Azene et al.
Food Production, Processing and Nutrition (2022) 4:33
https://doi.org/10.1186/s43014-022-00114-z

Food Production, Processing and Nutrition

REVIEW

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Nutritional, health benefits and toxicity of underutilized garden cress seeds and its functional food products: a review

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Abstract

Garden cress seed is a potential source of macro and micronutrients including essential fatty acids and amino acids as well as minerals such as iron, potassium, calcium and phosphorus. The seed also provides appreciable amount of health-protective bioactive compounds used to treat diabetes, hypercholesterolemia, bone fracture, asthma, constipation and some forms of cancer. Besides,, it is used to develop functional foods of therapeutic value in food manufacturing industries and traditional food preparations. Even though, it is known for its superior health benefits, provision of essential nutrients, and wider application in functional food development it is among the most underutilized crop in the world. Additionally, majority of studies conducted on garden cress seeds are mainly animal trials and hence needs to conduct studies on human. Therefore, the aim of this review paper is to provide up to date research evidence on the nutrient composition and therapeutic use of underutilized garden cress seeds and its functional food products, promising for the prevention of non-communicable and communicable diseases.

Keywords: Garden cress seeds, *Lepidium sativum L.*, Underutilized, Phytochemicals, Therapeutic value, Chronic and infectious disease, Functional foods

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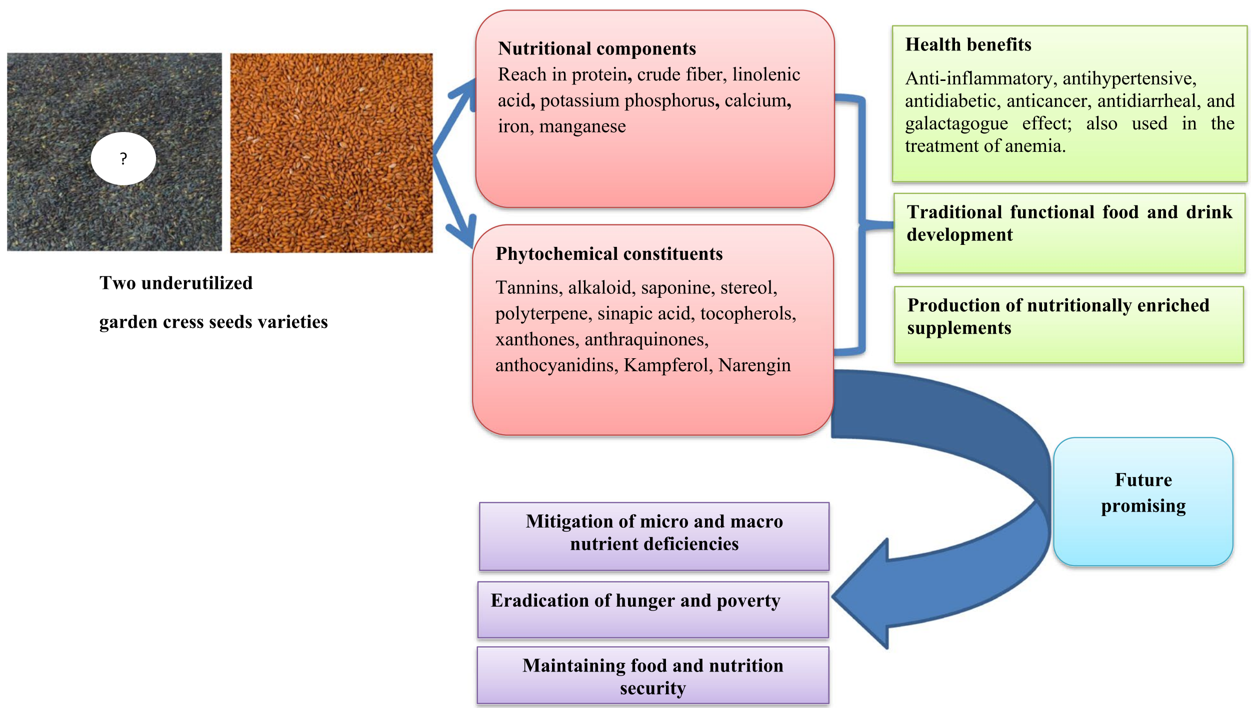
Graphical Abstract



Introduction

These days non-communicable diseases (NCDc) such as heart disease, stroke, cancer, diabetes, and chronic lung disease becoming a major public health issue (74% of all deaths in the globe). In low and middle-income countries (LMICs) it contributed to 77% of all deaths Diet-related NCDs such as cardiovascular diseases (CVDs) and diabetes and kidney diseases due to diabetes are among the top NCDs contributors to global annual deaths (17.9 and 2 million respectively) in 2019 (WHO 2022); overweight and obesity contributed to 160 million disability-adjusted life years (DALYs) in 2019 (IHME (Institute for Health Metrics and Evaluation) 2022) and DALYs due to type 2 diabetes was 66.3 million in 2019 (Safiri et al. 2022). Following unhealthy eating and metabolic risk factors such as hypertension, overweight/obesity, hyperglycemia and hyperlipidemia are major accountable risk factors of NCDs (WHO 2011).

An unhealthy diet, for instance is becoming one of the major causes of NCDs due to progressive changes in the food consumption patterns from whole, healthy diets to processed refined diets, and often containing high salt, free sugars, and trans-fats (Krishnaswamy et al. 2016; Matos et al. 2021; Miranda et al. 2008; Rauber et al. 2018; Tokunaga et al. 2012). Nowadays various plant-based diets and production of herbal medicines are interestingly used for the prevention of NCDs and communicable diseases due to their special nutrient source and bioactivity role (Figueroa et al. 2021; Hu 2003; Kim et al. 2019; Lopes et al. 2022; McMacken & Shah 2017; Tuso et al. 2013; Wong et al. 2022). Huge numbers of food and pharmaceuticals are produced from medicinal plants, and 80% of the world's population uses traditional medicines, mostly of herbs for primary healthcare needs (Alqahtani et al. 2019).

Garden cress (GC) seed or *Lepidium sativum Linn* is a herb of the family Cruciferae or Brassicaceae, has remarkable nutritional and medicinal value (Deshmukh et al. 2017). The seed of GC composed of significant amount of nutrients; for instance, important amino acids per protein (98% w/w), and outstanding content shown in specific amino acids like leucine (8.21 g/100 g protein), valine (8.04 g/100 g protein), glutamic acid (19.33 g/100 g protein), aspartic acid (9.76 g/100 g protein), leucine, phenylaniline, lysine and glycine (Singh et al. 2015). Further, higher amount of essential amino acids from the seed can be obtained using protein isolates through isoelectric point technique (Gaafar et al. 2013). In addition, the seed is high in essential fats, for instance (Oleic acid ~30%, Linolenic acid ~32%, Arachidic acid ~2.10 and Eicosaenoic acid ~13.40% (Singh & Paswan 2017).

In addition, the seed is a source of minerals like calcium, magnesium, potassium, and phosphorus (Singh et al. 2015; Singh & Paswan 2017). The seed contains several phytochemical substances responsible for its potential functional property such as saponins, flavonoids, alkaloids, tannins and terpenes (Berehe & Boru 2014; Hunter et al. 2019). Because of its high nutritional content, GC seed is considered a member of the "superfood" family, which is crucial for boosting the nutritional and therapeutic value of formulated and blended food products. This could be improved by applying various traditional processing methods (Jagdale et al. 2021). Although GC is commonly used in many parts of the world including Europe, Asia and most African countries, still the seed belongs to among underutilized crops (Wadhwa et al. 2012). Majority of people in the world rely on limited number of crop species, as an energy source among more than 7000 species recorded (Williams & Haq 2002). This may be due to inadequate attention given by the product development industries and low level of research outputs; moreover media based advocacy is almost none for underutilized crops compared to processed foods (Adhikari et al. 2017). If GC is incorporated as one of staple food, it would, contribute massively and play significant role in mitigating macro and micronutrient deficiencies, contribute for eradication of poverty and hunger and maintaining food and nutrition security (Sivakumar et al. 2020; Tyagi et al. 2018). Further, improving agricultural sustainability and dietary diversity (Mayes et al. 2012), as mentioned above due to its high nutritional composition, ability to grow in a wide ecological zone throughout the world and the potential to enrich various functional foods; GC seed can maintain food and nutrition security.

Therefore, this review compiled the current knowledge and body of science on the major nutritional composition, antioxidants and phytochemical content and the role of GC seed for various functional food developments. The review will provide a summary of insights for future researches.

Description of garden cress

Many scientific investigations indicate the, GC plant originated from Ethiopia and then distributed and domesticated on other countries (Falana et al. 2014; Wadhwa et al. 2012), however, still there are scientific debates in its origin.

Currently, GC is cultivated in many countries on a small scale, notably in India, Pakistan, Europe, and most African countries, as tolerance different temperate zones as well (El-Salam et al. 2019; Wadhwa et al. 2012). Though GC can grow in all temperatures, altitudes throughout the year but moist loam soil is favorable for its high productivity. Various parts of GC including leaves, seeds and roots can be used for different purposes, the raw leaves of the plant are used to prepare salad and can be cooked with other vegetables (El-Salam et al. 2019; Mali et al. 2007), dried leaves are used to treat different diseases conditions such as to alleviate inflammation, bronchitis, rheumatism, muscle pain and used as a diuretic (Prajapati et al. 2014), and the root is used as a condiment (Zia-Ul-Haq et al. 2012). Garden cress is mainly cultivated to get it's seeds, often harvested within 70–90 days, the productivity is about 800–1000 kg/hectare (Behrouzian et al. 2014). However, the seed yield can be improved from 1143 kg/hectare to 2010 kg/hectare using different sowing methods and seed rates (Chundawat et al. 2017). The seed called by different names globally such as garden peppercress, peppergrass, pepperwort, town cress and passer age (Sharma 2011), and across countries, for instance known as garden cress in English, Algaro in Nigeria, Lepido in Spanish, Chandrasur in India (Imade et al. 2018), Hurf Rashad and Thuffa in Arab (Sharma 2011). As explained by Poy et al. (2015); Doke and Guha (2014), the morphology of GC seeds as oval in shape, small in size, triangular at one end, smooth, length of 2 to 3 mm and width of 1 to 1.5 mm. The seeds have pale brown to black color; odorless, has pungent taste and mucilaginous Fig. 1 (Ramadan & Oraby 2020). The three most color based varieties of GC seeds are red, yellow and black (Prajapati et al. 2014). The seeds are composed of endosperm (80–85%), seed coat (12–17%) and embryo (2–3%) (Saraswathi et al. 2014). The seed flour has a creamy-yellow color (Falana et al. 2014).

Nutritional and anti-nutritional composition

Zia-Ul-Haq et al. (2012) determined the nutrient composition of GC seed and reported that GC seed has total crude protein (24%), lipid (28%), carbohydrate (33.0%), crude fiber 7.0%), moisture (3.92%) and ash (4.25%). However, the nutrient composition of the seed varies due to the seed varieties, variation in agronomic practices, climatic and geographical conditions of the seed grown. For example study conducted in Egypt indicated that the fatty acid composition of GC seeds differs among cultivars where Khider cultivar was higher in arachidonic acidthan by linoleic acid but behinic and arachidonic acid respectively were higher in both Haraz and Rajab cultivars (Ottai et al. 2012). Moreover, another study conducted in Turkey showed that mineral contents of Izmir and Dadas cultivars of GC seeds were significantly varied in which Izmir cultivar was highly rich in minerals like phosphorus, potassium, calcium and magnesium than

Fig. 1 Two major varieties of GC seeds available in Ethiopia **a**) Black **b**) Reddish brown

Dadas but Dadas is a rich sources of iron and manganese (Wadhwa et al. 2012).

The seed contains 20–25% yellowish semi-drying oil and the major fatty acid is alpha linolenic acid (32–34.0%) (Mehmood et al. 2011). Potassium and phosphorus are among the predominant minerals found in GC seed, but manganese contents are low (Table 1) (Chauhan et al. 2012). The potassium content of GC seed is higher than major potassium source foods such as banana (358 mg/100 g), dates (696 mg/100 g), white beans (561 mg/100 g), spinach (558 mg/100 g) and avocado (485 mg/100 g) (Lanham-New et al. 2012). It is a good source of calcium, iron and magnesium as shown in Table 1. In addition, it is also an appreciable source of vitamins such as thiamine (0.59 mg/100 g), riboflavin (0.61 mg/100 g) and niacin, (14.3 mg/100 g) (Paranjape & Mehta 2006).

The carbohydrate of the seeds is composed of 90% non-starch polysaccharides, but the rest is starch. This make it one of the preferred crops with prebiotic characteristics and useful to regulate digestion in the intestinal tract (Cruz-Rubio et al. 2018). Hence, can act as a non-viable food ingredient through fermentation by anaerobic bacteria found in the gut (Sargautiene et al. 2018). The seed is composed of endosperm (72%) and bran (28%) (Prajapati & Dave 2018). The seed bran has a high dietary fiber (75.0%) (Gokavi et al. 2004) and also it has high water holding capacity (4.51 ml/g) (El-Salam et al. 2019). The protein content of GC seeds (22.5%) (Doke & Guha 2014), which is fairly comparable to linseed (28–30%) (Kajla et al. 2015), but higher than commonly consumed cereals like teff (11%), maize (8–11%), sorghum (8.3%) and wheat (11.7%) (Baye 2014). However, the nutrient composition of the seed can be improved through different processing methods for example; soaking of the seed can enhance the ash (by 2.48%) and protein (by 2.1%) content of the seed and it also increases the retention of amino acids and fatty acids (Jain, Grover & Kaur 2016).

In addition to the nutritional components, GC seeds contain anti-nutritional compounds (Agarwal & Sharma 2013). Anti-nutritionals are plant product compounds which reduce the availability and utilization of nutrients and food intake (Thakur et al. 2019). Anti-nutritionals in plant based foods include tannins, phytic acid, saponins, lectins, protease inhibitors, amylase inhibitors, gossypol, lectins and goitrogens (Samtiya et al. 2020). The major anti-nutritional components in raw GC seeds were phytin phosphorus (447.2 mg/100 g) and oxalates (134.0 mg/100 g). This results were within the

Table 1 Selected mineral level of whole garden cress seed compared to commonly consumed cereals in Ethiopia

Mineral (mg/100 g)	Garden cress (Singh & Paswan 2017)	White teff (Baye 2014); (Dame 2020)	Red teff (Baye 2014); (Dame 2020)	Maize (Baye 2014); (Dame 2020)	Sorghum (Baye 2014); (Dame 2020)	Wheat (Baye 2014); (Dame 2020)
Iron	8.3	9.5–37.7	11.6–150.0	3.6–4.8	3.5–4.1	3.7
Calcium	266.4	17.0–124.0	18.0–178.0	16.0	5.0–5.8	15.2–39.5
Potassium	1236.5	128.9	114.7	54.8	–	117.3
Phosphorus	608.6	99.2	70.3	15.8	–	233.0
Magnesium	339.2	54.3	43.7	36.07	–	78.7
Zinc	7.0	2.4–6.8	2.3–6.7	2.6–4.6	1.4–1.7	1.7
Sodium	19.7	12.80	11.5	39.9	–	1.70

range for most phytic acid content of cereals reported 29.5–1310 mg/100 g and lower than a cereal with high amount of oxalate content (143–232 mg/100) (Satheesh & Fanta 2018).

Phytochemical constituents

As many phytochemical profiling studies indicated that, chloroform or methanolic extract of GC seed is composed of sterols, imidazole alkaloids, coumarins, flavonoids, sulphur containing glycosides and triterpenes (Deshmukh et al. 2017). Qusti et al. (2016) determined the total phenolic and flavonoids contents of the seed and was found to be 58.8 mg/100 g and 42.35 mg/100 g respectively. However, the phytochemical composition of GC seed varies due to the variation of procedures followed in the isolation and extraction process and extracting solvents used (El-Salam et al. 2019). For example, methanolic extract of GC seed showed the presence of tannins, alkaloid, saponine, stereol and polyterpene compounds but ethyl acetate extract showed merely the presence of alkaloid and saponine. The phenolic components found in GC seeds are sinapic acid and sinapin, high content of tocopherols, xanthones, tannins, anthraquinones and anthocyanidins (Chatoui et al. 2016). It also contains 3001.75 μg/10 g of gallic acid, 1460.80 μg/100 g of ellagic acid and 582.23 μg/100 g of protocatechuic. Garden cress seed contains rare imidazole alkaloids known as lepidine and semilepidine (Mehmood et al. 2011). Seven imidazole alkaloids (lepidine B, C, D, E and dimeric F and monomeric alkaloids known as semi-lepidine side A and B) are also found in GC seeds (Shukla et al. 2012). Furthermore, major flavonoid compounds found in GC seeds are Kampferol (70,966 μg/100 g) and Narengin (61,055 μg/100 g) (Nayak et al. 2009), hesperidin (4934.99 μg/100 g) and quercetin (El-Salam et al. 2019). It also contains Rosmarinic; 7-Hydroxyflavon and Quercetin in lowest amount (Halaby et al. 2015).

Therapeutic effect

The seeds of GC possess diuretics, aperient and an aphrodisiac property that is useful for treating inflammation, bronchitis, rheumatism and muscular pain (Behrouzian et al. 2014). The seed is effective in the treatment of asthma, dysentery and diarrhea, coughs, skin disease and poultices for sprains (Sharma 2015). Moreover, the seed is effective in the treatment of hypertension and diabetes (Connor 2000), and have antibacterial and antifungal properties (Bansal et al. 2012).

Anti-inflammatory nature

Raval et al. (2013) determined the anti-inflammatory activity of GC seed on carrageenan-induced hind paw edema and formaldehyde-induced edema at different phases of inflammatory process. A suspension of GC seed powder produced a moderate edema suppression effect at the dose of 550 mg/kg body weight of the rat. The possible mechanisms include inhibition of formation and release of phlogistic mediators like prostaglandins (PGs), kinins and others. Plus, modulation of reaction mediators with their respective receptors and blockade of receptor activity, inhibitory effect on proliferation of fibroblasts and connective tissue modulation effect. A mixture of bruised GC seed with lime juice o has been used to reduce inflammation and rheumatic pain. Garden cress seed show similar properties with medications used to treat osteoarthritis, having anti-inflammatory and analgesic actions, due to adequate amount of calcium ions which able to reduces pain/inflammation caused by osteoarthritis a such as joint pain, stiffness, swelling, tenderness and difficulty in movement (Falana et al. 2014).

Hepato-protective effect

Garden cress seed extracts exhibited hepato-protective effects against carbon tetrachloride (CCl_4) induced liver damage (Shail et al. 2016). Al-Asmari et al. (2015) demonstrated this with the ethanolic extracts of GC seed at a dose of 100, 200 and 400 mg/kg, once per day for 7 consecutive days, followed by hepatotoxicity induction with CCl_4. The result revealed that pretreatment with GC seed significantly reduced the level of enzymes such as serum alanine transaminase, aspartate transaminase, alkaline phosphatase, and bilirubin, which was increased significantly in toxified groups treated with only CCl_4. Histological analysis of liver tissues in groups of animals pretreated with GC seed showed mild necrosis and inflammation of the hepatocytes compared to the toxified groups. The reason behind this hepato-protective effect is the antioxidant effect of the seed due to the presence of phytochemical compounds, a decrease in free radical generation from CCl_4 as well as the presence of anti-inflammatory compounds in GC seed extract (Al-Asmari et al. 2015; Falana et al. 2014).

Fracture healing effect

Yadav et al. (2011) studied the fracture healing effect of ethanolic extracted GC seeds using X-ray photographs conducted at the second, fourth and eighth week at a dose of 400 mg/kg GC seed in rats, the result indicated a significant increase in callus formation in GC seed administered groups compared to control groups. Similarly, bin Abdullah Juma (2007) reported the fracture healing effect of GC seeds on fracture-induced healing rabbits, in which the study duration lasted 12 weeks from by feeding the rabbits with a normal diet and 6 g of GC seed; the study showed rapid recovery, good healing of wounds and fractures in the experimental rabbits than controls. The effectiveness of GC in wound and fracture healing is due to abundant source of glycosides, alkaloids, tannin, flavonoids, fatty acids and amino acids like glutamine, cysteine and glycine including (Yadav et al. 2011), which increase collagen deposition at fracture position (Mali et al. 2007).

Antihypertensive, diuretic, nephron-curative and nephron-protective property

Maghrani et al. (2005) investigated the antihypertensive and diuretic effect of aqueous extract of GC seed with daily 20 mg/kg oral administration for 3 weeks in normotensive and spontaneously hypertensive rats (SHRs). The study report indicated that the extract showed considerable decrease in blood pressure in SHRs from day 7 until treatment completion, while no change was observed in normotensive rats. The study also reported, electrolytes excretion increased in SHR, but no significant change was examined in water excretion. On the other hand, Patel et al. (2009) compared the diuretic effect of aqueous (50 mg/kg) and methanolic extracts (100 mg/kg) of GC seeds and control group (10 mg/kg of oral hydrochlorothiazide (diuretic drug)) in orally administered rats. The finding of the experiment showed that urine volume and excretion of sodium was significantly increased in the extract fed groups. Potassium excretion was only increased in the aqueous extracts rats while no significant change recorded in pH of their urine. The diuretic effect of GC seed extract was equally effective with that produced by hydrochlorothiazide treatment. This effect could be due to stimulation of regional blood flow or initial vasodilation, thus, inhibit tubular reabsorption of water and anions to initiate diuresis: rise in sodium and water excretion.

Moreover, Halaby et al. (2015) studied the nephron-curative and nephron-protective activity of GC seeds powder at 5 and 10% concentrations against cisplatin (anticancer drug) induced nephrotoxicity in male albino rats. Feeding of a basal diet enriched with the above seeds powder concentrations decreased bad cholesterols and improved good cholesterol level as well as decreased the level of kidney and liver functions tests (serum urea, serum creatinine and serum uric acid) against cisplatin which has renal failure effect. This could be due to an increment in the level of glutathione and reduced lipid peroxidation in both nephron-protective and curative groups. Hence, cisplatin depletes glutathione, raises thiobarbituric acid reactive substances and inhibits the activity of antioxidant enzymes in renal tissue (Yadav et al. 2011).

Anti-cancer property

Garden cress seeds used to treat some form of cancers mainly breast cancer and uterine tumors (Behrouzian et al. 2014). Studies reported that GC seed aqueous extract, notably benzyl iso-thiocyanate, suppress the proliferation of breast cancer cells (Mahassni & Al-Reemi 2013). Studies conducted in both animal and humans reported that, fatty acids present in GC seeds have chemo-preventive and chemotherapeutic effects on various types of cancers (Diwakar et al. 2008). Additionally, Mahassni and Al-Reemi (2013) studied the aqueous extract of GC seed in human breast cancer cell at different concentrations, and the finding indicated that the seed induces apoptosis and necrosis. It also showed the growth of breast cancer cells was inhibited by the extract; when the cells were treated with 25 and 50% extract, apoptosis was induced, whereas necrosis was observed while exposure to higher extract concentrations (75%).

Hypocholesterolemic activity

According to a study conducted in hypercholesterolemic rats GC seed powder and its extract have a preventive effect (Kadam et al. 2012). Al Hamedan (2010) investigated the effects of 5 and 10% of GC seed powder and its extract in hypercholesterolemic rats. Lower level of serum triglycerides, cholesterol, very low-density lipoprotein cholesterol, low-density lipoprotein cholesterol (LDL-c) level, cholesterol ratio to high density lipoprotein cholesterol, creatinine, urea and liver cholesterol level were decreased compared to positive control group. The hypocholesterolemic effect of GC seed could be attributed to suppression of cholesterol biosynthesis via inhibition of 3-hydroxy-3-methyl-glutaryl-CoA reductase, which is the rate-limiting enzyme that mediates the first step in cholesterol biosynthesis (Mohamed & Safwat 2016). The hypolipidemic effect of GC seed also might be due to inhibition of absorption and enhanced excretion of lipids through the gastrointestinal tract (Chauhan et al. 2012).

Its anti-diabetic effect

Garden cress seed extract is effective in the prevention and management of diabetes mellitus and related complications (Mishra et al. 2017). Eddouks et al. (2005) investigated the aqueous extract of GC seed had hypoglycemic effect in both streptozotocin induced diabetic rat and normal rat. Blood glucose levels were reduced in streptozotocin-induced diabetic rats after injecting 20 mg/kg body weight of the extract. Since there were no changes observed in basal plasma insulin concentrations, the investigation concluded that the seed extract had a powerful hypoglycemic effect in rats independent of insulin secretion. This effect was attributed to the prevention of renal glucose reabsorption which decreases blood sugar. Shukla et al. (2012) studied the antidiabetic effect of the seed; alkaloid specifically lepidine and semilepidine. The antidiabetic potency of the alkaloids (50, 150 and 250 mg/kg) was assessed on alloxan induced diabetic rats after 21 days. Alkaloids at a dose of 250 mg/kg showed potent hypoglycaemic activity than others. The potential antidiabetic effects of the alkaloids could be via reducing oxidative damage and modulation of the antioxidant enzymes. According to Mali et al. (2007) GC seeds also reduce starch hydrolysis by 41% when tested on type 2 diabetic patients, and the seeds were found significantly reduces glucose response to meals in both normal and diabetics.

Galactogogue and emmenagogue property

A galactagogue is a substance or process that stimulates milk production (Lawrence & Lawrence 2011), whereas emmenagogue is a herb or seed has ability to stimulate menstrual flow when not even reached the due date (Romm 2010). Sarkar et al. (2014) investigated the galactogogue effects of GC seed on thirty healthy lactating rats by providing 20% GC seed powder mixed with stock diet for 7 days during their lactating period. The study investigated that an enhanced weight development of mammary gland, proliferation of alveoli and increased accumulation of secretory material in treated lactating rats compared to their control groups. Due to its mild estrogenic and emmenagogue properties, GC seed can be used as a functional product to regulate menstrual cycle, via inducing abortion, causing hormonal disorders like oligomenorrhea and through preventing pregnancy (Singh & Paswan 2017).

Used as a treatment for bronchial asthma

In traditional medicine GC is used for the treatment of different airway disorders, such as asthma, cough and bronchitis (Rehman, Khan, et al. 2012). Garden cress seed powder was given orally for 30 patients of age 15–80 years with mild to moderate bronchial asthma at a dose of 1 g, three times a day. The study revealed that GC seed powder can moderate different indicators of pulmonary functions tests in asthmatic patients. Additionally, it can improve clinical symptoms asthma and severity of the attacks. All the subjects didn't show any adverse effects associated with the treatment (Paranjape & Mehta 2006). This bronchodilatory effect is mediated through a combination of anticholinergic, calcium antagonist and phosphodiesterase inhibitory mechanisms (El-Salam et al. 2019).

Promising for treatment of anemia

Garden cress seeds are rich sources of non-heme iron which helps to up surge the hemoglobin concentration in blood and used to alleviate anemia (Singh et al. 2015). A review study that 30 young adult girls administered a GC seed powder (25 g) prepared as 'Laddu' (a sweet palatable formulation with coconut kernel and molasses) for 7 days against the control groups showed a significant high haemoglobin level (Sarkar et al. 2014). Furthermore, studies indicated that, school children who took biscuits supplemented with roasted GC seeds raised their haemoglobin level from 10.63 to 11.06 g/dl (Jain & Grover 2017). Another study conducted in pregnant women indicated, the haemoglobin level was increased by 1.32 g/dl in women that consumed iron folic acid supplementation coupled with GC seed (Nair et al. 2014).

The antidiarrheal and antispasmodic effect

Manohar et al. (2009) examined the antidiarrheal activity of methanolic extract of GC seed at 50, 100 and 200 mg/kg doses using castor oil induced diarrhea model, charcoal meal test in mice and prostaglandin-E2 induced enteropooling in rats. Castor oil induced model showed a significant dose dependent reduction of cumulative wet fecal mass, whereas prostaglandin-E2 induced enteropooling model inhibited PG-E2 induced secretions and in the charcoal meal test, the movement of charcoal was decreased indicating its antimotility activity. The antidiarrheal effect of the seed extract may be resulted due to the inhibition of PG biosynthesis and/or decreasing the peristaltic movement (Manohar et al. 2009). However, the possible mechanism for the antidiarrheal activity is the combined blockade of both calcium channels and muscarinic receptors (Rehman, Mehmood, et al. 2012).

Potential of garden cress seed in functional food development

Garden cress seed is commonly used to develop various functional foods (Singh & Paswan 2017). In India, roasting and grounding of GC seed flour is used to formulate several traditional foods through enhancing the color, texture and overall acceptability of food products (Andrias et al. 2019). For example, GC seeds were used to produce iron rich ready to eat little millet flakes. The addition of GC seed enhances the iron, protein and trans-fat free fat content of the flakes. After addition, the iron, protein and fat content of the flakes rose by 4.41 mg/100 g, 13.15 and 114.28% respectively in the formulated product compared to the control (Kotagi et al. 2013).

Corn flour, 20% moth bean and different amounts of GC flour (2.5, 5 and 7.5%) were used to produce nutritionally enriched corn extruded snack. The developed snack had acceptable sensory qualities, protein and iron content. The product had better iron bioavailability, in vitro carbohydrate and protein digestibility which boost the digestion of the extruded snacks. The product had high protein content (15.08–16.9 g/100 g) than the control (9.1 g/100 g); particularly, the essential amino acids: methionine and cysteine were found in the concentration of 105.3–109.5 mg/100 g and 102.3–109.2 mg/100 g dry mater (DM). Iron and calcium content of the snacks were 18.4–21.3 mg and 54.6–57.3 mg/100 g DM respectively (Sisodia 2016).

Study by Jain, Grover, and Grewal (2016) indicated, addition of roasted GC seeds was crucial in India to produce many ready to eat Indian traditional supplementary foods. Addition of 10 and 15% GC seed in pinni (soaked and ground green gram, ghee, wheat flour and jaggery) and panjiri (mixture of wheat flour, ghee, powdered jaggery) improves the overall acceptability of the traditional foods. From the formulated supplementary products chikki (consisted of Jaggery, syrup and roasted peanut) was higher in iron (6.43 mg/100 g) and calcium (117.27 mg/100 g), but it's iron and calcium content in panjiri was 4.97 mg/100 g 64.3 mg/100 g.

Nutritionally enhanced drinks were developed from sugar (5% w/v), skimmed milk (1%), fat and suspending agent sodium salt of carboxymethyl cellulose by adding 1–5% boiled GC seed powder. Boiled GC seed had higher amount of phosphorus and energy (540 mg/100 g, 524 kcal/100 g) content than the raw seeds (49.0 mg/100 g, 92 kcal/100 g). The drink could be a preferred source of iron for children, malnourished people, elderly, and patients who recovered from injury or illness. In addition, the product can be used for individuals doing routine exercises to build their muscle, since it has high protein content (32%) (Ghosh 2012).

Rana and Kaur (2016) developed sensory acceptable and nutritionally enriched food products supplemented with whole and processed GC seed powder at 5–10% (roasted and microwave processed). The supplemented products were higher in protein, fiber and iron contents than their controls. These include ladoo, namakpare (made of ajwain, salt, oil, water and refined wheat flour) and biscuit (mix of creamed ghee, sugar, milk and wheat flour). Protein content of the formulated biscuit was 6.99%, whereas the control was 6.05%. The protein content of developed ladoo and the control was almost similar (14.91% versus 14.82%). The iron content of supplemented biscuit (13.6%), namakpara (7.6%) and ladoo (13.37%) were augmented compared to their controls.

Yadav et al. (2018) developed nutritionally enriched cookies (a mixture of butter, powdered sugar, oats flour, Bengal gram flour, semolina, cardamom powder with roasted GC seeds at different amount (2.5–10.5%)). The formulated product had good sensory quality and reasonable price. The highest amount (10.5%) presence of the seed enhances the nutritional composition of the cookie, which had a higher amount in the treatment group than control, for iron (13.89 versus 2.93 mg/100 g), calcium (75.0 versus 34 mg/100 g), and the energy value of the supplemented product was raised from 444.0 to 489.0 kcal/100 g. Moreover, the incorporation of GC seed enhanced the antioxidant content of the cookie product, particularly the phenolic and flavonoid contents.

Another study, conducted on nutritionally enriched biscuits (prepared from wheat flour, sugar, butter, milk, mixed with different amounts of GC seed powder (2.5–10%)) showed that the formulated product retained higher amounts of protein, lipid, crude fiber, and ash content. The potassium content of GC seed enriched biscuits were nearly five times (643 mg/100 g) than the control (134 mg/100 g). The calcium content of the enriched biscuits and control were 255.8 and 34.0 mg/100 g; and magnesium content was 195.25 and 89.0 mg/100 g, respectively. The total phenolic and flavonoids contents were also enhanced in the supplemented products than the control biscuits; the antioxidant content was highest in the 10% GC seed fortified biscuits, (5002 μmol ferrous/100 g) than the control (171.0 μmol ferrous/100 g). This formulated product could be promising therapeutic food for sportsmen, people with high blood pressure, crucial for another treatment option for cancer and atherosclerosis (Alshehry 2019).

Moreover, iron rich flour from GC seed powder was prepared with other flours; the first one was wheat flour (90%) and GC seed flour (10%), the other one was: wheat flour (60%), pearl millet flour (15%), rice flour (15% and GC seed flour (10%). The formulated product from wheat flour and GC powder was slightly higher in protein content (13.30 g/100 g) compared to the control (12.03 g/100 g) and fiber content of formulated product was 2.34 g/100 g, against 1.83 g/100 g in the control. The energy content of the formulated product rose from 350.24 kcal/100 g to 354.33/100 g kcal. The addition of pearl millet and rice augmented the protein content of the enriched product by 1.27 g/100 g and crude fiber content by 0.87 g/100 g (Khushbu & Renu 2018).

Due to appreciable amount of omega three (n-3) PUFA in GC seed, it uses to prepare omega three blended food products which can improve the essential omega three fatty acids content of blended food products. Blended product formulated from sunflower, rice bran, sesame, and GC oils at different ratios (50 and 40%) shown that omega six to omega three PUFA ratios was decreased by 2.3–2.6. The blended vegetable oil product had higher alpha linolenic (omega-3) fats content (Umesha & Naidu 2012), which could fundamentally suits for modulation of various types of lipid metabolism. However, due to the auto oxidative nature of omega three fatty acids; a mechanism like microencapsulation of GC seed oil is recommended to extend the shelf life of blended products (Umesha et al. 2015).

Study conducted in Tunisia indicated that ethanolic extract of water-soluble polysaccharide from GC seeds used to formulate cakes (composed of wheat flour, sugar, egg yolk, baking powder and butter). The formulated product had improved natural antioxidant content and cake quality like texture and color. The Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activities of the cake were 77.07 and 70.26% on the first and fifteenth day respectively. This could be due to the addition of antioxidant rich extracted water-soluble polysaccharide from GC ssed (Ben Slima et al. 2022). In line with this the addition of 5–20% of GC seeds was used to prepared fortified muffins from wheat flour, baking powder, baking powder, baking soda, sugar, cinnamon powder, vanilla essence, yoghurt, milk, lemon juice, coconut oil, egg whites and the addition of the seed enhances the protein (14%), fiber (68%), ash (74%), and healthy fats (45%) like alpha-linoleic acid contents of the muffins (Rabail et al. 2022). Additionally, mucilage isolated from GC seeds used to produce several types of food products, for instance study in Egypt shown that fresh cut potato strips were coated with mucilage extracted from GC seed in combination of with and without ascorbic acid and the coating was reduce the fat content of the fried product through lowering of oil uptake which could be preferred in health aspect for consumption. Additionally the coating prolonged the browning reaction in the fried product and further extends the shelf life (Ali et al. 2021).

In, most parts of Ethiopia GC seed used in the form of special dish known as "Feto Fitfit" (mix of ground GC seed powder, water, salt, lemon and pieces of injera) (Berehe & Boru 2014), which is often used once per year (at the day of the new year) due to the belief that it can avoid bad evil throughout the year. According to Gebremedhin (2008) the seed powder in Ethiopia is used in combination with other medicinal foods for treating various diseases. For instance, chopped bulb of garlic and GC ground seeds are mashed in *injera,* eaten as a remedy to stomachache. Crushed bulbs of garlic, seeds of GC diluted with water and sprayed on to a bleeding wound surface to prevent infection an stop bleeding. Seeds of crushed GC mixed with lemon used to treat abdominal pain and toothache. This indicates that the seed is used to treat different ailments at a homemade level which warrant further advancement in the formulation and determination of optimum dose of a seed for various disease treating, and as a recipes in development of diversified enriched and therapeutic food products at industry level. Table 2 below summarizes the benefits of GC seed and functional foods.

Table 2 Summary of uses and therapeutic benefits of garden cress seed and its functional food products

Forms	Uses/ major components	Health benefits	References
Raw whole seed	Powder form of GC seed extracted in various solvents	Hepato-protective effects, fracture healing effect, antihypertensive and diuretic effect, treating breast cancer, hypoglycemic effect, antidiarrheal activity	Shail et al. 2016; Yadav et al. 2011; Maghrani et al. 2005; Mahassni & Al-Reemi 2013; Eddouks et al. 2005; Manohar et al. 2009
Raw whole seed	-Powder form, with out solvent extract	Hypocholesterolemic effect, bronchial asthma, galactogogue effect	Kadam et al. 2012; Paranjape & Mehta 2006; Sarkar et al. 2014,
GC seed mixed with other ingredients	-Bruised GC seed mixed with lime juice -GC seed powder mixed with coconut kernel and molasses -Mixed with little millet in the production of flakes - Corn flour, moth bean and GC flour - GC seed mixed with green gram, ghee, wheat flour and jiggery - Boiled GC seed mixed with sugar, skimmed milk, fat, sodium salt of carboxymethyl cellulose -Production of GC seed supplemented ladoo, namakpare, biscuit and cookies -GC seed powder mixed with water, salt, lemon, pieces of injera and garlic in Ethiopia	-Reduce inflammation and rheumatic pain -Treatment of anemia - Enhances the iron, protein and trans-fat free flakes -Production of iron and calcium rich corn extruded snacks -Production of iron and calcium rich Indian traditional foods - Production of iron rich healthy drinks for malnourished people and building muscle - Production of high protein, fiber iron, potassium, calcium and antioxidant content of food products -Avoid bad evil, treatment of stomachache, prevent infection, abdominal pain and toothache	Falana et al. 2014 Sarkar et al. 2014 Kotagi et al. 2013 Sisodia 2016 Jain, Grover, & Grewal 2016 Ghosh 2012 Rana & Kaur 2016; Yadav et al. 2018; Alshehry 2019 Berehe & Boru 2014; Gebremedhin 2008
GC seed oil, and microencapsulated omega-3 fatty acid	GC seed oil blended with sunflower, rice bran, sesame	Production of omega three rich blended products and biscuits used in modulation of lipid metabolism	Umesha & Naidu 2012; Umesha et al. 2015

GC Garden cress

Toxicity and side effects of garden cress seeds

Acute toxicity studies conducted on GC seed reported that no death was recorded up to 1 g/kg body weight of rats (Malar et al. 2017). Garden cress seed powder (0.5–5 g/kg) produced no symptoms of any acute toxicity or death. Sub chronic toxicity (90 days) studies in animals at (1.0–10%) of GC seed powder had no adverse effect in weight gains, food intake and no changes in hematological parameters, macroscopic and microscopic examination of major organs; and were comparable with the control groups for most of the enzyme tests. Therefore, acute and sub-chronic feeding of GC seed powder at the given concentration for experimental rats, had no adverse effects shown, thus considered non-toxic and safe (Datta et al. 2011). Though 15% of GC had no effect on all hematological indices, however, it decreased plasma creatinine concentration, total protein, albumin and plasma globulin levels significantly over time and 50% of it has shown lethal effects (Khan 2018). On the other hand, GC seeds contain goitrogens that interfere with iodine absorption, which may lead to hypothyroidism, therefore it is not recommended particularly for hypothyroidism patients. Moreover, it is also an abortifacient (contain components that induces abortion), if taken in excess dose, therefore the seed doesn't allowed for pregnant women it, since it has capability to mimic uterine contractions, and might trigger spontaneous abortion (Singh & Paswan 2017).

Research gaps and future recommendations

In numerous low-income countries consumption of animal source foods as a source of protein, carbohydrate and fat is minimal due to limited production, availability and affordability of animal source foods. On the other side much attention has not been given for the multipurpose, under-utilized cereals like GC, despite can be used to formulate diverse functional foods due to themacronutrient and micronutrient (essential amino acids and fatty acids)content; apart from this it also promising source of bioactive (phytochemicals and polyphenols) compounds, which in deed potential to eradicate both undernutrition and range of NCDs (Sheehy et al. 2019). Hence, there is a need for more evidence generation, product formulation, and promotional work to scaling up agricultural production of the seed is important (Said & Kassahun 2015). Studies investigating the nutritional composition of different GC seed varieties (reddish brown and black GC seeds) are limited, which needs further exploration. Additionally, summary of studies focusing on component identification and isolation from various GC seeds varieties including wider pharmaceutical applications like mucilage of the seed recommended. Moreover, using different techniques such as microencapsulation of nanoparticles application in GC seed based drug formulation and functional food development needs further investigation. Since there is still a lot of evidence needs to be generated, this paper focused on exploring the body of evidence on GC seed and its formulated food products. However, a systematic review is recommended in the future by grading the quality of available evidence and summarizing the current state of Science.

Conclusion

Nutritionally enriched underutilized GC seed could be a future promising plant for fighting hunger and malnutrition, treating different disease conditions, formulating various healthy drinks and food products and producing blended supplements in traditional food product development as well as in modern food industries. Although, GC seeds are rich in various important nutrients, it is less familiar and neglected in common dishes of many countries, which needs further awareness and consumer promotion that helps to exploit the seed effectively. Exploration of nutritional composition of different varieties of GC seed and formulation of diverse food products warrants further experiment. Therefore, nutrition researchers, food scientists and food technologists need to give attention in broadening evidence, tailoring activities to improve the production, processing, formulation, and consumption of the seed. In addition to this promotion, rise the cultural adaptation and uptake of underutilized crops including GC seeds using the different media outlets increases familiarity within people around the globe.

Abbreviations

DM: Dry matter; GC: Garden cress; LMICs: Low- and middle-income countries; NCDs: Non-communicable diseases; PGs: Prostaglandins; SHR: Spontaneously hypertensive rats.

Acknowledgements

The authors would like to acknowledge Dr. Dawd Gashu (An associate professor of Food Science and Nutrition in the Addis Ababa University) for his valuable comments during presenting the work internally and made a glance review.

Authors' contributions

M.A and K.H. Conception wrote the first draft and reviewed the article. H.T. Wrote the first draft and reviewed the article. The final version of the manuscript has been read and approved by all authors.

Funding

This study received no external funding.

Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interest.

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Received: 11 July 2022 Accepted: 27 October 2022
Published online: 01 December 2022

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