The Phytochemical, Pharmacological and Medicinal Evaluation of Quinoa (Chenopodium quinoa Willd.)

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THE PHYTOCHEMICAL, PHARMACOLOGICAL AND MEDICINAL EVALUATION OF QUINOA (*Chenopodium quinoa* Willd.)

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ABSTRACT

Quinoa (*Chenopodium quinoa* Willd.) is acknowledged as golden grains, is widely regarded as a multipurpose crop. The nutritional and health benefits of quinoa have made it a popular food around the world in the last decade. It is a nutrient-rich pseudo-cereal crop that has been introduced in Pakistan in the recent past, because of its medicinal, commercial value. The plant contains huge number of phytochemicals i.e. amino acids, fiber, minerals, vitamins, secondary metabolites, bioactive proteins and peptides which could be used in various medicine for human and other animal's health. It has been reported that the quinoa leaves, root, and seed are used in the treatment of diabetes, cancer, inflammations, fungal infections, and other numerous health problems. In addition, its high energy, nutrient content, therapeutic properties, and lack of gluten, it is considered to be useful for children, the elder, lactose-intolerant people, and osteoporosis in women. Besides, it is considered a crop oil, because the seed oil fractions are extremely nutrient-dense and can be used in skin care, cosmetics, and as a raw material for other products. This comprehensive study provides medical uses, phytochemical constituents, and pharmacological activities of quinoa. Also, the anti-inflammatory, antimicrobial, antidiabetic, antioxidant, antitumor, antilipidemic, antibacterial, and antifungal effects have been reviewed. This review is providing the detail study about the phytochemicals and pharmacological evaluation of quinoa till date, and also provides pave for future investigations and exploitation of *C. quinoa.*

Keywords: *Chenopodium quinoa,* Ethno-medicinal study, Pharmacological properties, Phytochemicals.

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INTRODUCTION

Quinoa belongs to the class Dicotyledoneae, family Chenopodiaceae, and it is a domesticated species that has been grown in the Andes region of South Africa for more than 7,000 years (Abugoch, 2009). There are approximately 250 Chenopodium species found throughout the world (Bhargava *et al.,* 2006). It is an gynomonoecious annual plant that grows 1 to 3 meter high, with alternate leaves, straight stems with colors (yellow, red, black) due to betacyanins, and flowers clustered together in a panicle ranging in length from 15-70 cm (Vega Gálvez *et al.,* 2010; Pakbaz *et al.,* 2021). Quinoa can be planted in rows or groups with a row spacing of 25 to 50 cm and a depth of 1 to 2 cm in a variety of soils, including marginal soils with a high pH range (Jacobsen and Stolen, 1993; Jacobsen *et al.,* 2003). After being exposed to moisture, the seeds germinate quickly, usually within a few hours (Vega Gálvez *et al.,* 2010). The roots are well developed tap roots, which can reach 1.5 meters below underground, and also help in drought stress tolerance (Iqbal, 2015). The stem is branched and has a diameter of 3.5 cm (Jancurová *et al.,* 2009). The leaves are polymorphic, with lanceolate top leaves and rhomboidal lower leaves (Hunziker, 1943). Quinoa can produce both hermaphrodite and unisexual female flowers, and each of these flowers produces one seed with a weight of about 2.5 mg and a diameter of about 1 mm. Female flowers are always at the proximal end of a group, while incomplete blooms, which have no petals, are at the distal end. The inflorescence is at the top of the plant and has no branches (Hunziker, 1943). The fruits are known as achenes, and each one contains a single seed that is protected by a pericarp. The pericarp, which is attached to the seed, is full of saponins, which are responsible for quinoa's characteristic bitter flavour (FAO, 2011). The carbohydrate reserves are located in the central perisperm of the quinoa seed, which is surrounded by the circular embryo, which is rich in oil and protein, as well as the endosperm and the seed coat (Prego *et al.,* 1998). The seeds vary in size and colour, with black predominating over red and yellow, which then predominate over white seed color (Bazile *et al.,* 2015). The most edible part of quinoa is seed, which contain various bioactive compounds i.e. phytoesterols, peptides, betalains, isoflavones, which have been reported to use against a varieties of diseases (Nowak and Charrondière, 2016). Other bioactive components includes, polysaccharides, saponins, lectins, betains, flavonol glycosides, and phytoecdysteroids, which have antimicrobial, anti-inflammatory and antiallergic properties and can help to prevent diabetes (GawlikDziki *et al.,* 2013). Not only seed, quinoa as a whole contains a variety of secondary metabolites which have been reported in the prevention of inflammation, diabetic, cancer, lose weight, cardiovascular disease and other various health problems (Khan and Javaid, 2020). However, quinoa is widely regarded as an energizing, health-promoting, and endurance-enhancing food, with a wide range of medicinal applications, from wound and fracture treatment to gastrointestinal diseases prevention (Bhargava *et al.,* 2006; FAO, 2011). Due to its medicinal value, economic properties, the plant is also cultivated in farms and greenhouses. The current report summarizes the current knowledge about *C. quinoa's* pharmacological and phytochemical properties, and the literature for this review includes articles and books published in reputable journals.

Ethno-Medicinal Uses Of Quinoa

The fact that quinoa does not contain gluten is beneficial for people of all ages, including children, adults, high-performance athletes, consumers who are lactose intolerant, osteoporotic women, and those who are afflicted with anemia, diabetes, dyslipidemia, obesity, or celiac disease (Vega Galvez *et al.,* 2010). Quinoa leaves have phenolics, which improve health by modulating carbohydrate and lipid metabolism, improving pancreas-cell function, stimulating insulin excretion, and reducing hyperglycemia, dyslipidemia, and insulin resistance (Lin *et al.,* 2016; Vauzour *et al.,* 2019), also have properties to prevent cancer, reduce inflammation, reduce or control obesity and cardio protective properties (Jeong *et al.,* 2012). The leaves also have anticarcinogenic effects in vitro and inhibit cancer cell proliferation, motility, and cellular competence (Gawlik Dziki *et al.,* 2013). The stems can be used to make pungent ashes mixed with the leaves of *Erythroxylum coca* for sustaining energy levels (Martindale, 1894). The fruits and flowers contain water-soluble natural pigments called anthocyanins, which have shown antitumor, anticancer, anti-inflammatory, and antioxidant effects (Yang *et al.,* 2017). The seeds are gluten-free, they can be consumed by both celiac disease and wheat allergy sufferers (James, 2009), also, it is used to lose weight, prevent coronary heart disease, and lower blood sugar and insulin levels (Jenkins *et al.,* 2002; Berti *et al.,* 2004). Quinoa seeds contain bioactive compounds and have a variety of biological activities (Sobota *et al.,* 2020) as shown in Fig. 1. It has been shown that the seed contains an abundance of betalains, two of which are betanin and isobetanin. Both of these betalains have been demonstrated to exhibit antioxidant and anti-inflammatory characteristics (Tang *et al.,* 2015b). Choline and betaine, as well as the precursor of betaine, are both used in the treatment of diabetes, in addition to obesity and other chronic disease (Olthof and Verhoef, 2005). Tannins and flavonol glycosides have antiviral, anti-inflammatory, antimicrobial, antioxidant, and carcinogenic effects (Jarvis *et al.,* 2017). Similarly, phytosterols have anti-inflammatory, antioxidant, and anticarcinogenic properties (Ryan *et al.,* 2007). Quinoa seed coat contains saponins which have antiviral, anti-inflammatory, antiallergic, antimicrobial, antioxidant, and immune-boosting properties (Shi *et al.,* 2004; Jarvis *et al.,* 2017; Güçlü *et al.,* 2007). Quinoa saponins have also been shown in studies to have the potential to act as adjuvants for mucosally administered vaccines (Estrada *et al.,* 1998). According to Lamothe *et al.,* (2015), the seeds provide 10% of the total dietary fiber. And dietary fibre has been shown to enhance intestinal microbiota, decrease cholesterol and fat absorption, boost satiety, and reduce the severity of gastrointestinal infections and inflammation (De Carvalho *et al.,* 2014). Besides, the antioxidants and essential minerals in the seed are used for people with autoimmune diseases of the small intestine (celiac disease) (Sepahvand and Sheikh, 2015). The seed oil is edible, has cosmetic and medicinal properties, and is high in protein, vitamins, and minerals, which are used in skin care products, cosmetics, and as an excellent cosmetic raw material (Paweł *et al.,* 2009). Quinoa is used both as a food for humans and as a feed for animals; e.g., stems, leaves, inflorescences, tender, and grains fed to animals during lactation have been shown to increase milk production (Barros-Rodriguez *et al.,* 2018). Furthermore, quinoa can also be used to treat inflammation, fractures, and internal bleeding, as well as an insect repellent and urinary tract cleaner (Mujica, 1994). In addition to improving gastrointestinal indicators, the quinoa diet was shown to be effective in lowering total cholesterol, triglycerides, LDL (low-density lipoprotein), and HDL (high-density lipoprotein) (Zevallos *et al.,* 2014). Similarly, it has been claimed that intake of quinoa helps in the prevention of risk factors for cardiovascular disease, including total cholesterol, LDL levels, and triglyceride levels, as well as that it has a favorable impact on cholesterol overall (Farinazzi-Machado *et al.,* 2012). Both Halaby (2017) and Alghamdi *et al.,* (2018) showed that quinoa is good for the health of the heart and blood vessels. After ingesting quinoa powder, patients who had myocarditis brought on by a diet heavy in cholesterol had signs of improvement on histological examination, as revealed by these researchers. Quinoa contain bitter saponins compounds which is used in a number of industries i.e. cosmetics and pharmaceuticals. These compounds have hemolytic activity and are toxic to cold-blooded animals. It hasn't been proven that they are toxic to animals, but their presence could make it difficult to expand the quinoa market (Ahumada *et al.,* 2016).

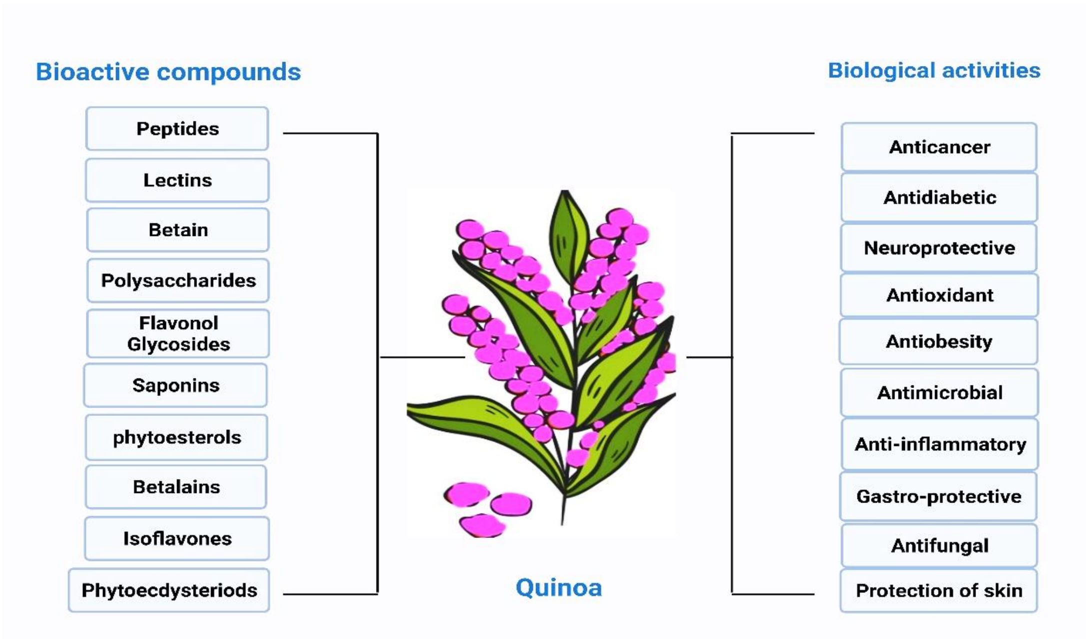

Fig. 1: Quinoa chemical constituents and their functions.

Phyto-Chemicals In Quinoa

Quinoa has wide range of chemical constituents in its different parts e.g. leaves, seeds, flowers, and fruits. These compounds have been classified, as shown in (Table-1). The leaves and seed contains phenolics which is classified into simpler phenolic acids and more complex polyphenols. Phenolic acids such as vanillic, protocatechuic, ferulic, caffeic, pcoumaric, 8, 5′-diferulic acids, and 4-hydroxybenzoic were the most identified (Hernández-Ledesma, 2019). About 29 phenolic acid analogues were identified and classified as analogues of benzoic acid and cinnamic acid. Benzoic acid derivatives such as syringic acid, gallic acid, benzoic acid, protocatechuic acid, vanillic acid, and analogues are plentiful in quinoa components i.e. seeds and leaves (Tang *et al.,* 2016). All of the following are derivatives of cinnamic acid: caffeic acid, chlorogenic acid, cinnamic acid, coumaric acid, ferulic acid, rosmarinic acid, sinapinic acid, and their respective equivalents (Tang *et al.,* 2017). The predominant polyphenols are flavonoids classified as flavones, flavonols, flavanones, flavanols, and isoflavones based on structural features. The flavones acacetin, isovitexin, orientin, and vitexin are mostly found in quinoa sprouts (Lin *et al.,* 2019). Similarly, 21 flavonols were isolated from the quinoa, the majority of which were discovered in seeds. Quercetin, which is found in glycoside form, and kaempferol were the most commonly detected flavonol glycosides (Tang *et al.,* 2016). Besides, the seed of quinoa was studied and found to contain three different flavanones: hesperidin, neohesperidin, and naringin. The chemical structure of Hesperetin has shown in Fig.5. Five isoflavanones, such as biochanin, daidzein, genistein, prunetin, and puerarin, were also identified in quinoa (Tang *et al.,* 2015b).

Quinoa seeds also contain phytoecdysteroids, the most abundant of which is 20-Hydroxyecdysone (20HE), constituting 62 to 90% of total quinoa phytoecdysteroids (Hernández-Ledesma, 2019). The chemical structure of 20-

Hydroxyecdysonehas shown in Fig. 6. Makisterone A, 24-epi-makisterone A, 24 (28)-dehydromakisterone A, polypodine B, 24,25-dehydroinokosterone, 25,27-dehydroinokosterone, and 5 hydroxy-24 (28) dehydromakisterone A were some of the other phytoecdysteroids that were discovered (Kumpun *et al.,* 2011). Also, it has been shown that the seeds contain phytosterol levels of up to 118 mg per 100 g of quinoa seed, with ß-sitosterol, campesterol, brassicasterol, and stigmasterol serving as the primary ingredients (Villacrés *et al.,* 2013).

The seed coats, fruits, and flowers contain terpenoids, including monoterpenoids and triterpenoids, among other types. Saponins are a variety of triterpene glycosides that are found on the surface of quinoa grains. They are mostly generated from hederagenin, phytolaccagenic acid, oleanolic acid, serjanic acid, and 30-trihydroxyolean-12-en-28-oic acid (Hernández-Ledesma, 2019). The chemical structure of hederagenin is shown in Fig. 3. Besides, 20 different saponins were isolated from quinoa and their chemical structures were identified (Kuljanabhagavad *et al.,* 2008). In quinoa, only one sesquiterpene, caryophyllene was found as shown in Fig. 4 (Dembitsky *et al.,* 2008). Tocopherols and tocotrienols are meroterpenoids found in quinoa. In quinoa seeds, all four isoforms of tocopherol (α, β, δ) were found; however, γ-tocopherol was found to be the most abundant of the four, followed by α-tocopherol, β-tocopherol, and δ—tocopherol (Alvarez-Jubete *et al.,* 2009).

Additionally, quinoa vegetative sections and seed contain betalain pigments. These betalain pigments come in a variety of colours, including red-violet betacyanins and yellow-orange betaxanthins. These pigments are nitrogen-containing aromatic indole derivatives that are generated from tyrosine. They give the various portions of the quinoa plant colours ranging from yellow to red to black (Bhargava *et al.,* 2006; Tang *et al.,* 2015b). The betacyanins present in red and black seeds include amaranthin, betanin, and isobetanin. Quinoa contains betaxanthins such as dopaxanthin, indicaxanthin, and miraxanthin V (Tang *et al.,* 2015b). The chemical structure of Miraxanthin V is shown in Fig. 2. Other metabolites that may be found in quinoa include betaine, trigonelline, and the derivatives of those two. Furthermore, quinoa grains have a high oil ratio. The grain oil contains 89.4 % unsaturated fatty acids and 58.3 % polyunsaturated fatty acids, and it has an omega-6/omega-3 ratio of 6/1, which is higher than the ratios found in other grain oils (Tang *et al.,* 2015a). There is a high concentration of natural antioxidants in quinoa oil, such as alpha-tocopherol (5.3 mg/100 g) and beta-tocopherol (2.6 mg/100 g), and there is also a high concentration of essential fatty acids, such as linoleate and linolenate. Quinoa oil also contains a high concentration of polyunsaturated fatty acids (Ruales and Nair, 1992). Apart from that, quinoa contains unsaturated lipids, fibers, and complex carbohydrates, and it is the only plant that contains all of the body's essential amino acids (FAO, 2015).

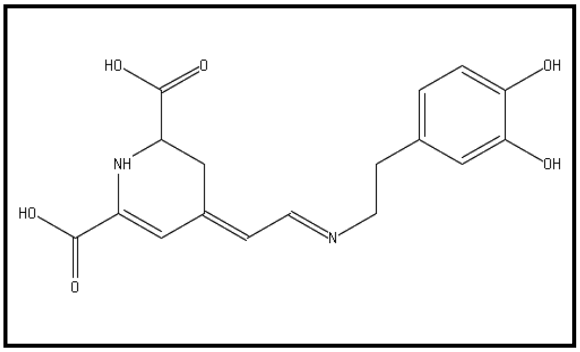

Fig. 2: Miraxanthin V (Betaxanthins)

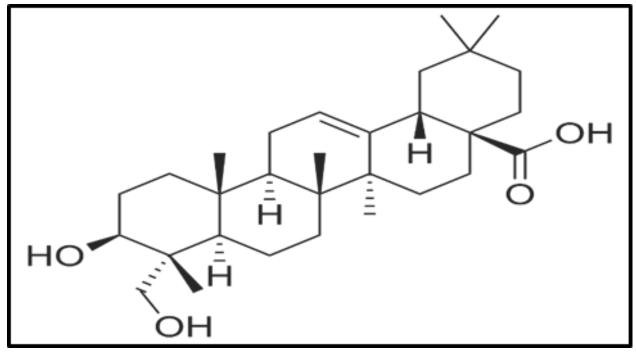

Fig. 3: Hederagenin (Saponins)

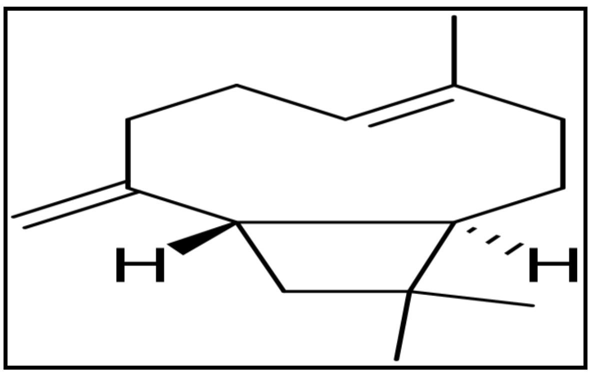

Fig. 4: Caryophyllene (Sesquiterpen)

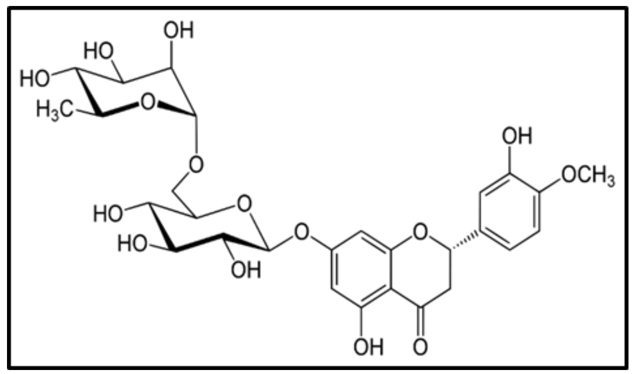

Fig. 5: Hesperetin (Polyphenols)

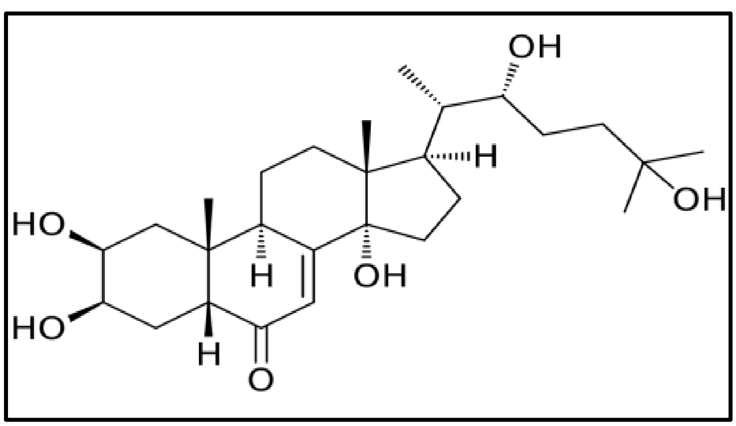

Fig. 6: 20-hydroxyecdysone (Phytoecdysteroids)

Table 1: Chemical constituents isolated from *C. quinoa*.

Classification	Chemical compound	Plant parts	Reference
Phenolic Acids	Benzoic acid	Leaf	Gawlik-Dziki *et al.,* 2013
	Gallic acid	Seed and leaf	Gawlik-Dziki *et al.,* 2013
	Protocatechuic acid	Seed	Tang *et al.,* 2016
	Syringic acid	Seed and leaf	Tang *et al.,* 2016
	Vanillic acid	Seed and leaf	Tang *et al.,* 2016
	Caffeic acid	Seed	Tang *et al.,* 2016
	Chlorogenic acid	Seed and leaf	Tang *et al.,* 2016
	Cinnamic acid	Seed	Pasko *et al.,*2008
	Coumaric acid	Seed and Leaf	Tang *et al.,* 2016
	Ferulic acid	Seed and leaf	Pasko *et al.,*2008
	Rosmarinic acid	Seed	Tang *et al.,* 2016
	Sinapinic acid	Leaf	Gawlik-Dziki *et al.,* 2013
Triterpenoids	Oleanolic acid	Seed	Mizui *et al.,*1990
	Hederagenin	Seed	Mizui *et al.,*1990
	Serjanic acid		Mizui *et al.,*1990
	Phytolaccagenic acid	Seed	Mizui *et al.,* 1988
	Gypsogenin	Seed, flower, fruit	Kuljanabhagavad *et al.,*2008
	3β-Hydroxy-27-oxo-olean-12-en-28-oic acid	Seed, flower, fruit	Kuljanabhagavad *et al.,*2008
	3β,23,30-Trihydroxy-olean-12-en-28-oic acid	Seed, flower, fruit	Kuljanabhagavad *et al.,*2008
Other Triterpenoids	α-Amyrin	Seed	Burnouf-Radosevich *et al.,* 1985
	β-Amyrin	Seed	Burnouf-Radosevich *et al.,* 1985
	Echinocystic acid	Seed	Burnouf-Radosevich *et al.,* 1985
	Erythrodiol	Seed	Burnouf-Radosevich *et al.,* 1985
	Queretaroic acid	Seed	Burnouf-Radosevich *et al.,* 1985
	Ursolic acid	Seed	Burnouf-Radosevich *et al.,* 1985
	Gramisterol	Seed	Burnouf-Radosevich *et al.,* 1985
	24-Methylene cycloartenol	Seed	Fanali *et al.,* 2015
	Citrostadienol	Seed	Fanali *et al.,* 2015
	Parkeol	Seed	Fanali *et al.,* 2015
Sesquiterpenoids	Caryophyllene	Seed	Dembitsky *et al.,* 2008
Monoterpenoids	Cis-Ascaridole	Leaf	Dembitsky *et al.,* 2008
	Cis-Isoascaridole	Leaf	Dembitsky *et al.,* 2008
	Camphor	Leaf	Dembitsky *et al.,* 2008
	Penstebioside	Leaf	Gomez-Caravaca *et al.,*2011
	Pinocarvone	Leaf	Dembitsky *et al.,* 2008
	α-Terpinene	Leaf	Dembitsky *et al.,* 2008
	γ-Terpinene	Leaf	Dembitsky *et al.,* 2008
	Terpin-1-ol	Leaf	Dembitsky *et al.,* 2008
Meroterpenoids	α-Tocopherol	Seed	Kozioł, 1992
	β-Tocopherol	Seed	Alvarez-Jubete *et al.,* 2010
	γ-Tocopherol	Seed	Kozioł, 1992
	δ-Tocopherol	Seed	Alvarez-Jubete *et al.,* 2010
	α-Tocotrienol	Seed	Tang *et al.,* 2015a

	β-Tocotrienol	Seed	Tang *et al.*, 2015a
Steroids	20-Hydroxyecdysone	Seed	Zhu *et al.*,2001
	20,26-Dihydroxyecdysone	Seed	Zhu *et al.*,2001
	20-Hydroxyecdysone 22-glycolate	Seed	Zhu *et al.*,2001
	Lathosterol	Seed	Fanali *et al.*, 2015
	Polypodine B	Seed	Kumpun *et al.*, 2011
	Cholesterol	Seed	Ahamed *et al.*, 1998
	Brassicasterol	Seed	Villacrés *et al.*, 2013
	Campestanol	Seed	Fanali *et al.*, 2015
	Campesterol	Seed	Fanali *et al.*, 2015
	Dacrysterone	Seed	Kumpun *et al.*, 2011
	Episterol	Seed	Fanali *et al.*, 2015
	Kancollosterone	Seed	Dini *et al.*, 2005
	Makisterone A	Seed	Zhu *et al.*,2001
	5β-Hydroxy-24(28)-dehydromakisterone A	Seed	Kumpun *et al.*, 2011
	24-Methyl-20,26-dihydroxyecdysone	Seed	Kumpun *et al.*, 2011
	Makisterone C	Seed	Kumpun *et al.*, 2011
	Sitostanol	Seed	Fanali *et al.*, 2015
	Stigmast-8-en-3-ol	Seed	Fanali *et al.*, 2015
	Stigmasterol	Seed	Fanali *et al.*, 2015
	Stigmast-4,22-dien-3-one	Seed	Villacrés *et al.*, 2013
	Stigmast-4-en-3-one	Seed	Villacrés *et al.*, 2013
	β-Sitosterol	Seed	Ahamed *et al.*, 1998
Flavonoids	Vitexin	Seed	Pasko *et al.*,2008
	Isorhamnetin	Leaf	Gawlik-Dziki *et al.*, 2013
	Kaempferol	Seed and leaf	Tang *et al.*, 2016
	Orientin	Seed	Pasko *et al.*,2008
	Kaempferol 3-glucoside	Seed	Tang *et al.*, 2015b
	Kaempferol 3-galactoside	Seed	Tang *et al.*, 2015b
	Kaempferol 3,7-dirhamnoside	Seed	Tang *et al.*, 2015b
	Morin	Seed	Pasko *et al.*,2008
	Myricetin	Seed	Repo-Carrasco *et al.*, 2010
	Quercetin	Leaf	Gawlik-Dziki *et al.*, 2013
	Quercetin-3-rutinoside	Seed	Tang *et al.*, 2015b
	Quercetin 3-arabinoside	Seed	Tang *et al.*, 2015b
	Rutin	Seed and leaf	Gawlik-Dziki *et al.*, 2013
	Hesperidin	Seed	Pasko *et al.*,2008
	Neohesperidin	Seed	Pasko *et al.*,2008
	Naringin	Seed	Tang *et al.*, 2015b
	Catechin	Seed	Tang *et al.*, 2016
	Epicatechin	Seed	Tang *et al.*, 2015b
	Epigallocatechin	Seed	Tang *et al.*, 2015b
	Biochanin A	Seed	Tang *et al.*, 2015b
	Prunetin	Seed	Tang *et al.*, 2016
	Puerarin	Seed	Tang *et al.*, 2015b

Nitrogen containing compounds	Amaranthin	Seed	Escribano *et al.,* 2017
	Betanin	Seed	Tang *et al.,* 2015b
	Isobetanin	Seed	Tang *et al.,* 2015b
	Dopaxanthin	Seed	Escribano *et al.,* 2017
	Indicaxanthin	Seed	Escribano *et al.,* 2017
	Miraxanthin V	Seed	Escribano *et al.,* 2017
	Betaine	Seed	Tang *et al.,* 2015b
	Trigonelline	Seed	Dini *et al.,* 2006

Pharmacological Activity Of Quinoa

Quinoa has a variety of bioactive substances in its many sections, including its roots, stems, leaves, and seeds. These compounds have been shown to have a number of beneficial biological effects, such as those shown in (Table-2), which include antioxidant, antimicrobial, antidiabetic, antifungal, anti-inflammatory, and anticancer effects. In addition, it has been reported that these compounds have anti-inflammatory effects. In the following sections, the pharmacological effects of quinoa have been examined in more in detail.

Antioxidant Effect

Quinoa has antioxidant properties that are higher than most cereals, suggesting that it could be used as a disease-prevention food (Filho *et al.,* 2017). In clinical studies, the most beneficial components of antioxidants and lowering of cholesterol levels were revealed to be proteins, fiber, vitamins, minerals, saponins, phytosterols, phytoecdysteroids, and phenolics (Farinazzi-Machado *et al.,* 2012). Quinoa's antioxidant capacity was demonstrated in vivo using quinoa extracts fermented with *Rhizopus oligosporus* (made with 80% methanol). A positive influence on increasing the activity of essential antioxidant enzymes was found (Matsuo, 2005). Chen *et al.,* (2017) investigated the antioxidant and immune modulatory properties of quinoa leaf extracts. The findings show that quinoa leaf extracts have antioxidant properties and that quinoa leaf extract has the potential to be used in natural health products. It has also been shown that quinoa contains antioxidant capabilities in mice that were given a high-fructose diet, which is known to produce oxidative metabolic stress (Paśko *et al.,* 2010). Similarly, Yao *et al.,* (2015) investigated the antioxidant and immune regulatory properties of quinoa polysaccharides. Quinoa polysaccharides (QWP) and alkali-extractable polysaccharides (QAP) were extracted, as well as their polysaccharide sub-fractions, QWP-1, QAP-1, and QAP-2, which were shown to have considerable antioxidant and immunological regulating activities. The gastrointestinal digestion of quinoa flavonoids resulted in a twofold increase in antioxidant capacity, as stated by Balakrishnan and Schneider (2020). This indicates that consuming quinoa directly may be sufficient to give a good antioxidant effect on the body. Furthermore, consuming quinoa led to an increase in the activity of antioxidant enzymes and antioxidant-related biomarkers in animal studies, such as a lower level of malondialdehyde (MDA) and a higher level of glutathione. This was shown by the fact that lipid peroxidation levels dropped (Mohamed *et al.,* 2019). Park *et al.,* (2017) investigated the antioxidant and antimicrobial properties of quinoa and discovered that quinoa extracts had excellent antioxidant abilities in both ferric reducing antioxidant power and 1-diphenyl-2-picrylhydrazyl values. They also found that quinoa had antimicrobial properties that inhibited the growth of certain bacteria. Total flavonoid content (TFC) and Antioxidant activity were also found to have a strong relationship. Also, Kaur and Tanvar, (2016) conducted research on the antioxidant properties of quinoa beverages made from quinoa flour. They found that beverages made from malt flour had higher levels of antioxidant and antidiabetic activity. Currently, many studies have suggested that phytochemicals, such as saponins and quinoa flavonoids, have strong antioxidant activity. The in vivo effects of these compounds are still not well known, and more in vivo research is needed.

Antimicrobial Effect

Quinoa leaves and seeds are rich in second-active metabolites like polyphenols and tannins, which have a wide range of physiological properties, including antimicrobial properties (Soheilikhah and Sharifi, 2021). According to Miranda *et al.,* (2014) quinoa seeds, obtained from six different seeds and grown in various parts of Chile, have an antimicrobial effect, which is associated with the plant's phenolic compounds and leads to a reduction in *E. coli* and *Staphylococcus aureus* growth. Khan and Javaid, (2019) investigated the antibacterial, antifungal, and antioxidant properties of quinoa stem ethyl acetate extract. The GC-MS analysis of the ethyl acetate fraction of methanolic stem extract revealed 13 compounds, 11 of which were antibacterial, antifungal, and antioxidant. The foremost phytochemical component was mono (2-ethylhexyl) ester of 1, 2-benzenedicarboxylic acid. This compound, which was discovered in the n-hexane extract of *Turbinaria ornata* and possesses antimicrobial properties against *Bacillus subtilis, Escherichia coli, Aspergillus niger*, and *Pseudomonas aeruginosa*, was previously identified (Deepak *et al.,* 2017). In addition, Bhaduri *et al.,* (2016) found that quinoa seed extracts from all six solvents i.e. hexane, acetone, methanol, ethanol, ethyl acetate, and water, had antimicrobial activity against the Gram-positive bacteria such as *Enterococcus faecalis* and *Staphylococcus epidermidis*. Methanol, ethyl acetate, and water extracts all had significant antimicrobial activity against *E. coli*. Also, Pompeu *et al.,* (2015) isolated a novallectin from quinoa crude extract after two Sephadex G50 and Mono Q purification steps. This lectin was tested for antimicrobial activity against a variety of bacteria strains and effectively inhibited *E. coli*, *Pseudomonas aeruginosa, Salmonella enterica* gram-negative bacteria. In addition, research conducted by Sun *et al.,* (2019) investigated the efficacy of alkali-transformed saponin derived from quinoa husks as an antibacterial agent against the bacteria that are responsible for halitosis. In tests designed to detect the presence of bacteria, both quinoa saponin (QS-80) and alkali-transformed saponin (ATS-80) demonstrated inhibitory efficacy. Although it had a lower minimum inhibitory concentration (31.3 g/mL) and a lower minimum bactericidal concentration (125 g/mL), ATS-80 was able to inhibit a greater number of bacteria than QS-80, most notably *Fusobacterium nucleatum*. This was the case despite the fact that both concentrations were lower. The structure of the bacterial membrane was compromised after being exposed to ATS-80, which led to the death of the bacteria.

Antidiabetic Effect

Quinoa is high in phenolic acids, tocopherols, protein, fibre, 20HE, and bioactive peptides, all of which may contribute to its Antidiabetic properties (Cisneros-Yupanqui *et al.,* 2020). Quinoa consumption reduces BMI and HbA1c levels and also helps patients with prediabetes maintain their blood glucose levels and improve their health (Abellan Ruiz *et al.,* 2017). Graf *et al.,* (2014) studied phytoecdysteroids and other Antidiabetic compounds leach from quinoa seeds. To optimize leaching efficiency, a 70% ethanol concentration, an 80°C temperature, a 4 hour time period, and a solvent ratio of 5 ml/g seed were used. The optimized quinoa leachate with 0.86% 20-hydroxyecdysone, 1.00% total phytoechydsteroids, 2.59% flavonoid glycosides, 11.9% oil, and 20.4% protein significantly reduced fasting blood glucose in obese hyperglycemic mice. According to the study Li *et al.,* (2018) conducted on patients with cardiovascular disease, fat and glucose levels were examined after using quinoa-rich bread and revealed that patients' blood glucose levels were lower than in the control group. In addition, Hanan *et al.,* (2019) studied the antioxidant activity of quinoa seed powder and its effect on diabetic rats. After consuming quinoa in various concentrations, blood and glucose levels were reduced. Thyroid hormones T3 and T4 were significantly reduced after rats were fed different concentrations of quinoa seed powder. Furthermore, Hemalatha *et al.,* (2016) investigated the enzyme inhibitory effects of quinoa extract on α-amylase and α-glucosidase. They discovered that quinoa extract inhibited α-amylase with an IC50 value of (163.52 2.5 g/ml, for whole grain), which was significantly higher than acarbose (IC50 = 7.21 0.4 g/ml). It was also discovered that the inhibition of beta-glucosidase was greater than that of beta-amylase, which is an outcome that should be desired.

Anti-inflammatory Effect

Quinoa seed contains bioactive components such as phenolic compounds, polysaccharides, and saponins that are linked to several biological activities i.e. anti-inflammatory, anticancer, and antioxidant activities (Al-Qabba *et al.,* 2020). According to the research undertaken by Khan *et al.* (2020), the ethyl acetate fraction of the methanolic extract of quinoa inflorescence contains phytochemicals with anti-inflammatory, antimicrobial, antifungal, antibacterial, cancer preventative, and cytotoxic effects. The substances that were found the most often were the 1, 2-benzedicarboxylic acid, diisooctyl ester; the 12- octadecadienoic acid and the 11- octadecadienoic acid, methyl ester. Leaf, root, and stem extracts of *Cenchrus biflorus* were analyzed, and the chemical 12-octadecadienoic acid (Z, Z) was shown to possess powerful anti-inflammatory, antibacterial, insecticide, and anticoronary activities (Arora *et al.,* 2018). Similar research was conducted by Khan *et al.,* (2020) who used GC-MS to investigate the bioactive components of the ethyl acetate fraction of the methanolic root extract of quinoa. There were nine constituents found in the ethyl acetate fraction of the quinoa methanolic root extract. These constituents included 1, 2-benzedicarboxylic acid, diisooctyl ester, ascorbic acid, 2, 6-dihexadecanoate, octadec-9-enoic acid, 10-nonadecanone, and 1-triacontanol. These constituents possessed anti-inflammatory.

Antifungal Effect

Quinoa saponins have antifungal activity because of their ability to associate with steroids in fungal membranes, which disrupts the integrity of the membranes and causes pore formation (Armah *et al.,* 1999). Woldemichael and Wink, (2001) found that five quinoa saponins (oleanolic acid glycosides and hederagenin) have antifungal activity against *Candida albicans.* Stuardo and San Martn, (2008) found that alkali-treated quinoa saponin had higher antifungal activity against *Botrytis cinerea.* When saponin extracts were treated with alkali, mycelial growth and conidial germination were significantly reduced, and conidial germination inhibition was observed at doses of 5 mg saponins/ml after 96 hours of incubation. Further, Khan *et al.,* (2022) investigated the antifungal potential of a polar solvent soluble fraction of quinoa methanolic stem extract against *Macrophomina phaseolina*. In vitro bioassays showed that a concentration of 25 mg mL-1 of the n-butanol fraction in malt extract broth is sufficient to control fungal growth completely. GC-MS analysis revealed 9 volatile compounds, including stigmasterol and 1, 2-benzedicarboxylic acid, diisooctyl ester, which were reported to have antifungal properties against a variety of fungal species, suggesting that they may be responsible for the control of *M. phaseolina.* Similarly, Khan *et al.,* (2022) found several bioactive constituents in the non-polar n-hexane fraction of quinoa methanolic leaf extract. GC-MS analysis showed 15 constituents, among which 9, 12-octadecadien-1-ol, 1-(+)-ascorbic acid, 2, 6-dihexadecanoate and 9, 12, 15-octadecatrienoic acid methyl ester were found in abundance. These compounds showed antifungal, antibacterial, antioxidant, anticancer, anti-inflammatory and other properties. Compound 2, 6-dihexadecanoate is a fatty alcohol which has high antifungal activity (Kalsum *et al.,* 2016).

Antilipidemic Effect

Pseudocereal-rich diets have been linked to hypocholesterolemic, antioxidant, and antitumor effects, as well as lower blood glucose levels and improved hypertension and anemia (Giménez-Bastida *et al.,* 2016). Quinoa's effect on lowering hyperlipidemia among overweight menopausal women was investigated in a prospective study. Quinoa consumption reduced TG, LDL, and serum cholesterol levels in the women (De Carvalho *et al.,* 2014). Farinazzi *et al.,* (2012) studied the effects of dietary quinoa on cardiovascular risk in twenty-two 18–45-year-old students after 30 days of consumption. Blood pressure and body weight were observed to be lower in the participants. Meneguetti *et al.,* (2011) investigated the physical and chemical analysis of quinoa seeds. The blood cholesterol and triglyceride levels of male Wistar rats were measured after 30 days after they were given plant extracts. The use of quinoa extract resulted in a decrease in blood lipids. According to prospective and double-blind intervention studies, consuming 25 g of quinoa flakes daily for a period of four weeks resulted in a reduction in serum levels of triglycerides, total cholesterol, and LDL cholesterol in overweight women (De Carvalho *et al.,* 2014). In addition, Foucault *et al.,* (2014) revealed that feeding quinoa to mice increased energy expenditure and favoured glucose oxidative metabolism, inhibiting lipogenesis and reducing fat accumulation in adipose tissue. Also, Zevallos *et al.,* (2014) used quinoa as a safety test for celiac patients and found improvements in gastrointestinal parameters as well as minor reductions in total cholesterol, LDL, HDL, and triglyceride levels after 6 weeks of daily consumption of 50 g quinoa. Furthermore, In a study conducted by Pasko *et al.,* (2010) on male Wistar rats fed a fructose-enriched diet, quinoa seeds were found to lower serum levels of total cholesterol, LDL cholesterol, triglyceride cholesterol, and glucose.

Antitumor Effect

Quinoa seeds and leaves are high in polyphenolic compounds, saponin, betalain, carotenoids, and flavonoids, which are natural antioxidants with anticancer properties (Pellegrini *et al.,* 2017). Some other studies have found that quinoa polysaccharide, bioactive peptides, and phytoecdysteroids have anticancer properties (Hu *et al.,* 2017). Quinoa has been shown to have antitumor properties in a few studies. An in vitro study found that quinoa seeds have a promising cytotoxic effect against the liver cancer cell line HepG2, with an IC50 value of 14.6 μg/ml (Mohamed *et al.,* 2019). Besides, an in vitro study investigated the cytotoxic activity of pseudocereal seeds against human cervical carcinoma cell lines (C4-I, HTB-35, and HTB-34). Quinoa was shown to be the most effective (Pasko *et al.,* 2019). Quinoa contains phytoconstituents such as Benzaldehyde, 4-hydroxy-, and 1H-Indole-3-carboxaldehyde, which have anticancer, antimicrobial, antiacetylcholisterenase, and cytotoxic properties (Kumar *et al.,* 2018; khan *et al.,* 2020). In addition, Gawlik *et al.,* (2013) isolated the phenolic compounds from quinoa leaves and exposed them to MAT-LyLu and AT-2 rat cancer cells and showed that the phenolic chemicals helpful in the fight against cancer as well as other diseases that are linked to oxidative stress. Quinoa's antitumor effect in living organisms needs to be studied further.

Table 2: Biological activities or function of some chemical constituents present in *C. quinoa*.

Name of compound	**Part of plant**	**Bioactivity**	**References**
Betaine, choline	Seeds	Anti-obesity, anti-diabetes, and prevent cardiovascular disease	Olthof and Verhoef, 2005
20-Hydroxyecdysone	Seeds	Anti-diabetic and anti-obesity	Foucault *et al.*, 2011
1,2-Benzedicarboxylic acid	Inflorescence	Anti-bacterial, antioxidant, and anti-microbial	Devi *et al.*, 2014
9,12-Octadecadienoic acid (Z,Z)	Inflorescence	Antifungal, nematicide, anti-inflammatory, anti-coronary, antieczemic, insecticide, antioxidant, cancer preventive, and anti-histaminic	Arora *et al.*, 2018
8,11-Octadecadienoic acid, methyl ester	Inflorescence	Antibacterial, antioxidant, and cancer-preventive	Kianinia *et al.*, 2018
Undecane	Root	Anti-bacterial and anti-fungal	Jeong-Ho *et al.*, 2008
Cis-9-hexadecenal	Root	Antimicrobial and antioxidant	Qadir *et al.*,2018
1-Triacontanol	Root	Anti-inflammatory, antiviral and plant growth stimulator	Verma and Batra, 2013
n-Hexadecanoic acid	Inflorescence	Bactericide, antioxidant, antimicrobial, anti-inflammatory, and anti-androgenic	Vats *et al.*,2017
Octadec-9-enoic acid	Root	Cardio protective, reduces blood level of cholesterol, and cancer preventive	Dubal *et al.*, 2013
Sinapinic, gallic acids, kaempferol	Leaves	Anti-cancer and anti-oxidant	Gawlik-Dziki *et al.*, 2013
Oleanolic acid glycosides and hederagenin	Seed and leaves	Antifungal	Woldemichael and Wink, 2001
Stigmasterol, diisooctyl ester	Stem	Antifungal (against *M. phaseolina*)	Khan *et al.*, 2022
1-(+)-ascorbic acid, 2,6-dihexadecanoate and 9,12,15-octadecatrienoic acid methyl ester	Leaves	Antifungal, antibacterial, antioxidant, anticancer, and anti-inflammatory	Khan *et al.*, 2022
Chlorogenic acid	Seeds and leaves	Antimicrobial, anti-diabetic, and anti-obesity	Tang *et al.*, 2016, Tsou *et al.*,2000
Ferulic acid	Seeds and leaves	Antimicrobial activity, anti-inflammatory, anti-cancer, and cholesterol-lowering activity	Tsou *et al.*,2000, Sakai *et al.*,1999
Protocatechuic acid	Seed	Anticancer activity, anti-inflammatory, hyperlipidemic, and analgesic	Tang *et al.*, 2016, Kakkar *et al.*, 2014

Syringic acid	Seed and leaves	Antioxidant and antimicrobial	Ti *et al.*, 2014
Saponins, tannins, and flavonol glycosides	Seeds	Analgesic, antiviral, anti-inflammatory, anti-allergic, antimicrobial, antioxidant, immune-boosting, and anticarcinogenic	Shi *et al.*, 2004, Güçlü *et al.*, 2007, Jarvis *et al.*, 2017
Myricetin	Seeds	Anti-inflammatory and analgesic activity	Wang *et al.*, 2010
Quercetin	Seeds and leaves	Antioxidant and anti-inflammatory	Fukumoto *et al.*, 2000
Gramisterol	Seeds	Anti-cancer	Fanali *et al.*, 2015
α-Tocopherol, β-Tocopherol, γ-Tocopherol, δ-Tocopherol	Seeds	Antioxidant and anticancer	Sookwong *et al.*, 2009 Kozioł, 1992
α-Tocotrienol, β-Tocotrienol	Seeds	Antioxidant and anti-inflammatory	Ahsan *et al.*, 2014 Tang *et al.*, 2015b
β-Sitosterol	Seeds	Anti-inflammatory, anti-oxidant, and antidiabetic	Ahamed *et al.*, 1998
Amaranthin, Betanin, Isobetanin	Seeds	Anti-inflammatory and anti-oxidant	Tang *et al.*, 2015b Escribano *et al.*, 2017, Esatbeyoglu *et al.*, 2014
Vitexin	Seeds	Anti-viral effect	Knipping *et al.*, 2012
γ-Terpinene	Leaves	Anti-bacterial activity	Yoshitomi *et al.*, 2016
Mono(2-ethylhexyl) ester of 1,2-benzenedicarboxylic acid	Stem	Antimicrobial (against *Bacillus subtilis*, *Escherichia coli*)	Deepak *et al.*, 2017
Methanol, ethyl acetate	Seeds	Antimicrobial activity (against Gram-positive bacteria)	Bhaduri *et al.*, 2016
Benzaldehyde, 4-hydroxy-, and 1H-Indole-3-carboxaldehyde	Seeds	Anti-cancer, anti-microbial, and anti-acetylcholisterenase	Kumar *et al.*, 2018, khan *et al.*, 2020

CONCLUSION

This review reveals that the quinoa has remarkable ethno and pharmacological properties. In all quinoa parts, the presence of stigmasterol, kaempferol, betacyanins, betaxanthins, diisooctyl ester, 20-Hydroxyecdysone (20HE), 1,2-benzenedicarboxylic acid, benzaldehyde, 4-hydroxy, 2,6-dihexadecanoate, and 4-hydroxybenzoic clarifies the majority of the biological effects. The plant is mostly used to treat diabetes, cancer, obesity, allergies, inflammations, fungal infections, and inflammatory, celiac, and cardiovascular diseases. Therefore, quinoa has the potential to benefit the world by providing the best nutrition and medicine to the millions of health impaired people. Today quinoa is a source of a number of drugs for the majority of the world's population. Therefore, it remains a challenge for researchers to provide effective, low-cost medications for that we need more research work. However, the available studies on quinoa's medical benefits are still limited. Quinoa medicinal and pharmacological studies should be further investigated.

CONFLICT OF INTEREST

There is no conflict of interest.

AUTHOR CONTRIBUTION

Conceptualization by YK, SS write the manuscript. Revised by HY.

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