Review Article

Mushroom Consumption as a Proactive Approach for Improving Human Health: A Review

ABSTRACT

Mushrooms have been considered as a therapeutic food due to its high nutritional and medicinal values. It is a good source of proteins and carbohydrates and also contain essential vitamins like vitamin B complexes, C, A, D and E; essential as well as non-essential amino acids; and valuable minerals such as iron, calcium, zinc, selenium, magnesium, sodium, manganese, potassium, copper, phosphorous and cobalt which play a vital role in stimulating immune function and improving metabolism, and thus, beneficial for human health. Various extracts and biologically active compounds such as polysaccharides, glycoproteins, terpenoids, alkaloids, sterols, phenolics, cordycepin and cordycepic acid from fruitbodies of different mushroom species showed beneficial effects in the treatment of many human diseases including life-threatening disease like respiratory illness, tuberculosis, cardiovascular disease, diabetes mellitus, cancers, microbial infection and also showed positive effect against HIV, influenza A virus, hepatitis B virus and herpes simplex virus type 1. This review describes the importance of White button mushroom (*Agaricus bisporus*), Oyster mushroom (*Pleurotus sajor-caju*), Paddy straw mushroom (*Volvariella volvacea*), Milky mushroom (*Calocybe indica*), Termitarium mushroom (*Termitomyces* spp.), Rugra mushroom (*Astraeus hygrometricus*), Cordyceps mushroom (*Cordyceps militaris*) and Reishi mushroom (*Ganoderma lucidum*) so that, people include mushroom in their diet to make themselves healthy and strong enough to fight against infections caused by foreign substance (antigens) like bacteria and virus.

Keywords: Biologically active compounds; Human health; Minerals; Mushrooms; Proteins; Therapeutic food; Vitamins

1. INTRODUCTION

The word 'Mushroom' generally represent the sporocarp of the fungi. Some mushrooms are poisonous and some are found safe for human consumption. The edible mushroom contain high value of nutrients (proteins, carbohydrates, fibers, vitamins and mineral elements) and biologically active compounds such as polysaccharides, glycoproteins, terpenoids, alkaloids, sterols and phenolics [1-4]. These nutritional components and biologically active compounds are known to have beneficial effects on human health and also contribute in treatment of many human diseases like diabetes mellitus, cardiovascular disease, immune disorders, microbial infections, cancers and many more [5-7].

Very small number of mushroom species are commercially cultivated and rest are still remain wild in the forest. Most commonly cultivated edible mushrooms that are easily available for consumptions in different regions of India are White button mushroom (*Agaricus bisporus*), Oyster mushroom (*Pleurotus sajor-caju*), Paddy straw mushroom (*Volvariella volvacea*) and Milky mushroom (*Calocybe indica*) [8]. Termitarium mushroom (*Termitomyces* spp.) and Rugra mushroom (*Astraeus hygrometricus*) are the wild edible mushroom that are commonly consumed during its natural availability in monsoon season due to its taste, nutritional values and also as a substitute to vegetables which are in limited supply during rainy season [9-11]. Cordyceps mushroom (*Cordyceps militaris*) and Reishi mushroom (*Ganoderma lucidum*) are the two commercially cultivated medicinal mushroom in India [12,13]. The nutritional values of *Agaricus bisporus*, *Pleurotus sajor-caju*, *Volvariella volvacea*, *Calocybe indica*, *Termitomyces* spp. and *Astraeus hygrometricus*; and therapeutic potentials of *Cordyceps militaris* and *Ganoderma lucidum* are discussed in this review study so that people get aware about its importance and consume regularly to maintain balance diet, improve health and make immune system strong.

2. STATUS OF MUSHROOM PRODUCTION: AT A GLANCE

According to FAOSTAT, 2022, global mushroom production accounted to 42.79 million tonnes in 2020, increased by 2.5% from 41.73 million tonnes in 2019 and estimated an average in the annual production rate in last five years of 2.12% (Figure 1). China, mainland was the top producer with more than 40 million tonnes of mushroom production in 2020, which contribute about 93.47% of the total global mushroom production, followed by Japan (1.10%), USA (0.86%), Netherlands (0.60%), and India (0.46%). Countries like Poland, Spain, Canada, UK and Iran were among the top ten global producers (Figure 2). In last few years, mushroom production increases in India and becoming the important mushroom producing country. As per ICAR-DMR annual report 2018-19, India accounted to more than 0.15 million tonnes of mushroom production in 2018, and as per FAOSTAT, in 2020, accounted more than 0.2 million tonnes and marked increase in production by 33.33% and now become top five global mushroom producers. As per the annual report of ICAR-DMR, 2018-19, Haryana, Odisha, Maharashtra, Himachal Pradesh, Punjab, Gujarat, Uttarakhand, Tamil Nadu, Uttar Pradesh, and Goa were the top ten mushroom producing state/UT in India, out of these, Haryana was the largest producer, which accounted approximately 20050 tonnes of mushroom followed by Odisha (19532 tonnes) and Maharashtra (18380 tonnes), and they collectively contributed approximately 38% of the total mushroom production of the country. North eastern region of India like Sikkim, Meghalaya, Arunachal Pradesh, Mizoram, Manipur reported very low production with less than 100 tonnes, whereas, Assam status of mushroom production is far better than other north eastern states but still not matching with the other states/UT of India. Based on the FAOSTAT trade data, in 2020 global export and import of mushrooms (also include canned mushrooms and truffles) estimated to more than 1.79 million tonnes and 1.27 million tonnes which was amounted to more than USD 5.02 billion and USD 3.03 billion respectively. China (mainland), Netherlands, and Belgium were the top three exporters and contributed around 41.53% of the total share, whereas, Belgium, Germany, and USA were the top three importers with 30.74% of the total imports of the mushrooms worldwide. China is the leading mushroom exporter and exported more than 0.39 million tonnes of mushroom which valued more than USD 1.24 billion to all over the world. Other major exporters like Netherlands and Belgium exported 0.24 million tonnes and 0.10 million tonnes with value USD 488.39 million and USD 164.28 million respectively. On the other hand, Belgium was the largest importer of mushroom with 0.11 million tonnes which valued USD 170 million, followed by Germany and USA with 0.14 million tonnes and 0.12 million tonnes of mushroom of value USD 368.09 million and USD 478.33 million respectively. In 2020 as per FAOSTAT, India exported total 573 tonnes and imported total 65 tonnes of mushroom of value USD 0.87 million and USD 0.44 million respectively. As compared to past year India's mushroom export and import data with 2020, export quantity increased by 42.89% and import decreased by 33.67%, this shows increase in mushroom production and consumption in the country. Maximum of mushroom is generally exported from India to Nepal, Germany, Austria, Oman, and Norway; whereas, maximum of the mushroom imported from China. Among different cultivated edible and medicinal mushroom species, only few of them are generally cultivated commercially by seasonal farming method as well as by growing in controlled condition method with the use of air conditioner, humidifiers and other instruments in all over the world. These include White button mushroom, Paddy straw mushroom, Black ear mushroom, Oyster mushroom, Milky mushroom, Winter mushroom, Reishi mushroom, Shitake mushroom, and Caterpillar mushroom. Production of White button mushroom is the highest among all the cultivated mushroom in the world and widely consumed by people across the globe. In India White button mushroom, Paddy straw mushroom, Milky mushroom, and Oyster mushroom are most commonly cultivated, out of which White button mushroom contributed maximum share around 73% of the total mushroom production, followed by Oyster and Milky mushroom [16].

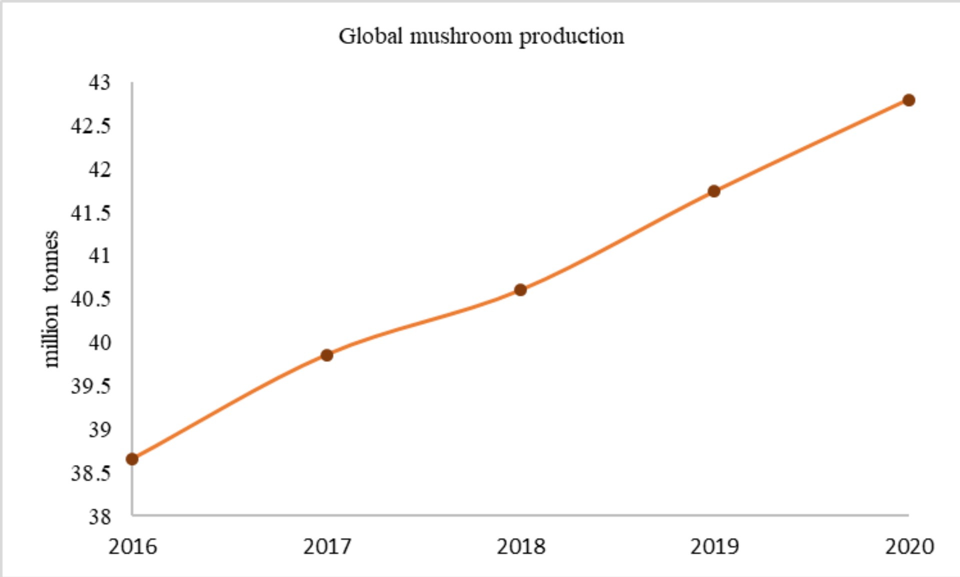

Fig. 1. Global mushroom production of 5 years. Data source: FAOSTAT. Note: Data also include small portion of truffles.

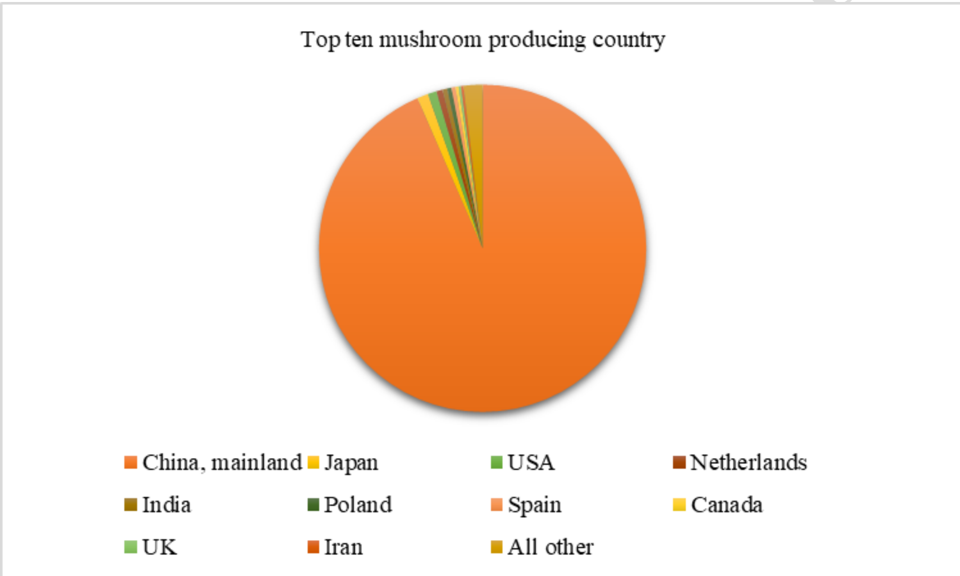

Fig. 2. Top ten mushroom producing country in 2020. Data source: FAOSTAT. Note: UK also include Northern Ireland; data also include small portion of truffles.

3. NUTRITIONAL VALUE OF EDIBLE MUSHROOM

Mushrooms are the excellent source of nutrients such as proteins, essential amino acids carbohydrates, fiber, vitamins and mineral elements such as iron (Fe), calcium (Ca), zinc (Zn), potassium (K), phosphorous (P), selenium (Se), magnesium (Mg), sodium (Na), manganese (Mn) and copper (Cu) [17]. Adding mushroom in diet could help to reduce malnutrition, improve health and enhance immunity. Nutritional constituent and values differ among species and also within similar species due to different types or combination of substrate used for cultivation, developmental stage, environmental conditions and post-harvest management of mushrooms [18-20]. The moisture content in almost every mushroom ranges between approximately 80 to 95% [21].

3.1 Proteins and Amino Acids

Proteins and carbohydrates are the major component of mushroom. It is a rich source of soluble and digestible (up to 90%) proteins and considered higher quality than that of vegetable proteins [22]. The protein content on dry weight basis in *Agaricus bisporus* was found to be 41.06% by Pushpa and Purushothama (2010); 39.10% in *Pleurotus sajor-caju* by Johnsy *et al*. (2011); 38.90% in *Volvariella volvacea* by Eguchi *et al*. (2015); 27.25% in *Calocybe indica* by Sumathy *et al*. (2015); 40.95% in *Termitomyces heimii* by Atri *et al*. (2014) and 16.37% (11.71% and 4.66% in outer and inner part of fruitbody respectively) in *Astraeus hygrometricus* by Singh (2010) (Figure 3). Due to the huge amount of protein content, mushroom considered a rich source of essential as well as non-essential amino acids [28]. Nutrient component analysis on *Volvariella volvacea* done by Eguchi *et al*. (2015) revealed that the fully matured fruiting body contains the maximum amount of amino acids. They also found that Paddy straw mushroom contain high concentration of valine and considered as a substitute to meat, fish and cheese which are considered as a rich source of valine. Bano *et al*. (1981) stated that the presence of even small concentration of sulfur containing amino acids in mushroom is highly beneficial. The largely consumed White button mushroom consists of alanine, arginine, aspartic acid, cysteine, glutamic acid, methionine, serine, tyrosine, threonine, isoleucine, leucine, proline, lysine, and phenylalanine [30].

3.2 Carbohydrates, Fibers and Fatty Acids

The carbohydrate content on dry weight basis in *Agaricus bisporus* was found to be 28.38% by Pushpa and Purushothama (2010); 38.57% in *Pleurotus sajor-caju* by Johnsy *et al*. (2011); 42.30% in *Volvariella volvacea* by Eguchi *et al.* (2015); 49.06% in *Calocybe indica* by Sumathy *et al.* (2015); 36.20% in *Termitomyces heimii* by Atri *et al.* (2014) and 64.89% (29.48% and 35.41% in outer and inner part of fruitbody respectively) in *Astraeus hygrometricus* by Singh (2010) (Figure 3). Mushroom carbohydrate comprises of glycogen, chitin, trehalose, α- and β-glucans, glucose, mannitol, hemicelluloses, etc [6,31]. Cultivated edible mushrooms contain more mannitol, trehalose and glucose than sucrose and fructose [6,19]. Eguchi *et al.* (2015) found that with the maturation of fruitbody of Paddy straw mushroom, the carbohydrate level decreases with the increase in protein level. Mushrooms are the good source of fiber, its high content in mushroom shows beneficial effect in digestion process [25]. The maximum crude fiber content of 18.23% was reported in White button mushroom [23], followed by 14.07% in Milky mushroom [26] while lowest of 0.15% in Rugra mushroom [9] (Figure 3). Mushrooms are low in fat content, major portion of fat in mushrooms are polyunsaturated fatty acids, mostly linoleic acid which is an essential fatty acid and are beneficial for human health [4,21].

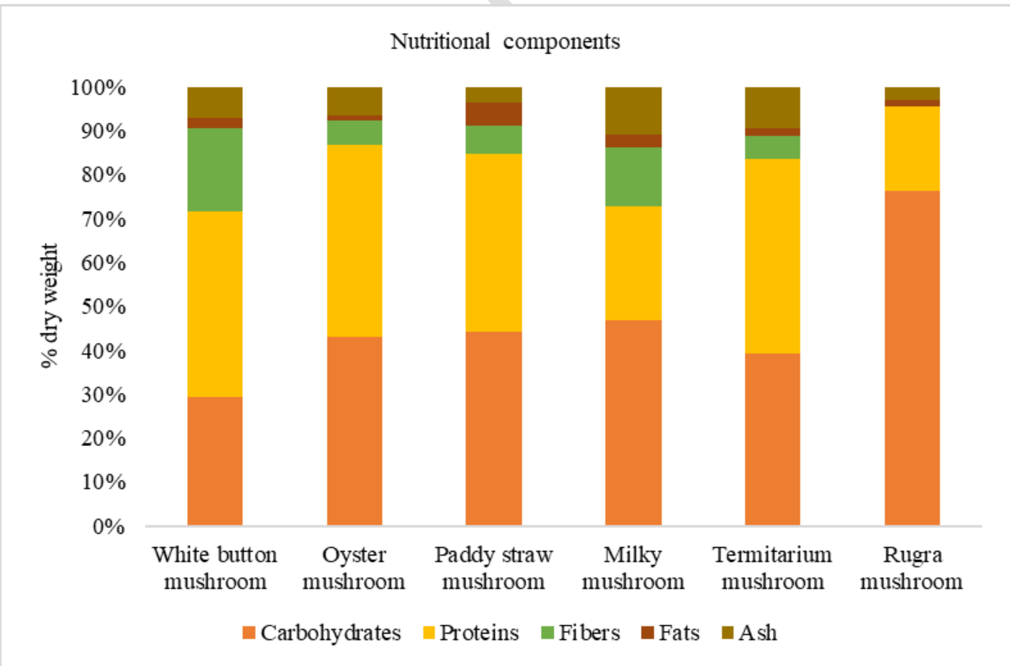

Fig. 3. Nutritional components of cultivated and wild edible mushroom [9,23-27].

3.3 Vitamins

Mushroom could be a good alternative for vitamin diet. They are the rich source of vitamin B complexes, C, A, D and E [6]. Mushrooms are the only food source of vitamin D and B12 for vegetarians. Vitamin D content was found to be higher in wild mushroom than that of cultivated one [4,17,19,20,32,33]. A good amount of vitamin B3 (niacin), B2 (riboflavin), B9 (folic acid) and B1 (thiamine) were reported in White button mushroom [34]. Eguchi *et al*. (2015) found only vitamin B complexes in Paddy straw mushroom in their study. Vitamin B content in Milky mushroom was found higher than vitamin E, A and C by Sumathy *et al.* (2015). Vitamin A, C, B1 and B2 were reported in Termitarium mushroom, among different *Termitomyces* spp. maximum amount of vitamin C was found in *Termitomyces reticulatus* and vitamin A in *Termitomyces heimii* [27]. Singh (2010) reported vitamin C and B1 in Rugra mushroom.

3.4 Minerals

The amount of ash content indicate the mineral profile of the mushroom [25]. Mineral content in fruiting bodies of wild mushrooms have been found to be higher than commercially farm raised mushrooms [17]. It has beneficial effects on human health [35] such as Zn and Mg function as a co-factor of many enzymes, Fe is an essential component of haemoglobin in red blood cells and myoglobin in muscle cells, Cu and Mn help in biochemical as well as physiological process, Na has an important role in regulation of blood pressure, Ca help in bone development and constitute a major component of bone, K has as an important function in proteins and amino acids synthesis, other trace elements like Co, Ni, Li, Se, Cr are also beneficial for human health as some of these elements play a vital role in stimulating immunity [9,36]. Saiqa *et al*. (2008) found K (8.35 mg), Na (27.28 mg), Ca (0.204 mg), Cu (0.108 mg), Mg (0.0136 mg), Mn (0.056 mg) and Zn (0.083 mg) per gram of cultivated *Agaricus bisporus*. Anakalo *et al*. (2008) analysed mineral content in *Pleurotus sajor-caju* cultured on three different substrate (water hyacinth, wheat straw and corncob) and found that mineral concentration was higher on water hyacinth substrate than that of other two selected substrate. They reported Na (2.93 mg), K (11.68 mg), P (10.80 mg), Ca (6.40 mg), Fe (1.92 mg), Cu (0.03 mg), Mg (7.74 mg) and Zn (0.30 mg) per gram on dry weight basis in *Pleurotus sajor-caju* cultured on water hyacinth substrate. Sumathy *et al*. (2015) found Na, K, P, Ca, Fe, Zn, Mg, Mn and Se at 13.15 mg, 59.34 mg, 469.30 mg, 20.94 mg, 59.16 mg, 10.36 mg, 11.20 mg, 1.00 mg, 0.001 mg per gram in *Calocybe indica* respectively. Eguchi *et al*. (2015) found K at 33.45 mg/g as most abundant mineral element followed by Ca 3.98 mg/g in *Volvariella volvacea*. Mineral elements Ca (2.40 mg), P (2.20 mg), Mg (1.60 mg), K (12.80 mg), S (1.70 mg), Fe (3.25 mg), Cu (0.016 mg), Mn (0.329 mg), Zn (0.203 mg) and B (0.002 mg) per gram on dry weight basis reported from matured fruiting bodies of *Astraeus hygrometricus* [38]. Mineral analysis study conducted by Atri *et al*. (2014) on 7 species of *Termitomyces* viz., *T. heimii*, *T. microcarpous*, *T. striatus*, *T. medius*, *T. badius*, *T. mammiformis* and *T. radicatus* revealed the mineral content of wild edible Termitarium mushroom. The authors found maximum of Fe (6.73 mg/g) in *T. mammiformis*, maximum of Ca (2.04 mg/g), Mg (3.30 mg/g), Mn (0.13 mg/g) in *T. medius* and maximum of Cu (0.11 mg/g) in *T. striatus* on dry weight basis.

4. MEDICINAL MUSHROOM WITH HIGH THERAPEUTIC POTENTIAL

A part from nutritional value, a number of mushroom species comprises numerous phytochemicals that have been shown to exhibit therapeutic effect and thus are beneficial in cure of various diseases. The bioactive compounds isolated from mushroom are known to be a natural source of antiviral, anti-oxidative, immune-modulatory, anti-microbial, anti-tumor, anti-parasitic, anti-inflammatory, anti-diabetic, hepatoprotective, anti-nociceptive agents [39,40]. Bioactive compounds found in mushrooms are polysaccharides, glycoproteins, terpenoids, alkaloids, sterols, polyphenols, carotenoids, flavonoids [6,11,41,42]. Fungal β-glucans help to enhance the immune system, protect from pathogenic microbes and have been reported to possess antioxidant, anticancer, neuroprotective activities [6]. Lectins isolated from mushroom exhibit antiviral, immunemodulatory, antitumor and anti-proliferative activity [39,43]. Sterol (ergosterol) from mushroom help in the prevention of cardiovascular disease [20]. Flavonoids show hepatoprotective, anti-diabetic, anti-inflammatory activities [41]. Like vegetables, β-caroten is also found in mushroom and shows anti-oxidative properties [11,44]. Guillamón *et al*. (2010) stated the anticholesterolemic properties of lovastatin and chitin isolated from mushroom.

4.1 Reishi Mushroom

Ganoderma lucidum, 'the king of medicinal mushrooms' or 'the mushroom of immortality' is commonly known as Lingzhi mushroom in China or Reishi mushroom in Japan [4,6]. The major bioactive compound found in *Ganoderma lucidum* are polysaccharides, peptidoglycans and triterpenes and has been shown to exhibit broad range of pharmacological effect such as antiviral, anti-oxidative, immune-stimulating, antiinflammatory, hepatoprotective, anti-allergic, anti-mutagenic, antiulcer, antitumor, antibacterial, anti-parasitic, anti-diabetic, radioprotective [6,45]. Polysaccharides and triterpenoids from *Ganoderma lucidum* showed immunomodulation effect by promoting the production of cytokines, including IL-2, IL-6, IL-10, TNF-α and interferon by stimulating the components of immune system such as macrophages, T lymphocytes, B lymphocytes and natural killer cells [46]. Several extract from *Ganoderma lucidum* fruitbodies also exhibit antiviral effect against HIV, influenza A virus, hepatitis B virus and herpes simplex virus type 1 [47,48]. Gao *et al*. (2004) found that extract from *Ganoderma lucidum* showed better result than oral anti-diabetic drugs in lowering blood glucose level in diabetes type II patients. *Ganoderma lucidum* has numerous health benefits and act as an immune system enhancer [48].

4.2 Cordyceps Mushroom

Cordyceps militaris popularly known as orange caterpillar mushroom, specifically cultivated for its immense medicinal value. Cordyceps mushroom contain wide range of biologically active compounds such as cordycepin (3'-deoxyadenosine), cordycepic acid, cordymin, cordyheptapeptide, polysaccharides, adenosine [50]. These bioactive compounds exhibit wide range of therapeutic effects like antioxidant, anti-diabetic, antitumor, antimicrobial, antiinflammatory, antiviral [50,51]. Studies conducted by various researcher on extract from Cordyceps mushroom fruitbodies, found beneficial effects in the treatment of asthma, tuberculosis, diabetes, dizziness, cold virus, myodesopsia, leukemia, insomnia, sexual impotence, sperm motility and productivity, coughing and sputum, nervous prostration, anemia [52-54].

5. CONCLUSION

The fruitbodies of cultivated and wild mushroom contain good amount of nutrients like proteins, carbohydrates, vitamins and mineral elements which may help to solve the problem of malnutrition and also help to maintain healthy and balance diet; and wide range of biologically active compounds which are known to have number of therapeutic properties are beneficial in the treatment of many human diseases. Due to its high nutritional and medicinal values, regular consumption could be beneficial for human health and also could be considered as an alternative solution for boosting immunity to fight against microbial infection like bacteria, virus and other harmful pathogenic microbes causing life-threatening diseases.

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