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Phytochemistry of *Allium cepa L.* (Onion): An Overview of Its Nutritional and Pharmacological Importance

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Abstract

The present study was conducted to review the phytochemical composition, as well as nutritional and pharmacological values of Allium cepa L. (Onion). Onion is cultivated all over the world. Onion bulbs are composed of polysaccharides such as peptides, fructans, flavonoids (mostly quercetin), saccharose and organosulfur compounds having salutary effects on human health. Onion is beneficial for human health since it has a high nutritional value. The nutritional constituents of an onion bulb are crude oil, vitamin E, sodium, potassium, and zinc. The onion bulb has the potential to reduce diseases such as stomach cancer, osteoporosis, and brain cancer in human beings. Additionally, onion is antidiabetic, anti-inflammatory, anti-scar, antispasmodic, antiseptic, anti-genotoxic, anti-mutagenic, diuretic, anti-parasitic, antimicrobial, antipyretic, and analgesic.

Keywords: Allium cepa L., disease treatment, nutrients, onion, phytochemicals

Introduction

Onion is cultivated commercially almost everywhere in the world [1]. Out of the fifteen vegetables reported by Food & Agriculture Organization of United Nations (FAO), onion falls second to tomato in terms of total annual world production [2]. It is an agricultural crop having short growing periods, [3] it requires cold temperature and high moisture content [4]. Onion is used throughout the year in medicines, salads and is cooked with many vegetables. It is also used in the production of various types of processed foods such as pickles. Onions have been used for several purposes since the Neolithic period [5]. China and India are the first and second largest

producers of onions, respectively. The United States harvests about 125,000 acres, producing 6.75 billion pounds each year. The four largest onion producing regions of United States are Washington, Idaho-Eastern Oregon, California, and West-Central Oregon. In Pakistan, onion is commercially grown on 131.4 thousand hectares and the annual production is around 1.8 million tones. The top ten onion producing districts of Pakistan are Chaghi, Hyderabad, Sanghar, Swat, Kharan, Kalat, Mirpurkhas, Nawabshah, Nasirabad, and Dir, which contribute to more than 59% of the total production [6].

Onion was reported to be grown during the rainy seasons in the river Afram basin of the Eastern region of Ghana because irrigation water and rainfall was easily available in that area. However, onion was mainly grown after mid-June to mid-July due to the prevalence of onion thrips and fungal diseases. About 94.6% of the farmers grew Malavi (a local onion cultivar) only, which was susceptible to the onion thrips as well as basal fusarium rot [7]. The onion plant has more than 780 morphologically described species with great diversity. Onion's chromosome number is 16 (2n). It (*Allium cepa L.*) belongs to genus Allium, order Liliaceae, subclass Liliales, division Liliopodia, super division Spermatophyta, subkingdom Tracheobionta, and kingdom Plantae [8]. According to FAO reports based on the 2000-2004 average production, China is the world's leading producer of onion (contributing 31.43 percent to the total production). Other eight major onion producing countries are India (10.22%), Turkey (3.83%), Pakistan (2.97%), Russia (2.84%), Iran (2.80%), Japan (2.35%), Brazil (2.22%), and Spain (1.95%) [9-12].

Keeping in view the great nutritional and medicinal value of this plant, this paper overviews phytochemical composition, nutritional, and pharmacological value of onion.

2. Phytochemical Composition

Onion is an important source of nutritional contents such as flavonoids. It is especially rich in three important phytochemicals, namely flavonoids, organosulfur compounds, and fructans. Such substances are known for their positive health benefits. Onions are the main suppliers of flavonoids and organosulfur compounds which are potent antioxidants. If we look into the

parameters that contribute antioxidant properties to onions, we can see a decline in the range of ascorbic acid. Its concentration currently ranges from 1.18 to 3.89 mg/100 g of fresh weight (FW).

In the wild onion varieties, ascorbic acid content was identified to be usually between 5.0 and 10.0 mg/100 g fresh weight (FW) [13]. Organosulfur constituents of onions are mainly comprised of four diallyl sulfides: diallyltetrasulfide (DTTS), diallylmonosulfide (DMS), diallyltrisulfide (DTS) and diallyldisulfide (DDS). Di- and tri- sulfides were the principal compounds extracted by steam distillation of volatile fraction of onion. The primary sulfur-containing components in onions are salk(en)yl-L-cysteine sulfoxides (ACSOs) such as alliin, they act as biosynthetic intermediates for ACSOs and also act as storage peptides. Volatile compounds including allicin and lipid-soluble sulfur compounds such as diallyl disulfide (DADS) and diallyl sulfide (DAS) originate from different metabolic pathways in the vegetables [14]. The unique smell and taste of onion oil is due to the presence of these compounds [15]. In addition to these sulfur containing compounds and flavonoids, there are several other ingredients found in onions such as lectins (highly abundant), prostaglandins, pectin, fructan, adenosine, biotin, phospholipids, fatty acids, glycolipids, nicotinic acid and vitamins B1, B2, B6, C and E. Its biological effects have been a focus of study for a number of decades [16]. Other than the above mentioned constituents, the presence of some steroidal sapogenins and saponins has also been reported in onions. These components play an important role in pharmacological and biological activities and have antibacterial, antithrombotic, anti-inflammatory, antitumor, antifungal and hypocholesterolemic properties [16]. The presence of volatile S-compounds causes onions to have a pungent flavor. Onions are known as an excellent source of flavonoids which are the part of Flavonols family of polyphenols. The flavonoid subclass which includes quercetin (Figure 1) is considered a leading and prominent nutritional flavonoid of onions. Other flavonols such as quercetin, isorhamnetin, and kaempferol were also found in onions [15, 17, 18]. The secondary metabolites (phenolics) present in onions have an antioxidant effect and cause aromatic hydroxylated rings [19]. The phenolics are important antioxidant contents of plants [20].

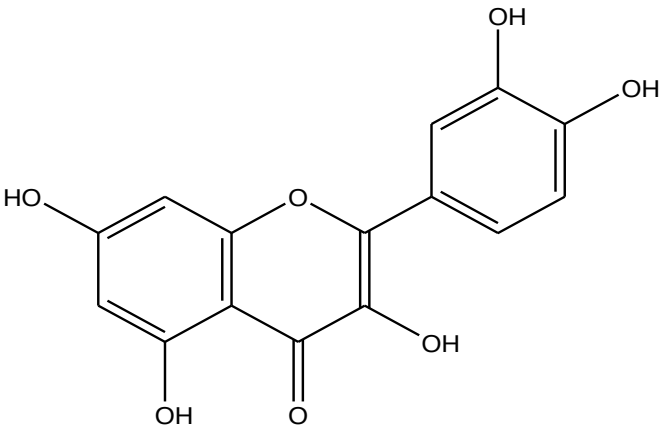

Figure 1. Structure of quercetin [15]

The other sources of phytochemicals in onion bulbs are the fructans. The fructans mainly contain fructooligosaccharides such as nystose, inulin, fructofuranosylnystose and kestose. The health benefits of these carbohydrates have been recorded extensively in the recent years because of their prebiotic effect [21].

It has been reported that onion samples exhibit the presence of 10 various organic acids (Table 1). The results were in agreement with those found in cvs Recas of industrial onions [22].

Table 1. Ten Organic Acids Identified in Onion

No	Acid	Quantity	No	Acid	Quantity
1	Myristic acid	0.004 g	6	Linoleic acid	0.013g
2	Palmitic acid	0.034 g	7	Linolenic acid	0.004 g
3	Stearic acid	0.004 g	8	Monounsaturated acids	0.013 g
4	Saturated acids	0.043 g	9	Polyunsaturated acids	0.017 g
5	Oleic acid	0.013 g	10	Glutamic acid	0.258 g

A study analyzed onion landraces for their unique composition of phenols. The most abundant phenol found in all landraces was gallic acid, its amount varies in Febbrarese and Giugnese from 55.66 to 64.90µg/g DW/, respectively. From a nutritional standpoint, quercetin has an important role among identified phenols. Quercetin is the aglycone

component of many other flavonoid glycosides such as quercitrin and rutin. They are present in citrus fruits, buckwheat, and onions [23], and are bases of proteins and sugars. The fructo-oligosaccharides, fructose, sucrose and glucose are the principal non-structural sugars in onion bulb tissue. Onions bulbs contain remarkable mineral composition, particularly potassium and phosphorus [24, 25]. The richest minerals found in the 'Red Amposta' are phosphorus (107.33 mg/100g DW), potassium (136.82 mg/100g DW), soluble protein (3.78%), water (86%), sodium (9.11 mg/100g DW), magnesium (3.17 mg/100g DW), calcium (60.47 mg/100g DW), and soluble sugar (4.72%) [26].

3. Nutritional Value

In fact, onion plants have many health benefits due to their nutritious content. Crude fiber in food products is being increasingly recognized as a useful agent for controlling oxidative processes and as a functional ingredient in food. Additionally, crude fiber in diet is required for digestion and waste disposal [27]. Fiber causes the muscle walls of the digestive tract to contract, which counteracts constipation [28].

A. cepa. L have high moisture content. Its varieties are susceptible to deterioration and need to be protected from environmental hazards. For this reason, they are susceptible to microorganism infection. Due to high moisture content in raw vegetables, the water required for their digestion is minimal. This ensures faster digestion, less pressure on the digestive system, and better assimilation. [29].

Examination of the composition of the mineral elements found in onions revealed that calcium and iron are essential for bone development and hemoglobin production, respectively. In addition to this, many important health benefits are associated with onion when it is consumed raw in salads. Onions are very significant in the food industry due to its rich nutritional contents. However, further investigations must be conducted to find ways to preserve valuable nutritional contents (for human health) of processed onions by the use of appropriate technologies**.**[30]. In both varieties of onions (*Allium cepa L.)*, sodium was found to be substantially lower than potassium. It has been stated that a low sodium diet is helpful in the prevention of high blood pressure, while high potassium protects against the

effects of excessive intake of sodium. Zinc, a constituent of onions, plays a significant role in maintaining the appropriate functioning of nucleic acid metabolism and reproductive system [31].

Onion bulbs are enriched with vitamin C, dietary fiber and folic acid. Anti-oxidant compounds present in onions help fight inflammation. They are enriched with high soluble fibers called fructans. Onions contains low quantity of calcium, iron, folate, magnesium, phosphorus and potassium. These minerals have significant effect on human health [32]. Raw onions contain 9-10% carbohydrates in the form of glucose fructose [33]. Fibers comprise 0.9-2.6% of the total weight of onion. Fructan fibers present in the onion help feed friendly bacteria in the gut [34]. They contain small amount of protein (less than 1 gram).

3.1. Vitamins and Minerals

Onions contain many vitamins and minerals. They are a rich source of vitamin C, vitamin B, particularly B6. Vitamin C helps in maintaining immune functions, and is necessary for healthy skin and hairs. Vitamin B is necessary for growth and metabolic activities, especially during pregnancy. Vitamin B6 helps in the formation of RBCs. Onions also contain minerals such as potassium and calcium. These minerals are required for proper functioning of the heart since they lower blood pressure**.** Calcium is also present in onions and helps to strengthen bones [35].

According to the recommended daily allowance (RDA) and adequate intake (AI) values, the required intake percentage of vitamin C for male is13.11% and 15.73% for females. Vitamin B-6 is required 11 to 15% (depending on age). The required intake percentage of manganese is 9% for males and 11.5% for females. Onions have different varieties in different regions of the world. They vary contents in terms of contents such as vitamins, carbs, and fibers present [36].

4. Pharmaceutical Importance

Onions are rich in many nutritional and pharmaceutical ingredients which are used to treat a large number of diseases (Figure 1). Onions can be used in raw form, juice, poultice, powder, liquid extract, syrup and capsules (Table 2).

Table 2. Medicinal Applications of Onion

Benefit	Action	Component responsible
Anti-inflammatory agents	Reduces the swelling, pain and symptoms associated with severity of inflammation.	vitamin C and quercetin
Heart issues	Reduces heart disease risk.	vitamin B6
Diabetes	Reduces the fasting blood glucose levels.	allyl propyl disulfide and chromium
Osteoporosis	Inhibits the osteoclasts.	gamma-L-glutamyl-trans-S-1-propenyl-L-cysteine sulfoxide (GPCS)

4.1. Antioxidant Effect

This is the most well-studied and defined onion flavonoid action since it protects cells and tissues from reactive oxygen species (ROS). ROS generates free radicals, which destroy cells in various organs exogenously [37-39]. Flavonoids like kaempferol and quercetin have also been shown to stabilize free electrons generated by ROS *in vitro* [40, 41]. The flavonoid hydroxyl structure contributes hydrogen and an electron to peroxyl and hydroxyl to stabilize it, which helps to scavenge ROS [42]. Flavonoids' heterocycles initiate conjugation between a free 3-hydroxyl and aromatic bands resulting in antioxidant activity [43]. A study reported that flavonoid aglycones are more potent antiperoxidative rather than their corresponding glycosides[44]. The antioxidant function of quercetin and its dimerized derivatives is similar to that of tocopherol. As a result, the onion's outer layer is assumed to be a source of nutritional constituents [45]. Flavonoids also have metal chelating properties, which prevent the formation of free radicals [46]. Iron stabilization and iron chelation are properties of quercetin [47]. Kaempferol is a powerful antioxidant since its high concentration promotes the synthesis of antioxidant enzymes such as superoxide dismutase, catalase, and others. It also inhibits atherosclerosis by preventing the oxidation of low-density lipid protein (LDLP) [48].

4.2. Anti-diabetic

Onions are used for treating diabetes and its complications [49]. In Zucker diabetic fatty (ZDF) rats, onions have an anti-obesity effect. The use of raw red onions on a regular basis dissolves fat and helps obese women lose weight [50]. Type 2 diabetes and other lifestyle conditions are also treated with onion soup [51]. The extract recovers the α-glucosidase function of the intestines, regulates spikes in the postprandial blood glucose levels in Sprague Dawley (SD) rat models, and protects mice from diabetic neuropathy. In diabetic rats, it increases hyperglycemia and insulin resistance caused by a high-fat diet and streptozotocin. The *A. Cepa* (red onion) exhibits hypoglycemic symptoms in Types 1 and 2 diabetic patients [52]. In the high fat diet streptozotocin diabetes rodent model, dietary *A. Cepa* bulbs showed anti-diabetic properties [53]. The onion is a healthy medicinal plant that is used to treat diabetes patients. All anti-diabetic ingredients, including onions, can be used to treat diabetes mellitus [53]. In alloxane induced diabetic rats, *A. Cepa* has hypoglycemic impact. Additionally, onions have an antihyperglycemic effect and reduces metabolic defects in rats with streptozotocin induced diabetes [54].

4.3. Wound Healing and Anti-scar

Onion is widely used in the preparation of ayurvedic wound healing medicine [55]. This also indicates its biological efficacy in preventing infection of median sternotomy wounds in pediatric patients [56]. Onion extract has a beneficial health effect on human skin fibroblast cell line and is used to treat keloids. Onion peel abstract show biological efficiency for hypertrophic scar prevention and keloid. Onion extract gel also demonstrates hypertrophic parasternal scar defense [57]. This is also used as topical medication and prevents postoperative hypertrophic wounds after keloid surgery [58]. Likewise, *A. Cepa*-allantoin in pentaglycan gel is used to treat hypertrophic skin wounds and to enhance the cosmetic appearance of postoperative scars and burn scars [59].

4.4. Anticancer Activity

Organosulfur compounds produced by onions (*A. Cepa*) inhibit the proliferation of six different tumor cells [60]. Allium contains the flavonoid quercetin which has been shown to have anticancer properties. It has the

ability to stop the development of various cancer cells. The consumption of allium vegetables, especially garlic, is linked to a lower risk of prostate cancer [61].

4.5. Anti-genotoxic and Anti-mutagenic Effects

By inhibiting FAS, onions (*A. Cepa* L.) have inhibitory effects on cancer cells and adipocyte proliferation [62]. Allium vegetables inhibit the proliferation of MCF-7 breast cancer cells and reduce the risk of prostate cancer [53]. Onions (*A. Cepa)* displays anti-mutagenic and antigenotoxic activity against carcinoma in the gut. Zidovudine or nevirapine causes cytogenotoxic changes in *A. cepa* root cells [63]. Onions contain flavonoid quercetin, which has anticancer properties at particular sites. Isolated polyphenols from onions (*A. Cepa)* induce apoptosis in human leukaemia cells by inhibiting PI3K/Akt signaling pathways and suppressing apoptosis protein-1 inhibitors [64].

4.6. Antimicrobial

Green extract of onion dissolved in ozonated water inactivates the typhimurium Salmonella enterica. It also inactivates internalized and infected enteric viruses on the surface [65] and prevents the development of gram-positive and gram-negative bacteria *in vitro* [66]. Internalized S. Typhimurium is inactivated with radiated UV-C and chemical sanitizers using green onions [67]. To decontaminate *Escherichia coli* O157:H7 water, green onions, pulsed light (PL), and PL-surfactant-sanitizer are used. In one study, red and white cepa displayed chemical differences from each other and showed good antimicrobial and antioxidant activity [68].

4.7. Antiparasitic

Onion oil was found to be successful against Schistosoma mansoni cryptosporidium parvum infection in mice in an experiment [69]. Onion (*A. Cepa)* oil has been shown to be extremely effective in the treatment of worm infections. Onions are also successful against dealing with eelworms (Ditylenchusdipsaci), a small soothing parasitic nematode that causes swollen, twisted leaves [70].

4.8. Antihyperlipidemic

Onion derivative sulfur compounds, such as S-methyl cysteine sulfoxide and allylpropyl disulfide [71], exhibited hypolipidemic effect. These

compounds have been found to reduce the effects of diet induced atherosclerosis, maintain hypolipidemic action, and inhibit platelet production in rats and rabbits. These compounds are found in abundance in raw onion, which has antithrombotic effects [63].

4.9. Analgesic

Onions are used as antidepressants [72] since they suppress the synthesis of the lachrymatory factor synthase (LFS). In a rat as a depression model, onion powder has an antidepressant like effect. Fresh onion juice can reduce pain and inflammation in both acute and chronic conditions since it has a stronger anti-inflammatory effect [73].

4.10. Antipyretic

A. Hepatotoxicity is caused by cepa-liquid bulb extract on paracetamol and carbon tetrachloride [74]. Usage of alliums reduces genotoxicity caused by series of synthetic pharmaceutical compounds. It also decreases toxicity, genotoxicity, and cytotoxicity of metamizole sodium and acetylsalicylic acid [75].

5. Conclusions

Onion bulbs are a rich source of many important polysaccharides, flavonoids, and organosulfurs. Other than these macronutrients, onion provides many micronutrients such as vitamin E and several minerals including potassium, zinc, and sodium. Many studies have reported the nutritional, pharmaceutical and medicinal value of onion in the field of phytomedicine. Its anticancer, anti-inflammatory, antigenotoxic, antidiabetic, antioxidant, wound, and scar healing properties are well documented in existing literature. The review of existing literature revealed that studies have been conducted on different parts of *A. cepa*. Moreover, the extracts of onions and the experimental conditions in which they were prepared also varied in different studies. For this reason, the reported phytochemical constituents and the properties may vary greatly. These differences should be accounted for while considering *A. cepa* as a potential candidate for pharmaceutical interventions.

Conflict of Interest

The authors declare no conflict of interest.

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