregorio et al. 2010) and more (see Table 2). When compared to other species of vegetables and fruits, *A. cepa* has 5 to 10 times higher content of quercetin (300 mg kg^{-1}) than broccoli (100 mg kg^{-1}), apples (50 mg kg^{-1}), and blueberries (40 mg kg^{-1}) (Hollman and Arts 2000).

In addition, several studies have identified various anthocyanins in onion: cyanidin 3-O-(3″-O-*β*-glucopyranosyl-6″-O-malonyl-*β*-glucopyranoside)-4′-O-*β*-glucopyranoside, cyanidin 7-O-(3″-O-*β*-glucopyranosyl-6″-O-malonyl-*β*-glucopyranoside)-4′-O-*β*-glucopyranoside, cyanidin 3,4′-di-O-*β*-glucopyranoside, cyanidin 4′-O-*β*-glucoside, peonidin 3-O-(6″-O-malonyl-*β*-glucopyranoside)-5-O-*β*-glucopyranoside and peonidin 3-O-(6″-O-malonyl-*β*-glucopyranoside) were present in minute amounts from pigmented parts of red onion (Pérez-Gregorio et al. 2010). Additionally, four anthocyanins with the same novel 4-substituted aglycone, carboxypyranocyanidin, were isolated from methanolic extracts of red onion. The structures of two of them were identified as 5-carboxypyranocyanidin 3-O-(6"-O-malonyl-*β*-glucopyranoside and 5-carboxypyranocyanidin 3-O-*β*-glucopyranoside (Fossen et al. 2003). Moreover, peonidin 3′-glucoside petunidin 3′-glucoside acetate and malvidin 3′-glucoside were successfully identified by Fredotović et al. (2017).

Vazquez-Armenta et al. (2014) identified dipropyl disulfide and dipropyl trisulfide as the main constituents in onion oil. A class of biologically active organo-sulfuric compounds, S-alk(en)yl-L-cysteine sulfoxides (such as alliin and *γ*-glutamylcysteine) were dominant. Upon crushing the plant material, allicin, methiin, propiin, iso-alliin, and lipid-soluble sulfur compounds (such as diallyl sulfide, diallyl disulfide) are released which are responsible for the smell and taste of fresh onion. The irritating lachrymatory factor which is released by chopped onion has been presumed to be produced spontaneously following the action of the enzyme alliinase (Imai et al. 2002). Another compound from the sulfur volatiles, thiopropal S-oxide, is a lachrymatory factor uniquely found in onions, which eventually converts to methylpentanols, another tear up factor (Thomas and Parkin 1994). Moreover, several radicals of disulfides (allyl, methyl, propyl) were found in red onion varieties by thin layer chromatography using dichloromethane extraction (Griffiths et al. 2002). Quantitative analysis showed that di- and trisulfides, such as cis- and trans-methyl-1-propenyl disulfide, methyl-2-propenyl disulfide, dipropyl disulfide, cis- and trans-propenyl propyl disulfide, methyl propyl trisulfide, and dipropyl trisulfide, were in abundance representing about 60% of sulfur-compounds.

Additionally, Dhumal et al. (2007) confirmed the presence of pyruvic acid, reducing, and non-reducing sugars in both red and white onion. The amount (g/100 g FW) of reducing, non-reducing, and total sugars (6.69, 9.56 and 16.1 respectively) were higher in red onion compared to that of white onion (3.17, 7.17 and 10.4, respectively). The pungency of *A. cepa* is measured indirectly as pyruvic acid content, which is a product of alkenyl-cysteine sulfoxide enzymatic degradation (Vavrina and Smittle 1993; Yoo et al. 2006). Among the organic acids detected in the bulb extracts were ascorbic, citric, malic, succinic, tartaric, and oxalic acids.

Furthermore, Liguori et al. (2017) detected some aldehydes and ketones in onion landraces belonging to Bianca di Pompei cv., cultivated in Campania region (Italy). Furfuraldehyde was the most abundant in all samples, and its highest content was found in Aprilatica landrace. Propionaldehyde and 2-methyl-2-pentenal contents were different in landraces samples. The concentration of 1,2-cyclopentanedione differed at harvest time; in spring months, Aprilatica, Maggiaiola, and Giugnese onions had a higher content than those yielded in winter (Febbrarese and Marzatica). The butyrolactone compound was found only in onions harvested in spring periods (Aprilatica, Maggiaiola, and Giugnese).

An antifungal peptide, allicepin, was isolated by aqueous extraction, ion exchange chromatography on DEAE- cellulose,

Table 2. Isolated compounds from *A. cepa* and their biological properties.

Onion type	Extracting solvent	Compound (s) identified	Observed biological activity (if tested)*	Mechanism of action	References
Yellow	Ethanol (50%)	Quercetin	Antioxidant	Increased the antioxidant capacity of the hydrophilic fraction in the rat serum	(Grzelak-Błaszczyk et al. 2018)
			Bacterial enzyme activity-enhancer	Increased the activity of α-glucosidase, β-glucosidase, and β-galactosidase released from bacterial cells (extracellular activity) to the cecum	
			Hypolipidemic	Reduce the levels of alanine transaminase, aspartate transaminase, total cholesterol, non-HDL cholesterol, triglycerides, and increase HDL level in rats fed high-fat diets	
Yellow	Solvent free microwave extraction	Quercetin aglycon	NT	–	(Zill-e et al. 2011)
		Quercetin-3,4′-diglucoside	NT	–	
		Quercetin-4′-monoglucoside	NT	–	
		Quercetin-3-monoglucoside	NT	–	
		Kaempferol	NT	–	
		Myricetin	NT	–	
Yellow	80% ethanol containing 0.1% hydrochloric acid	Quercetin 3-glycosides	NT	–	(Zhang et al. 2016)
		Delphinidin 3,5-diglycosides	NT	–	
		Cyanidin 3,5-diglycosides	NT	–	
		Cyanidin 3-glycosides	NT	–	
		Quercetin	NT	–	
		Quercetin 3-glycosides	NT	–	
Yellow	Freshly Cut Onions	Hydrogen sulfide	NT	–	(Løkke et al. 2012)
		Methanethiol	NT	–	
		Propanethiol	NT	–	
		Dipropyl disulfide	NT	–	
Green	Sequentially extracted with hexane and ethyl acetate. The residual material was then extracted with anhydrous methanol	5-(hydroxymethyl) furfural	Cancer chemopreventive	Reduced murine hepatoma (Hepa 1c1c7) cells survival ($IC_{50} = 997\ \mu M$), induced maximum quinone reductase (QR) activity at a concentration of 958 μM. Also induced maximum activity of glutathione S-transferase at a concentration of 958 μM	(Xiao and Parkin 2007)
		Acetovanillone	Cancer chemopreventive	Reduced murine hepatoma (Hepa 1c1c7) cells survival ($IC_{50} = 1060\ \mu M$), induced maximum quinone reductase (QR) activity at a concentration of 888 μM. Also induced maximum activity of glutathione S-transferase at a concentration of 888 μM	
		5-hydroxy-3-methyl-4-propylsulfanyl-5H-furan-2-one	Cancer chemopreventive	Reduced murine hepatoma (Hepa 1c1c7) cells survival ($IC_{50} = 890\ \mu M$), induced maximum quinone reductase (QR) activity at a concentration of 665 μM, and doubled QR activity at 83.0 μM. Also induced maximum activity of glutathione S-transferase at a concentration of 665 μM	
		Methyl 4-hydroxyl cinnamate	Cancer chemopreventive	Reduced murine hepatoma (Hepa 1c1c7) cells survival ($IC_{50} = 115\ \mu M$), induced maximum quinone reductase (QR) activity at a concentration of 65 μM, and doubled QR activity at 20.4 μM. Also induced maximum activity of glutathione S-transferase at a concentration of 109 μM	
White	Acetone extract was partitioned between EtOAc and H2O	Ceposide A,B,C	Antifungal	Antifungal activity was in the order ceposide B > ceposide A > ceposide C. The three compounds displayed synergistic activity against *Botrytis cinerea* and *Trichoderma atroviride*. On the oher hand, *Fusarium oxysporum* f. sp. *lycopersici*, *Sclerotium*	(Lanzotti et al. 2012)

(*continued*)

Table 2. Continued.

Onion type	Extracting solvent	Compound (s) identified	Observed biological activity (if tested)*	Mechanism of action	References
				cepivorum, and *Rhizoctonia solani* were very little affected bythese saponins	
White	Distilled water, 2-octanol, and dichloromethane	**Aldehydes**			(Liguori et al. 2017)
		Propionaldehyde	NT	–	
		2-Methyl-2-pentenal	NT	–	
		Furfuraldehyde	NT	–	
		5-Methyl-2-furfuraldehyde	NT	–	
		Sulfur-containing compounds			
		1-Propanethiol	NT	–	
		Propylene sulfide	NT	–	
		Dimethyl sulfide	NT	–	
		Methyl propyl disulfide	NT	–	
		cis-Methyl-1-propenyl disulfide	NT	–	
		5-Methyl-1,3-thiazole	NT	–	
		trans-Methyl-1-propenyl disulfide	NT	–	
		3,4-Dimethyl thiophene	NT	–	
		Methyl-2-propenyl disulfide	NT	–	
		Dipropyl disulfide	NT	–	
		1,2,4-Trithiolane	NT	–	
		trans-Propenyl propyl disulfide	NT	–	
		cis-Propenyl propyl disulfide	NT	–	
		Methyl propyl trisulfide	NT	–	
		Dipropyl trisulfide	NT	–	
		Ketones			
		1,2-Cyclopentanedione	NT	–	
		Butyrolactone	NT	–	
		Phenols			
		Gallic acid	NT	–	
		Ferulic acid	NT	–	
		Quercetin	NT	–	
		Kaempferol	NT	–	
		Chlorogenic acid	NT	–	
Red	Acid and alkaline hydrolysis, and enzymatic autolysis	Quercetin 3,7,4′-triglucoside,	NT	–	(Pérez-Gregorio et al. 2010)
		Quercetin 7,4′-diglucoside	NT	–	
		Quercetin 3,4′-diglucoside	NT	–	
		Isorhamnetin 3,4′-diglucoside	NT	–	
		Quercetin 3-glucoside	NT	–	
		Quercetin 4′-glucoside	NT	–	
		Isorhamnetin 4′-glucoside	NT	–	
		Cyanidin 3-glucoside	NT	–	
		Cyanidin 3-laminaribioside	NT	–	
		Cyanidin 3-(3"-malonylglucoside)	NT	–	
		Pedonidin 3-glucoside	NT	–	
		Cyanidin 3-(6"-malonylglucoside)	NT	–	
		Cyanidin 3-(6"-malonyl-laminaribioside)	NT	–	

(*continued*)

Table 2. Continued.

Onion type	Extracting solvent	Compound (s) identified	Observed biological activity (if tested)*	Mechanism of action	References
		Peonidin 3-malonylglucoside	NT	–	
		Cyanidin 3-dimalonylaminaribioside	NT	–	
Red	80% ethanol containing 0.1% hydrochloric acid	Delphinidin 3,5-diglycosides	NT	–	(Zhang et al. 2016)
		Cyanidin 3,5-diglycosides	NT	–	
		Cyanidin 3-glycosides	NT	–	
		Cyanidin 3-(6′-malonyl)-glucopyranoside	NT	–	
		Quercetin	NT	–	
Red	Methanol-acetic acid-water (25:4:21, v:v:v)	Cyanidin 3 glucoside	NT	–	(Ferreres et al. 1996)
		Cyanidin 3-arabinoside	NT	–	
		Cyanidin 3-malonylghtcoside	NT	–	
		Cyanidin 3-malonylarabinoside	NT	–	
		Quercetin 3,4′-diglucoside	NT	–	
		Quercetin 7,4′-diglucoside	NT	–	
		Quercetin 3-glucoside	NT	–	
		Dihydroquercetin 3 glucoside	NT	–	
		Isorhamnetin 4′-glucoside	NT	–	
Red	Methanol-Acetic acid	Quercetin 3,7,4′-*O*-*β*-triglucopyranoside	NT	–	(Fossen et al. 1998)
		Quercetin 4′-*O*-*β*-glucopyranoside	NT	–	
		Quercetin 3,4′-*O*-*β*-diglucopyranoside	NT	–	
		Taxifolin 4′-*O*-*β*-glucopyranoside	NT	–	
Red	5% Methanoic acid	Cyanidin 3-glucoside	NT	–	(Terahara et al. 1994)
		3-malonylglucoside	NT	–	
		Cyanidin 3-laminaribioside	NT	–	
		3-malonyllaminaribioside	NT	–	
Red	Methanol	5-carboxypyranocyanidin 3-*O*-(6"-*O*-malonyl-*β*-glucopyranoside	NT	–	(Fossen and Andersen 2003)
		5-carboxypyranocyanidin 3-O-*β*-glucopyranoside	NT	–	
Brown	Water	Allicepin	Antifungal	Exerted an inhibitory activity on mycelial growth in several fungal species including *Botrytis cinerea*, *Fusarium oxysporum*, *Mycosphaerella arachidicola* and *Physalospora piricola*.	(Wang and Ng 2004)
Sochaczewska	80% methanol	Quercetin-3,4′-di*O*-*β*-glucoside	NT	–	(Zielińska et al. 2008)
		Quercetin-3-O-*β*-glucoside	NT	–	
		Quercetin-4′-O-*β*-glucoside	NT	–	
NI	Methanol	Quercetin	Antioxidant	Exhibited DPPH (IC_{50} = 87.5 μg/ml), FRAP (IC_{50} = 90.4 μg/ml), and OH• (IC_{50} = 78.6 μg/ml) radical scavenging effect	(Nile et al. 2017)
			Enzyme inhibition	Inhibited the enzymes urease (IC_{50} = 8.2 μg/ml) and xanthine oxidase (IC_{50} = 10.5 μg/ml)	
		Quercetin-4′-O-monoglucoside	Antioxidant	Exhibited DPPH (IC_{50} = 65.2 μg/ml), FRAP (IC_{50} = 70.5 μg/ml), and OH• (IC_{50} = 60.5 μg/ml) radical scavenging effect	
			Enzyme inhibition	Inhibited the enzymes urease (IC_{50} = 15.5 μg/ml) and xanthine oxidase (IC_{50} = 17 μg/ml)	
		Quercetin-3,4′-O-diglucoside	Antioxidant	Exhibited DPPH (IC_{50} = 80.5 μg/ml), FRAP (IC_{50} = 85.4 μg/ml), and OH• (IC_{50} = 75.6 μg/ml) radical scavenging effect	

(*continued*)

Table 2. Continued.

Onion type	Extracting solvent	Compound (s) identified	Observed biological activity (if tested)*	Mechanism of action	References
			Enzyme inhibition	Inhibited the enzymes urease ($IC_{50} = 10.5$ μg/ml) and xanthine oxidase ($IC_{50} = 15.3$ μg/ml)	
		Isorhamnetin-3-glucoside	Antioxidant	Exhibited DPPH ($IC_{50} = 72.4$ μg/ml), FRAP ($IC_{50} = 75.2$ μg/ml), and OH• ($IC_{50} = 68.7$ μg/ml) radical scavenging effect	
NI	Essential oil	Dipropyl disulfide, Dipropyl sulfide	Antioxidant	Caco-2 cell line derived from human colon carcinoma (ATCC HTB-37) underwent significant reductions in reactive oxidative species (ROS) content after 48 h of exposure to each compound. Higher reductions were shown when Caco-2 cells were exposed to a mixture of both compounds	(Llana-Ruiz-Cabello et al. 2015)
NI	25% ethanol	Lectin (agglutinin)	Immunoprotective	Promoted the restoration of lymphoid cell count and promoted the immune response by dose dependently elevated the production of pro-inflammatory molecules (COX-2 and nitric oxide) and expression levels of immune regulatory molecule (TNF-α)	(Kumar and Venkatesh 2016)
NI	25 % ethanol	Lectin (agglutinin)	Immunoprotective	Using macrophage cell line, RAW264.7 and rat peritoneal macrophages, the compound showed an increase in the production of nitric oxide at 24 h, and stimulated the production of pro-inflammatory cytokines (TNF-α and IL-12) at 24 h. Also enhanced the proliferation of murine thymocytes at 24 h. Also elevated the expression levels of cytokines (IFN-γ and IL-2) in murine thymocytes.	(Prasanna and Venkatesh 2015)
NI	100% methanol	Quercetin 4′-glucoside	Anti-allergy	Displayed β-Hexosaminidase inhibitory activity ($IC_{50} = 6.5$ μM)	(Sato et al. 2015)
		Isorhamnetin 4′-glucoside	Anti-allergy	Displayed β-Hexosaminidase inhibitory activity ($IC_{50} = 17.5$ μM)	
		Quercetin	Anti-allergy	Displayed β-Hexosaminidase inhibitory activity ($IC_{50} = 3.2$ μM)	
cv . Skvirsky	96% ethanol	1,3-dion-5-octyl-cyclopentane, 1,3-dion-5-hexylcyclopentane	Phytoalexin	Inhibit conidial germination and germ-tube growth of *Botrytis cinerea* in liquid culture	(Dmitriev et al. 1990)
NI	50% ethanol	Zwiebelane A (cis-2,3-dimethyl-5,6-dithiabicyclo[2.1.1]hexane 5-oxide)	Antifungal	Amplifies the disruptive effect of Polymyxin B on the vacuole of *Saccharomyces cerevisiae*, which has been found to represent a target for antifungal agents.	(Borjihan et al. 2010)
NI	Essential oil	Isoamyl alcohol	NT	–	(Mnayer et al. 2014)
		Dimethyl disulfide	NT	–	
		Diallyl sulfide	NT	–	
		Dimethyl thiophene	NT	–	
		Methyl propyl disulfide	NT	–	
		Methyl 1-propenyl disulfide	NT	–	
		Dimethyl trisulfide	NT	–	
		Allyl propyl disulfide	NT	–	
		Dipropyl disulfide	NT	–	
		1-Propenyl propyl disulfide	NT	–	
		3,5-Dimethyl-1,2,4-trithiolane	NT	–	
		Methyl propyl trisulfide	NT	–	
		Methyl 1-propenyl trisulfide	NT	–	
		Methyl-1-(methylthio)ethyl-disulfide	NT	–	
		Dimethyl tetrasulfide	NT	–	
		3-Ethyl-5-methyl-1,2,4-trithiolane	NT	–	
		3-Ethyl-5-methyl-1,2,4-trithiolane	NT	–	
		Methyl 1-(methylthio-propyl) disulfide	NT	–	
		2-Undecanone	NT	–	
		Tridecane	NT	–	
		Dipropyl trisulfide	NT	–	

(*continued*)

Table 2. Continued.

Onion type	Extracting solvent	Compound (s) identified	Observed biological activity (if tested)*	Mechanism of action	References
		Allyl propyl trisulfide	NT	–	
		Di-1-propenyl trisulfide	NT	–	
		2-Hexyl-5-methyl 3(2H)-furanone	NT	–	
		2-Tridecanone	NT	–	
		2-Methyl-3,4-dithiaheptane	NT	–	
		Dipropyl tetrasulfide	NT	–	
		Methyl palmitate	NT	–	
		Ethyl palmitate	NT	–	
		Methyl linoleate	NT	–	
		Ethyl oleate	NT	–	
NI	80% ethanol and boiled water	Trans-(+)-S-propenyl-L-cysteine sulfoxide (PeCSO)	NT	–	(Ueda et al. 1994)
		y-glutamyl peptide (y-Glu-PeCSO)	NT	–	
NI	Essential oil	Methyl propyl disulfide	NT	–	(Vazquez-Armenta et al. 2014)
		Dimethyl trisulfide	NT	–	
		Isopropyl disulfide	NT	–	
		Dipropyl disulfide	NT	–	
		Dimethyl tetrasulfide	NT	–	
		Dipropyl trisulfide	NT	–	
NI	70% methanol	Quercetin 3,4′-diglucoside	NT	–	(Fredotović et al. 2017)
		Quercetin 4′-monoglucoside	NT	–	
		Myricetin	NT	–	
		Quercetin aglycone	NT	–	
		Isorhamnetin	NT	–	
		Peonidin 3′-glucoside	NT	–	
		Petunidin 3′-glucoside acetate	NT	–	
		Delphinidin 3′-glucoside	NT	–	
		Malvidin 3′-glucoside	NT	–	

NI: Not indicated.
NT: Not tested.
*The reported biological activities include only those of the isolated compounds from onion which have been tested, and not from other sources.

affinity chromatography on Affi-gel blue gel, and FPLC-gel filtration on Superdex 75 (Wang and Ng 2004). Another compound isolated from onion bulbs is Zwiebelane A (cis-2,3-dimethyl-5,6-dithiabicyclohexane 5-oxide), which was found to enhance the potential fungicidal activity of the typical bactericidal antibiotic Polymyxin B (Borjihan et al. 2010). Zwiebelane A is the compound responsible for the flavor released by onion during frying. Additionally, Tverskoy et al. (1991) isolated two new phytoalexins: 5-octyl-cyclopenta-1,3-dione and 5-hexy-cyclopenta-1,3-dione from the bulbs of *A. cepa* which were elucidated by gel filtration, HPLC and thin layer chromatography (TLC). The main chemical constituents present in *A. cepa* are shown in Figure 2 and their bio-functions are summarized in Table 2.

Pharmacological properties of *A. Cepa*

Antimicrobial activity

Allium cepa has been described as a potent antimicrobial agent to fight against infectious diseases. Many bacteria, fungi, and viruses were found to be susceptible to different solvents extracts of *A. cepa* (Table 3). Sulphur compounds have proven to be the principal active antimicrobial agent present in onion (Rose et al. 2005). Many studies (Liguori et al. 2017; Thomas and Parkin, 1994; Vazquez-Armenta et al., 2014) have reconsidered the effect of organosulphur-containing compounds on the growth of microorganisms. *A. cepa* also possesses other antimicrobial phenolic compounds including protocatechuic, *p*-coumaric, ferulic acids, and catechol. Quercetin and kaempferol have been found as significant contributors to this activity. The effectiveness of kaempferol was greater than quercetin in inhibiting bacterial growth of *B. cereus*, *L. monocytogenes*, and *P. aeruginosa* and was as effective as quercetin in inhibiting the growth of *S. aureus* and *M. luteus* (Santas et al. (2010). Other studies also showed that quercetin oxidation products from yellow onion skin such as 2-(3,4-dihydroxyphenyl)-4,6-dihydroxy-2-methoxybenzofuran-3-one demonstrated selective activity against *Helicobacter pylori* strains while 3-(quercetin-8-yl)-2,3-epoxyflavanone showed antibacterial activity against both multi-drug resistant *Staphylococcus aureus* and *H. pylori* strains (Ramos et al. 2006).

Moreover, Benkeblia (2004) observed that essential oil of three types of onion (yellow, green and, red) displayed marked antimicrobial activity against specific pathogens, including *Staphylococcus aureus*, *Salmonella enteritidis*, *Aspergillus niger*, *Penicillium cyclopium*, and *Fusarium oxysporum* (Benkeblia 2004). Several researchers (Begum and Yassen 2015; Hamza 2015; Palaksha et al. 2013; Zohri et al. (1995) have studied the activity of onion extracts on the Gram-negative bacteria *Klebsiella* spp. However, contradicting results were obtained from Srinivasan et al. (2001) and Gomaa (2017) whereby there was no inhibition of *K. pneumonia* with onion extracts.

Besides, the antibacterial activity of the red variety of *A. cepa* extract was found to be higher compared to yellow and white varieties (Sharma et al. 2017). In the study of Park and Chin (2010), onion extracts did not express antimicrobial activities against two pathogens (*E.coli* and *L. monocytogenes*). Ziarlarimi et al. (2011) also found that the aqueous extract of onion did not show any effect against *E.coli* and this corroborates with the study of Penecilla and Magno (2011) in which the hexane and ethanol extracts were also ineffective.

The similar result by Ponce et al. (2003) who studied antimicrobial activities of natural plant extracts, reported that onion oleoresin did not present inhibitory activity against *L. monocytogenes* in agar diffusion method. Also, they suggested that the lack of antimicrobial activity of onion might be due to its used concentration and low purity of onion oleoresin. Interestingly, Azu et al. (2007) found that *A. cepa* was effective against *P. aeruginosa* isolated from patients suffering from urinary tract infections indicating its potential in the management of such condition. *In vivo* study of Ur Rahman et al. (2017) showed that birds fed with onion at a rate of 2.5 g/kg of feed had a decrease of *E. coli* population and a significant increase of *Lactobacillus* spp. The result corresponded to that of Goodarzi et al. (2014) whereby broilers were fed with diets containing 10–30 g onion/kg.

Interestingly, a recent study conducted by Lekshmi et al. (2012) showed how nanoparticles synthesized from onion displayed a positive effect in inhibiting *Klebsiella* spp. Saxena et al. (2010) also reported the synthesis of silver nanoparticles by using onion extract and demonstrated that these nanoparticles, at a concentration of 50 µg/mL, presented a complete antibacterial activity against *E.* and *Salmonella typhimurium*.

Moreover, onion extracts are potent against fungal species, and its essential oil inhibits the dermatophyte fungi (Zohri et al. 1995). *Aspergillus niger* and *Fusarium oxysporum* were strongly inhibited (minimum fungicidal concentration (MFC) = 75 and 100 mg/mL, respectively) by the ethyl alcohol extract of dehydrated onion (Irkin and Korukluoglu 2007; Irkin and Korukluoglu 2009). Anti-fungal saponins (ceposide A and C) discovered by Lanzotti et al. (2012) were able to inhibit the growth of soil-borne pathogens (*R. solani*), air-borne pathogens (*A. alternata*, *B. cenerea*, *Mucor* spp and *Phomopsis* spp) and antagonistic fungi (*T. atroviride* and *T. harzianum*). High inhibitory effect against *M. furfur* (minimum inhibitory concentration (MIC) = 8.062 mg/ml) and *C. albicans* (MIC =4.522 mg/ml) were reported by Shams-Ghahfarokhi et al. (2006). Kocić-Tanackov et al. (2009) stated that essential oil of *A. cepa*, at a concentration of 7%, had complete inhibition on the growth of two yeasts (*C. tropicalis* and *S. cerevisiae*) and this was also confirmed by the study of Kivanc and Kunduhoglu (1997). High concentration of the essential oil also weakened the growth of molds (*A. tamarii* and *P. griseofulvum*) as well and complete inhibition was observed for *E. astelodami*.

Goren et al. (2002) conducted a clinical experiment to find out if dehydrated *A. cepa* could be used in the treatment of AIDS. Eight persons (from 28 to 30 years old) who were HIV positive started a dietary regimen comprising of 9–13 g/day of *A. cepa* extract. After the treatment, all the HIV positive patients experienced a total remission of

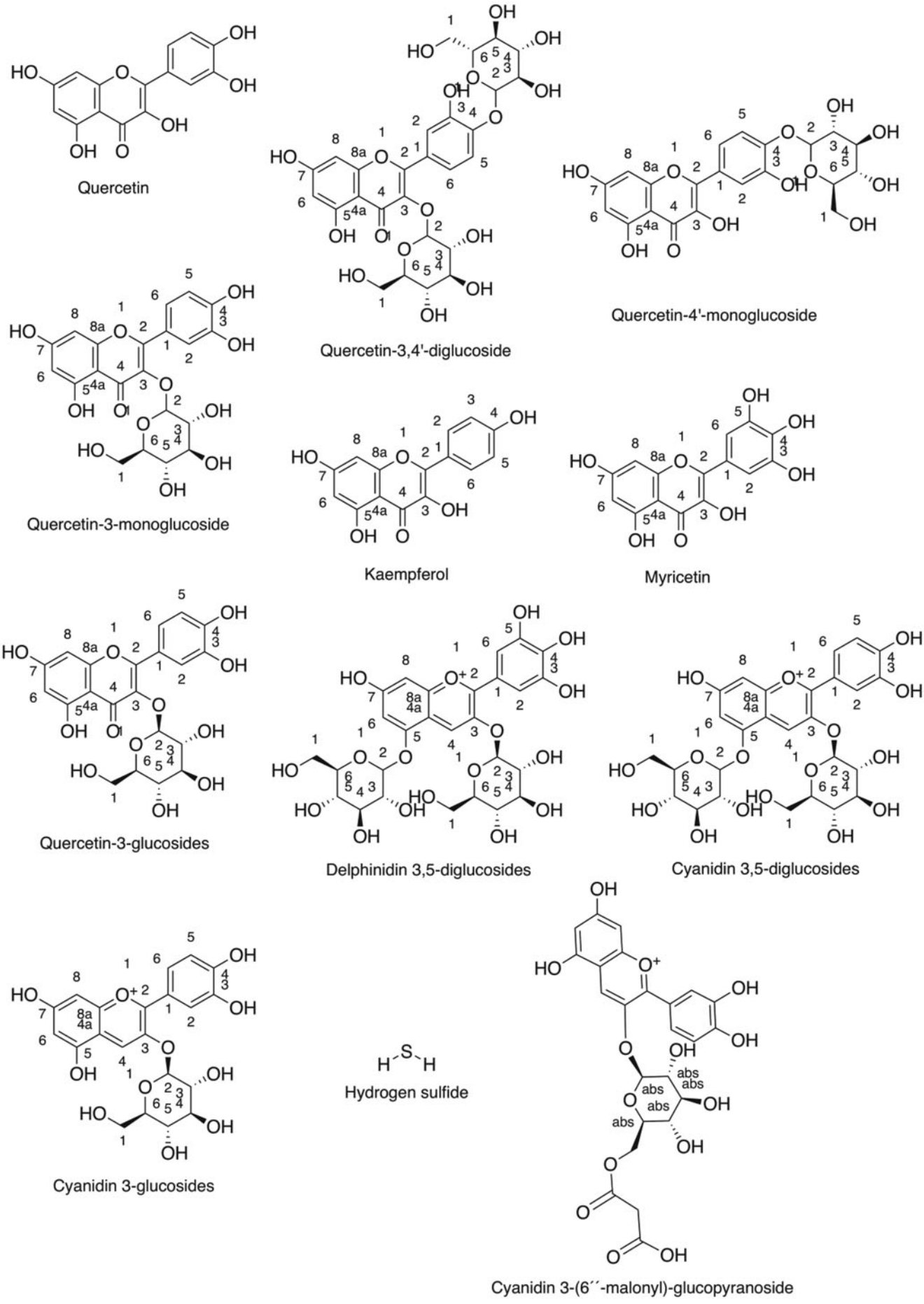


Figure 2. Chemical strucures of major bioactive compounds from *Allium cepa*.

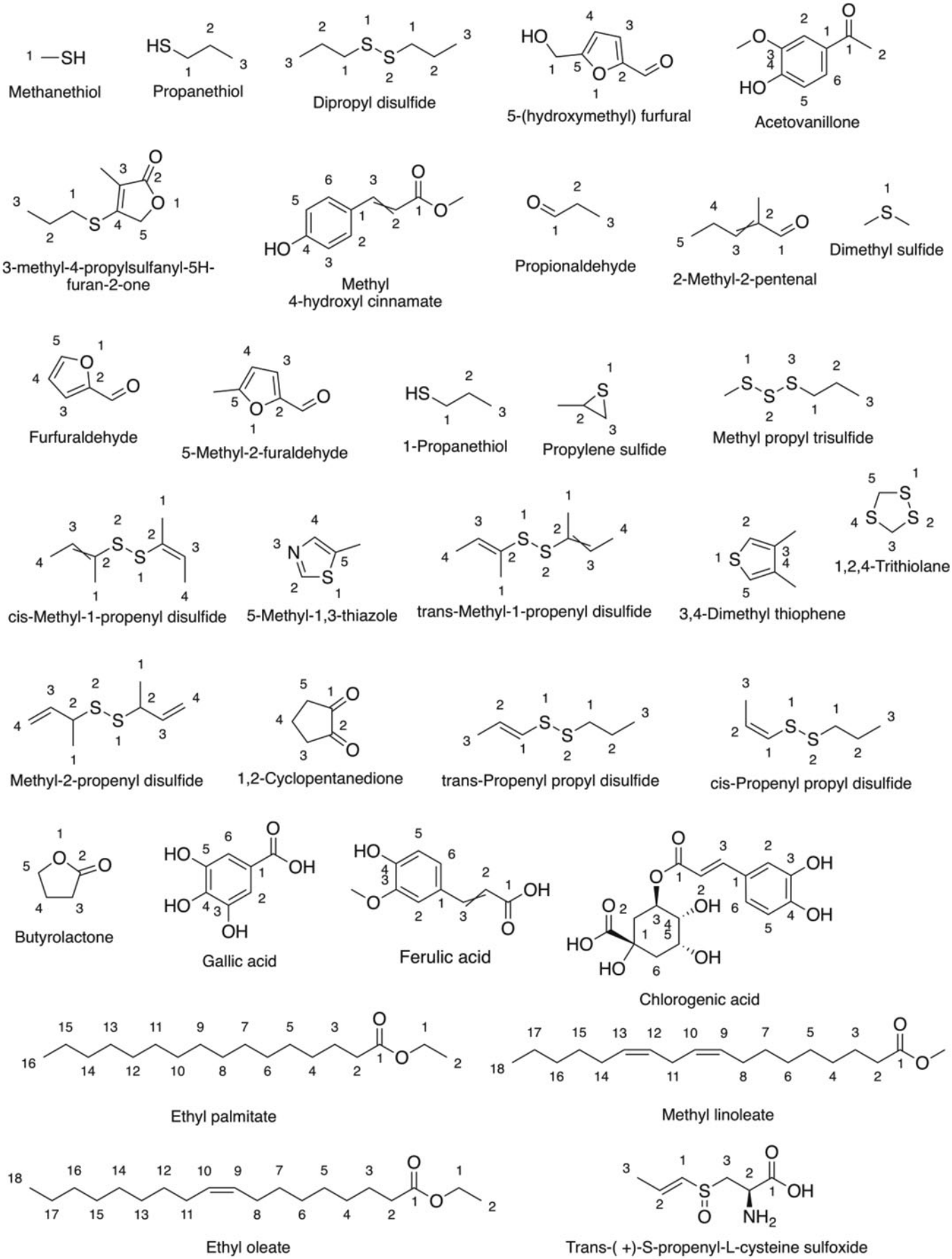
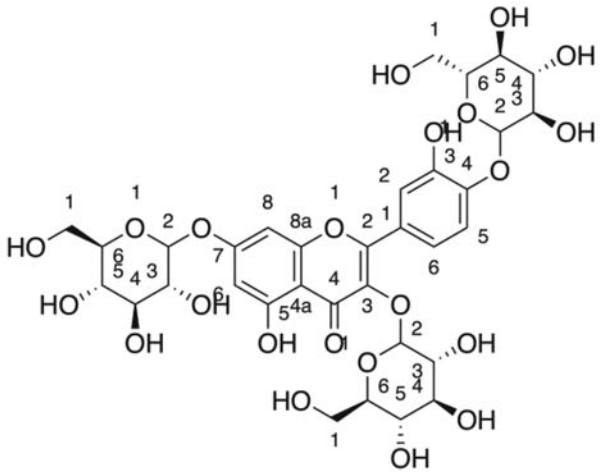
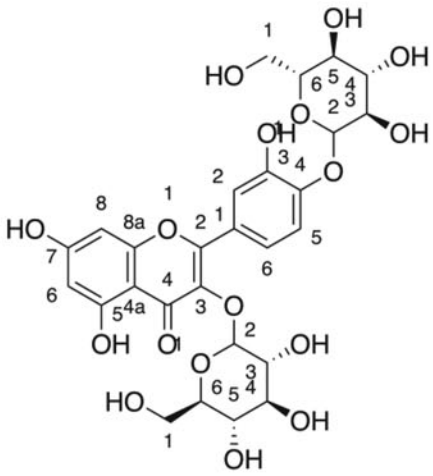


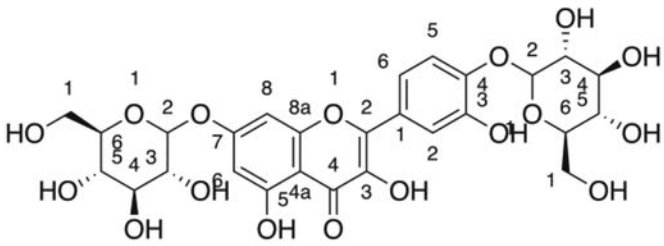
Figure 2. Continued



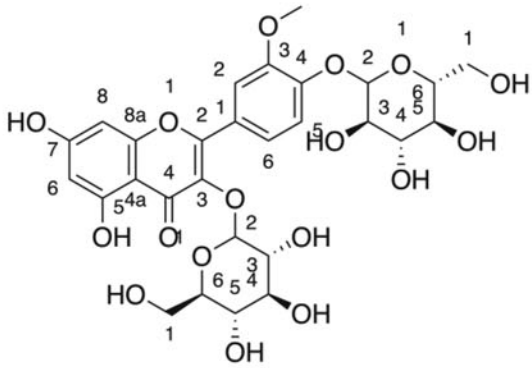
Quercetin 3,7,4'-triglucoside



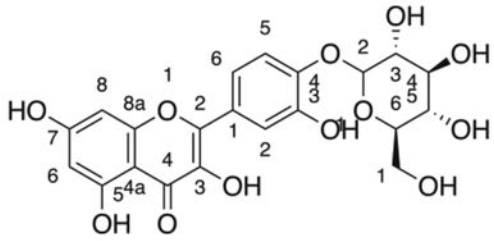
Quercetin 3,4'-diglucoside



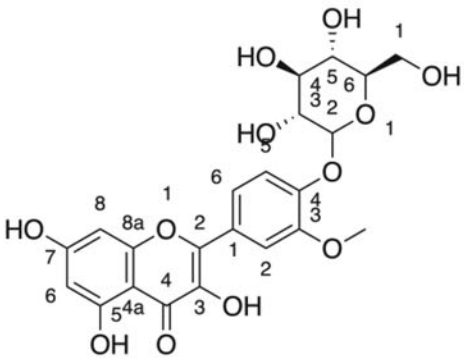
Quercetin 7,4'-diglucoside



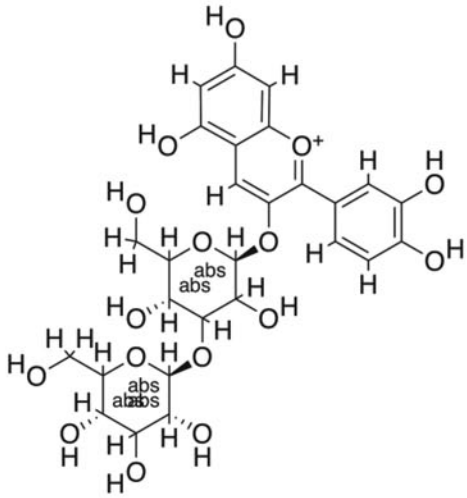
Isorhamnetin 3,4'-diglucoside



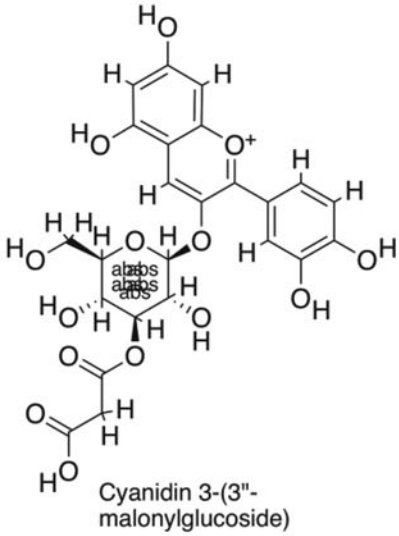
Quercetin 4'-glucoside



Isorhamnetin 4'-glucoside

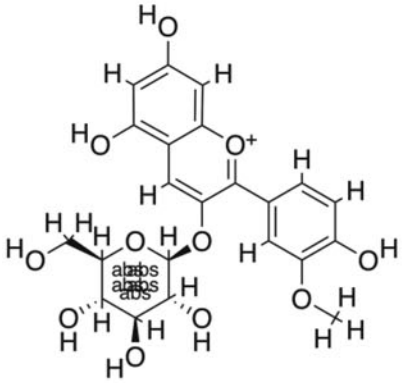


Cyanidin 3-laminaribioside

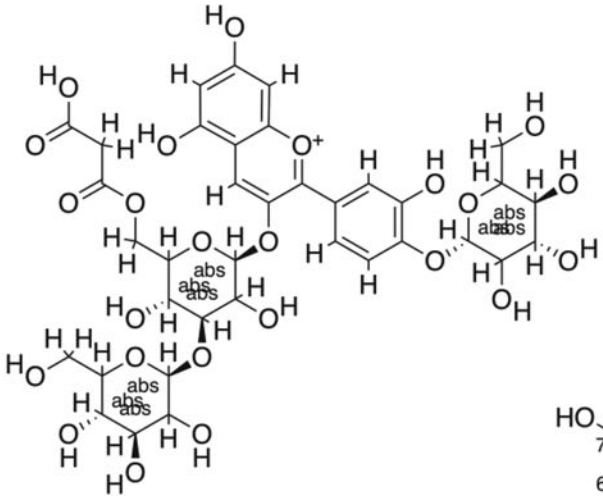


Cyanidin 3-(3"-malonylglucoside)

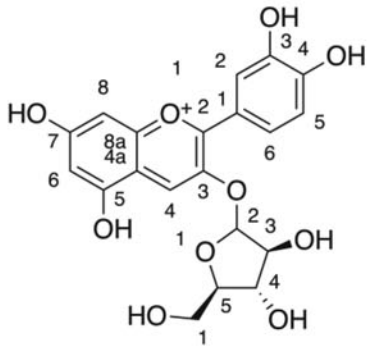
Figure 2. Continued.



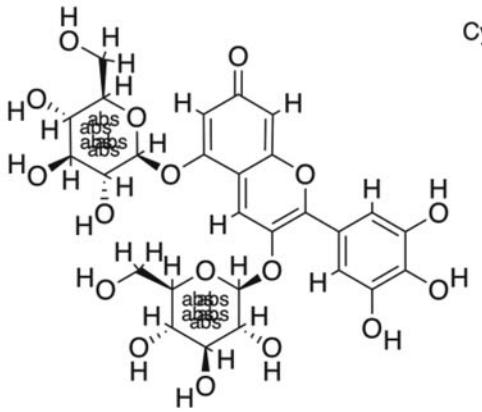
Pedonidin 3-glucoside



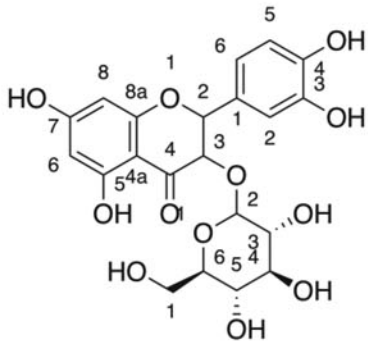
Cyanidin 3-(6"-malonylglucoside)



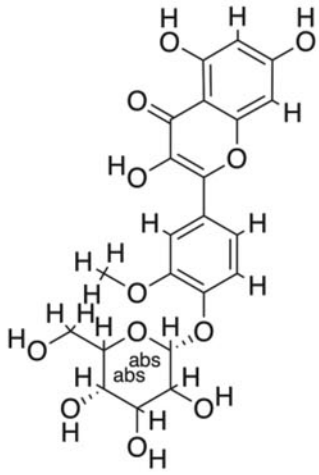
Cyanidin 3-arabinoside



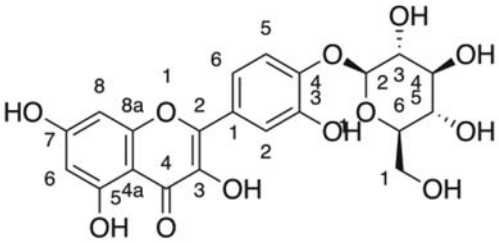
Delphinidin 3,5-diglycosides



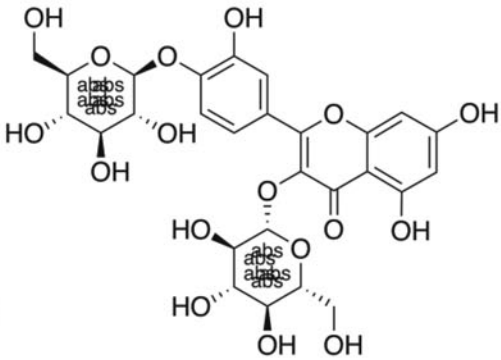
Dihydroquercetin 3 glucoside



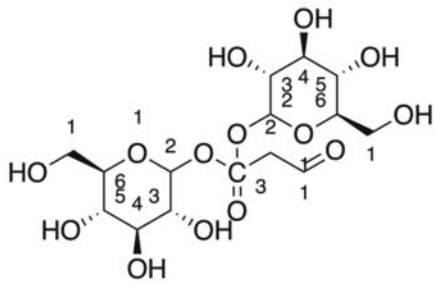
Isorhamnetin 4'-glucoside



Quercetin 4'-O-β-glucopyranoside

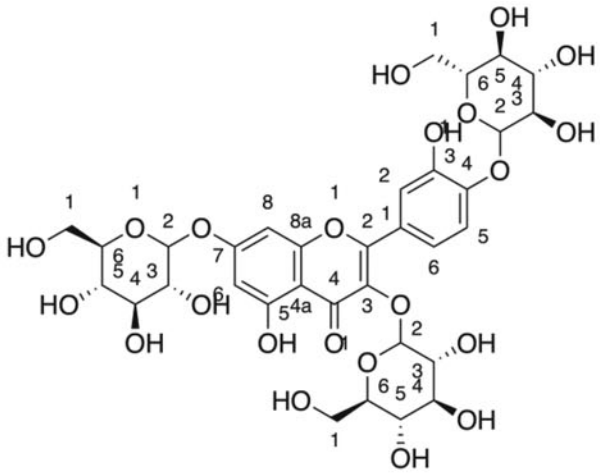


Quercetin-3,4'-O-di-β-glucopyranoside

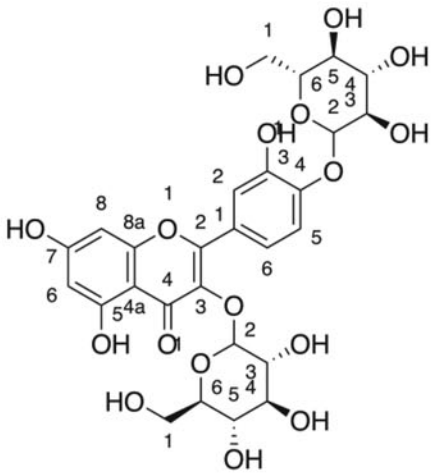


3-malonylglucoside

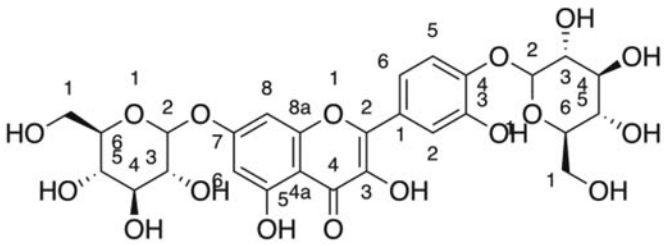
Figure 2. Continued



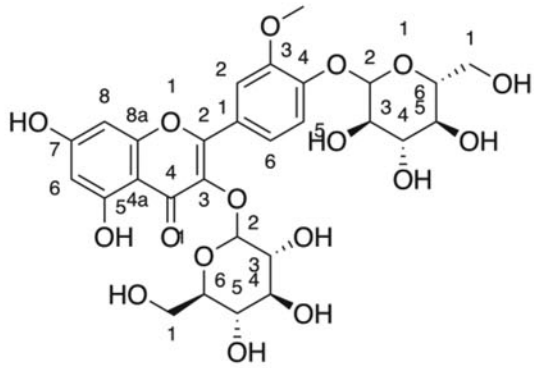
Quercetin 3,7,4'-triglucoside



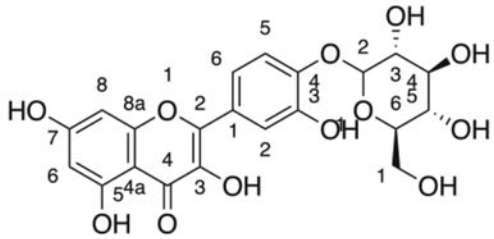
Quercetin 3,4'-diglucoside



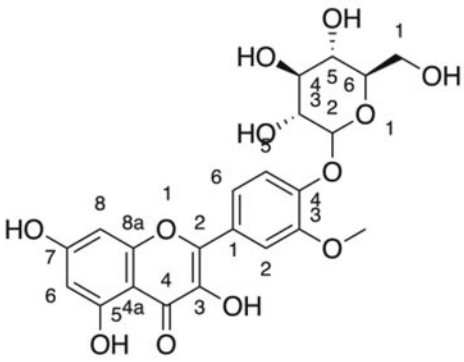
Quercetin 7,4'-diglucoside



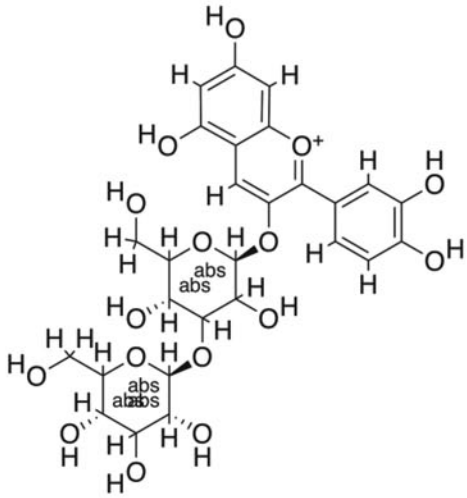
Isorhamnetin 3,4'-diglucoside



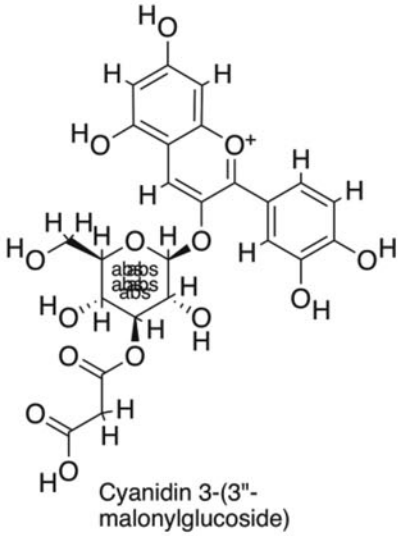
Quercetin 4'-glucoside



Isorhamnetin 4'-glucoside

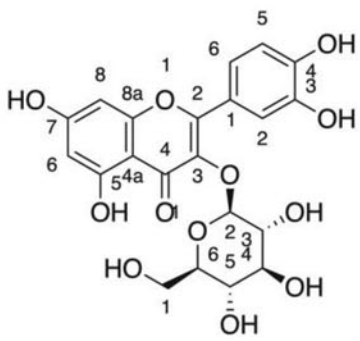


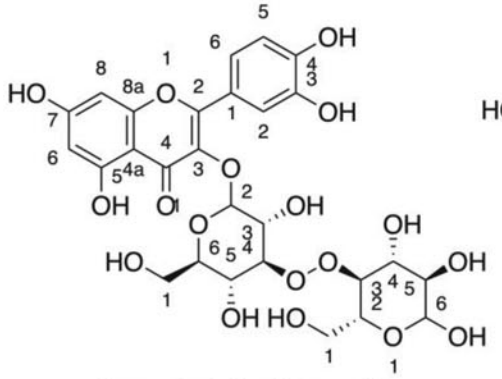
Cyanidin 3-laminaribioside

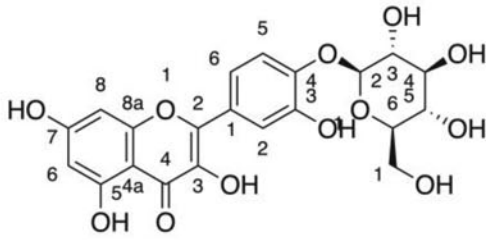


Cyanidin 3-(3"-malonylglucoside)

Figure 2. Continued.


Quercetin-3-O-β-glucoside


Quercetin-3,4'-o-biglucoside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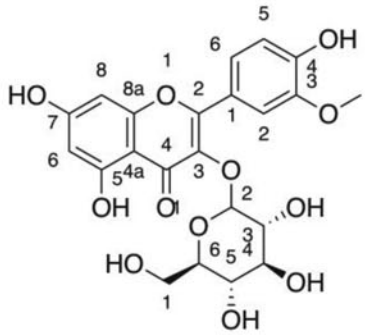
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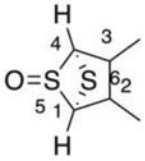
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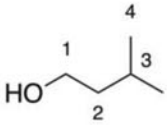
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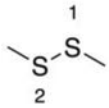
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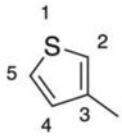
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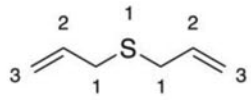
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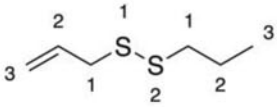
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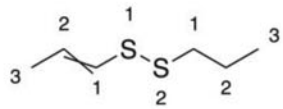
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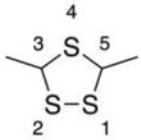
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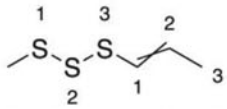
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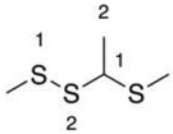
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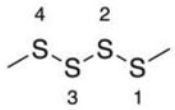
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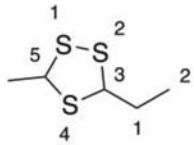
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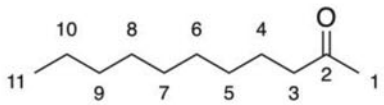
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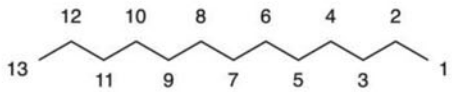
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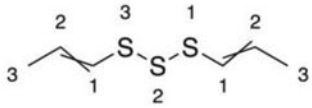
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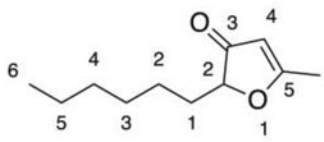
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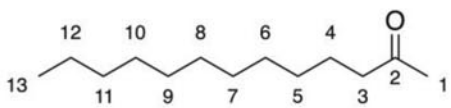
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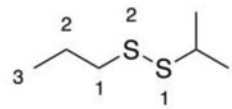
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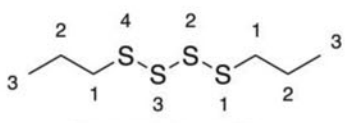
Dipropyl tetrasulfide

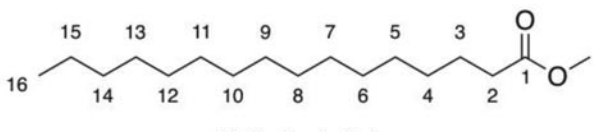
Methyl palmitate

Figure 2. Continued

Table 3. Antimicrobial activity of *Allium cepa*.

Antimicrobial activity	Mircroorganisms	Main findings	References
Ethanol extract (87%) of purple and yellow onion against bacterial isolates of *Vibrio cholerae*. (*In vitro*)	33 bacterial isolates of *V. cholerae*	Activity of extracts of two types (purple and yellow), with purple type having minimal inhibitory concentration (MIC) range of 19.2–21.6 mg/mL and yellow type having an MIC range of 66–68.4 mg/mL	(Hannan et al. 2010)
Methanol extract of red and white inner and outer layer of onion against four bacterial strains. *(In vitro)*	*Pseudomonas aeruginosa* (ATCC 27852), *Escherichia coli* (ATCC 25992), *Staphylococcus aureus* (ATCC 25923) and *Staphylococcus aureus* (ATCC 43300)	The outer layer of onion is rich in flavonols with contents of 103 ± 7.90 μg/g DW (red variety) and 17.3 ± 0.69 μg/g DW (white variety) and had larger inhibition on the growth of *Escherichia coli* than those of *I. verum* and *C. oxyacantha* ssp *monogyna*.	(Benmalek et al. 2013)
Efficacy of supercritical CO2 extraction of onion essential oil against food spoilage and food-borne microorganisms. *(In vitro)*	*Escherichia coli* (ATCC 25922), *Bacillus subtilis* (ATCC 21216), *Staphylococcus aureus* (ATCC 25923), *Rhodotorula glutinis* (ATCC 16740), *Saccharomyces cerevisiae* (ATCC 9763), *Candida tropicalis* (ATCC 13801), *Aspergillus niger* (ATCC 16404), *Monascus purpureus* (ATCC 36928), and *Aspergillus terreus* (ATCC 20542)	The essential oil exhibited a potent inhibitory effect against all bacteria and molds. It showed a high antimicrobial effect on *B. subtilis, C. tropicalis* and *M. purpureus* with the diameter of inhibition zones of 19.3, 15.1 and 13.2 mm, respectively.	(Ye et al. 2013)
Essential oil (EO) extracted by steam distillation of three types of onion (yellow, green and, red) against microbial strains. *(In vitro)*	Two species of bacteria: *Staphylococcus aureus* (ATCC 11522) and *Salmonella Enteritidis* (ATCC 13076) and three species of fungi: *Aspergillus niger* (ATCC 10575), *Penicillum cyclopium* (ATTC 26165), and *Fusarium oxysporum* (ATCC 11850	The inhibition zone increased with increasing concentration of extracts. *S. aureus* was less sensitive to the inhibitory activity of the onions and garlic extracts than *S. enteritidis* which was more inhibited at same concentrations of EO extracts.	(Benkeblia 2004)
Crude onion extracts by Soxhlet extraction against *Mycobacterium tuberculosis* isolated from tuberculosis patients' sputum. (*In vitro*)	Isolates of *Mycobacterium tuberculosis*	An inhibitory action against *M. tuberculosis* by crude onion extracts was effective.	(Adeleye et al. 2008)
Crude ethanol extracts fresh allium cepa against gram Positive and gram-negative bacteria and fungi. (*In vitro*)	Clinical isolates of Gram positive bacteria: (*Bacillus subtilus, Bacillus cereus, Staphylococcus aureus*) Gram negative bacteria: (*Erwinia caratovora, Escherichia coli, Pseudomonas aeruginosa, Salmonella typhi* and *Klebsella pneumonia*) Fungus: *Candida albicans*	Susceptibility to *Allium cepa* extracts was positive for *B. cereus B. subtilis, S. aureus* and *C. albicans*	(Bakht et al., 2013)
Onion (*Allium cepa* L.) oil at a concentration of 0.5ml/disc against bacteria and dermatophytic fungi. (*In vitro*)	Gram-negative bacteria (*Escherichia coli, Klebsiella pneumonia, Pseudomonas fluorescens* and *Serratia rhadnii*) Gram-positive bacteria (*Bacillus anthracis, Bacillus cereus, Micrococcus luteus* and *Staphylococcus aureus* Dermatophytic Fungi: *Chrysosporium carmichaelii, C. indicum, C. keratinophilum, C. queenslandicum, C. tropicum, Microsporum canis, M. gypseum, Trichophyton*, and *mentagrophytes* *T. simii)*	Inhibitory effect of onion oil was highly active against all Gram-positive bacteria tested and only one isolate (*Klebsiella pneumoniae*) of Gram-negative bacteria Onion oil completely inhibited mycelial growth of *Microsporum canis, M. gypseum* and *Trichophyton simii* and highly reduced the growth of *Chrysosporium queenslandicum* and *Trichophyton mentagrophytes* when added to the solid medium at 200 ppm. The growth of *Chrysosporium queenslandicum* and *Trichophyton mentagrophytes* was completely inhibited in the presence of 500 ppm of onion oil.	(Zohri et al. 1995)
Yellow, white, white boiling, and red Bermuda onion extracted with 0.5 to 2.0 mL buffer per gram tested against microorganisms. (*In vitro*)	Bacteria*: Escherichia coli and Staphylococcus aureus* Fungi: *Trichophyton mentagrophytes, Trichophyton rubrurn,Trichophyton tonsurans, Trichophyton schoenleinii, Microsporum canis, Microsporum audouinii and Aspergillus furnigatus, Candida albicans)*	Four different types of onion had similar inhibitory activity (MIC =125-250 mg/mL) for *Candida albicans*, while onion powder demonstrated a range in activity from some activity to no activity at 200 mg/mL.	(Hughes and Lawson 1991)
Anti-tubercular activity of aqueous extracts of *A.cepa* against 2 multi-drug resistant strains. *(In vitro)*	*Mycobacterium tuberculosis* (H37Rv) *Mycobacterium fortuitum* (TMC-1529)	*A. cepa* displayed 35% inhibition against *M. tuberculosis.*	(Gupta et al. 2010)
Anti-bacterial action of onion extracts made by steam-processing against oral pathogenic bacteria (*In vitro*)	*S. mutans* (JC-2) and *S. sobrinus* (OMZ176), *P. gingivalis* (ATCC33277) and *P. intermedia (*ATCC256II)	No colony was observed in *S. mutans* and *S. sobrinus* at 24 hours. A few colonies were observed for *P. gingivalis* or *P. intermedia* at 48 hours (MIC =40 μg/mL). Survival rates became <1% in *S. mutans* and *S. sobrinus* after 3 hours and in *P. gingivalis* and *P. intermedia* after 1 hour.	(Kim 1997)

(*continued*)

Table 3. Continued.

Antimicrobial activity	Mircroorganisms	Main findings	References
Nanoparticles of onion by centrifugation against some pathogens. (*In vitro)*	*Proteus* sp., *Klebsiella* sp., *Staphylococcus* sp., *Bacillus* sp., *Pseudomonas* sp. and *Enterobacter* sp.	The particles showed higher activity against the pathogenic *Klebsiella* sp. (12.93 ± 0.15) These onion particles also showed the activity against gram positive and gram-negative organism.	(Lekshmi et al. 2012)
Acetone extracts of white onion against soil-borne pathogens, air-borne pathogens, and antagonistic fungi. (*In vitro)*	Soil-borne pathogens: *Fusarium oxysporum f. sp. lycopersici, R. solani* and *Sclerotium cepivorum* Air-borne pathogens: *Alternaria alternata, Aspergillus niger, B. cinerea, Mucor sp., Phomopsis sp*. Antagonistic fungi: *T. atroviride* and *Trichoderma harzianum*	Ceposides A and C were effective in reducing the growth of all fungi with the exception of *A. niger, S. cepivorum*, and *Fusarium oxysporum f. sp. Lycopersici*. Ceposide B showed a significant growth inhibition of all fungi with the excep tion of *Fusarium oxysporum f. sp. lycopersici, Sclerotium cepivorum* and *Rhizoctonia solani*. Growth of *B. cinerea* (a much larger inhibition at 10 and 50 p.p.m.) and *Trichoderma atroviride* was strongly inhibited.	(Lanzotti et al., 2012)
75% methanol extracts of three Spanish onion (two white and one yellow) against food spoilage microorganisms in micro-well dilution assay (*In vitro)*	Strains of *B. cereus* (CECT 5144), *S. aureus* (CECT 239), *M. luteus* (CECT 5863), *L. monocytogenes* (CECT 911), *E. coli* (CECT 99), *P. aeruginosa* (CECT 108) and *C. albicans* (CECT 1002)	Quercetin inhibited all strains of bacteria tested (from 9.8 ± 0.6 to 15.0 ± 1.0 mm). Kaempferol was only efficient against the gram positive bacteria *S. aureus* and *Micrococcus luteus* (9.3 ± 1.2 and 10.3 ± 0.6 mm, respectively). Kaempferol works best than quercetin in inhibiting bacterial growth of *B. cereus, L. monocytogenes*, and *P. aeruginosa* and found as effective as quercetin in inhibiting the growth of S. aureus and *M. luteus* (MIC =40 μg/mL).	(Santas et al. 2010)
Aqueous extracts of fresh onion against some pathogenic yeasts and dermatophytes (*In vitro)*	Isolates of *M. furfur, C. albicans, C. glabrata, C. tropicalis, C. parapsilosis, T. mentagrophytes, T. rubrum, M. canis, M. gypseum, E. fluccosum*	High inhibitory effect against *M. fufur* (MIC =8.062 mg/ml) and *C. albicans* (MIC =4.522 mg/ml) was reported for the first time.	(Shams-Ghahfarokhi et al. 2006)
Effects of onion powder on the selected gut microflora and intestinal histomorphology in broiler (320 days old). *(In vivo)*	*Lactobacillus species, Streptococcus species, E. coli*	Birds fed with onion at the rate of 2.5 g/ kg of feed showed a decrease in the population of *E. coli* in the ileum whereas an increased number of *Lactobacillus* was observed.	(Ur Rahman et al. 2017)
Different onion extracts against microorganisms isolated from high vaginal swab from patients with urinary tract infection. (*In vitro)*	Isolates of *Staphylococcus aureus* and *Pseudomonas aeruginosa*	The ethanolic extract of onion gave the widest zone of inhibition (11 mm with 0.8 mgl^{-1}) against *P. aeruginosa*.	(Azu et al. 2007)
Article I. Effect of dietary supplementation with fresh onion on performance, carcass traits and intestinal microflora composition in broiler chickens (1 day old) *(In vivo)*	Isolates of *Lactobacilli* spp. and *Escherichia coli*	The *Lactobacilli* spp. population in birds supplemented with onion at the level of 30 g/kg significantly was higher than other groups at 42 d of age ($P < 0.05$). The lowest *Escherichia coli* loads were detected in broilers fed diets containing 15 mg virginiamycin/kg. The *Escherichia coli* loads significantly decreased in broilers fed diets containing 10 or 30 g onion/ kg ($P < 0.05$).	(Goodarzi et al. 2014)
Influence of Serbian essential oil extracts from onion on three yeasts isolated from air and clinically, and three molds isolated from spices *(In vitro)*	Three yeasts*: Rhodotorula sp*. (isolated from air), *Candida tropicalis* (clinical isolate), *Saccharomyces cerevisiae* 112 Hefebank Weinhenstephan, Three molds: *Aspergillus tamarii, Penicillium griseofulvum* and *Eurotium amstelodami* (isolated from spices)	Concentrations of 1 and 4% inhibited the growth of two yeasts, *C. tropicalis and S. cerevisiae*, with inhibition zones of 13–14 mm, and 14–16 mm, respectively, and complete inhibition at concentration of 7%. Strong influence of 1% of onion essential oil on the growth of S. cerevisiae (21 mm inhibitory zone) High concentrations (7 and 10%) lowered the growth of these molds by 18.5 and 57% (*A. tamarii*) and 21.7% (*P. griseofulvum). E. amstelodami* was completely inhibited with concentration of 10%	(Kocić-Tanackov et al. 2009)
	Escherichia coli ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853, *Streptococcus pyogenes* ATCC 19615,	Onion showed inhibition properties against all microbes but *Staphylococcus aureus* was more sensitive.	(Al Masaudi and Al Bureikan 2012)

(*continued*)

Table 3. Continued.

Antimicrobial activity	Mircroorganisms	Main findings	References
Efficacy of Egyptian red onion concentration (100, 50,20 and 10%) on some sensitive and multi-resistant microbes. *(In vitro)*	*Staphylococcus aureus*; (Methicillin-Sensitive *Staphylococcus aureus* - MSSA) ATCC 25923, (Methicillin-Resistant *Staphylococcus aureus*-MRSA) ATCC 10442, *Enterococcus faecalis*; (VancomycinSensitive *Enterococci* - VSE) ATCC 29212, (Vancomycin - Resistant *Enterococci* - VRE) ATCC 51299 and *Candida albicans* ATCC 10291		
Dehydrated onion bulb by Soxhlet extraction (ethyl alcohol and acetone solvent) against some filamentous fungi. *(In vitro*	Isolates of *Aspergillus niger* and *Fusarium oxysporum* from food. *Candida albicans* ATCC 10231 and *Metschnikowia fructicola*	*A. niger* and *F. oxysporum* were inhibited strongly (75 and 100 mg/mL MFC) by ethyl alcohol extract of dehydrated onion.	(Irkin and Korukluoglu 2009)
A. cepa extract biosynthesized silver nanoparticles (AgNPs) against some pathogenic microorganisms. *(In vitro)*	*Bacillus subtilis* (ATCC 6633,) *Bacillus subtilis* (NCTC 10400), Bacillus *cereus* (ATCC14579), *Bacillus licheniformis* (ABRII6), *Bacillus* sp. (BSG-PDA-16), *Bacillus* sp. (DV2-37), *Staphylococcus aureus* (NCTC 7447), *Streptococcus mutans* (ATCC 3654), *Escherichia coli* (NCTC 10418), *Klebsiella pneumonia* (ATCC 10031), *Salmonella typhimurium* (NCIMB 9331), *Pseudomonas aeruginosa* (ATCC 10145), *Proteus vulgaris* (ATCC 27973), *Serratia marcescens* (ATCC 25179), *Cida albicans* (ATCC 70014)	All the microorganisms had inhibitory properties except for *Klebsiella pneumonia, Proteus vulgaris* and *Serratia marcescens*. These three microorganisms *(Bacillus subtilis* (MIC =5mg/ml), *Bacillus licheniformis* (MIC =5 mg/ml), *Cida albicans* (MIC =10 mg/ml) had the highest MIC amongst the others.	(Gomaa 2017)
Aqueous extract of onion bulb against bacterial and fungi strains. *(In vitro)*	1) Gram-negative bacteria: *Chromobacterium Tiolaceum, Escherichia coli, Enterobacter faecalis, Klebsiella pneumonia, Proteus mirabilis, Pseudomonas aeruginosa, Salmonella paratyphi* *S. typhi* 2) Gram-positive bacteria: *Bacillus subtilis*, *Staphylococcus aureus* 3)Fungi: *Aspergillus flatus, A. fumigatus, A. niger, Candida albicans*	*A.cepa* had inhibitory effect against all microorganisms except for *Klebsiella pneumonia* and the largest inhibition zone formed was for *Candida albicans* (22mm).	(Srinivasan et al. 2001)
Essential oil extract of *A. cepa* against bacterial strains of Escherichia coli *(In vitro)*	*Escherichia coli* O157:H7	The strain tested had MIC =93.8 ± 44.2 µl/ml and MBC =312.5 ± 265 µl/ml showing that *A cepa* had antibacterial effect to a certain extent.	(Golestani et al. 2015)
Efficacy of essential oil of onion extracted by hydrodistillation against food-borne bacterial strains. *(In vitro)*	*Bacillus cereus*, *Listeria monocytogenes* *Micrococcus luteus*, *Staphylococcus aureus*, *Escherichia coli* and *Salmonella typhimurium*	All bacteria projected inhibition zone but a greater inhibitory effect was seen for *Staphylococcus aureus* (IZD =6.90 ± 1.26)	(Bag and Chattopadhyay 2015)
Inhibitory properties of fresh onion juice (onion) towards 11 bacteria and 10 yeasts. *(In vitro)*	Bacteria: *B. cereus, B. subtilis, E. aerogenes, E. coli, K.pneumoni, P. vulgaris, P. aeruginosa, S. aureus, S.typhimurium, S.marcescens, V. parahaemolyticus* Yeast: *C. crucei, C. utilis, C. tropicalis, P. membrafaciens, R. rubra, S. bailii, S. cerevisiae, S. octoporus, S. pombe, S. rouxii*	Three cultivars of onion were tested (1, 2 and 3). Onion 1 had inhibitory properties towards *B. cereus* (IZD =14 mm), *B. subtilis* (IZD =28 mm) *and E. aerogenes* (IZD =12 mm). Onion 2 was effective towards, *E. aerogenes* (IZD =12 mm) and *S.marcescens* (IZD =20 mm). Onion 3 had inhibited B. cereus (18 mm) and *E. aerogenes* (IZD =13 mm). The three onion cultivars had inhibitory effect towards all yeast except onion 3 was not effective towards *S. bailii*.	(Kivanc and Kunduhoglu 1997)
Different extracts (Ethanol, Ethanol/methanol, Acetone, Hexane and Aqueous) of onion from the Philippines against some microorganisms. *(In vitro)*	*S. aureus, B. subtilis, E.coli, P.aeruginosa*	Highest inhibition zone was formed by Hexane extracts of onion against *S. aureus* (IZD =16 mm). Acetone extract showed inhibition zone for all bacteria. Hexane and ethanol extracts were not effective towards *E. coli*.	(Penecilla and Magno 2011)
Chloroform, ethanol and aqueous extracts of *A. Cepa* against growth of microbes by Kirby-Bauer Method *(In vitro)*	Culture of *Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa, Staphylococcus aureus, Enterococcus faecalis, Proteus mirabilis* and *Salmonella spp*	Chloroform extract of *A. cepa* was more effective compared to ethanol and aqueous extracts.	(Yousufi 2012)

(*continued*)

Table 3. Continued.

Antimicrobial activity	Mircroorganisms	Main findings	References
Hexane, ethyl acetate and methanol extract of onion against *Streptococcus mutans. (In vitro)*	*Streptococcus mutans*	Crude onion extracts had inhibitory effects against *Streptococcus mutans* (IZD =6.0 mm)	(Ohara et al. 2008)
Fermented aqueous, aqueous and methanol extract of *A.cepa* against five gram-negative bacteria and five gram-positive bacteria. *(In vitro)*	Gram- negative strains: *Klebsiella pneumoniae* (ATCC 700603), *Stenotrophomonas maltophilia* (ATCC 13637), *Escherichia coli* (ATCC 25922), *Pseudomonas aeruginosa* (ATCC 27853), and *Acinetobacter baumannii* (ATCC 19606), Gram- positive strains: *Staphylococcus aureus* (ATCC 29213 and ATCC 43300), *Staphylococcus epidermidis* (ATCC 12228), *Enterococcus faecalis* (ATCC 29212), and *Enterococcus faecium* (ATCC 6057)	Fermented aqueous extract induced a growth inhibition on all Gram-negative bacterial strains compared to methanolic and aqueous extracts and slightly reduced the growth of the Gram-positive strains. The growth of *K. pneumoniae* was slightly induced by aqueous extracts and methanolic extracts. The growth of *P. aeruginosa* was strongly induced by methanolic extracts.	(Millet et al. 2012)
Aqueous extracts of onion against *Bacillus licheniformis* strain 018 and *Bacillus tequilensis* strain ARMATI by Kirby-Bauer method. *(In vitro)*	Isolates of *Bacillus licheniformis* strain 018 and *Bacillus tequilensis* strain ARMATI	An inhibition zone of 18 mm with *A. cepa* extracts was seen for *Bacillus licheniformis* strain 018 only.	(Khusro et al. 2013)
Four concentrations (1000, 100, 10, and 1 μg/ml) of *A. cepa* crude extract on *Staphylococcus aureus. (in vitro)*	Cultures of *Staphylococcus aureus*	Methanolic suspension at 1000 μg/ml was found to be more effective than the other concentrations with an inhibition zone reached to 29 mm. For aqueous extract an inhibitory zone of 23 mm was the highest which obtained by the effect of the concentration of 1000 μg/ml. The lowest effect (13 mm) was gained with the concentration of 1 μg/ml.	(Eltaweel 2013)
Essential oil extract of onion by hydrodistillation against two gram-negative bacteria and two gram- positive bacteria. *(In vitro)*	Gram-positive bacteria: *Staphylococcus aureus* (ATCC 25923), *Listeria monocytogenes* (ATCC 19115) Gram-negative bacteria *Salmonella Typhimurium* (ATCC 14028), *Escherichia coli* (ATCC 8739), *Campylobacter jejuni* (ATCC 33291)	The essential oil of onion with the antibacterial effects produced the largest inhibition zone 15.5 ± 2.1 mm diameter for *S. aureus* and lowest inhibition zone 6 mm *for E. coli*.	(Mnayer et al. 2014)
Section 1.01 95% ethanol extracts of onion bulb on *Salmonella typhi* isolates in Nigeria. *(In vitro)*	Isolates of *Salmonella typhi*	Onion extracts inhibited the growth of *S. typhi* at MIC =0.4 g/ml and inhibition diameter =13mm.	(Odikamnoro et al. 2015)
Alcohol extracts of onion by maceration against multi-resistant gram positive and gram negative bacteria by agar well diffusion method *(In vitro)*	Bacterial strains of *Staphylococcus aureus* (ATCCBAA1026), *Klebsiella pneumoniae* (ATCC33495), *and Escherichia coli* (ATCC10536)	Onion extracts (100 μg/ml) had inhibitory effects towards *S. aureus* (IZD = 12 ± 0.707 mm), *K. pneumoniae* (IZD =18 ± 0.707) and *E. coli* (IZD =10.8 ± 0.490)	(Palaksha et al. 2013)
95% ethanol extract of *A. cepa* against bacterial strains by agar well diffusion method. *(In vitro)*	Bacterial Test strains: *Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa,* and *Staphylococcus aureus.* Fungal test Strains: *Fusarium oxysporum, Colletotrichum spp,* and *Phythium*	*Klebsiella pneumonia* is the most sensitive bacteria while *Pseudomonas aeruginosa* is susceptible but least. *Fusarium Oxysporum* is susceptible as compared to the *Colletotrichum spp.* and *Phythium spp.* shows no activity against any extract.	(Begum and Yassen 2015)
80% methanol extract of onion by maceration against standard strain of *Listeria Monocytogenes*. *(In vitro)*	*L. monocytogenes ATCC 19114*	Positive inhibitory effect was seen with MIC =125 μg /ml and MBC =500 μg /ml.	(Anzabi 2015)
Aqueous and ethanol extracts of 50 onion bulbs against pathogenic microorganisms. *(In vitro)*	*E. coli, Salmonella spp., Streptococcus pneumonia, Shigella spp., Staphylococcus aureus*	Both extracts were effective towards inhibiting the bacteria.	(Oyebode and Fajilade 2014)
Fresh juices of red and white onion bulb against multidrug resistant bacteria. *(In vitro)*	Isolates of *Pseudomonas aeruginosa, Staphylococcus aureus, Escherichia coli and Salmonella typhi*	Fresh juice of white onion was more effective towards inhibition of *Pseudomonas aeruginosa* (MIC =3.125 % v/v), *Escherichia coli* (MIC =25 % v/v) and *Salmonella typhi* (MIC =3.125 % v/v).	(Adeshina et al. 2011)
Effect of boiling water and organic solvents (mixture of chloroform, cyclohexane, and methanol) extracts of white onion bulb on *Listeria monocytogenes (In vitro)*	*Listeria monocytogenes*	Inhibition was more effective with organic solvents extract compared to boiling water extracts and cold water extracts.	(Shakurfow et al. 2016)
Aqueous onion extracts (50% concentration) against 8 Gram negative, 5 Gram positive and 1 yeast isolated from patients. *(In vitro)*	Isolates of *Staphylococcus aureus, Staphylococcus epidermidis, Streptococcus pyogenes, Streptococcus pneumoniae* and *Streptococcus viridans* (G + ve), and *Pseudomonas aeruginosa, Klebsiella pneumoniae, Proteus mirabilis, Enterobacter aerugenes, Acinetobacter baumanni, Escherichia coli, Serratia marcescans* and *Salmonella typhi* (G-ve), and *Candida albicans* (fungus).	Aqueous onion extract inhibited all of the microorganism and *Salmonella typhi* had the largest inhibition zone (30mm)	(Hamza 2015)

(*continued*)

Table 3. Continued.

Antimicrobial activity	Mircroorganisms	Main findings	References
Aqueous, ethanolic, chloroform and petroleum ether extracts of fresh onion bulb against some fungi by disc diffusion method. *(In vitro)*	*A. niger, A. fumigatus, C. albicans* and *A. flavus*	The chloroform extract of onion showed highest zone of inhibition with *A. niger* (IZD =28 ± 1.4 mm), *A. fumigatus* (IZD =31 ± 1.3 mm) and *C. albicans* (IZD =32 ± 1.5 mm) but less in case of *A. flavus* (IZD =24 ± 1.1)	(Singh 2017)
Time-Kill and Antiradical Assays on Green Onion ethanolic extract (75%) against gastrointestinal tract pathogens. *(In vitro)*	Pure cultures of *E. arerogenes* and *E. coli*	100% aqueous extracts of green onion bulbs displayed maximum bacterial kill and its kill rate is slightly higher than the kill rate by positive control for *E.arerogenes*	(Thampi and Jeyadoss 2015)
Cold water extract and fresh onion extracts (70% ethanol) on some pathogenic bacteria associated with ocular infections. *(In vitro)*	Isolates of E. *coli, S. aureus, S. pneumonia and S. pyogenes*	*S. pyogenes* and *S. aureus* were sensitive to the fresh onion extracts with the zone of inhibition ranging from 17mm in *S. aureus* to 20mm in *S. pyogenes*. *E. coli* was sensitive to fresh onion extracts with the zone of inhibition of 15mm in diameter and *S. pneumonia* had a zone of inhibition of 8mm on fresh onion extract.	(Shinkafi and Dauda, 2013)
Aqueous extraction and methanolic extract (95%) of onion against *Streptococcus mutans* isolated from dental caries of humans *(In vitro)*	Isolates of *Streptococcus mutans* from the patients having dental caries.	Aqueous extract of onion at 50% concentration displayed an inhibition zone of 10.37 ± 0 .65 mm against *Streptococcus mutans*.	(Shukla et al. 2013)
Active compounds from methanolic extract of onion against gram-negative and gram-positive bacteria. *(In vitro)*	Gram- negative *E. coli* and Gram-positive *S. aureus*	The highest zone of inhibition for *S.areus* was observed to be 13.5 ± 0.9 mm for the red onion extract, whereas for the yellow onion extract was 11.3 ± 0.7 mm	(Sharma et al. 2017)
Essential oil of onion by steam distillation against food-borne spoilage and pathogenic bacteria. *(In vitro)*	*Brochothrix thermosphacta* (CECT 847), *Escherichia coli* (ATCC 25922), *Listeria innocua* (CECT 910), *Listeria monocyto-genes* (CECT 5873), *Pseudomonas putida* (CECT 7005), *Salmonella typhimurium* (ATCC 14028) and *Shewanella putrefaciens* (CECT 5346)	The highest inhibition zone detected was 32 mm for *Shewanella putrefaciens.*	(Teixeira et al. 2013)
Aqueous and oil extract of onion at 50% concentrations on 8 gram-negative, 5 gram-positive, and 1yeast isolates by disk diffusion method. *(In vitro)*	*S.aureus, S.epidermidis, S.pyogenes, S.pneumoniae*& *S.viridans*, and *Pseudomonas aeruginosa, Klebsiella pneumonia, Proteus mirabilis, E. aerugenes, Acinetobacterbaumanni,Escherichia coli,Serratiamarcescans*& *Salmonella* ,and *Candida albicans*(fungi).	The maximum inhibition zone of Gram positive bacteria to Onionextract were observed against *S. pyogenes* (25 mm), *S. pneumonia* (25 mm) and the minimum was against *S.epidermidi* (18mm). The maximum inhibition zone of Gram negative bacteria to same extract were observed against *Salmonella typhi* (30mm), the minimum was against *Proteus mirabilis* (18mm).	(Hamza 2015)
Effects of onion extract on haematological parameters, histopathology and survival of catfish Clarias gariepinus (burchell, 1822) sub-adult infected with *Pseudomonas aeruginosa (In vitro)*	*P. aeruginosa ATCC 27853*	Onion extract achieved the same inhibition level (19.50 ± 0.5) chloramphenicol achieved at 50% at 100% concentration. A. cepa was found to be active against *P. aeruginosa*. It exhibited a high antibacterial activity against the test organism (19.04 ± 4.0mm) and an MIC and MBC of 190mg/ml and 50 mg/ml respectively.	(Oyewusi et al. 2015)
Crude extract of onion (98.8 methanol) by Soxhlet extraction tested on bacterial and fungal cultures. *(In vitro)*	*E.coli*, *Staphylococcus aureus*, *Bacillus subtilis*, *Klebsiella pneumoniae* (*Aspergillus niger* (ATCC 9763), *Candida albicans* (ATCC 7596)	The methanol extract of bulbs of *Allium cepa* exhibited high activity against *Bacillus subtilis* (2.3 cm), and *A. niger* (0.9 cm) and was moderately active against others.	(Sharma et al. 2009)
Essential oil extract, aqeous, and ethanolic extract of fresh red onion against three pathogenic and three fungal strains. *(In vitro)*	Bacterial strains: *E. coli* O157:H7, *S. aureus*and *S. typhimurium* Fungal strains*: A. niger,* H.U.B., *1, Aspergillus ochrecies*, H.U.B., 2 and *Fusarium oxysporum*, H.U.B., *3)*	*S. typhimurium* was more sensitive to ethanolic aqueous extracts and essential oils of onion than *E. coli* O157:H7, *S. aureus*, *A. niger*, H.U.B., 1, *A. ochrecies*, H.U.B., 2 and *F. oxysporum*, H.U.B., No.3 . *F. oxysporum exhibited* inhibition zones 7, 9 and 10 mm for aqueous at concentrations (20, 40 and 60 mg/ml) respectively.	(Abdel-Salam et al. 2014)

Abbreviation: IZD-Inhibition Zone Diameter, MIC- Minimum Inhibition Concentration.

clinical symptoms associated with AIDS and were able to resume their healthy lifestyle.

Other pharmacological activities of Allium cepa

Allium cepa has a miscellany of phytochemicals involving flavonoids, phenolic acids, and organosulfur compounds which contributes to its bioactivities. *A. cepa* possess a wide range of pharmacological properties including antimicrobial, antioxidant, analgesic, anti-inflammatory, anti-diabetic, hypolipidemic, anti-hypertensive, and immunoprotective effects, which are displayed in Table 4.

Dietary antioxidants play a crucial role in the suppression of oxidative stress, which may cause initiation and progression of several diseases, including cancer, diabetes, inflammation, and cardiovascular diseases (Razavi-Azarkhiavi et al. 2014). Recently, numerous studies have emphasized the antioxidant activity of *A. cepa*. Kaur et al. (2009) studied the antioxidant activity in ten cultivars of Indian onion. Red cultivars (Sel-383, N-53, Pusa red, and Sel-402) displayed higher ferric reducing antioxidant power (FRAP), cupric reducing antioxidant capacity (CUPRAC) compared to white cultivars (Pusa white flat, Pusa white round and Early grano). In the study of Lee et al. (2015), the antioxidant activity of fifteen onions of white, yellow, or red colors, based on the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay. Red onions displayed the highest DPPH scavenging effect unlike white onions were less active. The DPPH assay also showed correlations with anthocyanin ($r^2 = 0.65$) and quercetin ($r^2 = 0.76$) contents which indicates that onions with higher levels of anthocyanin and quercetin tend to exhibit higher antioxidant power. Abdel-Salam et al. (2014) found that the essential oil of red onion showed stronger scavenging effect against DPPH radicals (30.81%) compared to the essential oil extract of garlic (22.04%). Gorinstein et al. (2008) observed the phenolic content in the red onion to be higher than in white onion and garlic, which could explain its higher antioxidant activity compared to garlic.

Ouyang et al. (2017) reported the DPPH radical-scavenging activity, FRAP radical-scavenging activity, and OH· radical scavenging activity of total polyphenols from onion ($IC_{50} = 43.24\,\mu g/mL$, $560.61\,\mu g/mL$, and $12.97\,\mu g/mL$, respectively). In addition, these polyphenols significantly inhibited xanthine oxidase activity ($IC_{50} = 17.36\,\mu g/mL$). Moreover, (Sellappan and Akoh, 2002) investigated into the total polyphenols and Trolox equivalent antioxidant capacity (TEAC) of Vidalia onion varieties: Nirvana, DPS 1032, Yellow 2025, King-Midas, and SBO 133 grown at Vidalia, Georgia, which ranged from 73.33 to 180.84 mg/100 g FW and from 0.92 to 1.56 μM TEAC/g FW, respectively. In another recent study, Ma et al. (2018) found that polysaccharide extracted from *A. cepa* displayed strong antioxidant activity towards 2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical cations, Fe^{2+} chelating and superoxide anion radical scavenging.

Onion extracts of different cultivars in Ontario were also found to significantly induced apoptosis, decreased the rate of proliferation, and slowed the migration of human adenocarcinoma (Caco-2) cells. Bioactive flavonoids and organosulfur compounds present in onions have been reported to affect signal transduction pathway, leading to cell cycle arrest in the G1 and G2/M (Manohar et al. 2017). The ethyl acetate extract of onion also could induce apoptosis of human breast cancer MDA-MB-231 cells and reduce intercellular lipid accumulation of 3T3-L1 adipocytes via the inhibition intracellular animal fatty acid synthase (FAS) activity (Wang et al. 2012). Also, the methanol extract of onion displayed inhibition of two kinds of human lung cancer cell lines (NCI-H522, NCI-H596) with IC_{50} values of 1.04 and 0.79 mg/mL, respectively (Rho and Han 2000). Onion oil also showed marked suppression of HL-60 human promyelocytic leukemia cells proliferation; the suppression was almost identical with those obtained by the positive controls, all-trans-retinoic acid or dimethyl sulfoxide. Also, the combination of onion oil with all-trans-retinoic acid showed higher effect than either alone (Seki et al. 2000). Moreover, at a concentration of 100 μg/ml, the methanol extract of white, yellow, and red onion peel displayed an inhibition of 78.43, 81.90, and 96.52%, respectively, against human breast cancer cell (MCF-7) and an inhibition of 71.58, 77.93, and 98.47%, respectively, on human prostate cancer cell (LNCaP) (Jeong et al. 2009). Onion extracts also dose-dependently inhibited the proliferation of four human tumorigenic cell lines such as HT-29 (colon), MCF-7 (breast), DU-145 (prostate) and HepG2 (liver) (Shon and Park 2006).

Furthermore, Lee et al. (2012) investigated the effect of red onion in rats and found that rat consuming red onion experienced an increase in the plasma superoxide dismutase activity and the glutathione peroxidase activity. Interestingly, it was also found that liver malondialdehyde levels were significantly decreased. Pretreatment with *A. cepa* also protected against doxorubicin-induced hepatotoxicity in rats due to its antioxidant properties (Mete et al. 2016). The ethyl acetate fraction from onion also showed excellent enhancing effects on spatial cognitive function and learning and memory functions and also protected against trimethyltin-induced cognitive dysfunction in mice (Park et al. 2015). Another study (Hyun et al. 2013) demonstrated that onion extract prevented brain edema, blood-brain barrier hyperpermeability, and tight junction proteins disruption, possibly through its antioxidant effects in mice. The study revealed that onion could be helpful in preventing blood-brain barrier function during brain ischemia.

Besides, it was observed that *A. cepa* was also effective in reducing liver oxidative stress by preventing the decrease in antioxidant parameters such as superoxide dismutase, catalase, catalase, in glutathione peroxidase in diabetic rabbits (Ogunmodede et al. 2012). The level of free radicals was decreased in plasma and tissues of alloxan-diabetic rats after treating them with onion extract (El-Demerdash et al. 2005) and this result was in agreement with the study of Baynes and Thorpe (1999), Kumari and Augusti (2002), and Campos et al. (2003).

Besides, onion also displayed hypoglycemic effect. For instance, many experimental studies on animals showed that

Table 4. Summary of pharmacological studies on *Allium cepa*.

Activity Tested	Model Used/ Assay	Onion variety used	Extract type	Positive Control	Results	References
Antioxidant	*In vitro,* DPPH assay,	NI	Methanol extract	Dimethyl sulfoxide	Quercetin extracts from *A.cepa* had the strongest antioxidant activity with $IC_{50} = 125\,\mu l/ml$ compared to other quercetin extracts	(Lesjak et al. 2018)
Antioxidant	*In vitro*	Red	*A.cepa* polysaccharide extracted as HBSS, CHSS, DASS and CASS	Ascorbic acid	At a concentration of 0.5-2.0 mg/mL, CHSS provide the highest antioxidant action towards ABTS radical cations (97.52%), Fe^{2+} chelating (98.94%) and superoxide anion radical scavenging (76.27%).	(Ma et al. 2018)
Antioxidant	*In vitro,* DPPH assay	Stanley, Safrane, Fortress, Lasalle and Ruby Ring	Ethanolic extract	Quercetin Ascorbic acid	Ruby Ring, the red onion variety, showed the highest percentage of inhibition of $21.52 \pm 1.30\%$ using 0.5 mg/ml of extract, followed by Lasalle ($15.46 \pm 3.88\%$), Fortress ($13.44 \pm 4.19\%$), Stanley ($11.38 \pm 1.96\%$) and Safrane ($11.1 \pm 2.89\%$).	(Manohar et al. 2017)
Antioxidant	*In vivo,* hypercholesterolemic male Wistar rats weighing 250g	Recas	Onion powder	NI	There was a significant improvement in HCO-fed rats by ameliorating hepatotoxicity, decreasing oxidative stress and modulating inflammation. It was confirmed by the decrease in circulating levels of ALT and AST enzymes, the enhancement of defense systems against oxidative damage, and the modification of cytokine levels amongst other parameters	(Colina-Coca et al. 2017)
Antioxidant	*In vitro*, DPPH assay	Red	Essential oil, aqueous and ethanol extract	NI	Essential oils extracts have more stronger antioxidant properties than ethanol and aqueous extracts of red onion.	(Abdel-Salam et al. 2014)
Antioxidant	*In vitro*, DPPH assay,	Red: Sel-383, Pusa Madhvi, Pusa red, Sel-402, N-53, H-44, Yellow: Sel-126 White: Pusa white flat, Pusa white round Early grano	Ethanol extract	Gallic acid	Sel-383 had the highest antioxidant activity by FRAP assay (3.4 mmol Trolox/g) and CUPRAC method (7.6 mmol Trolox/g). In the DPPH test, Pusa red had the highest percentage of inhibition (85%).	(Kaur et al. 2009)
Antioxidant	*In vitro*, DPPH assay	Red	Ethanol extract	Butylated hydroxyanisole	IC50 > 1.0 mg/mL for red onion. Red onion had a higher TPC (i.e. 53.43 ± 1.72 mg GAE/100 g) compared to garlic (i.e. 37.60 ± 2.31 mg GAE/100 g)	(Che Othman et al. 2011)
Antioxidant	*In vitro,* F-C assay DPPH assay	Red Yellow White	Fresh juice extract Methanolic extract	Gallic acid	White onion had the lowest levels of ~440 μg GAE/mL. Yellow onions showed medium AOA between 500 and 750 μg GAE/mL. The red onion showed the highest levels between 700 and 780 μg GAE/mL. In DPPH assay, antioxidant activity were between 20 and 80 μg GAE/mL and were less than those of the F-C assay (400-800 μg GAE/mL).	(Lee et al., 2015)
Antioxidant	*In vitro,* DPPH assay	Giza 6 and Photon	Fresh onion extract Frozen onion extract	NI	Antioxidant activity was greater in fresh onion (25.61%) compared to processed onions by freezing.	(El-Hadidy et al. 2014)
Antioxidant	*In vitro,* TEAC Assay	Red White Yellow	Methanol extraction	Trolox	Red onion obtained the highest values 28.18 ± 4.59 (μmol Trolox/g FW) for total antioxidant activity.	(Lu et al. 2011)
Antioxidant	*In vitro,* FRAP assay	Red	Raw onion extract Cooked onion extract	NI	After incubation, the FRAP value of ascorbic acid in the presence of onion cell walls (1.22 mM) retained 92% of antioxidant activity which was considerably higher than that of ascorbic acid alone (0.34 mM)	(Sun-Waterhouse et al. 2008)
Antioxidant	*In vitro,* DPPH assay	Red, yellow, white and grelot onion	Methanol extraction	NI	The IC50 values ranging from 17.09 mg/ml to 85.18 mg/ml. The red onion extracts had the lowest IC50 values followed by the yellow, white and grelot onions. The yellow onion extract obtained by microwave hydrodiffusion and gravity has IC50 of 36.35mg/ml versus 58.61 mg/ml by conventional solid–liquid extraction.	(Zill-e et al. 2011)

(*continued*)

Table 4. Continued.

Activity Tested	Model Used/ Assay	Onion variety used	Extract type	Positive Control	Results	References
Antioxidant	*In vitro,* DPPH assay	'Grano de Oro'	Methanol extract of pressurized onion	NI	There was an increase in onion antioxidant activity when applying pressures from 100 to 400 MPa and the mass of onion used was 1g.	(Roldán-Marín et al. 2009)
Antioxidant	*In vitro,* DPPH assay, FRAP assay and ABTS assay	White Yellow Red	Ethanolic extract	Gallic acid	The red onion presented the maximum antioxidant activity ((82.04 ± 1.98) mg 100 g–1 FW for DPPH ˙; (175.2 ± 4.35) mg 100 g–1 FW for ABTS ˙+; (143.37 ± 2.82) mg 100 g–1 FW for FRAP, respectively).	(Zhang et al. 2016)
Anti-cancer	*In vitro,* cell viability analysis	NI	Methanol extracts of fermented onion	NI	All extracts increased PBMCs proliferation in a dose-dependent manner up to 350μg/mL.	(Ravanbakhshian and Behbahani 2017)
Antithrombotic, antiplatelet and anticoagualant	*In vivo,* Male Wistar ST rats, 10-11 weeks old and male C57BL/6 mice, 10 weeks old using laser-induced thrombosis test *In vitro* (haemostatometry)	Yellow: Kita- miko27, Toyohira, Kitawase3, Tsukisappu, Superkitamomiji, CS3-12, Tsukiko22, Rantaro, 2935A, K83211 Red: Gekko22	Methanol extract of onion juice	NI	Toyohira showed a significant inhibition of thrombus growth was observed after a single oral treatment of 3.85ml/kg onion juice. Toyohira inhibited both platelet reactivity and dynamic coagulation. Tsukisappu and Rantaro had inhibitory effects on platelet reactivity and coagulation at a ratio of blood:filtrate =9:1.	(Yamada et al. 2004)
Neuroprotective	*In vivo* Swiss albino male mice weighing 22–28 g	Agrifound dark red	Hydroethanolic extract, solet extraction	NI	Attenuation of oxidative damage, indicated by reduction in lipid peroxidation, nitrate/nitrite levels with elevated GSH and catalase activities. AChE activity and abnormal aluminum deposition were reduced. The dosage taken ranges from 50-200 mg/kg/day of *A. cepa* orally with aluminum chloride 50 mg/kg/day.	(Singh and Goel 2015)
Androgenic	*In vivo,* 30 adult Wistar albino male rats were 8 weeks old and weighed 250 ± 10 g	Yellowish-white bulb	Onion juice	Quercetin	An increased in serum total testosterone and sperm motility and viability in both experimental groups as compared to the control group were observed. The dosage taken was 0.5 g/rat and 1 g/rat of freshly prepared onion juice for 20 consecutive days.	(Khaki et al. 2011)
Antiallergic	*In vitro,* *β*-Hexosaminidase inhibitory activity assay and HPLC	Advance, Answer, Momiji No. 3, Momiji no kagayaki, Satsuki, Shippokan 70, Shippososei No. 7, and Tarzan	Methanol extract	NI	Satsuki cultivar exhibited the highest anti-allergic activity (44.3 ± 4.0%) at 100 μg/mL. Quercetin 4′-glucoside (IC50 = 6.5 ± 0.5 μM) was the most effective substance for the suppression of type I allergy.	(Sato et al. 2015)
Antispasmodic	*In vitro*, ileum of Male guinea pigs (250-350 g,)	Tropea (red)	Methanol extract	NI	Tropeosides A1/A2 and B1/B2 reduced, in a concentration-dependent manner, the contractions evoked by both acetylcholine and histamine at a significant concentration of 10^{-5} M (∼50% inhibition).	(Corea et al. 2005)
Immunoprotective	*In vivo,* cyclophosphamide induced immunosuppression in male Wistar rats (4–5-weeks-old	NI	*A. cepa* agglutinin (ACA)	Azathioprine, cyclophosphamide	ACA administration improves the immune parameters in immune-suppressed animals. SRBC (group C) and 10 μg ACA (group E) treatment significantly increased (∼1.5 fold) the weight of spleen. 10 μg and 100 μg of ACA treatment (groups E and F) significantly improved (∼2.5 fold) the thymic index. Leucopenia was significantly induced (∼5 fold)	(Kumar and Venkatesh 2016)
Anti-amnesic	*In vivo*, mice (male, 4 weeks old)	NI	Ethanol extract	NI	The inhibitory effect against cellular acetylcholinesterase (AChE) showed that the EtOAc fraction of peel (EOP, IC50 value =37.11 μg/mL) was higher than the EtOAc fraction of flesh (EOF, IC50 value =433.34 μg/mL). Increased in spontaneous alternation behavior in the TMT-injected mice when tested for impair the spatial cognitive function.	(Park et al. 2015)

(*continued*)

Table 4. Continued.

Activity Tested	Model Used/ Assay	Onion variety used	Extract type	Positive Control	Results	References
Anti-inflammatory	*In vivo*, 24 fertile, inbred, healthy, male Sprague– Dawley rats, weighing 200–250 g and aged 16 weeks	NI	*A.cepa* juice extract (ACE)	20-40% polyphenols	In the ACE pretreated group serum aspartate transaminase, alanine transaminase, and tissue MDA and glutathione levels were significantly lower, while superoxide dismutase and glutathione peroxidase were higher compared with the doxorubicin group. A dosage of 1 mL of fresh ACE juice orally for 14 consecutive days was given.	(Mete et al. 2016)
Attenuation of brain edema	*In vivo*, 150 mice weighing 30-35 g (8weeks old) induced by middle cerebral artery occlusion (MCAO)	NI	Methanol extract	NI	Increase of brain ischemia was significantly attenuated by onion extract at 0.3 and 1 g/kg. Onion extract significantly prevented brain ischemia-induced reduction in catalase and glutathione peroxidase activities and elevation of MDA level in the brain tissue.	(Hyun et al. 2013)
Wound-healing	*In vivo*, 54 adult male and female Clarias gariepinus weighing 1 kg	NI	Ethanol extract	Water	Treatment with 1.5% onion bulb residues displayed healing properties in the first 7 days.	(Bello et al., 2013)
Anti-diabetic	*In vivo*, 15 Alloxan-induced diabetic rabbits	NI	Aqueous extract	Insulin	*A. cepa* at 100 mg kg^{-1} reduced fasting blood glucose levels by 53.3% (300.2 ± 11.2 to 140.1 ± 3.4) and 300 mg kg^{-1} it reduced fasting blood glucose levels by 73.3% (300.2 ± 11.2 to 80.4 ± 1.2)	(Ogunmodede et al. 2012)
Anti-diabetic and Antioxidant	*In vivo*, Alloxan-induced diabetic male albino rat weighing 120-180g	NI	Isolates of S-methyl sulphoxide (SMCS) from onion	NI	Diabetic rat showed significant loss in weight after 2 months. Urine sugar showed a gradual decrease. MDA, HP and CD were lowered by 11.6% in diabetic mouse treated with SMCS.	(Kumari and Augusti 2002)
Hypoglycemic	*In vivo*, Diabetic Wistar male rats weighing 150-180 g	NI	Raw and boiled juice	Insulin Metformin	*A. cepa* juice of raw and boiled (400mg/kg and 600mg/kg) respectively reduced the blood glucose in diabetic rats with the group treated with 400 mg/kg of the raw extract of *A. cepa* showing most reduction in the blood glucose.	(Ojieh et al. 2016)
Hypoglycemic	*In vivo*, 28 adult male alloxan-induced diabetic rats (240– 300g)	NI	Onion juice	NI	Treatment of alloxan-diabetic rats with the 1ml onion juice/100 g BW/day reduced their plasma glucose levels by 70% and 68%, respectively compared with the diabetic group. Brain LDH activity was significantly increased by 58% in alloxan-diabetic rats	(El-Demerdash et al. 2005)
Anti-hyperlipidemic	*In vivo*, Sprague–Dawley rats fed on 1% cholesterol diet	NI	SMCS from fresh onion	NI	The total lipoprotein lipase activity in the adipose tissue was decreased with also a decrease in the free fatty acid levels in serum and tissues at a dosage of 200 mg/kg body weight for 45 days.	(Kumari and Augusti 2007)
Anti-hypertensive	*In vivo*, hypertensive rats, male 6 weeks old rats weighing approximately 200 g	NI	Freezed-dried onion powder	NI	The blood pressure in rats of the onion diet group increased more slowly and grew to about 160 mmHg at the end of 4 weeks. The significant antihypertensive effect of onion was observed from 1 to 4 weeks. Dietary onion decreased the thiobarbituric acid reactive substances (TBARS) in plasma in these hypertensive rats.	(Sakai et al. 2003)
Analgesics and anti-inflammatory	*In vivo*, Paw edema induced-male albino mice (25 to 30 g) and male Sprague-Dawley rats (220 to 250 g)	White	Fresh onion juice	Diclofenac	7.5ml/kg dosage had the best analgesic effect for the first 30 minutes.	(Nasri et al. 2012)

Abbreviation: HCO- hypercholesterolemic onion die, SMCS- *S*-methyl cysteine sulfoxide, PBMCs- Peripheral blood mononuclear cells, DPPH- 1,1-Diphenyl-2-picryl-hydrazyl, TEAC- Trolox equivalent antioxidant capacity, FRAP- ferric reducing ability of plasm, GAE-Gallic acid Equivalet, FC-Folic-Ciocalteu, HBSS, CHSS, DASS and CASS-fractions of *A.cepa* polysaccharide, MDH- malondialdehyde, HP- hydroperoxide, CD- conjugated dienes, BW-body weight, TMT- trimethyltin.

the hypoglycemic effects of *A. cepa* are attributed to its sulfur-containing compounds such as S-methlycysteine sulfoxide (SMCS) and S-allylcysteinesulpoxide which can directly act on the pancreas and increase insulin levels in the blood (Akash et al. 2014). SMCS from onion showed a gradual decrease in urine sugar (Kumari and Augusti (2002). On top of that, intake of essential oil of onion in streptozotocin-induced diabetic albino rats caused a significant decrease in serum lipids, lipid peroxide formation, blood glucose and increase in serum insulin (El-Soud and Khalil 2010). In another experiment conducted by Kumari and Augusti (2002), they found that SMCS isolated from onion improved diabetic condition significantly in rats, viz. maintenance of body weight and control of blood sugar. Ur Rahman et al. (2017) also elucidated that dietary supplementation of onion increase the weight gain and feed consumption of broilers chicken, producing a positive effect on performance, gut microflora, and intestinal histomorphology (Goodarzi et al. 2014).

Moreover, consumption of fresh onion juice had both spermatogenesis and antiprotozoal effects in *Toxoplasma gondii* infected rats (Gharadaghi et al. 2012; Khaki et al. 2011). Zhou et al. (2017) also found that the essential oil of *A. cepa* displayed an acetylcholinesterase inhibition of 41.46% at 100 µg/ml. Additionally, Nasri et al. (2012) tested for the analgesic effect of fresh onion juice in chronic pain model with a hot plate and acute pain in mice by formalin test. They also investigated its anti-inflammatory properties using carrageenan-induced paw edema in rats. As results, fresh onion juice was able to decrease the hind paw thickness significantly compared to the control group and also demonstrated better results than the standard treatment, diclofenac with a 10 mg/kg dosage. The anti-inflammatory effect was attributed to the fact that onion extract can prevent the formation of leukotrienes and thromboxanes by the inhibition of COX and LOX pathways which is usually responsible for its anti-apoptotic effect (Alpsoy et al. 2013).

Toxicity

The exploration of medicinal plants and other natural products has increased drastically due to the belief that natural products tend to be safer with minimal to no side effects. Even though plants have many pharmacological benefits; some of them may be toxic or generate adverse effects to human (Celik 2012). Concerning the toxicity of *A. cepa*, Votto et al. (2010) reported that at a concentration of 2 mg/ml, onion extracts (aqueous, methanolic, and ethyl acetate) exhibited significant DNA damage in Lucena MDR human erythroleukemic and its K562 parental cell line. In K562 cells, an increase of apoptosis was found whereas in Lucena cells there was an increase in necrosis. This damage was attributed to the compound quercetin and propyl disulfide present in onion. Genotoxic effects of organosulfur compounds were recorded in the micronucleus test on mammalian cells (L5178YTk$^{b/-}$ cells) after propyl propane thiosulfinate exposure at the highest concentration tested (17.25 mM). Additionally, in the comet assay, propyl propane thiosulfinate caused DNA damage in Caco-2 cells at a high concentration (280 mM), but it did not induce oxidative DNA damage (Mellado-García et al. 2016). Moreover, the toxic effects of aqueous onion extract were investigated in lung and liver tissues of rats. Administration of high doses of onion (500 mg/kg) showed histological changes and even resulted in 25% rate of mortality in the treatment group (Thomson et al. 1998). Cattle fed with onion also reported clinical signs such as dehydration, ataxia, pale mucous membranes, brown-colored urine, a distinct odor of onions and tachycardia. When the blood samples from acutely affected animals were tested, a decrease in packed cell volume and evidence of hemolysis was seen (Parton 2000). Knight et al. (2000) also observed that lambs fed with onions developed clinical signs of onion toxicity, but none of them died from the toxic effects.

Limitations and recommendation

During the preparation of literature search, a disparity in the contemporary knowledge of the ethnopharmacology of *A. cepa* was noticed, which demands more emphasis in future studies. Despite being used traditional in many regions, mostly Asian and African countries, there was a lack of specific information regarding the dosage, variety of onion used, and the detailed method of preparation. Therefore, it is essential to perform more detailed ethnomedicinal studies in these regions. Furthermore, based on the result from Tables 3 and 4, it was found that out of fifty studies reviewed, only two were conducted *in vivo*. This implies that further research should be carried out in *in vivo* models. Also, it was found that some studies have not provided a consistent result. For example, for the antimicrobial activity, there was variation in the dimension of inhibition against the same strain of tested microorganisms. These variations could be attributed to different samples of *A. cepa* collected from different regions whereby they differ concerning soil, climatic conditions, and agricultural and processing techniques. This could also be due to the different extraction techniques used. In some studies, the varieties used for *A. cepa* were not mentioned, and thus it was difficult to compare the results. Consequently, future research should prioritize these gaps and strive to study factors responsible for alterations based on phytochemical composition and bioactive properties. Moreover, it was observed that in many studies the conventional extraction method, maceration, was used. It can be suggested that other modern extraction methods such as ultrasound- assisted extraction, microwave-assisted, and supercritical fluid extraction can be further examined to achieve higher yield at lower cost. Last but not least, pharmacological data amassed on *A. cepa* should be further explored for potential applications in various fields besides drug discovery, such as food development, food preservation, livestock feed, biofarming, and other biotechnological applications.

Conclusion

The current review imparts to revise and provide an updated compilation of studies focused on *A. cepa*. It should

be taken into account that there have been other reviews aimed to compile the medicinal aspects of *A. cepa* with limited emphasis laid on the ethnopharmacological uses of this crop. Nevertheless, this work can be considered as an initiative to incorporate scientific shreds of evidence based on the ethnopharmacology of *A. cepa*. There was also an attempt made to critically assessed and broaden the knowledge of the traditionally used plant for its superfluous medicinal properties, bioactive composition, and pharmacological aspects. *A. cepa* can be regarded as a source of critical phytopharmaceutical agents with potential applications in emerging fields of interest.

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