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QUALITY ASSESSMENT OF GAMMA IRRADIATED POWDERED DRIED MUSHROOMS (*PLEUROTUS PULMONARIUS* AND *VOLVARIELLA VOLVACEA*) IN EXTENDING SHELF LIFE DURING STORAGE

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Abstract:

Mushrooms are soft textured and prone to deteriorate shortly after harvest if not properly stored. In view of their short shelf life under normal ambient conditions of temperature and humidity, it is imperative to preserve it by processing to extend shelf life for off season use. Drying is one of the common methods used for mushrooms for preservation owing to its easiness and economical nature. Irradiation is known to be a safe technology for treating food products using ionizing radiation. Gamma ray ionizing radiation is used to extend the shelf-life of food products and results in the inactivation of foodborne pathogens. This paper showed the ability of gamma irradiation for decontamination of powdered dried mushrooms (*Pleurotus pulmonarius* and *Volvariella volvacea*) and reliable process for edible mushrooms storage in commercial industries. The mushrooms were dried at temperature of 45-55ºC, powdered and given gamma irradiation at 0 (control), 2, 5 and 10 kGy. Results showed that irradiation at 2 kGy had the ability to reduce the microbial loads (bacterial and fungal colonies) in powdered dried mushrooms and there was no

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presence of microbes after irradiated at 5 and 10kGy. Nevertheless, after storage 9 months, the microbial loads increased in the control samples but maintained low in samples (*Pleurotus pulmonarius* and *Volvariella volvacea*) irradiated at 5kGy ($1.4x10^2$, $1.5x10^1$ cfu/g) and 10kGy ($4x10^1$, $5x10^1$ cfu/g). There were no significant changes in colour of all samples during storage. Although there were some changes observed for proximate compositions due to the gamma irradiation, the results obtained were no significant differences ($P<0.05$) and showed that the integrity of these compositions in the mushrooms were minimally affected as no adverse effects were observed. Irradiation at dose 5 and 10kGy are suitable in maintaining the quality of the powdered dried samples and also extended the storage period.

Keywords:

Gamma, Irradiation, Mushroom, Microbial, Storage

Introduction

There is an increased effort in planting and producing mushrooms in Malaysia due to the demands for variety dishes and awareness of the people about the benefits in consuming mushrooms. Mushrooms have been consumed for century as food or food supplement due its delicate taste, flavour and therapeutic effects (Chockchaisawasdee et al. 2010). Literally, there are less than 25 species of edible mushroom out of more than 2000 species that exists. Oyster mushrooms (*Pleurotus* species) are commercially produced mushroom in the world and are cherished due to their culinary, nutritional, as well as medicinal properties (Singh et al., 2012; Deepalakshmi and Mirunalini, 2014). They are considered as source of proteins, vitamins, fats, carbohydrates, amino acids, and minerals (Kortei & Wiafe-Kwagyan, 2015). Because of the presence of numerous nutritional compositions and various active ingredients in *Pleurotus* sp., have been reported to have antidiabetic, antibacterial, anticholestrolic, antiarthritic, antioxidant, anticancer, eye health and antiviral activities (Deepalakshmi and Mirunalini, 2014)

Volvariella volvacea mushrooms or Tropical Button Mushroom is suitable for growing in Malaysia and this mushroom cultivation industry has great potential because of the high demand and short growth process. This mushroom is also capable in generating lucrative income to farmers on a continuous basis with low initial costs. Mushroom production throughout the year allows it to have good prospects in producing downstream products (Yusof et. al., 2019). *V. volvacea* has its own properties of good sources of vitamin B including riboflavin, niacin and pantothenic acid. These properties are important for nervous system, blood cells, healthy skin and also are important in breaking proteins, fats and carbohydrate (Rop et al., 2009). ***V****. volvacea* is a good source of polypeptides, terpenes, steroids (Shwetha and Sudha, 2012) and phenolic compounds such as flavonoids, phenolic acid and tannins which contribute to high antioxidant capacity. Hung and Nhi (2012) found that the free phenolics are higher in the *V. volvacea* which are the major contributor to the antioxidant activity.

Mushrooms are soft textured, highly perishable and prone to deterioration shortly after harvest if not stored properly. In view of their short shelf life under normal ambient conditions of temperature and humidity, it is imperative to preserve it by processing to extend shelf life for off season use. Drying is one of the common methods used for mushrooms for preservation

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owing to its easiness and economical nature (Kumar *et al*., 2013). According to Labuza and Altunakar (2007), the principle behind drying is primarily reduction of moisture to levels low enough to inhibit microbial growth and also slow down enzymatic and other biological reactions that may contribute to food spoilage. Powdered dried mushrooms is used for soups, flavours, pastes, seasonings and other neutraceutical products. A common problem in the mushroom industries is related to storage period after drying procedures. Gradually in time dried mushrooms will be degraded by microbes after certain time in storage containment.

Food irradiation is the intentional exposure of food to ionizing radiation (such as gamma and electron beam) in order to enhance its shelf life without any detrimental effect on food quality as well as the safety of food. After decades of research, development, public debate and consumer acceptance trials in many countries, irradiation has emerged as a safe and viable technology for ensuring the safety and quality of food and for combating food-borne diseases. According to IAEA, (2009), it is currently the best available technology according to as suitable for treating raw and partially raw food products and those countries which adopt it will benefit greatly in both domestic and international markets.

Ionizing irradiation is known to be a safe technology for treating food products. Gamma ray ionizing radiation is used to extend the shelf-life of food products and results in the inactivation of foodborne pathogens. Gamma ray ionizing radiation is known to be a safe technology for treating food products and used to extend the shelf-life of food products and results in the inactivation of foodborne pathogens (Jiang et al., 2010). This study was carried out to observe the ability of gamma irradiation for decontamination of dried mushrooms (*Pleurotus pulmonarius and Volvariella volvacea*) and reliable process for edible mushrooms storage in commercial industries.

Materials and Methods

Powdered dried *Pleurotus pulmonarius* and *Volvariella volvacea* mushrooms were packed each 10gm in plastic packages, sealed, packed in boxes and sent for irradiation with doses 2 kGy, 5 kGy and 10 kGy. The control samples (0 kGy) and all irradiated samples were stored at room temperature for 0, 3, 6 and 9 months.

Samples (2g) in duplicates from the irradiated and their corresponding non-irradiated control batches were aseptically homogenized for 1 min with 225 ml sterile saline in a Stomacher (Seward Medical, UK). Appropriate serial dilutions of the homogenate were carried out. Total plate count by spread plate method, was determined using Plate Count Agar incubated at 30^{o}C for 48 hours and Potato Dextrose Agar for molds (incubated at 30^{o}C for 5 days). The results were expressed as colony forming units per gram (cfu/g).

Proximate composition analysis of the samples were carried out to determine the content (gram) of moisture, ash, protein, fat and carbohydrate using standard procedures according to the Association of Official Analytical Chemists (AOAC, 2002). Colour changes of the products were recorded using Colorimeter (Minolta) with L, a, b values i.e. lightness (L), redness (a) and yellowness (b). Statistical analysis using ANOVA test (SAS Institute, 1991) and comparisons were made by Duncan's multiple range tests.

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Results and Discussion

Irradiation at 2 kGy reduced the fungal loads in powdered dried *Pleurotus pulmonarius* samples and there was no presence of microbes in samples irradiated at 5 and 10 kGy. After storage at 3, 6 and 9 months, the fungal loads increased in the control samples but maintained low in samples irradiated at 2, 5 and 10 kGy (Table 1).

Irradiation Doses (kGy)	Number Of Fungal Colony (CFU/g) - *Pleurotus pulmonarius*			
	Months Of Storage			
	0	3	6	9
0	3.33 x10^3	5.8 x10^3	6.4 x10^3	11.3 x10^3
2	2.4 x10^2	3.2 x10^2	4.3 x10^2	5.2 x10^2
5	0	1.7 x10^2	1.7 x10^2	1.8 x10^2
10	0	5.0 x10^1	3.0 x10^1	4.0 x10^1

Table 1: The Number Of Fungal Colonies In Powdered Dried *Pleurotus pulmonarius* Samples After Irradiation With Different Doses And Storage Time

Irradiation at 2 kGy reduced the fungal loads in powdered dried *Volvariella volvacea* samples and there was no presence of microbes in samples irradiated at 5 and 10 kGy. After storage at 3, 6 and 9 months, the fungal loads increased in the control samples but maintained low in samples irradiated at 2, 5 and 10 kGy (Table 2).

Irradiation Doses (kGy)	Number Of Fungal Colony (CFU/g) – *Volvariella volvacea*			
	Months Of Storage			
	0	3	6	9
0	3.17 x10^3	5.0 x10^3	8.0 x10^3	8.7 x10^3
2	2.4 x10^2	4.7 x10^2	6.0 x10^2	7.4 x10^2
5	0	1.4 x10^1	1.5 x10^1	1.6 x10^1
10	0	4.0 x10^1	4.0 x10^1	5.0 x10^1

Table 2: The Number Of Fungal Colonies In Powdered Dried *Volvariella volvacea* Samples After Irradiation With Different Doses And Storage Time

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Irradiation Doses (kGy)	Number Of Bacterial Colony (CFU/g) - *Pleurotus pulmonarius*			
	Months Of Storage			
	0	3	6	9
0	4.8×10^3	6.9×10^3	9.0×10^3	13.8×10^3
2	3.0×10^2	4.1×10^2	3.4×10^2	3.0×10^2
5	0	1.8×10^2	1.9×10^2	1.4×10^2
10	0	7.0×10^1	3.0×10^1	4.0×10^1

Table 3: The Number Of Bacterial Colonies In Powdered Dried *Pleurotus pulmonarius* Samples After Irradiation With Different Doses And Storage Time

Irradiation at 2 kGy reduced the bacterial loads in powdered dried *Pleurotus pulmonarius* samples and there was no presence of microbes in dried mushrooms irradiated at 5 and 10 kGy. After storage at 3, 6 and 9 months, the bacterial loads increased in the control samples but maintained low in samples irradiated at 2, 5 and 10 kGy (Table 3).

Irradiation at 2 kGy reduced the bacterial loads in powdered dried *Volvariella volvacea* samples and there was no presence of microbes in samples irradiated at 5 and 10 kGy. After storage at 3, 6 and 9 months, the bacterial loads increased in the control samples but maintained low in samples irradiated at 2, 5 and 10 kGy (Table 4).

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Irradiation Doses (kGy)	Number Of Bacterial Colony (CFU/g) – *Volvariella volvacea*			
	Months Of Storage			
	0	3	6	9
0	6.87×10^3	4.1×10^3	5.8×10^3	9.2×10^3
2	3.1×10^2	3.9×10^2	5.0×10^2	6.4×10^2
5	0	1.5×10^1	4.0×10^1	1.5×10^1
10	0	5.0×10^1	3.0×10^1	5.0×10^1

Table 4: The Number Of Bacterial Colonies In Powdered Dried *Volvariella volvacea* Samples After Irradiation With Different Doses And Storage Time.

The irradiated powdered dried mushrooms with doses of 5 and 10 kGy were free from microbial and fungi counts and very low counts during storage until 9 months. Application of gamma irradiation up to a dose level of 10 kGy can be used to reduce the numbers of food spoilage microorganisms as well as food-borne pathogens in food products (Abu-Tarboush et al. 1996).

Although there were some changes observed for proximate compositions due to the gamma irradiation, the results obtained were no significant differences ($P<0.05$) and showed that the integrity of these compositions in the mushrooms were minimally affected as no adverse effects were observed (Table 5 and 6).

Irradiation Dose kGy	Protein	Fat	Carbohydrate	Ash	Moisture
0 (non-irradiated)	24.90 ± 0.09	0.70 ± 0.01	63.90 ± 0.09	0.60 ± 0.01	9.90 ± 0.09
5	24.88 ± 0.03	0.73 ± 0.03	63.89 ± 0.03	0.64 ± 0.03	9.86 ± 0.03
10	24.87 ± 0.17	0.75 ± 0.07	63.87 ± 0.17	0.66 ± 0.01	9.85 ± 0.17

Table 5: Proximate Composition Of Powdered Dried *Pleurotus pulmonarius* Samples After Irradiation With Different Doses (gm/100g Sample)

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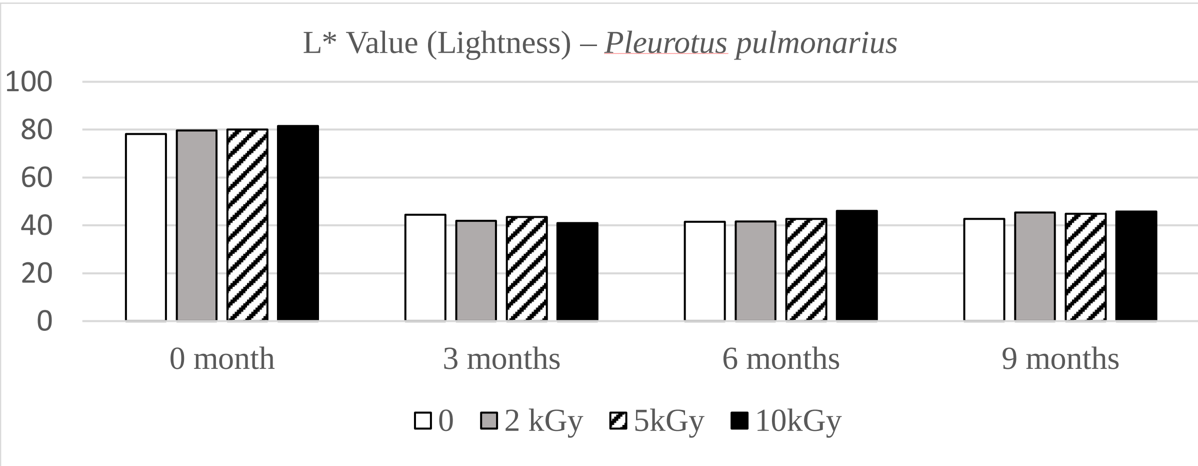
Irradiation Dose kGy	Protein	Fat	Carbohydrate	Ash	Moisture
0 (non-irradiated)	33.35 ± 0.07	1.56 ± 0.22	49.65 ± 0.15	7.14 ± 0.20	8.30 ± 0.02
5	32.42 ± 0.05	1.61 ± 0.64	50.50 ± 0.07	7.21 ± 0.13	8.26 ± 0.05
10	32.37 ± 0.91	1.64 ± 0.15	50.53 ± 0.20	7.24 ± 0.11	8.22 ± 0.07

Table 6: Proximate Composition Of Powdered Dried *Volvariella volvacea* Samples After Irradiation With Different Doses (gm/100g Sample)

There was significant reduction of lightness of both powdered dried mushroom samples after irradiation. However, there was no significant changes ($P<0.05$) in lightness of all samples during storage (Figure 1). There was significant increment of redness of both powdered dried mushroom samples after irradiation. However, there was no significant changes ($P<0.05$) in redness of all samples during storage (Figure 2). There was no significant increment of yellowness of both powdered dried mushroom samples after irradiation. There were also no significant changes ($P<0.05$) in yellowness of all samples during storage (Figure 3). Irradiation dose of 5kGy and 10kGy completely decontaminate the dried mushroom samples, but high doses are not recommended for food products as it would affect the taste and coloration.

Irradiating with more than 7kGy negatively affect organoleptic features and meat quality including colour, flavour & oxidation rate (Rahimi et al., 2012). Irradiation with low doses (<5kGy) is suggested for reducing microbial load of food product. Pewlong et al (2018) reported that gamma radiation eliminated the total viable and total yeast and molds count at a dose of 5 kGy in irradiated dried shiitake mushroom powder. A similar result was found in green tea leaf samples (Fanaro et al., 2015) which showed the gamma irradiation at a dose of 5 kGy was the minimum dose to eliminate bacterial and fungal growth.



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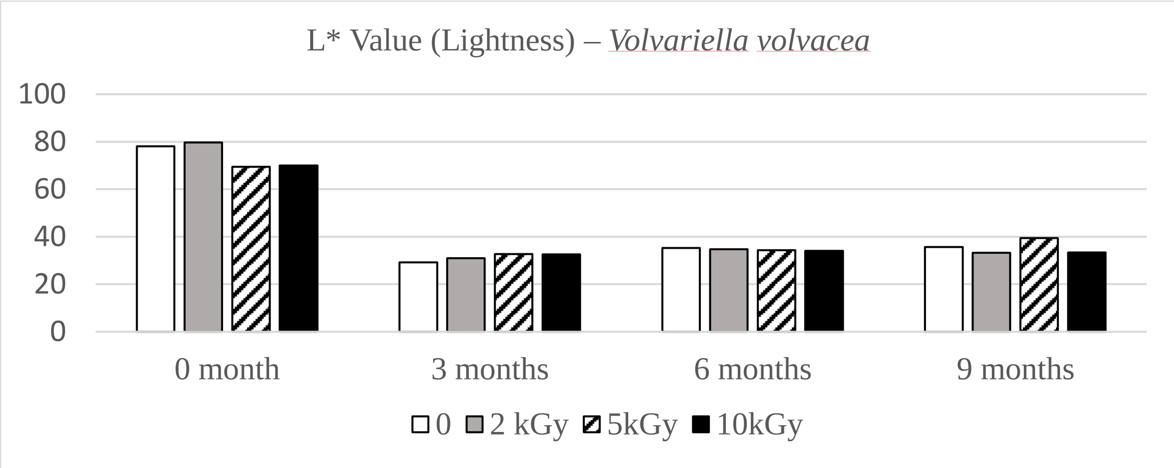
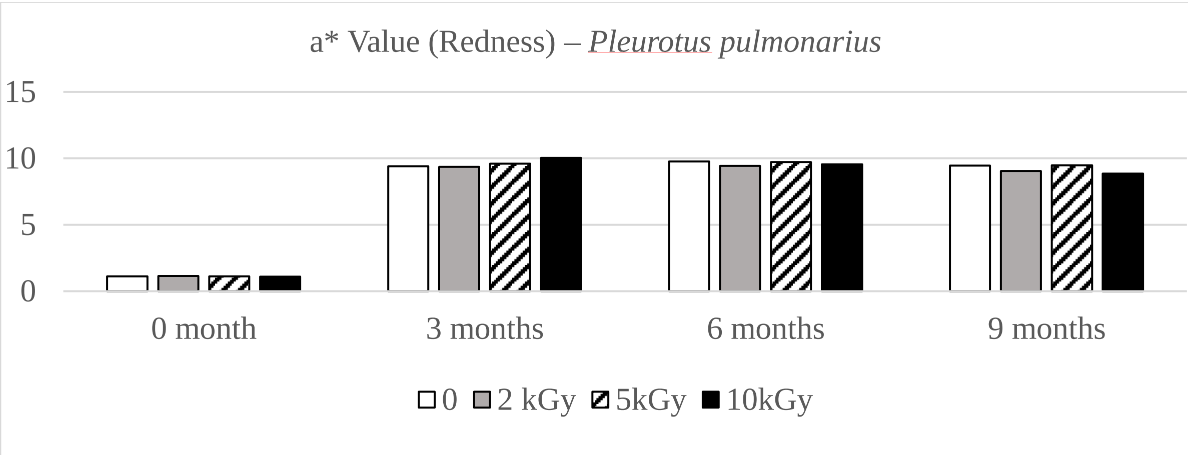


Figure 1: The L* (Lightness) Values Of Powdered Dried *Pleurotus pulmonarius And Volvariella volvacea* Samples



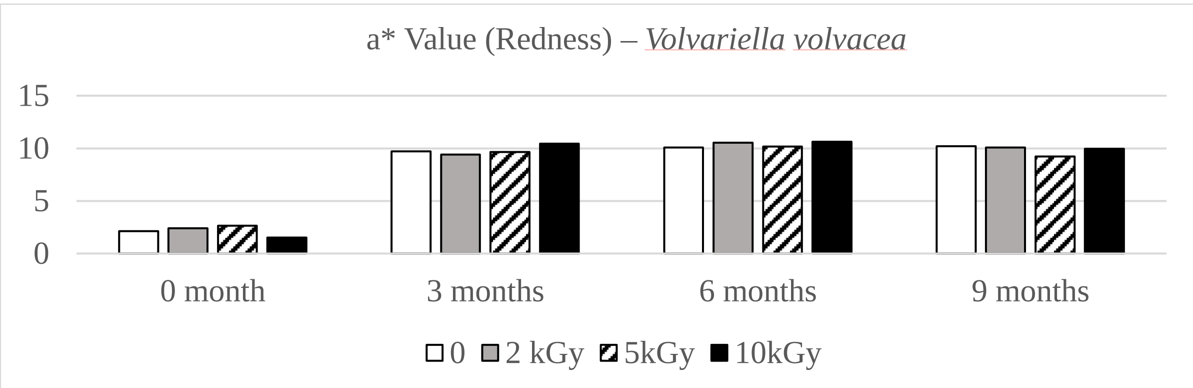


Figure 2: The A* (Redness) Values Of Powdered Dried *Pleurotus pulmonarius And Volvariella volvacea* Samples

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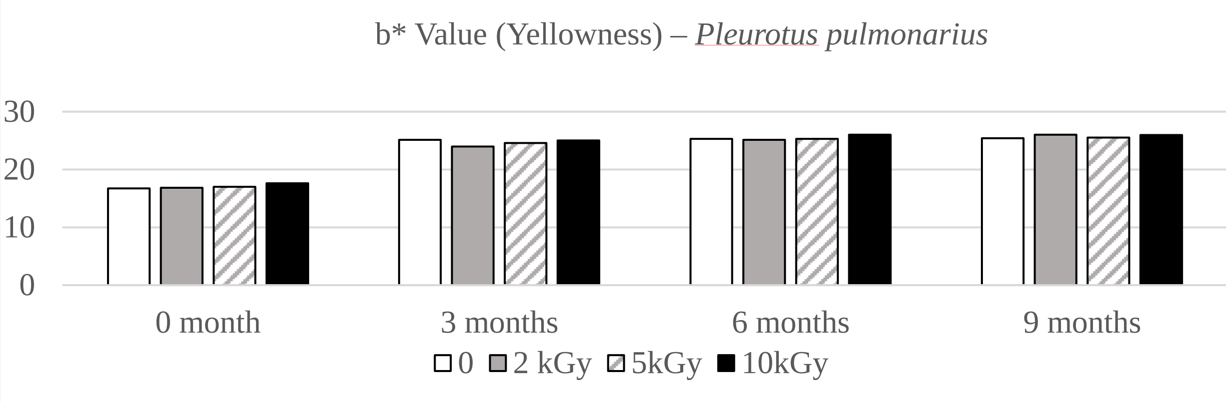

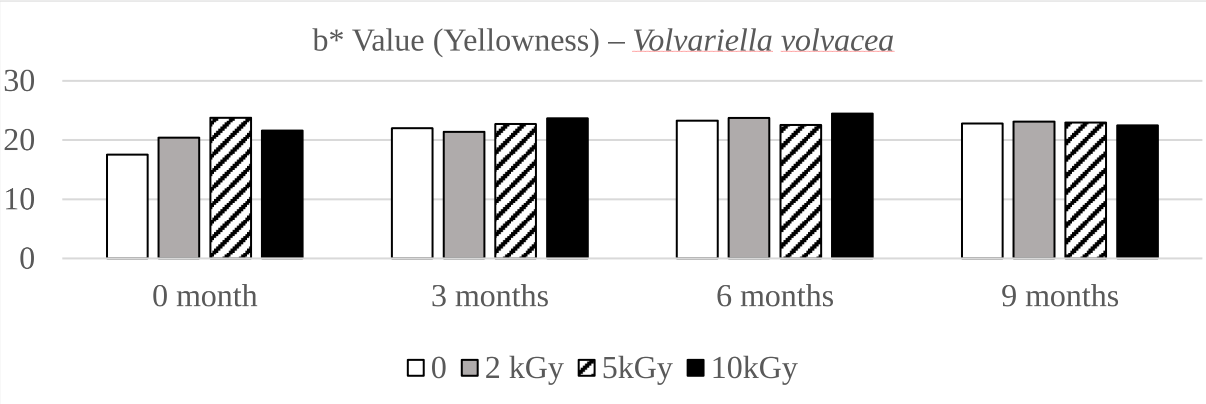

Figure 3: The B* (Yellowness) Values Of Powdered Dried *Pleurotus pulmonarius And Volvariella volvacea* Samples

A B

Figure 4: A- *Pleurotus Pulmonarius* and B-*Volvariella Volvacea.*

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The highly penetrative ionising energy has the ability to inactivate spoilage and disease-causing microorganisms without causing harmful changes to the products. The ionising energy passes completely through the products and their packaging. Thus, the products can be irradiated in their final packaging ready for the end-user. This process is a cold treatment and suitable to retain the acceptability of the products. Other food preservation methods such as chemical and heat treatment can kill microorganisms including pathogens. However, chemical leaves residues and heating treatment can change the texture, colour and flavour of the products (MINTec-SINAGAMA).

Kortei et. al. (2017) stated that current research demonstrates the ability of gamma irradiation to be used in the preservation of nutritional qualities of foods as changes that occurred due to gamma irradiation were minimal irrespective of the packaging material used. Non-irradiated dried mushroom last not more than 6 months because of insect and pests damage. Additionally, gamma irradiation eliminated all these insects and pests to prolong its shelf life to 12 months. Gamma irradiation with its enormous attributes could be employed in food manufacturing industries to enhance product quality and shelf life.

Conclusion

Irradiation in conjunction with drying process inhibits microbial growth in powdered dried mushrooms and prolonged their shelf life. The ability of gamma irradiation to decontamination of dried powdered mushrooms (*Pleuratus pulmonarius* and *Volvariella volvacea*) is effective and reliable process for edible mushrooms storage in sustaining commercial industries sources.

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