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THE ANTIOXIDANT COMPONENTS AND UMAMI MOLECULES IN MUSHROOMS: A REVIEW

Anshika Phutela and Aparajita Bhasin*
Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India, 144411
*Corresponding author: jita.84@gmail.com, Phone: +916239266925

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ABSTRACT

Mushrooms possess several therapeutic properties such as antioxidant, antifungal, antimicrobial, anticancer, antineoplastic, antidiabetic, anti-inflammatory, antibacterial, cholesterol-lowering, and immune-stimulating effects. Antioxidants are defined as the molecules which occur in our food and helps in the prevention or reduction of oxidative stress. Antioxidants are known for elevating good health and minimizes the risk of cardiovascular diseases, certain types of cancers, diabetes, cirrhosis, and stroke. The antioxidants are categorized into natural antioxidants and synthetic antioxidants. Various ingredients (like polyols, free amino acids, soluble sugars, and 5′-nucleotides) are present. The common flavor present in mushrooms is named umami taste, also known as the perception of satisfaction which is produced by MSG (Monosodium glutamate). MSG present in the mushroom is responsible for its rich, brothy, or meaty taste.

Keywords **:** Mushrooms, Antioxidants, Free Radicals, Ummai Flavor.

INTRODUCTION

Mushrooms are recognized throughout the world, not merely for the unique flavor, but also their medicinal and nutritional properties (Heleno *et al.,* 2015). Mushrooms, also known as "boneless vegetarian meat" or "white vegetables" comprises plenty amounts of protein, dietary fiber, various vitamins (especially Vitamin C and B), and minerals (mainly sodium, potassium, and phosphorus) (Huchchannanavar *et al.*, 2020). They are low in carbohydrates and fats, so have low calories (Kakon *et al.,* 2012). Protein content in mushrooms is approximately 20-35% on a dry basis, which is furthermore than those of vegetables and fruits and is of higher quality (Kumari *et al.*, 2015). The consumable carbohydrate content of mushrooms comprises starches, pentoses, hexoses, sugar alcohols, disaccharides, amino sugar, and sugar acid. The amount of carbohydrates in mushrooms is 26-82% varying from species to species. The insoluble carbohydrates i.e., the crude fiber found in mushrooms contain partially digestible chitin and polysaccharides (Manikandan, 2011).

Mushrooms possess several therapeutic properties such as an antioxidant, antifungal, antimicrobial, anticancer, antineoplastic, antidiabetic, anti-inflammatory, antibacterial, cholesterol-lowering, and immune-stimulating effects (Gan *et al.,* 2013) (Enoma *et al.*, 2018) (Siwulska *et al.*, 2018) (Sana *et al.*, 2017) (Sharma *et al.,* 2015) (Sánchez, 2017) (Soares *et al.,* 2013). Mushrooms possess several metabolites, such as phenolic compounds, terpenes, polyketides, and steroids (Gan *et al.*, 2013). Moreover, phenolic compounds found in mushrooms are known to be great antioxidants and synergistic which is not mutagenic (Adebayo *et al.*, 2014). Henceforth, mushrooms can act as a good and natural antioxidant source as they are easily available in the market (Enoma *et al.,* 2018).

Antioxidants are defined as the molecules which occur in our food and helps in the prevention or reduction of oxidative stress (Pal *et al.*, 2014). Antioxidants are known for elevating good health and minimizes the risk of cardiovascular diseases, certain types of cancers, diabetes, cirrhosis, and stroke (Atta *et al.*, 2017) (Adebayo *et al.,* 2014). Additionally, the utilization of dietary antioxidants helps in the prevention of free radical damage (Gan *et al.*, 2013). According to Olajire and Azzez (2011), antioxidants can remove free radicals by prohibiting the initiation step or interfering with the propagation step in lipid oxidation.

The antioxidants are categorized into natural antioxidants and synthetic antioxidants. Further, natural antioxidants are sorted into fungal and plant extracts, glutathione, spices (like thyme, oregano, sage, clove, cinnamon, rosemary, marjoram, pepper, and nutmeg), selenium (Se), zinc (Zn), ubiquinol (reduced form of coenzyme Q10), Vitamin A (along with carotenoids), Vitamin E (along with tocotrienols and tocopherols) and Vitamin C. While, synthetic antioxidants comprises of butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), etc. Additionally, various synthetic antioxidants have negative impacts under certain conditions (Kozarski *et al.*, 2015).

Overall, mushrooms contain the entire features of food- taste, nutrition, and physiological features. For the first feature of taste, mushrooms have a unique and subtle flavor. The flavor of mushroom contains some taste components (i.e., water-soluble taste components) concluding 5′-nucleotides and free amino acids. For the second feature of nutrition, mushrooms are enriched with proteins, chitin, polysaccharides, vitamin D_2, and minerals; lack cholesterol; and have less fat and calories. The third feature of physiological effects, along with various physiologically active substances, also consists of therein, which makes mushrooms- a valuable and healthy food (Mau, 2005).

Free Radicals and Their Sources

Free radical or pro-oxidant is described as any species efficient for independent existence consisting of one or more unpaired electrons (Webb *et al.*, 2008). These are generally produced during oxidation reactions, subsequently begin the chain reactions, which causes damage to the cells (Lawal *et al.,* 2017). These are very reactive molecules and normally unstable. Major sources of free radicals are represented in figure 1.

Free radicals obtained from molecular oxygen are generally called reactive oxygen species (ROS). Though in aerobic life there is the great importance of O_2, still in several conditions it can act as toxic. This process is known as the "oxygen paradox" (Ferreira *et al.*, 2009). The term 'ROS' comprehends not merely free radicals (like hydroxyl radical, superoxide radical), but also molecules (like singlet oxygen, hydrogen peroxide and, 4-hydroxyl-2-nonenal (HNE). Out of these, superoxide anion is recognized as the primary ROS because it creates by adding one electron in molecular oxygen (Khatua *et al.*, 2013). Additionally, in an aqueous environment, the hydroxyl radical is considered as extremely reactive ROS with a half-life smaller than 1 ns (Jomova *et al.*, 2011).

Oxidative Stress

Oxidative stress originates from the variance in a redox system. It is a common process occurred by either excessive formation of Reactive Oxygen Species (ROS) or abnormality in the antioxidant defense system (Saleem *et al.*, 2020). Howsoever, ROS production in high concentrations is very harmful to organisms. When the ROS formation surpasses, it can cause damage to nucleic acids, proteins, lipids, and cell structure (Sánchez, 2017). As mitochondria act as an extremely important source of ROS, due to which mitochondrial lipid membrane tends to get attacked easily by ROS. Consequently, it leads to lipid peroxidation. Further, lipid peroxidation leads to a greatly reactive lipid radical (L.) and finally forms peroxyl radical (LOO.). This peroxyl radical reacts with other closest lipids forming hydroperoxides lipids (LOOH) that further easily decompose for the production of new lipid radical. Additional products in the process of peroxidation are 4-hydroxy-2-nonenal (HNE) and malondialdehyde (MDA). Both are mutafacient (Khatua *et al.*, 2013).

There may be the possibility that oxidative stress has natural causes like inflammation processes, extreme exercise or, non-natural causes like the occurrence of xenobiotics in some organisms which are linked to several diseases. Additionally, the non-controlled formation of free radicals has been linked with many diseases such as various types of cancer, cirrhosis, diabetes, neurological disorders, cardiovascular diseases, etc. However, the excessive production of ROS has also been linked with the early aging phenomenon (Ferreira *et al.*, 2009).

Antioxidant Components in Some Species of Mushrooms

Phenolic compounds are those compounds that contain aromatic rings attached with one or more hydroxyl groups. Mainly, phenolic acid is present as the main phenolic compound. Tocopherols contain α, β, γ and δ tocopherol. Tocopherols are the main components found in the biological membrane (Khatua *et al.,* 2013).

Palacios *et al.* (2011) observed the antioxidant activity in phenolic compounds of various species like *Agaricus bisporus, Cantharellus cibarius, Calocybe gambosa, Lactarius deliciosus*, and *Pleurotus ostreatus*. It was found that *Cantharellus cibarius* and *Pleurotus ostreatus* showed the highest effect as compared to other species.

According to Sharma *et al.* (2015), the phenol content in *Agaricus arvensis* is 2.83±0.09 (mg/g). The values of some antioxidant components in various species like *Amanita porphyria, Collybia fusipes, Fomitopsis pinicola, Heleboma sinapizans, Lactarius hepaticus* are evaluated by Reis *et al.* (2011) as mentioned in table 1. Additionally, Barros *et al.* (2007) have evaluated the various antioxidant components in species like *Agaricus arvensis, Lentinus tigrinus, Leucopaxillus giganteus,* and *Sarcadon imbricatus* have also mentioned in the table 1.

Taste Ingredients Present in Mushrooms

Various ingredients (like polyols, free amino acids, soluble sugars, and 5′-nucleotides are present (Mau, 2005). Chen (1986) carried several sensory evaluations on some extracts of synthetic mushroom, which is formed by addition and removal of soluble components, and observed that the taste-active ingredients which are mostly found in mushrooms are oxalic, citric, malic, glutamic acids, alanine, glycine, threonine, mannitol, 5'-guanosine monophosphate (5'-GMP), 5'-inosine monophosphate (5'-IMP), and 5'-xanthosine monophosphate (5-XMP). Out of them, organic acids and mannitol found in mushrooms contribute to sour and sweet flavor.

The common flavor present in mushrooms is named umami taste, also known as the perception of satisfaction which is produced by MSG (Monosodium glutamate) (Mau, 2005). MSG present in the mushroom is responsible for its rich, brothy, or meaty taste. The name "umami" was termed for the scrumptious and palatable taste and was distinguished as a basic taste including the amino acid, glutamic acid (Phat *et al.*, 2016). However, along with four basic tastes like sweet, bitter, salty, hot, and sour taste, the umami taste is considered as sixth taste (Mau, 2005). Umami was first reported by Ikeda in the year 1908, who coined the term. The umami taste helps in the improvement of satiety and regulation of appetite (Sun *et al.*, 2020).

Effect of Processing on Umami Taste of Mushrooms

For various purposes like increasing the shelf life, taste, and utilization efficiency, processing is required for edible mushrooms. The processing method, heating is applied for the improvement in availability and digestibility of various nutrients. Though, the heating method was not much as beneficial in the preservation of umami components in soups made of edible mushrooms. In other methods like autoclaving, microwave cooking, and boiling, loss of 5'-nucleotides and MSG-like amino acids were noticed in button mushroom soup. Autoclaving showed an immense loss of umami tastes, while microwave cooking showed minimum loss and boiling stands in the middle. Irradiation gave good results and has low effects on the quality of mushrooms. Whereas, gamma irradiation reduced 5'-GDP and 5'-AMP nucleotides contents in button mushrooms (Zhang *et al.*, 2013). Pukkila *et al* (2013) told the effect of cooking on different species of mushrooms like *Cantharellus cibarius, Lactarius trivialis*, *Suillus variegatus*, *Cantharellus tubaeformis*, and *Agaricus bisporus.* 5'-GMP nucleotide was observed in cooked samples only. Saito *et al*. (2020) told that half-dry processing applied in various species of mushrooms and vegetables by exposure to the sunlight does not improve the umami flavor. Additionally, it has also been reported that there may be chances of increasing the umami taste in some species. Also, Pei *et al*. (2014) observed the effect of processing in umami taste. Methods like freeze-drying in the combination with microwave vacuum drying or only freeze-drying were used. After the application of the method, there was seen no changes in the contents of 5'-nucleotides.

CONCLUSION

Overall, it has been concluded that mushrooms contain various properties like antioxidant, antifungal, antimicrobial, anticancer, antineoplastic, antidiabetic, anti-inflammatory, antibacterial, cholesterol-lowering, and immune-stimulating effects. Phenolic compounds found in mushrooms are known to be great antioxidants and synergistic which is not mutagenic. Henceforth, mushrooms can act as a good and natural antioxidant source as they are easily available in the market. Additionally, the taste-active ingredients which are mostly found in mushrooms are oxalic, citric, malic, glutamic acids, alanine, glycine, threonine, mannitol, 5'-guanosine monophosphate (5'-GMP), 5'-inosine monophosphate (5'-IMP), and 5'-xanthosine monophosphate (5-XMP). Out of them, organic acids and mannitol found in mushrooms contribute to sour and sweet flavor.

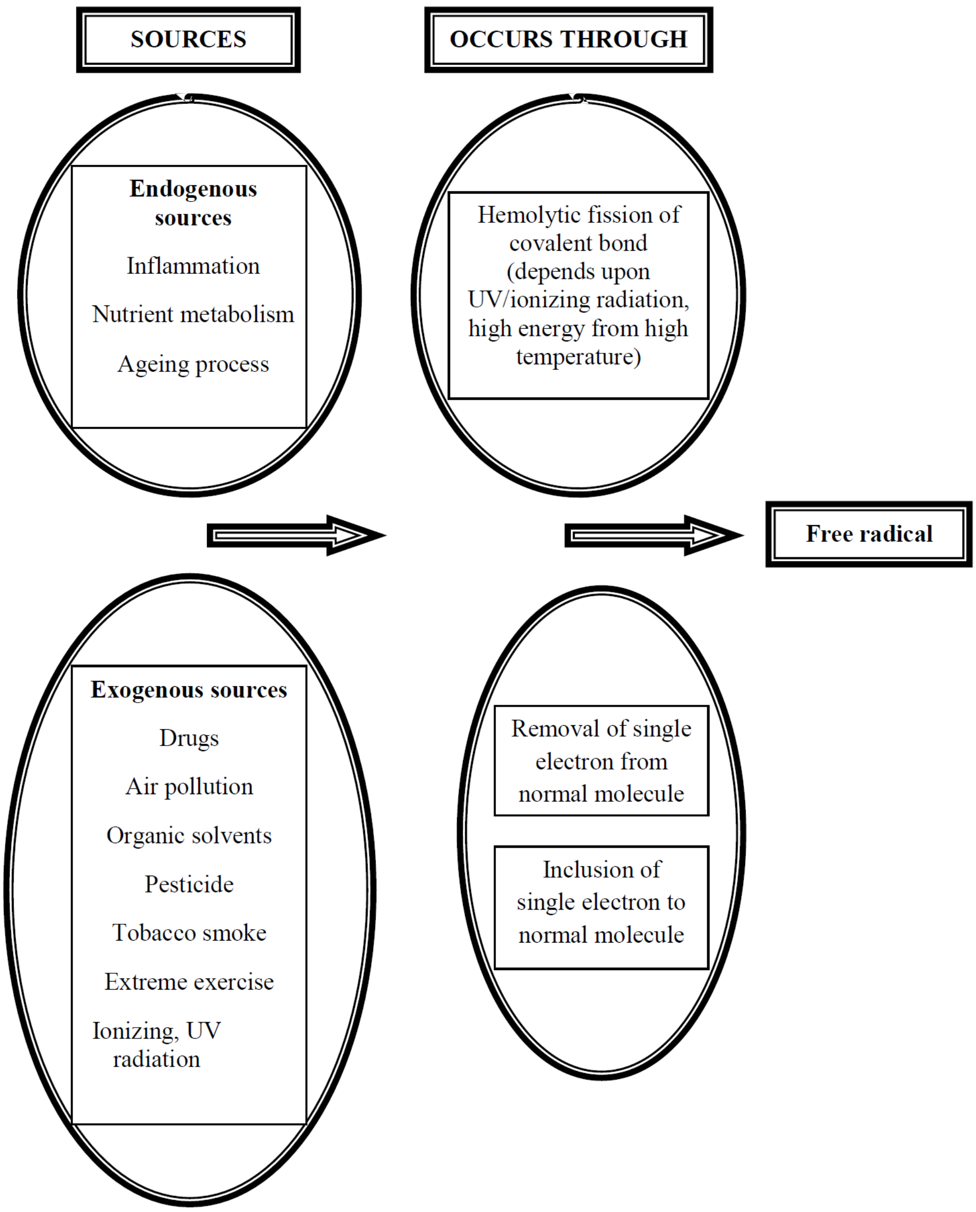

Fig. 1 : Sources of free radicals and their occurrence.

Table 1 : Antioxidant content of different species of mushrooms.

S. No.	Species Name	Common name	Antioxidant content					References
			Total tocopherol	Phenols	Ascorbic Acid	β-carotene	Lycopene	
1.	*Agaricus arvensis*	Horse mushroom	3.01 ± o.o[d] (µg/g)	2.83±0.09 (mg/g)	0.35± 0.0015 (mg/g)	2.97±0.12 (µg/g)	1.0±0.049 (µg/g)	(Sharma *et al.*, 2015) (Barros *et al.*, 2007)
2.	*Amanita porphyria*	Grey veiled Amanita	245.58± 27.29 e (µg/100g dw)	-	211.17± 30.08 d (mg/100g dw)	0.13± 0.00 d (mg/100g dw)	0.01±0.00 d (mg/100g dw)	(Reis *et al.*, 2011)
3.	*Collybia fusipes*	Gymnopus fusipes	7.75± 0.7 ef(µg/100g dw)	-	278.15± 12.70 a (mg/100g dw)	0.24±0.009 (mg/100g dw)	nd	(Reis *et al.*, 2011)
4.	*Fomitopsis pinicola*	Red-belted fungus	125.25± 10.13 ed (µg/100g dw)	-	108.97 ± 2.24 g (mg/100g dw)	0.22 ± 0.00 b (mg/100g dw)	nd	(Reis *et al.*, 2011)
5.	*Heleboma sinapizans*	Rough-stalked heleboma	71.62±3.11 ef (µg/100g dw)	-	280.55 ± 7.46 a (mg/100g dw)	0.01±0.001 (mg/100g dw)	0.06±0.00e (mg/100g dw)	(Reis *et al.*, 2011)
6.	*Lactarius hepaticus*	Birch milkcap	30.56±2.22 f (µg/100g dw)	-	149.07± 1.76 f (mg/100g dw)	Nd	0.19±0.00b (mg/100g dw)	(Reis *et al.*, 2011)
7.	*Leuco-paxillus giganteus*	Giant leucopax	-	6.29±0.20 (mg/g)	3.76±0.11 (mg/g)	1.88±0.090 (µg/g)	0.69±0.034 (µg/g)	(Barros *et al.*, 2007)
8.	*Lentinus tigrinus*	Tiger sawgill fungus	716.77± 79.22a (µg/100g dw)	-	248.13± 1.34c (mg/100g dw)	6.15±0.00c (mg/100g dw)	nd	(Reis *et al.*, 2011)
9.	*Piptoporus betulins*	Birch polypore	577.62± 52.95b (µg/100g dw)	-	87.9±3.09h (mg/100g dw)	0.09±0.00f (mg/100g dw)	0.23±0.00a (mg/100g dw)	(Reis *et al.*, 2011)
10.	*Sarcadon imbricatus*	Shingled hedgehog	-	3.76±0.11 (mg/g)	0.16 ± 0.0072 (mg/g)	2.53 ± 0.11 (µg/g)	1.30±0.070 (µg/g)	(Barros *et al.*, 2007)

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