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Improvement of Post-harvest Shelf-life of Mushrooms Through the Application of Gamma Radiation

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ABSTRACT

Mushrooms are valued for their sensory qualities, good textures and enriched nutritional content. Unfortunately, mushrooms are vulnerable to post-harvest damage because of the absence of an extra-outer layer. Edible mushrooms are good hosts for microbial pathogens as they have higher respiratory activity and water content. This ultimately reduces the shelf-life of mushrooms, rendering mushroom harvesting commercially unfeasible. So, developing preservation and sterilizing techniques is crucial to combat this post-harvest loss. Gamma-radiation is an efficient modern irradiation technology with high energy and penetration capacity, which can increase shorter shelf-life of them. It may delay browning by reducing melanin production, reducing microbial load, altering enzymatic activity, where generally the activities of the enzymes like Catalase, Superoxide dismutase, Phenylalanine ammonia-lyase are upregulated and activities of enzymes like Polyphenol oxidase are downregulated, improve nutritional parameters by enhancing fatty acids and vitamins' profile in them. Gamma-radiation can also be able to enhance volatility and color retention power in mushroom which ultimately leads to extended shelf-life. The purpose of this study is to amalgamate the gamma irradiated mushroom species, all the factors responsible for the mushroom's limited shelf-life, along with their amelioration through the application of gamma-radiation.

Keywords: Gamma-radiation, Mushroom-browning, Shelf-life of mushroom, Post-harvest loss

INTRODUCTION

Mushrooms are amazing creatures that span the gap between science and nature, providing both nutritional and therapeutic value for human health in addition to ecological advantages. Their flexibility encompasses advanced applications in biomedicine, environmental restoration, and sustainable food sources. For various people in different nations, the word "mushroom" can mean different things (Chang and Miles, 1992). Mankind has been fascinated by mushrooms from ancient times; the Romans referred to them as the "food of God" while the Greeks believed that they could give warriors strength during combat (Zhang *et al*., 2014).

Edible mushrooms serve a key factor in food security through contributing to self-sufficiency and addressing protein deficiencies often present in cereal, vegetable, and fruit diets (Bhatiya *et al.*, 2024). They have a lower fat and oil content compared to their protein and carbohydrate levels (Barros *et al.*, 2008). Edible mushrooms have an abundance of several different nutraceuticals e.g., polysaccharides (β-glucans), terpenes, dietary fibres, peptides, glycoproteins, unsaturated fatty acids, minerals, antioxidants like phenolic compounds, Vitamin C, Vitamin E (Pradeshi, 2009). However, most of the edible mushrooms are devoid of an external protective coat, in contrast to other horticultural crops (Yeom *et al*., 2023). Furthermore, following harvest, microbial growth and digestive enzymes induce a quick decline in quality of mushrooms because of the high water content and vigorous respiratory activity (Guo *et al*., 2023). The rate of respiration in mushrooms is 200–500 mg/kg/h at the temperature 20°C, which is significantly greater than vegetables as they possess very porous epidermis (John *et al*., 2023). Regarding this, postharvest alterations happen in them, such as stipe elongation, cap diameter increase, and cap opening (Lin and Sun, 2019). This further results in discolouration (Wu *et al*., 2016), moisture loss (Weijn *et al*., 2011) and texture changes (Aday, 2016), which lowers the culinary, economic value and influences customer purchase decisions. Thus, post-harvest treatment techniques should be developed for enhancing shelf-life of edible mushrooms.

One useful promising physical technique is food irradiation, which has the ability to improve shelf life, food security and to develop resilient crop systems. Electron beams, X-rays, and gamma rays are the domestic sources of radiation for food (Yeom *et al*., 2023). Particle-based high-energetic ionizing radiation or electromagnetic irradiation results in chemical bond breaking (Mitra *et al*., 2024).

Gamma (**γ**) radiation is a prominent technique in irradiation technology because of its high energy and potent penetrating capability. In the electromagnetic spectrum, gamma radiation, with extremely short wavelength (typically under 0.1 nanometre) it produces high energy, spanning from hundred kilo-electron volts (KeV) to multiples of mega-electron volts (MeV) (Bharath *et al*., 2024). When atomic nuclei emit α or β rays, electromagnetic waves are created that cause gamma irradiation (Zhong *et al*., 2023). Up to 10 Kilogray (kGy) dose, food irradiation is safe from a toxicological, nutritional, and microbiological standpoint. For better storability and sanitisation, countries like Argentina, China, Hungary, Israel, Mexico, Poland allow a maximum radiation exposure of 1-3 kGy doses for mushrooms (Akram and Kwon, 2010) .

The main focus of this review is to demonstrate the sources and common types of gamma-radiation for irradiation, the factors which are mainly responsible for the shorter shelf-life of mushroom including the browning process in them, gamma-irradiated popular edible mushroom species till date and overall beneficial role of gamma-irradiation to improve the shelf-life of mushroom after harvesting through the reduction of pathogen, enhancement of sensory-quality attributes, amplification of nutritional profile and alteration of enzymatic activity. This review intends to present a theoretical framework to prolong shelf-life of edible mushroom with few proposed future prospectives.

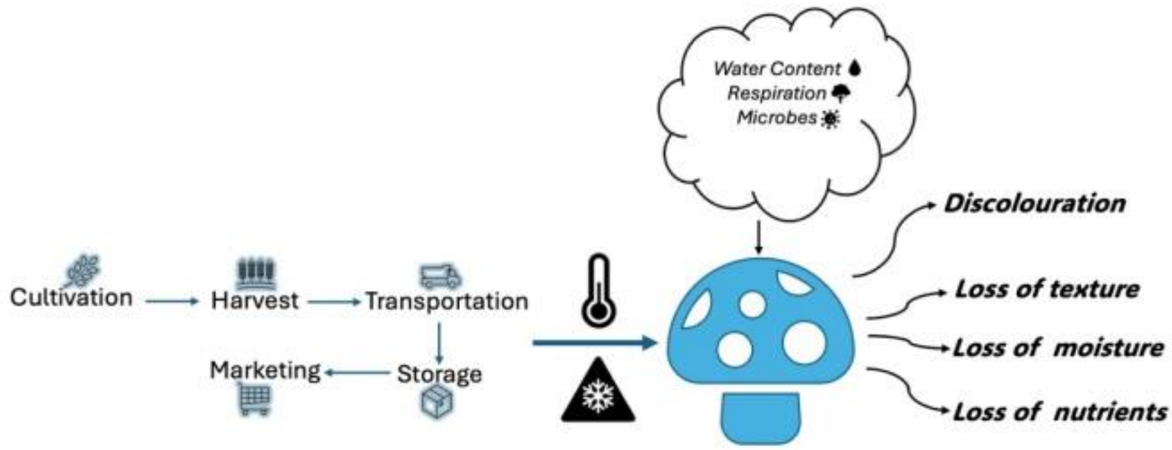

Figure 1: Factors affecting the post-harvest life of the mushroom

SOURCES AND TYPES OF GAMMA RAYS

The main sources of gamma radiation-induced mutations in mutational breeding are isotopes which are radioactive, particularly Cesium-137 (^{137}Cs) & Cobalt-60 (^{60}Co). ^{60}Co is the stable source of gamma (**γ**)-rays, having a lower half-life (5.27 years) . Another synthetic radioactive isotope used in mutation breeding for gamma-ray irradiation is ^{137}Cs. ^{137}Cs offers consistent radiation source for **γ**-rays having a greater half-life than ^{60}Co (30.17 years) (Beyaz and Yildiz, 2017);(Riviello-Flores *et al*., 2022). In nuclear reactors, as well as during the evaluation of nuclear weapons and their associated radiation fallout, the emission of gamma rays is also observed (Brun and Tanugi, 2016).

Presently three types of gamma radiation facilities are available- (i) Gamma greenhouse (ii) Gamma phytotron & (iii) Gamma cell irradiator (Bharat *et al.*, 2024). Among them, Gamma cell irradiators are most frequently employed to expose materials to regulated dosages for research purposes. The target tissue components are exposed to the gamma rays released during the decay of the radioactive ^{60}Co (Typically used in gamma-cell irradiator), which is housed in a protected room (Bharat *et al.*, 2024). To guarantee that the samples receive the appropriate dosage of gamma radiation, the irradiation procedure is meticulously regulated.

Figure 2: A typical Gamma-cell Irradiator (Uses ^{60}Co as source)

FACTORS AFFECTING SHELF-LIFE OF MSUHROOM

Mushroom usually have a limited shelf-life due to postharvest alterations, including browning, stipe elongation, cap opening, cap expansion, reduction in weight, texture modifications, elevated rate of respiration and insufficient protection against pathogenic contamination and loss of water (Akram and Kwon, 2010);(Singh *et al.*, 2010);(Sommer *et al.*, 2010). The significant limitation of edible mushrooms is their extremely short post-harvest shelf life, typically ranging from 1 to 3 days under standard storage conditions. Moreover, ageing, hard handling, vibrations, and other factors that can compromise cellular integrity cause the browning of mushroom cells (Jiang *et al.*, 2010). The amounts of phenolics, active PPO (Polyphenol oxidase) in the tissue, temperature, activity of water, pH are primary determinants of browning (Fernandes *et al.*, 2012).

The copper-containing enzyme known as PPO (Polyphenol oxidase), which is found in the cap of mushrooms, catalyses two distinct reactions: (i) monophenols to ortho-dihydroxyphenols, & (ii) ortho-dihydroxyphenols to ortho-quinones, which subsequently undergo polymerization and produce brown coloured pigment-melanin (Beaulieu *et al.*, 2002). The formation of browning pigments has also been linked to phenylalanine ammonia-lyase (PAL) , peroxidase (POD) where PAL is essential for breaking down of phenols as PAL catalyses deamination process of L-phenylalanine, which produces trans-cinnamic acid and ammonia as by-product. (Benoît *et al.*, 2000). Catalase (CAT) removes H_20_2, which is first produced by super-oxide dismutase (SOD) from super-oxide anions and these combined actions prolong food freshness by preserving membrane integrity (Xing *et al.*, 2007).

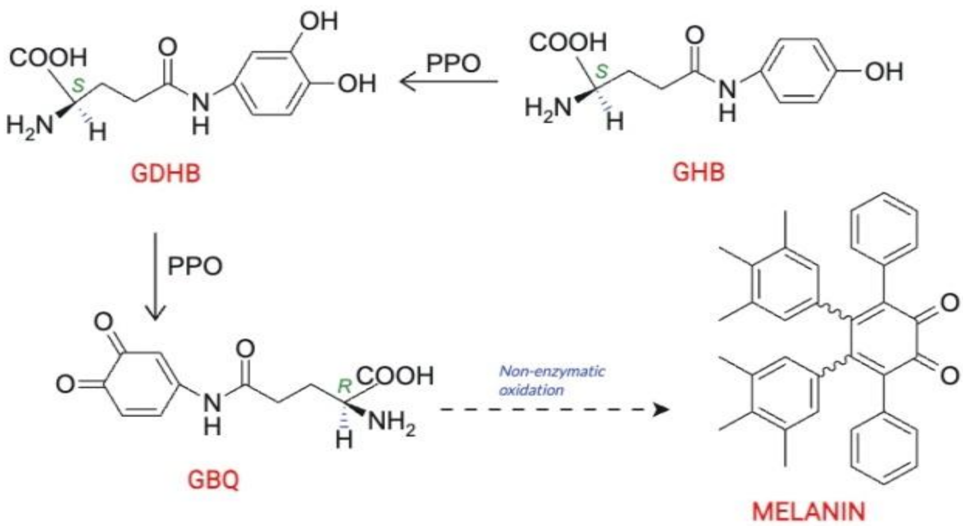

Figure 3: Browning causing reactions in mushroom by melanin production (Beaulieu *et al.*, 1999); (Sommer *et al.*, 2009). [PPO = Polyphenol oxidase, GHB = **γ**-L-glutaminyl-4-hydroxybenzene, GDHB = **γ**-L-glutaminyl-3,4-dihydroxybenzene, GBQ = **γ**-L-glutaminyl-3,4-benzoquinone]

Mushroom softening entails action of glucan catabolism enzymes, including endo-β-1,3-glucanase (Leglu1 and Letlg1), endo-β-1,6-glucanase (Lepus30a) & exo-β-1,3-glucanase (Leexg1 and Leexg2) (Huang *et al*., 2019). Therefore, destruction of hydrolytic enzymes of cell wall components is essential to the postharvest mushroom's softening process (Sharma et al., 2024). Exposure to elevated temperatures and extended storage would accelerate the reduction in mushroom firmness (Li *et al*., 2022).

Additionally, microbial load has a key impact on reducing shelf-life of mushroom. Since mushrooms have high water and moisture content, they are the prime target for microbes (Sharma *et al*., 2024). Of the bacteria isolated from mushroom, 10% were *Flavobacteriia* and 54% were fluorescent *Pseudomonas* (Rossouw and Korsten, 2017) which creates blotchy and brown appearance. Awol *et al*., (2024) interpreted that bacterial population escalated from 7 log CFU/g to 11 log CFU/g for a storage of ten days (CFU-colony forming unit). Spoilage bacteria accelerate degradation by rapidly colonizing, secreting harmful enzymes, applying significant osmotic pressure, and depleting nutrients, hence diminishing economic and edible value (Zhang *et al*., 2023). Following harvest, mushrooms have a bacterial burden of 2.5–5.8 log CFU/g which ultimately leads to the reduction of shelf-life by spoilage (Zhang *et al*., 2020). During spoiling, microbes release many volatile, reeking substances, including ammonia, amines, sulphur compounds, and indoles (Sharma *et al*., 2024).

GAMMA-IRRADIATED SPECIES

In order to meet the goals of preservation and storage, postharvest edible mushrooms are exposed to **γ**-radiation, which has a great penetrating power and inhibits the growth of microorganisms, reduces enzyme activity and delays bacterial metabolism (Fernandes *et al*., 2012). Advised dose for extending shelf life of edible mushroom across various nations is below 3 kGy, however suggested dosage for decontaminating dried edible mushroom is 10 kGy to 50 kGy (Jeong *et al*., 2020). According to Zhong *et al*., (2023), a table of gamma-irradiated species of mushroom till date has been prepared with the optimum doses.

Table 1 : Optimum doses of Gamma-radiation on different edible mushroom

Species	Dosages (kGy)	Reference
Agaricus bisporus	5, 10, 20, 30 and 50	(Khan *et al*., 2015)
Boletus edulis	2, 6 and 10	(Fernandes *et al*., 2017)
Boletus pinophilus	2	(Fernandes *et al*., 2016)
Clitocybe subconnexa	2	(Fernandes *et al*., 2016)
Lentinus edodes	2,5 and 10	(Akram *et al*., 2013)
Lentinula edodes	1 and 2	(Shi *et al*., 2020)
Volvariella volvacea	0.2,0.4,0.6,0.8 and 1	(Hou *et al*., 2018)

In general, **γ**-radiation is administered to fresh mushrooms in the majority of situations (Zhong *et al*., 2023), but it can also be applied to samples that have been freeze-dried (Fernandes *et al*., 2014).

BENEFICIAL ROLE OF GAMMA-RADIATION ON MUSHROOM

Reduction of Microbial load

Various investigations have demonstrated that certain harmful microorganisms exhibit heightened sensitivity to irradiation treatment (Chen *et al*., 2012). Gamma-radiation also has the potential to enhance the anti-microbial activities of edible mushrooms. A suitable dose of 2 kGy of gamma-radiation can elevate anti-microbial capacity of various edible mushrooms- *B. edulis*, *Russula delica, Hydnum repandum* while 1 kGy dose can yield better results in *Macrolepiota procera* (Alves *et al*., 2015). According to them, the activities generated in above mushrooms were mostly against gram-positive bacteria.

In case of *A. bisporus,* 2 kGy dose could reduce microbial load by 5.8 logs and also made the mushroom resistant to formation of brown patches (Wani *et al*., 2009). Based on their results , a comparative graphs have been prepared.

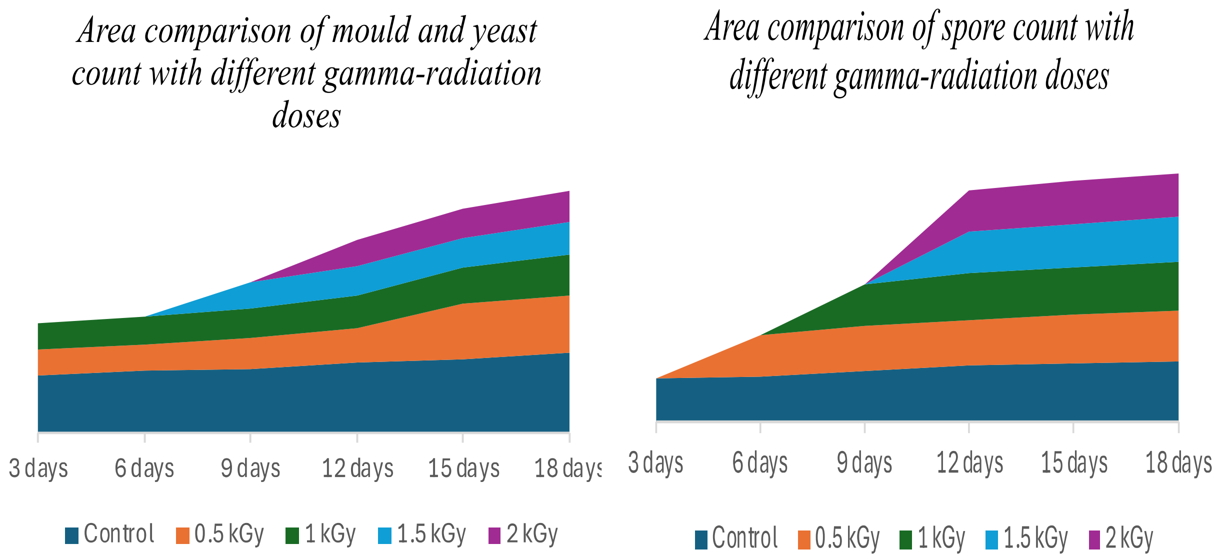

Figure 4: A graphical representation to compare the area of yeast and mould count (log CFU/g of sample) & spore count (log CFU/g of sample) on gamma-irradiated and non-irradiated white button mushroom (Wani *et al*., 2009). A dosage of 2 kGy effectively eliminated microbial load for the initial 9 days in both cases. In the non-irradiated control, a majority of pathogens were observed, and as the dosages of gamma radiation increased, the pathogen load diminished progressively.

Enhancement of colour-appearance attributes

The primary criteria that customers use to assess the freshness of edible mushroom is texture (Ghasemi-Varnamkhasti *et al*., 2018). So, changes in texture and also colours should be assessed for evaluating the shelf-life of mushroom. The primary eight-carbon chemicals that made up the aromatic compounds present in fresh mushrooms were 1-octanol, 1-octen-3-ol, 1-octen-3-one, 2-octen-1-ol, 3-octanol & 3-octanone (Jung *et al*., 2019); (Ouzouni *et al*., 2009). The most significant chemical among them was 1-octen-3-ol, and its level would decrease as the postharvest storage duration increased (Zhong *et al*., 2023). A work by Akram *et al*., (2013) who discovered that fresh *L. edodes* treated with 2 and 3 kGy gamma-irradiation created some novel volatile chemicals, including methyl ethyl disulfide and sulfonyl bis(methane) and 1 kGy irradiation boosted the its eight-carbon volatile compounds. A dose of 2 kGy of γ-radiation might sustain volatile compounds in large quantities in the mushroom *Morchella angusticeps* (Meng *et al*., 2023). Analysing through E-nose data reveals the potential of γ-radiation to enhance volatility of mushrooms (Akram *et al*., 2012).

In King oyster mushroom, *Pleurotus eryngii* , a suitable dose of 1 kGy maintained better textures and colour during storage of 4 weeks. At 1 kGy, High L-values (Hunter L values) were maintained throughout storage whereas at higher doses (3 kGy), negative result was observed due to drastic changes in pigmented cells (Akram *et al*., 2012).

Gamma-radiation can be effective also in preserving colour matrices during drying of edible mushroom. Increased gamma-radiation doses led to decrease colour indices, browning index, total colour difference in dried white button mushroom sample where least colour changes were observed at 3.6 kGy dose (Naeimi *et al*., 2022). In their experiment though γ-irradiation slightly increased area shrinkage in dried mushroom samples but effect of temperature during drying process has more impact on the appearance of edible mushroom.

Table 2: Gamma-radiation's impact on reducing pathogenic microorganisms and colour-texture profile change in edible mushroom

Species	Microbial effects	Colour changes	Texture changes	References
A. bisporus	2 kGy dose + Silver nanoparticles inhibited *Staphylococcus aureus* & *E. coli.*	Colour stability maintained at 2 kGy	Hardness and elasticity were greater in irradiated samples.	(Ghasemi-Varnamkhasti *et al.*, 2018)
A. bisporus	--	Less colour difference at 3.6 kGy	Shrinkage area increased	(Naeimi *et al.*, 2022)
V. volvacea	^{60}Co-gamma irradiation lowered bacterial counts during storage	Non-irradiated group had higher browning	0.8 kGy samples showed minimal softening over time	(Hou *et al.*, 2018)
P. eryngii	--	Increased lightness at 1 KGy	1 kGy retained better texture, 3 kGy caused poor texture (SEM analysis)	(Akram *et al.*, 2012)
Inonotus obliquus	--	As dose increased, brightness and yellowness increased and redness diminished.	--	(Kim *et al.*, 2009)

Enrichment of nutritional-profile

In light of the limited shelf life of edible mushrooms, gamma-irradiation technology may be the most effective means of preserving their rich nutritional profile. *B. pinophilus* irradiated with 2 kGy of -radiation showed preliminary reductions of soluble protein availability (Fernandes *et al.*, 2016). The concentration of soluble protein in *L. edodes* subjected to **γ**-irradiation exhibited a small drop with the rate of decline accelerating at elevated doses (2 kGy), where initially the concentration was 54.1% (Jiang *et al.*, 2010). But Pewlong *et al.*, (2019) couldn't find any significant protein difference in gamma-irradiated (2.5 kGy to 10 kGy) and non-irradiated *A. bisporus*. *Tuber melanosporum* treated with combined electron-beam and gamma-radiation, which led to decreased protein content but after the initial decline, it remained constant throughout the 35-day storage while comparatively lower irradiation doses (1.5 kGy) minimised protein degradation in this mushroom (Tejedor-Calvo *et al.*, 2019).

Free sugars are a critical characteristic in quality evaluation and serve as an effective indicator of appropriate conservation strategies because they are highly affected by technical methods (Barreira *et al.*, 2010). Mannitol, fructose & trehalose are the primary free sugars found in edible mushrooms (Zhong *et al.*, 2023). According to Cardoso *et al.*, (2021), there was no discernible relationship between the storage duration and the irradiated *A. bisporus*'s total sugar content, which progressively dropped over the course of a year while its trehalose concentration increased. *L. edodes* exposed to 1 kGy of gamma-radiation showed greater rises in the amount of overall sugar content (Jiang *et al.*, 2010). The sugar may break down during this process, creating a specific environment that is mostly made up of hydrogen and carbon-di-oxides, with very tiny amounts of carbon-monoxides, methane, and water (Bisht *et al.*, 2021).

According to Cardoso *et al.*, (2021), gamma-radiation kept the amount of polyunsaturated fatty acid (PUFA) in dried edible mushroom in approximately 81% to 82%, whereas monounsaturated fatty acid (MUFA) was less than 2% and the ranges of saturated fatty acid (SFA) varied between 12% to 34%. Fernandes *et al.*, (2017) noted that intensely irradiated samples (10 kGy) and non-irradiated samples of *B. edulis* exhibited unstable fat content but comparatively minimal doses (2 kGy to 6 kGy) could maintain the stability. Gamma-irradiation could enhance the fat content in the mushroom, *M. angusticeps* where abundance of stearic acid, palmitic acid, myristic acid were elevated by 20%, 15%, 5% respectively (Meng *et al*., 2023). The principal process of lysis of lipid molecules through radiation involves initial ionization, subsequently resulting in the translocation of a cation to double bond or carbonyl group, culminating in breakdown of fatty acids (Bisht *et al*., 2021).

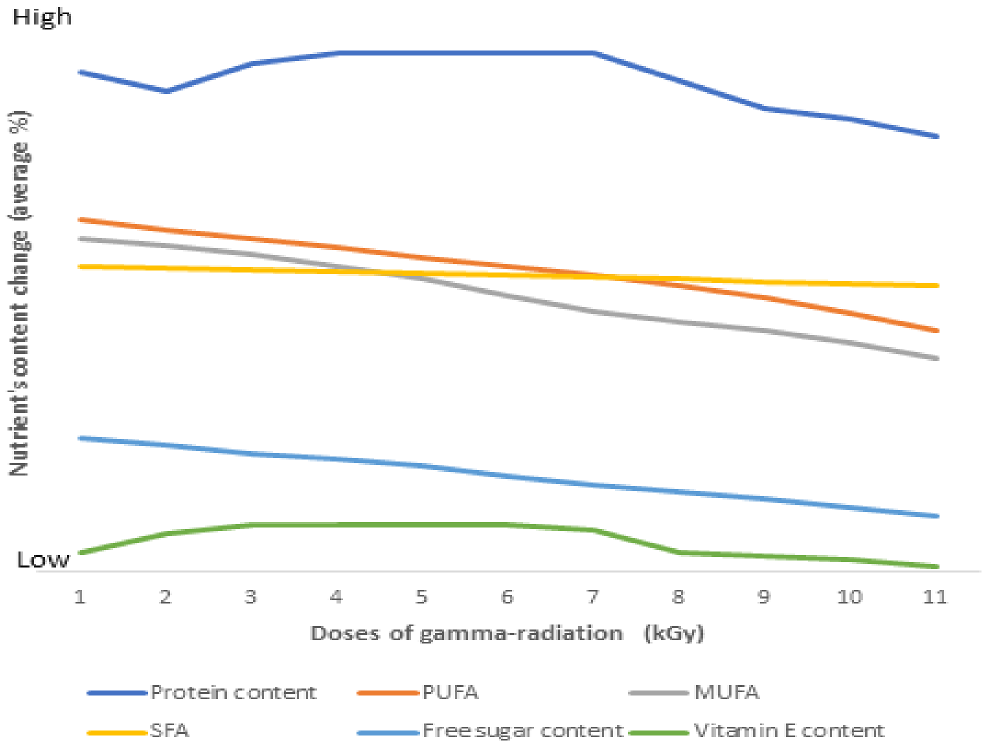

Figure 5: Impact of **γ**-radiation on nutritional profile of overall mushroom at lower doses (Typically, 0.5 kGy to 2 kGy), moderate doses (2 kGy to 6 kGy) and high doses (6kGy to 10 kGy) of **γ**-irradiation.

0.5 kGy gamma-irradiation dose can effectively maintain significant level of Vitamin E content (Tocopherol) in *M. procera* (Fernandes *et al*., 2014). However, mushrooms irradiated at 0.75 kGy gamma-radiation dose can promote Vitamin D content whereas gamma radiation has little or no effect on vitamin B9 (folic acid) or vitamin C content (Bandi and Kola, 2022). According to a study, Vitamin A content in oyster mushroom was slightly decreased after gamma-irradiation during a storage of 12 months whereas in minerals, Calcium (Ca) and Magnesium (Mg) levels were significantly elevated (Kortei *et al*., 2017).

Changes in Enzymatic Activity

Irradiation significantly influences the activity of several enzymes in edible mushroom, including phenylalanine ammonia-lyase (PAL), polyphenol oxidase (PPO), superoxide dismutase (SOD), catalase (CAT) (Zhong *et al*., 2023). Among these, SOD and CAT are essential elements for cellular defence, safeguarding them from reactive oxygen species and preserving food freshness by maintaining cell membrane integrity (Xiong *et al*., 2009).

A work by Hou *et al*., (2018) found that SOD and CAT enzyme's activity tended to be higher in **γ**-irradiated *V. volvacea* mushroom than the non-irradiated mushroom. PAL enzyme's level in *L. edodes*, when subjected to **γ**-radiation along with ultrasonic treatment, exceeded than control samples throughout storage in refrigerated condition, exception of days 4 and 20 (Shi *et al*., 2022) . However, the rise in PAL activity promotes phenolic retention during late storage by causing phenols to accumulate and higher PAL activity produces phenolic compounds like flavonoids (Zhong *et al*., 2023). According to research, samples of several mushroom species exposed to radiation showed a decline in PPO activity, whereas the control group showed increased level in PPO activity during the course of storage

(Gautam *et al*., 1998). *Hypsizygus marmoreus* mushroom samples irradiated to 0.8 kGy **γ**-radiation had noticeably greater levels of SOD than non-irradiated controls (Xing *et al*., 2007) . So, gamma-radiation is an effective way in regulating all the defence enzymes which ultimately gives rise to phenol content in the tissue and conversely the higher levels of phenol can lower the melanin production.

On the basis of enzymatic activity regulation by **γ**-radiation in edible mushroom, a table has been prepared.

Table 3: Effect of Gamma-radiation on enzymatic activity in edible mushroom

Species	Effect on Enzymes	References
V. volvacea	Irradiation at 0.8 kGy dose increased SOD and CAT level in mushroom's fruit bodies compared to non-irradiated control. Here the activities of SOD and CAT rose by 35% and 28% respectively after irradiation	(Hou *et al*., 2018)
L. edodes	Along with ultrasonic treatment, PAL activity increased. This combined treatment led to a 1.5 fold increase in PAL activity compared to control	(Shi *et al*., 2022)

Also, gamma-radiation has the potential to enhance the antioxidant properties of edible mushrooms. Methanolic extract of *Agaricus blazei* was irradiated with gamma-radiation (2.5 kGy to 20 kGy) and it showed considerably superior antioxidant activity than the control groups (Huang and Mau, 2006). Gamma-irradiated β-D-Glucan, isolated from *A. bisporus* showed significantly higher anti-oxidant properties than non-irradiated control, where 50 kGy dose was most effective (Khan *et al*., 2015).

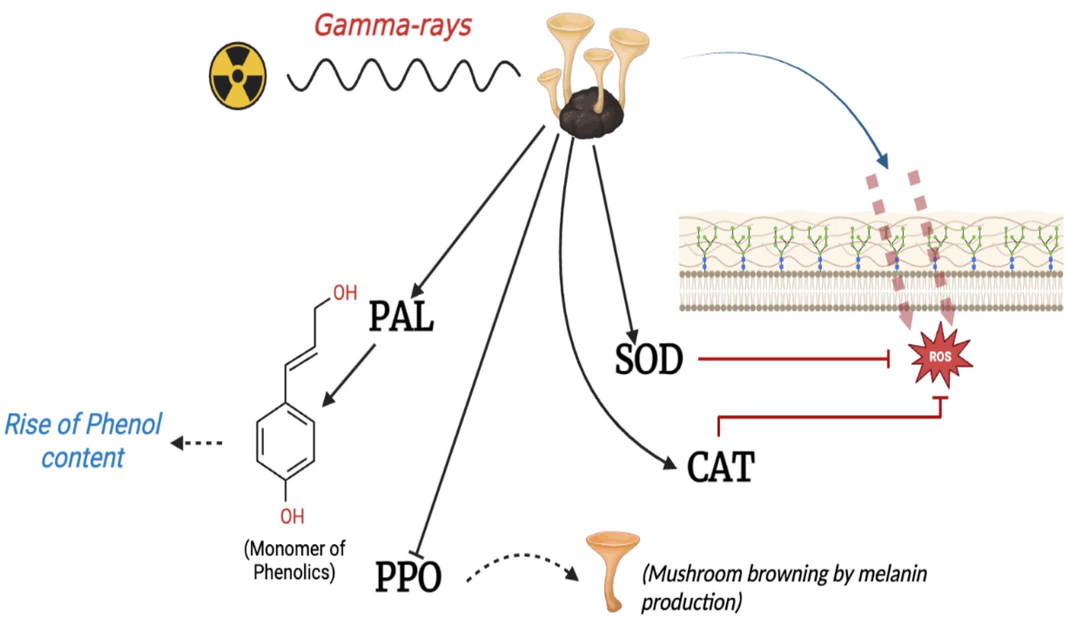

Figure 6: Impact of Gamma-irradiation technology on the enzymatic activities in edible mushrooms, which ultimately enhances the shelf-life.

Extension of shelf-life in edible mushroom

Extending shelf life is crucial for the postharvest marketing of edible mushroom, facilitating their distribution across regions and to enhance its economic market value. Numerous studies have been carried out for investigating shelf life of mushrooms, which, under normal temperature conditions, lasts only 1-3 days after harvest (Lin and Sun, 2019). Gamma-radiation could dramatically lessen the loss of weight in *A. bisporus* and stop browning with an increased shelf-life for 12 days at optimum dose of 2 kGy and their cap opening was postponed for 9 days (Wani *et al*., 2009). According to other research, shiitake mushrooms can be stored for up to 20 days when gamma-radiation (1 kGy & 1.5 kGy) is applied and combined with atmospheric packing (Jiang *et al*., 2010). A dose of 3 kGy was suitable for enhancing shelf-life of *A. bisporus* where irradiated fruit body showed delay in cap opening, impeded desiccation, reduced browning and reduction in the length of stipe (Lescano, 1994). **γ**-radiation of 2.5 kGy dose of was very much effective in extending the storage period of *Tuber aestivum* truffles with no significant losses of bioactive compounds (Tejedor-Calvo *et al.,* 2019). Conversely, the impact of **γ**-irradiation for extending shelf life of mushroom is less evident at higher dosage rates. This could be because the higher dose significantly damages integrity of fungal outer membrane, altering its permeability and causing the external hazardous substances to infiltrate and the edible fungal cell defence function to be attenuated (Chen *et al.*, 2012);(Reis *et al*., 2012).

Table 4: Impact of Gamma-radiation on extending the shelf-life of few edible mushrooms

Species	Optimum Dose (kGy)	Extended period	References
A. bisporus	3	16 days	(Lescano, 1994)
A. bisporus	2	10 days	(Gautam *et al.*, 1998)
A. bisporus	2	12 days	(Wani *et al.*, 2009)
L. edodes	1, 1.5	20 days	(Jiang *et al.*, 2010)
T. aestivum	2.5	42 days	(Tejedor-Calvo *et al.*, 2020)
L. edodes	1	20 days	(Shi *et al.*, 2020)

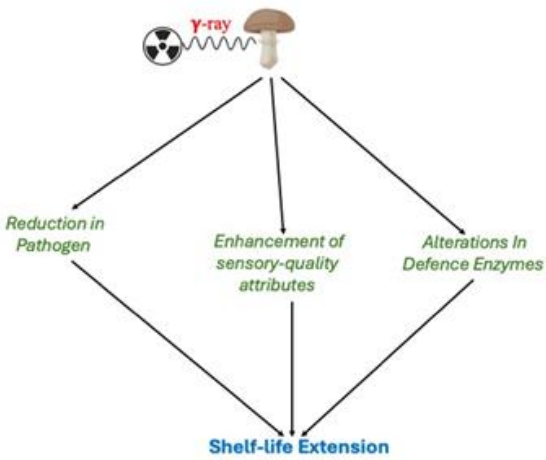

Figure 7: The beneficial roles of gamma radiation leading to the extension of the shelf-life of edible mushrooms

FUTURE PROSPECTS

Gamma-radiation can be a dose-dependent effective method in maximizing the shelf-life of edible mushroom. Controlled irradiation doses, typically ranging between 1–3 kGy, have been employed to enhance various physiochemical and microbiological attributes of fresh edible mushrooms. This review can give rise a brief idea about how gamma radiation is able to control and improve shelf-life of mushroom but further investigations are required to elucidate its long-term effects on sensory and quality parameters, retention of bioactive compounds, and microbial protection. Since the high **γ**-radiation dose may damage the integrity of fungal cell membrane, further research is also needed to make the irradiation doses very specific to particular species to minimize the weakening of cellular defence mechanisms. To maximize its use, it is crucial to look at the possible changes in flavour profiles of edible mushrooms brought on by gamma irradiation. Since **γ**-radiation can effectively postpone mushroom's decay and browning, developing a preservation technology that integrates gamma radiation with other postharvest treatment strategies is crucial to ensure financial sustainability by reducing capital costs and processing times. Future research should extend the focus of gamma-radiation to explore its influence on other vitamins and micronutrients. Kumar et al., (2014) irradiated tomato fruits with gamma-radiation along with magnetic field and examined the defence parameters and shelf-life. A comparable approach can be explored on edible mushrooms to evaluate whether a combined treatment like this can yield better preservation than gamma-irradiation alone. Gamma irradiation may negatively impact the content of fatty acids. Thus, further research is crucial to develop strategies which can be able to preserve nutritional as well as biochemical integrity of mushrooms when applying gamma radiation as a postharvest preservation technique.

CONCLUSIONS

Gamma-irradiation technology with controlled lower doses can maintain post-harvest qualities, inhibit microbes, delay spoilage and enhance shelf-life of mushroom. With its low energy consumption, lack of hazardous leftovers, and environmental friendliness, this novel method provides an efficient sterilizing and quality-retention capacity in edible mushrooms. The benefits of this technology extend beyond microbial control, as it also influences enzymatic activity, thereby reducing browning and delaying early spoilage. Although certain adverse effects are primarily associated with higher radiation doses, which are generally avoided in mushroom irradiation protocols. Consequently, the advantages of gamma irradiation largely outweigh its potential drawbacks. This contemporary techniques not only improves the preservation and post-harvest shelf-life of edible mushroom but also align with sustainability guidelines, increasing their marketability in an environmentally conscious market. As food preservation technologies continue to develop, gamma-radiation stands as a scientifically validated and adaptable technique. With careful optimization, application of gamma-radiation has great ability to develop the global mushroom supply chain while maintaining food quality and safety.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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