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Browning and Color Characteristics in Mushrooms (*Agaricus bisporus*) As Influenced by Ionizing Energy

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Abstract

Browning and color characteristics of stored mushrooms (*Agaricus bisporus*) following ionizing irradiation were investigated in connection with quality deterioration. The phenolic compounds of stored mushrooms showed a gradual decreasing tendency, while extractable browning pigments apparently rose from around 3 days of storage under the conditions of 9 ± 1 °C, 80 ± 7% RH and packaging with a corrugated paper box wrapped up in PE. γ-irradiation at 2 to 3 kGy resulted in a significant reduction of their changes. Immediately after treatment, irradiated mushrooms were more discolored, i.e. a lower Hunter L value and higher Hunter a and b values than control. However, the subsequent storage for 15 days resulted in a preventive influence of ionizing energy on mushroom discoloration. This beneficial effect of ionizing energy was somewhat higher in the pilei than in the stipes of mushrooms and was found to increase lineally with increasing doses up to 3 kGy.

Key words: fresh mushrooms (*Agaricus bisporus*), browning, Hunter color values, ionizing irradiation

Introduction

Deterioration of fresh mushrooms is marked primarily by a brownish discoloration of the surfaces, by opening of veils, elongation of stalks, and a general softening of the tissue due to loss of mositure.

Degree of whiteness is one of the most important quality factors in *Agaricus bisporus* and generally the whitest mushrooms command the higher price.[1] When mushrooms are subjected to vibrations or rough handling the oxidizing enzyme polyphenol oxidase acts on the substrate tyrosine causing browning.[2] This also occurs as the mushroom ages and fungal infection is another cause of loss of whiteness.[3,4]

Chemical treatments,[5,6] prepackaging[7-9] and low storage temperature[1] have been used to maintain mushroom whiteness but all of these methods have only been moderately successful. Over the last many years much research has been conducted using ionizing energy in an attempt to obtain the shelf-life extension of mushrooms. Gamma- or electron-irradiation was demonstrated to have a beneficial effect on the growth retardation of fresh mushrooms.[4,9,10] Several workers also dealt with irradiation effects on whiteness and polyphenol oxidase activity of mushrooms.[2,9,10,13] However, little is known of the changes in polyphenolic substances and browning pigments associated with mushroom discoloration induced by post-irradiation storage conditions.

This work investigated the effects of ionizing energy treatment and subsequent storage on the skin and flesh discoloration of packaged mushrooms by determining browning substances and Hunter color values.

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Materials and Methods

Materials

Cultured mushrooms (*Agaricus bisporus*, white strain) having a pileus diameter of 3.5 to 4.0 cm were harvested at the stage of 45 days after cultivation. The fresh mushrooms were aerobically packed into a corrugated paper box (18 × 11 × 17 cm) and the boxes were wrapped up in polyethylene film (0.06 mm thickness).

Irradiation and storage

The packaged mushrooms were irradiated by a 7.4 nBq Co-60 gamma irradiator (does rate: 20 Gy/hr) with doses of 0,1,2 and 3 kGy, respectively at ambient temperature. Treated mushrooms were used for experiments immediately after irradiation or during the course of storage at 9 ± 1 °C and 80 ± 7% relative humidities for 20 days.

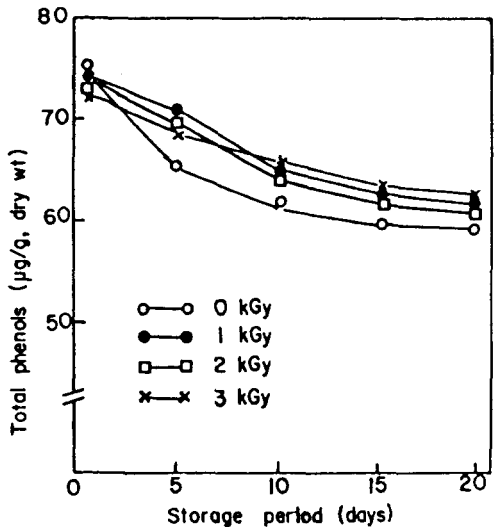

Fig. 1. Changes in total phenols of gamma-irradiated mushrooms (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH.

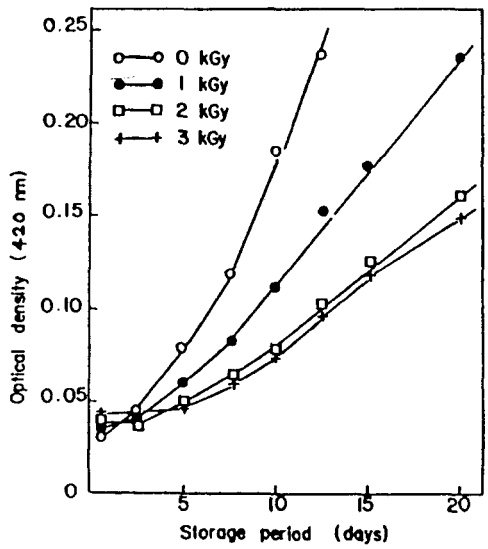

Fig. 2. Extractable browning pigments of gamma-irradiated mushrooms (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH(1% HCl soln./MeOH)

Determination of polyphenols and browning pigments

Total phenols of the sample were determined by the colorimetric method[11] (Bausch and Lomb, spectronic 710) using Folin-Denis reagent. The extractable browning pigments in a solvent of 1% methanolic HCl[12] were measured as optical density at 420 nm to compare the discoloration of each sample. Homogeneous samples excluding gills were used for analyses. Each value reported here represents the average of triplicate determinations.

Measurement of Hunter color values

Color parameters of the pileus (skin, flesh) and stipe flesh in mushrooms were measured with a color/color difference meter (ND-1001 DP, Nippon Denshoku Kogyo Co., Japan) which was standardized with a white plate (L: 90.6, a: 0.4, b: 3.3). Each color value for whiteness(L), redness(a) and yellowness(b) was expressed as the mean of 30 measurements.

Results and Discussion

Browning of mushrooms

Discoloration is a major factor contributing to quality loss of mushrooms after harvest and is known to result mainly from the action of o-diphenol oxidase (o-DPO, E.C. 1.10.3.1, polyphenol oxidase, tyrosinase) on phenolic compounds.

Fig. 1 and 2 illustrate the changes in the contents of total phenols and extractable browning pigments of irradiated mushrooms during storage at 9 ± 1 °C and 80 ± 7% RH for 20 days. The total phenols of stored mushrooms showed a gradual decreasing tendency, whereas extractable pigments apparently rose from the 3rd day of storage period. The rate of loss of phenolic compounds appeared to be negatively correlated with the discoloration of mushroom bodies. Our results are correlated with the finding of Murr and Morris[3] who investigated the effect of temperature on surface discoloration as related to total phenolic content and o-DPO activity.

Among treated groups there was a singificant difference ($p<0.05$) in the change of total phenolic contents from the 5th day of storage period between the control and irradiated samples. Gamma irradiation caused some initial browning of mushroom bodies as illustrated in Fig. 2, which seems to relate with a temporal stimulation of enzyme and respiratory systems as noted by Skou *et al.*[2,10] and Kwon *et al.*[14,15] With storage time, however, 2 to 3 kGy ionizing energy showed a preventive effect on mushroom discoloration.

The results are generally agreed to the literature

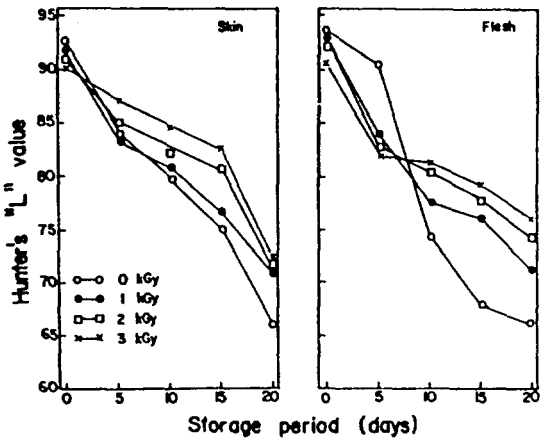

Fig. 3. Effect of gamma irradiation on pileus color (Hunter "L" value) of mushrooms (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH

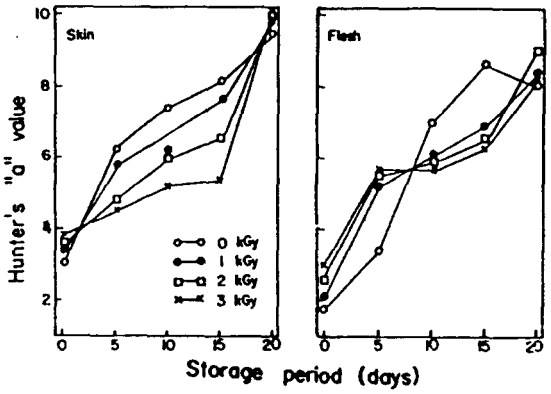

Fig. 4. Effect of gamma irradiation on pileus color (Hunter "a" value) of mushrooms (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH

that irradiation with 0.5 kGy or more improves the skin color of stored mushrooms.[4,9,10,16] This beneficial influence of ionizing energy treatment is reasonably explained as a result of its action on delaying maturity and retarding physiological activities of fresh mushrooms, as previously reported.[17]

Color characteristics of mushrooms

Determination of irradiation effects on color are often contradictory, dependent upon whether the surface or flesh is measured and whether objective instrumentation or subjective observations are employed. In this study, both skin and flesh were used for measuring the color parameters, L(whiteness), a(redness) and b(yellowness).

Hunter L values are presented in Fig. 3 as affected by irradiation dose and storage period. The initial L values of pileus skin were higher in control (91.8) than irradiated samples (91.1-90.1), showing a linear decreasing tendency depending on an irradiation-dose increase. This undesirable influence of irradiation was well demonstrated in the contents of browning pigments of mushrooms.

The lapse of storage time resulted in a distinct decrease of whiteness of the sample in both skin and flesh. But irradiation-dose dependance was apparent. Mushrooms irradiated at 2 to 3 kGy maintained whiteness by more than 80 with up to 15 days of storage, while values for the control and 1 kGy-irradiated samples were considerably low.

Whiteness has been used as the major quality index in mushroom acceptability. Gormley[1] adopted six categories of Hunter L values associated with mushroom grades; excellent (>93), very good (90-93), good (86-89), fair (80-85), poor (69-79) and very poor (<69). In practical terms, he suggested a reluctant line of whiteness values for both wholesalers and retailers as <80 and 69-79, respectively. Based on this reluctant line, it was feasible that gamma energy at 2 to 3 kGy could keep the color quality of fresh mushrooms until 15 days under the storage conditions of 9 ± 1 °C, 80 ± 7% RH and packaging with a corrugated paper box wrapped with polyethylene film. In the same conditions the storage life of control samples was less than 10 days. The changes in whiteness of pileus flesh showed similar patterns during storage to pileus skin except that control samples were whiter than irradiated ones until 8 days of storage. The above results confirm earlier reports concerning the irradiation effects on color of stored mushrooms.[9,10,18]

Freshly harvested mushrooms had closed caps and were white and attractive in color. However, the subsequent storage lead to discoloration of mushroom bodies together with physical changes such as veil opening, stipe elongation, and texture softening. The skin color always changes towards the brownish. In the sealed boxes, the mushrooms sometimes became pinkish very soon after picking and as time progressed, this discoloration changed from isabella-colored to brownish.[10]

Fig. 4 and 5 show the changes in redness (Hun-

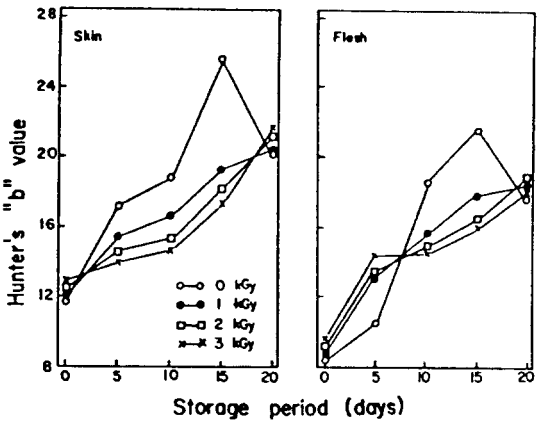

Fig. 5. Effect of gamma irradiation on pileus color (Hunter "b" value) of mushrooms (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH

ter a value) and yellowness (Hunter b value) of mushroom pilei during post-irradiation storage at 9 ± 1 °C and 80 ± 7% RH. These two color parameters adversely changed during the whole storage period to Hunter L value of mushrooms. This is quite natural as mushroom color changes from white into brownish. Immediately after irradiation, it was observed that irradiated mushrooms were more discolored, i.e. they had higher a and b values than the nonirradited control samples.

The influence of ionizing energy treatment on the prevention of browning was found at different stages of the storage period. In case of pileus skin, irradiation effects at 2 to 3 kGy became significant from around 5 days to 15 days after treatment, while pileus flesh revealed a similar effect in the middle stage of storage time. There has been little interest in the effects of irradiation on the inside tissue of the mushrooms. It seems evident, however, that this is at least as important as other characteristics. Mercier and MacQueen[19] stated that the flesh color of mushroom pilei became better in 2 to 3 kGy-irradiated samples than the nonirradiated control with storage time. This agrees well with our results. It was indicated that the flesh color of mushrooms was affected by edaphic conditions and the age of the culture.[10]

The effects of ionizing energy treatment and subsequent storage on color parameters of the stipe flesh were given in Table 1. Stipe flesh represented considerably lowered values of Hunter L, a and b as

Table 1. Effect of gamma irradiation on color parameters of mushroom stipes during storage[a]

Color parameters[b] (Hunter)	Irradiation dose(kGy)	Storage period (days)				
		0	5	10	15	20
L	0	39.7	32.8	27.6	26.3	23.4
	1	39.3	31.6	24.3	22.4	20.6
	2	38.8	31.0	28.9	26.9	24.3
	3	36.8	30.0	28.6	27.9	24.7
a	0	0.5	3.5	3.9	4.1	2.9
	1	0.9	3.7	3.6	3.1	3.4
	2	1.0	3.8	3.4	3.0	3.1
	3	1.3	4.2	3.8	3.6	3.2
b	0	4.4	6.2	6.4	6.2	4.8
	1	4.5	6.8	6.6	4.8	6.5
	2	4.7	6.9	6.8	6.5	6.2
	3	5.2	7.1	6.9	6.6	7.4

[a] Sample was stored at 9 ± 1 °C and 80 ± 7% RH. Color was measured for stipe flesh and each value is the mean for 30 determinations.

[b] L: Degree of whiteness (white + 100 ↔ 0 black)
a: Degree of redness (red + 100 ↔ 0 ↔ −80 green)
b: Degree of yellowness (yellow + 70 ↔ 0 ↔ −80 blue)

compared to those for pileus flesh. The initial browning of flesh induced by irradiation was more appreciable in the stipes than in pilei.

Color is always more intense in the stipes than in the pilei and mushroom stipes are known to contain more active and latent forms of o-DPO than the pilei.[2,20] These facts correlate with our observations that immediately following irradiation flesh discoloration increased. This occurred more in the stipes than in the pilei.

On the other hand, it is resonable to assume that the preventive effects of ionizing energy on discoloration of stored mushrooms resulted mainly from its role in the controlling of physiological activities and microbial growth in mushroom bodies which were observed in our preliminary studies.[14,17]

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버섯의 갈변 및 색도에 대한 전리에너지의 영향

권중호 · 변명우 · 조한옥
한국원자력연구소

백색종 양송이의 보존기간 연장을 위한 전리에너지 처리가 저장 중 버섯의 갈변현상과 색도에 미치는 영향을 조사하였다. 버섯의 갈변현상과 관련된 polyphenol성 화합물은 저장 중(9± 1℃, 80± 7% RH, 20일간) 감소하였고 갈변색소는 저장 후 3일경부터 크게 증가하였으며, 이들의 증감현상은 2-3 kGy의 감마선 조사로서 유의적으로 감소되었다. 포장된(종이상자와 PE) 버섯의 갓 및 줄기 부위의 표피와 내부조직에 대한 기계적 색도 측정에서 감마선은 처리직후 Hurter L값(백색도)의 감소와 a 및 b값(적색도 및 황색도)의 증가현상을 초래하였으나 저장 후 15일까지 버섯의 변색방지 효과를 뚜렷이 나타내었다. 이같은 효과는 줄기에 비해 갓 부분에서 높았으며 조사선량(1-3 kGy)에도 비례하였다.