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Wheatgrass (*Triticum aestivum*): a miraculous microgreen: an overview

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ABSTRACT

Plants have been utilized by humans throughout history for a variety of purposes, including sustenance and medicinal intentions. Since ancient times, wheatgrass has been utilized as a type of microgreen for therapeutic purposes. Phenolic flavonoids, vitamins, minerals, proteins and enzymes are all abundant in wheatgrass. These nutrients and bioactive substances enhanced wheatgrass's therapeutic efficacy and made it a powerful antioxidant agent for the treatment of a range of diseases. It has been shown to have a wide variety of pharmacological potentials, including an antioxidative potential that helps to neutralize free radicals, anti-cancer, anti-ulcer, anti-diabetic, anti-arthritic, anti-microbial action, and many more. However, there is a dearth of scientific evidence to back up wheatgrass's possible pharmacological effects and clinical value. To investigate its clinical utility for human welfare, in-depth research studies are needed. Through this analysis of the review literature, an attempt has been made to explain wheatgrass and its therapeutic potentials.

1. Introduction

Microgreens are young and tender, edible seedlings that are harvested after the cotyledonary leaves have fully developed and the first true leaves emerge[1]. Microgreens, are nutrient-dense seedlings that can provide beneficial nutritional and health qualities in relatively small consumption quantities to mature veggies, are gradually drawing commercial attention on a global scale[2-3]. Microgreens, also referred to as "vegetable confetti," are developed from a wide range of commercial food crops, including grains, herbs, and vegetables, and they are made up of completely grown cotyledons with or without partially expanded true leaves[4]. Despite their small size, these valuable microvegetables showcase noteworthy sensory qualities like flavour, texture, aroma, appearance, exotic colours and unique hues. They are also overloaded with a multitude of different phytonutrients, which vary depending on the nature of plants employed to generate the microgreens[5]. The usage of various microgreens employed as garnishes to improve salads, soups, sandwiches, and other culinary inventories, has sparked the interest of consumers in microgreens. However, owing to its intriguing quality characteristics, their use has been extended to enrich the diet of a particular group of demanding consumers[6]. The microgreens are referred to as the next generation of "superfoods" or "functional foods" as they possess a wide array of health-promoting phytonutrients, including antioxidants, vitamins, minerals, phenolic compounds, and numerous additional health-promoting substances. Microgreens can be easily cultivated in a relatively simple manner, even in extremely small spaces, and are appropriate for both urban agriculture and space life support systems[7]. Therefore, incorporating microgreens into daily meals may thereby improve the nutritional value and assist consumers in obtaining better health benefits.

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Phytotherapeutic plants and microgreens have gained prominence over the recent decades, with implications across the global healthcare system and international trade. The immature shoots of the wheat plant *Triticum aestivum*, which are harvested when they are less than 15 days old, are referred to as wheatgrass (Tables 1 and 2). These vibrant green grass blades are typically consumed as a nutrient-dense functional food or nutraceutical in the form of juice or powder[8]. In current scenario, wheatgrass has gained popularity as a healthy food due to its high content of vitamins including vitamin A, vitamin C and vitamin E, minerals such as iron, magnesium and calcium along with antioxidants and several bioactive compounds possessing potential health benefits viz., anti-inflammatory, anti-cancer, anti-diabetic, immunomodulatory, cardiovascular protective and for good digestive health[9-10]. Since, to its functional ingredients and high nutritional composition, wheatgrass may also have therapeutic properties which render it a miraculous microgreen for cure for various chronic ailments. Although being widely used, there is not much information about the medicinal benefits of wheatgrass therefore further scientific study is needed to investigate the pharmacological potentials of this natural herbal microgreen. Considering these facts, the goal of the current review is to offer comprehensive details on the nutritional compositions and pharmacological properties of this microgreen.

Table 1
Classification of wheatgrass.

Kingdom	Plantae
Division	Magnoliophyta
Class	Liliopsida
Order	Cyperales
Family	Poaceae
Genus	*Triticum*
Species	*Aestivum*

Table 2
Physical characteristics of wheatgrass.

Nature	Grass/Microgreen
Taste	Acrid
Colour	Bright green/Dark green
Odour	Characteristic

2. Cultivation of wheatgrass

Wheatgrass is normally cultivated indoors on trays for medicinal purposes, though it can be grown outdoors. In order to the indoor cultivation of wheatgrass, good quality of wheat seeds are procured and cleaned properly, after that wheat grains are soaked in cold water for 12 h, after the water has been strained, they are tied in wet woven cotton cloth and hung for the next 12 h. Water is sprinkled over the cotton cloth at least 3 times during the germination period. Wheat sprouts contain 4 times as much folic acid and 6 times as much vitamin C than unsprouted wheat. Sprouted wheat is sown in a shaded area, although wheat can grow in any environment, it is best to plant it in a shady place to avoid excessive nutrient loss from exposure to direct sunlight. According to the literature, when the seeds are sowed, the grass develops slowly for the first 7 days before growing quickly during the next twelve to 15 days, reaching a length of 18−22 cm and being ready for harvest (Fig. 1)[11].

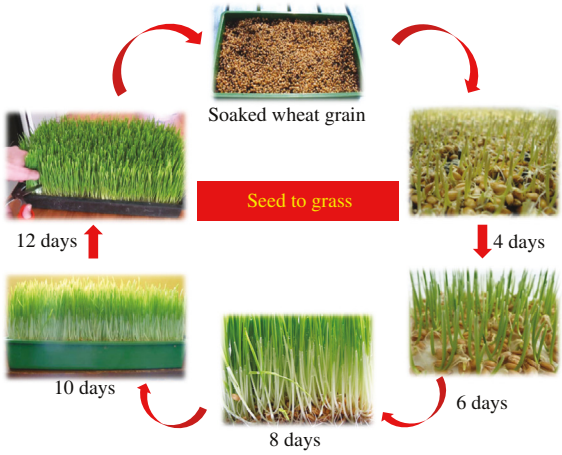


Fig. 1 Pictorial presentation of wheatgrass cultivation.

The nutritional composition of wheatgrass is influenced by several factors, namely the growing period, genetics, agronomic and environmental conditions, pH, light intensity, type of light exposure, temperature and minerals absorbed by the plant via roots[12-15]. Such variations in the nutritional and physiochemical properties were well documented by Skoczylas et al.[16] in their study, where they found that 15 days grown wheatgrass juice had increased level of chlorophylls, carotenoids, total polyphenols, and catalase activity than 10 days grown (Table 3). They also found differences in some of the characteristics of the juices made from wheatgrass grown in summer and winter season. In another study, Parit et al.[17] found that 16 days grown wheatgrass had maximum antioxidant activity than 6 and 8 days grown. These observations clearly indicates that wheatgrass has maximum nutritional content at 12−15 days.

Table 3
Physicochemical activity of wheatgrass during different harvesting period[16-17].

Parameter	Harvesting period of wheatgrass (day)	
	10	15
Dry matter (g/kg)	48.67	48.80
Ash (g/kg)	7.83	8.07
pH	5.65	5.70
Total chlorophyll (mg/L)	480.9	565.0
Carotenoids (mg/L)	94.5	105.5
Total polyphenols (mg/L)	983.6	979.3
Flavonoids (mg/L)	540.6	553.6
2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging ability (μmol Trolox/mL)	8.08	9.07
2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) cation radical scavenging ability (μmol Trolox/mL)	113.29	106.17
Catalase (U/mL)	84.92	213.28
Peroxidase (U/mL)	0.16	0.13

3. Nutritional composition of wheatgrass

The proximate analysis of wheatgrass juice and powder is shown in Table 4. In addition to minerals including iron, calcium, magnesium, copper, zinc, and sodium, wheatgrass provides a rich source of vitamins A, C and E. The B-complex vitamins, including

as thiamine, riboflavin, niacin, and folic acid, are also abundant in it (Table 5). Table 6 lists the essential amino acids, which are the building blocks of proteins that are present in wheatgrass. These amino acids are essential for the development and maintenance of bodily tissues. Several antioxidant compounds, including flavonoids, phenolic acids, chlorophyll and alkaloids are found in wheatgrass (Tables 7 and 8). These bioactive substances aid in defending the body against the oxidative damage caused by free radicals, which can result in chronic illnesses. Chlorophyll, a plant-based green pigment, is abundant in wheatgrass. Strong antioxidant properties of chlorophyll have been demonstrated to have an impact on cancer prevention, control of oxidative stress, enzyme activity, gene transcription, free radical scavenging, metal chelation, and aiding in the absorption of iron and other minerals and trace elements has also been demonstrated[14,16]. Wheatgrass contains a number of enzymes that help with digestion and nutritional absorption, including as oxidase, transhydrogenase, protease, amylase, and lipase. Wheatgrass's alkalizing properties aid to maintain a healthy pH level and lessen acidity in the body.

Table 4
Proximate analysis of wheatgrass powder and juice[13,18-21].

Nutrient	Wheatgrass powder	Wheatgrass juice
Moisture (g/100 g)	6.30	93.4
Protein (g/100 g)	25	2.96
Fat (g/100 g)	0.9	0.3
Carbohydrate (g/100 g)	33	2.45
Dietry fibre (g/100 g)	30	0.1
Ash (g/100 g)	4.80	0.89
Chlorophyll (mg/100 g)	513.50	360.3

Table 5
Levels of vitamins and minerals in wheatgrass powder and juice[13,18,22-26].

Vitamins and minerals	Wheatgrass powder	Wheatgrass juice
β-Carotene	182.46 μg/100 g	2.43 mg/100 mL
Vitamin C	14.4 mg/100 g	0.360 mg/100 mL
Vitamin E	9.146 3 mg/100 g	13.8 mg/L
Thiamine	0.616 μg/g	201.80 μg/mL
Riboflavin	2.620 μg/g	1.280 μg/mL
Vitamin B_6	0.96 mg/100 g	4.660 μg/mL
Folic acid	84 μg/100 g	28.900 μg/mL
Vitamin B_{12}	66 μg/100 g	7.660 μg/mL
Iron	5.27 mg/100 g	0.59 mg/L
Calcium	73.8 mg/100 g	39.2 mg/L
Magnesium	24 mg/100 g	133.9 mg/L
Phosphorus	36.66 mg/100 g	1 216.9 mg/L
Potassium	147 mg/100 g	3 383.4 mg/L
Aluminum	4.9 mg/100 g	0.31 mg/mL
Copper	0.2 mg/100 g	0.007 mg/mL
Zinc	3.90 mg/100 g	0.02 mg/mL
Sodium	9.46 mg/100 g	6.83 mg/L

Table 6
Amino acids profile in wheatgrass powder and juice[10,23].

Amino acid	Wheatgrass powder (mg/100 g)	Wheatgrass juice (μg/mL)
Aspartic acid	222	510.3
Threonine	105	105.8
Serine	242	201.8
Glutamine	242	200.6
Proline	94	33.6
Glycine	117	20.6
Alanine	137	166.4
Valine	125	272.1
Methionine	43	14.0
Isoleucine	88	145.1
Leucine	162	101.0
Tyrosine	50	121.8
Phenylalanine	108	200.9
Lysine	82	174.5
Histidine	45	232.2
Tryptophan	11	160.1
Arginine	111	252.9

Table 7
Photochemical screening from different solvent extracts of wheatgrass[27].

No.	Parameter	Ethanol	Methanol	Ethylacetate	Chloroform	Aqueous
1	Phenols	+	+	+	+	+
2	Flavonoids	+	+	+	+	−
3	Alkaloids	+	+	+	+	+
4	Tannins	+	+	−	−	+
5	Saponins	+	−	−	+	+
6	Glycosides	+	+	−	−	+
7	Steroids	+	+	−	−	−
8	Terpenoids	+	+	−	−	−

Note: + Indicates presence of compounds; − Indicates absence of compounds.

Table 8
Phytochemical assessment and antioxidant activities of wheatgrass[11,12,14,28].

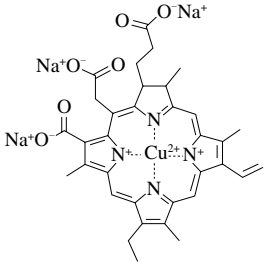
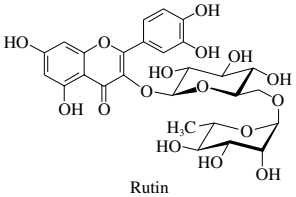
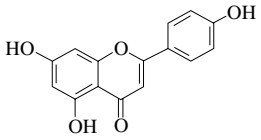
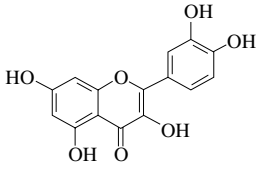
Parameters	Wheatgrass powder	Wheatgrass juice
Total phenolic	17.95−38.49 mg GAE/g	56.66 mg GAE/g
Total flavonoid	10.56−30.64 mg QE/g	4.4−10.1 mg QE/g
Chlorophyll	513.50 mg/100 g	360.3 mg/100 g
DPPH	62.12%−82.53%	13.5−17.3 μmol Trolox/mL
Ferric reducing antioxidant power (FRAP)	7.84−35.45 mmol Fe^{2+}/g	7.78 mg PYE/g extract
Metal chelating activity (MCA)	50.21%−87.79%	25.59 μmol EDTA/g extract

Note: GAE, gallic acid equivalent; QE, quercetin equivalant; PYE, pyrogallol equivalent; EDTA, ethylenediaminetetraacetic acid.

4. Therapeutic properties of wheatgrass

Wheatgrass is a microgreen that has been utilized for its medicinal and nutritional benefits. Fresh wheatgrass is composed of chlorophyll, which has antioxidant and cancer-preventive and also known as "green blood" or "living blood". Chlorophyllin, a chlorophyll derivative, demonstrated mitochondrial protection against oxidative damage. Apigenin, a flavonoid component, has been reported to have antioxidant and anti-inflammatory efficacy[8,10]. Other well-known bioactive compounds of wheatgrass are rutin and quercetin possessing antioxidant, anti-diabetic, anti-inflammatory, and numerous other pharmacological health benefits (Table 9).

Table 9
Physicochemical properties of major components of wheatgrass.

Chemical structure	Molecular weight (g/mol)	Melting point (°C)	Water solubility (mg/L)	Physical state	Reported pharmacological activities	References
 Chlorophyllin	724.15	152.3	Not available	Green powder	Antioxidant activity, chemoprotective potential, detoxifying agent	[81]
 Rutin	610.52	242	12.5	Greenish yellow powder	Antioxidant activity, antidiabetic, anti-inflammotry activity, anticancer, anti-osteoarthritis	[82-84]
 Apigenin	270.24	345−350	18.3	Yellow crystal	Antioxidant, antitumor, anti-inflammatory, nephroprotective, antidepressant agent, cardiovascular disease prevention properties	[85-86]
 Quercitin	302.23	314−316	0.001	Yellow powder	Antioxidant, anti-obesity, antiviral, anti-inflammation, anti-diabetic, as well as preventing asthma, cancer, hypertension and cardiovascular diseases	[87-88]

4.1 Wheatgrass and β-thalassemia

β-Thalassemia syndrome describe a group of genetic blood disorders caused by decreased or absent synthesis of the *β*-globin chain, resulting in reduced amount of hemoglobin (Hb) in red blood cells (RBC), low RBC production and anemia[9]. The two key components of wheatgrass that are used to cure beta thalassemia are its pH value and chlorophyll concentration. Wheatgrass contains a good amount of chlorophyll and has the capacity to increase Hb level. Since the pH of wheatgrass juice is a 7.4, same as that of human blood, because of this similarity, cholorophyll of wheatgrass is quickly absorbed into blood. Hb and chlorophyll have a tetraphyrrol ring in their chemical compositions. The only chemical difference between them is that Hb has an iron porphyrin ring while chlorophyll has a magnesium porphyrin ring[29]. Consequently, wheatgrass may be a useful substitute for blood transfusions in thalassemia major and intermediate patients by increasing Hb levels, lengthening the time between blood transfusions, and decreasing the total amount of blood that is transfused[30]. In a comparable trial with thalassemic children, Dey et al.[31] discovered that it reduced the requirement for blood transfusions in 50% of *β*-thalassemia major patients. Regular wheatgrass supplementation increased Hb levels, increased the intervals between blood transfusions, and decreased the total volume of blood transfused. In an *in vivo* investigation, Grunewald et al.[32] found that giving wheatgrass to rats with low RBC counts for 5 days raised their blood's RBC count. Similar findings have been observed by other researchers[33].

4.2 Anti-ulcer potential of wheatgrass

Wheatgrass is used as a natural herbal tonic for the treatment of ulcer, and has been shown anti ulcerative potential; the key components responsible for this effect being chlorophyll, apigenin, and chlorophyllin. Inspite that wheatgrass juice contains various water soluble biomolecules, protein and bioactive compounds. These components have been shown to exhibit anti stomach ulcer potential on experimental stressed rat model system. In a clinical trial, wheatgrass extract was discovered to have anti-ulcer potential and be used as a supplemental therapy to treat rectal bleeding by Ben-Arye et al.[34]. The scientific study also revealed that apeginen, a bioactive molecule with potential anti-inflammatory and antioxidant properties, is present in wheatgrass, and also supports suppression of tumour necrosis factor (TNF)-induced transactivation[35]. Other clinical study was conducted to evaluate anti-ulcer potential of chlorophyll a major water-soluble bioactive compound present in wheatgrass has shown various therapeutic potential to treat loss of odour associated

with infected wounds, drying effect in case of skin lesions, sinus, abscesses and surface rashes and promoting tissue generation[36]. Wheatgrass also contains chlorophyllin derivatives of chlorophyll, showed antibacterial activity, help in wound healing and increased Hb level in anemic animal. According to several studies, chlorophyll is used to cure concerns in a variety of circumstances, including ulcer, suppurative disease, and the growth of new tissues[37-38].

4.3 *Anti-diabetic potential of wheatgrass*

Alkaloids, flavonoids, phenolics, tannins, saponins, and natural fibre are the main elements in wheatgrass that lower blood glucose levels and have been shown to have anti-diabetic potential[39]. The anti-diabetic activity of wheatgrass was investigated by Mohan et al.[40] with streptozotocin-induced diabetic rats. They discovered that wheatgrass included phenolic, flavonoids, alkaloids, tannins, and saponins that have anti-diabetic activities and these bioactive substances work similarly to insulin to reduce blood sugar levels and boost insulin production by improving insulin sensitivity, and also stimulating regeneration of insulin from beta cells of pancreas in diabetic rats[41]. Contrarily, a study on animals by Shaikh et al.[42] revealed that wheatgrass's phenolic and flavonoid components lower animals' blood glucose levels. As a result, it was found through scientific research that wheatgrass is a rich source of natural fibres and bioactive compounds including chlorophyll, rutin, and apigenin that help to maintain blood sugar levels and are therefore believed to have beneficial effects against diabetes.

4.4 *Hepato-protective potential of wheatgrass*

Phytochemicals of wheatgrass acts as a defense mechanism against several elements that can harm liver. Under various clinical circumstances, rutin, chlorophyllin have reportedly been shown to regulate the levels of liver enzymes and so guard against liver cell damage. These compounds are able to normalize the levels of liver enzymes including serum glutamic oxaloacetic transaminase (SGOT) and serum glutamate pyruvate transaminase (SGPT) in a streptozotocin-induced rats[40]. Various studies reported that the level of liver enzymes returned to almost normal after the supplementation of wheatgrass extract to rat model[11,43-44]. Wheatgrass possess chlorophyll and choline compounds which are identified as the main nutrients causing the liver protection. Nutrients present in wheatgrass as magnesium, potassium prevent the buildup of fat in the liver and maintain the liver health.

4.5 *Antioxidant potential of wheatgrass*

Wheatgrass has been demonstrated to contain many antioxidants, including polyphenols and flavanoids, like many other medicinal plants. These bioactive substances have antioxidant properties. Wheatgrass's ability to scavenge free radicals has been linked to its antioxidant capacity[45]. Superoxide dismutase (SOD), an antioxidant enzyme found in wheatgrass, is also responsible for converting damaging free radicals into hydrogen peroxides and oxygen molecules[46]. Several clinical trials have demonstrated wheatgrass's capacity to scavenge free radicals; these free radicals are responsible for lipid peroxidation of membrane and cellular damage[47]. In lipid peroxidation process, the harmful free radicals react with polyunsaturated fatty acid of cellular membrane and produce free radical initiated lipid (LH), which is highly cytotoxic[48]. According to some studies, supplement of wheatgrass juice significantly decreased the formation and activity of free radicals in streptozotocin-induced diabetic rats as well as MDA levels and lipid peroxidation. Wheatgrass can exhibit antioxidant potential by scavenging the superoxide anion and hydroxyl radicals, according to a number of experimental experiments. Mohan et al.[40] did a clinical study and found that high levels of antioxidant enzymes including lipid peroxidase, glutathione peroxidase, and SOD are decreased by wheatgrass ethanol extract in various ailment conditions. Antioxidants like flavonoids, phenolic compounds, and chlorophyll are abundant in wheatgrass. Antioxidants aid in defending the body against oxidative stress brought on by free radicals, which can damage cells and exacerbate chronic illness. Wheatgrass enhance the general health and wellbeing by being incorporated into functional meals and nutraceuticals to take advantage of its antioxidant-rich properties (Fig. 2).

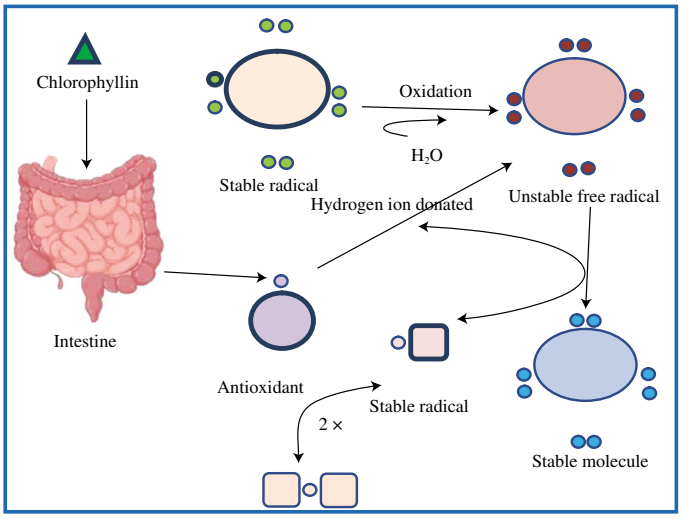


Fig. 2 Antioxidant activity of chlorophyll present in wheatgrass.

4.6 *Cardio-protective potential of wheatgrass*

Some studies carried out both ways *in vivo* and *in vitro* have shown that wheatgrass may be involved in protection of the function of heart. The chlorophyll content present in this plant has been shown to be responsible for it. Sethi et al.[49] stated that the oral administration of wheatgrass juice reduces the total cholesterol and very-low-density lipoprotein (VLDL) levels and increases high density lipoprotein (HDL) (good cholesterol) level in rat model which consumed high fat diet. The chlorophyll A, a green pigment present in the wheatgrass is responsible to keep heart healthy with smooth functioning. Wheatgrass juice has been found to reduce blood pressure by dilating the blood vessels so that they can carry the blood easily and efficiently. This plant is excellent source of minerals such as calcium and potassium which are required to maintain the electrolyte balance in heart for its proper function. Another study in the rat model system, the effect of fresh wheatgrass juice on lipid profile was evaluated[50]. The outcome of the study was that supplementation of fresh wheatgrass juice decreased the level of total cholesterol, LDL, VLDL and triglycerides in the rat blood.

4.7 Anti-cancer potential of wheatgrass

Wheatgrass constituents responsible for its anti-cancer effects were chlorophyll, chlorophyllin, rutin, and abscisic acid (ABA). Although there are no known causes for cancer to develop, numerous things, including smoking, inactivity, and radiation exposure, can cause this illness. Surgery, chemotherapy, and radiation are the most popular cancer therapies, but they are pricy and have negative side effects. Due to its natural makeup, dependability, and safety at known quantities, wheatgrass can be employed as an anti-cancer agent. Chlorophyll, phenolis and flavonoids content of wheatgrass been found to lower the risk of myelo toxicity associated with chemotherapy for breast cancer patients [51]. The chlorophyllin, derivative of chlorophyll and major bioactive compounds present in wheatgrass have been found to be associated with the anti-cancer property of the plant extract when tested both in various *in vivo* and *in vitro* studies[52].

Another study by Dey et al.[31] found that wheatgrass extract could improve the health of cancer patients by lowering the carcinogenic potential of mutagens[53-54]. Furthermore, another clinical study was conducted by Chiu et al.[55] with chlorophyllin, to evaluate its anti-cancer potential against human breast cancer. They have observed that chlorophyllin can reduce the risk of human breast cancer. Besides this chlorophyll, and derivatives of chlorophyll showed anti-cancer potential in cases of liver, colon, stomach, skin and gastrointestinal cancer[56-57]. The *in vitro* and *in vivo* studies have shown that chlorophyllin could reduce the activity of liver cytochrome P450, it has been observed the reduced activity of liver cytochrome P450, resulting in longer lifespan and lower cancer rates[58]. ABA, rutin are other bioactive compounds of wheatgrass concerned as an anti-cancer representative and anti-cancer potential of wheatgrass is due to its anti-oxidant activity, which prevents oxidative damage of DNA[46].

4.8 Detoxifying potential of wheatgrass

The phytochemicals present in wheatgrass such as choline, indole compounds, chlorophyll have been shown to be associated with the detoxification of xenobiotics in the living systems. Wheatgrass is a rich source of chlorophyll; indole compounds, vitamins and minerals, these nutrients and bioflavonoids compounds help make the plant as an excellent natural detoxifying agent. The chlorophyll in wheatgrass is regarded as a natural body cleaner because of its capacity to rebuild and neutralize toxins or toxic substances from the body and aid in the removal of medications and other potentially dangerous foreign substances[59]. Choline another component of wheatgrass acts as detoxifying agent, study was conducted to see the effect of choline on accumulation of fat in liver of experimental animals, when they received a diet supplemented cholesterol rich diet. It was observed that choline acts as detoxifying agent and helps removal of esters of cholesterols and sterols[24]. Choline also has been showed lipotropic action and promotes transportation of fatty acid in plasma and removes lipid from liver, thereby preventing accumulation of fat in the liver[30,60].

4.9 Anti-arthritis potential of wheatgrass

Rheumatoid arthritis symptoms include inflammation of joints, severe pain, stiffness and swelling. Females of above 50 years of age are mostly affected by the rheumatoid arthritis compared to males. It has been found that wheatgrass extract can help with joint discomfort and illnesses of the bones. The main elements of this microgreen, such as lactobacilli, chlorophyll, vitamins (beta carotene, thiamine, riboflavin, and niacin), minerals (calcium, magnesium, potassium sodium, iron, zinc, and copper), and antioxidants (vitamin A, C, E, and SOD), have been shown to have anti-arthritis potential. By several clinical studies, has been shown that the wheatgrass extracts are useful in reducing severity of symptoms of rheumatoid arthritis. An animal study was conducted by the Shaikh et al.[42] to evaluate the anti diabetic potential of fresh wheatgrass extract in alloxan induced diabetic rats and reported that the raw plant based vegetarian diet is rich source of lactobacilli, chlorophyll, soluble fraction and fiber, which exhibits anti arthritic potential, as it promotes to reducing the symptoms of rheumatoid arthritis in alloxan induced diabetic rats. According to a different study, fermented wheatgrass drink, also known as avemar, which is rich source of vitamins, minerals, antioxidants, bioactive substances, and chlorophyll, lessens the severity of rheumatoid arthritis. Due to its anti-inflammatory capabilities, daily ingestion of avemar helps to lessen the degree of joint inflammation, according to a clinical trial conducted by Nenonen et al.[61]. Wheatgrass was discovered to have anti-inflammatory potential because it improved bone mobility and function while reducing joint and bone inflammation.

4.10 Wheatgrass and Alzheimer's disease

The impact of plants and microgreens on Alzheimer's has been investigated in numerous studied but there is no scientific evidence has been found to date to support the use of natural herbal remedies to delay Alzheimer's disease symptoms. For the treatment of this ailment, numerous clinical researches have been conducted on the formulation of novel natural herbal substances from natural medicinal sources. Stevenson et al.[62] conducted a clinical investigation and found that wheatgrass functions as an antioxidant by scavenging free radicals (superoxide anion and hydroxyl radicals) and antioxidant enzymes that reduce free radicals and enhance memory, by enhancing cellular homeostasis and the body's defenses against oxidative stress, wheatgrass's antioxidant capability increased the neuroprotective impact[63]. Like all green plants, wheatgrass is a good provider of oxygen. The brain and other body organs must operate properly in an oxygenated atmosphere. Additionally, it fosters the growth of intellect[64]. According to their research, wheatgrass may be utilised to treat Alzheimer's disease.

4.11 Dermatological potential of wheatgrass

The bioactive components found in wheatgrass, including chlorophyll, apigenin, and agrophyere, have been discovered to be effective natural treatments for skin conditions. Wheatgrass is a great source of the green pigment chlorophyll A, which has anti-inflammatory and wound-healing properties and is used to treat a variety of skin conditions. In addition, wheatgrass contains apigenin, agrophyere, and flavonoids, have anti-inflammatory qualities. According to Chernomorsky et al.[35], wheatgrass chlorophyllin also has antimicrobial properties, which aids in wound healing by encouraging epithelialization of tissue and maintaining healthy skin.

4.12 Anti-microbial activity of wheatgrass

Anti-microbial is the act of killing or inhibiting or suppressing microorganisms from their multiplication or growth. There are certain phytochemicals that are known to have anti-bacterial properties which include flavonoids and alkaloids. Most of these phytochemical constituents are potent bioactive compounds found in wheatgrass, parts of which are precursors for the synthesis of useful drugs[65]. Das et al.[66-67] found that 80% acetone extracts of wheatgrass were effective against 5 food borne microorganisms, including the fungus *Aspergillus niger*, a common contaminant of food. Pallavi et al.[68] tested wheatgrass extracts against the Gram-positive bacteria; *Staphylococcus aureus*, *Bacillus subtilis* and Gram-negative *Eschericia coli*; using amoxicillin as standard. The findings were that certain extracts showed considerable activity against *B. subtilis* and moderate activity against *S. aureus* and *E. coli.* Plants contain thousands of constituents which are valuable sources of new and biologically active molecules having anti-microbial properties. A wide variety of secondary metabolites, such as tannins, terpenoids, alkaloids and flavonoids, are found to have anti-microbial properties *in vitro*[69]. These natural products are of great concern as a source of safer and/or more effective alternatives to synthetically produced anti-microbial agents. Wheatgrass extract has a high content of bioflavonoids which may add towards anti-microbial effects[50,70].

4.13 Prebiotic potential of wheatgrass

The human gastrointestinal microbiota, one of the most densely populated microbial communities on earth contains highly diverse microbial communities that provide metabolic, immunologic, and protective functions that play a crucial role in human health[71-73]. The gastrointestinal microbiota is influenced by a number of factors including genetics, host physiology (age of the host, disease, stress, etc.) and diet[74-77]. Indeed, consumption of specific dietary ingredients, such as fiber and prebiotics, is an avenue by which the microbiota can be modulated. Dietary fibers, carbohydrate polymers including inulin, polydextrose, resistant starch, β-glucan, galactooligosaccharide and other oligosaccharides which are neither digested nor absorbed, are subjected to bacterial fermentation in the gastrointestinal tract and thus impact the composition of bacterial communities as well as microbial metabolic activities, including the production of fermentative end products, can be classified as prebiotic[78]. Prebiotics are defined as selectively fermented ingredients that result in specific changes, in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health[79]. Wheatgrass is an excellent source of complex carbohydrates and fibers which shows its prebiotic potential. Inulin is the most tested carbohydrate and it occurs naturally in wheat (*Triticum* sp.), asparagus (*Asparagus officinalis*), chicory (*Cichorium intybus*), Jerusalem artichoke (*Helianthus tuberosus*), garlic (*Allium sativum*), onion (*Allium cepa*), banana (*Musa* sp.) and oats (*Avena sativa*). These compounds are currently being added to foods like cereals Roberfroid et al.[80] reported that wheatgrass by stimulation of growth of probiotic organism (*Lactobacillus casei*) and can be consumed as prebiotics.

4.14 Other potential efficacy of wheatgrass

In addition to its many therapeutic benefits, wheatgrass was found to be able to prevent gout symptoms by preserving a healthy amount of uric acid in the blood. Soluble dietary fibres included in wheatgrass powder are helpful in preventing obesity and managing weight. Due to its alkaline pH, wheatgrass has been proven to be effective in the therapy of acidity and is therefore used to cure a variety of gastrointestinal tract problems. Wheatgrass contains a significant amount of the chlorophyll A, which can be applied to burn victims as a dressing. Breathing disorders like bronchitis, asthma, and the common cold have all been successfully treated using wheatgrass juice as herbal medicine[27]. Wheatgrass is an alternative therapy in the prevention and treatment of teeth and gum related diseases such as pyorrhea, and tooth decay. Wheatgrass juice is used as mouth wash and also in relieving ear pain and ear diseases.

5. Conclusion

Wheatgrass, a miracle microgreen, is a rich source of protein, vitamins, minerals, and antioxidants that boost its pharmacological potential against a variety of ailments, such as anaemia, thalassemia, ulcerative colitis, diabetes, cardio vascular disease, and liver disorders. Wheatgrass is effective at boosting strength, reducing fatigue, and maintaining the blood pressure and blood sugar levels. It promotes healthy digestion, removes toxins, reduces weight, activates brain function, and delays ageing. Therefore, incorporating wheatgrass as an integral part of the daily diet enhances the nutritional level and elevate the health status of the individual.

Conflicts of interests

All the authors declared no conflicts of interest.

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Author contribution

Neetu Mishra: Conceptualization & supervision; Renu Tripathi: Writing original draft; Dhananjay Pandey: Writing-review & editing; Kamal Shah: Review & editing; Nagendra Singh Chauhan: Supervision & editing.

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