KOREAN J. FOOD SCI. TECHNOL.
Vol. 21, No. 5, pp. 669~675 (1989)

Effect of Ionizing Radiation of Physiological Characteristics of Fresh Mushrooms (*Agaricus bisporus L.*)

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Abstract

Fresh mushroom (*Agaricus bisporus L.*) was irradiated (0, 1, 2, 3kGy) and kept for 20 days at 9 ± 1° and 80 ± 7% RH. Parameters of qualities were investigated on the physical and physiological characteristics. The pileus and stipe on nonirradiated mushroom were expanded and elongated from the 3rd day of storage, thereby losing the acceptability as edible samples. After 5 days of storage, 2 to 3 kGy of gamma irradiation were especially effective for controllong natural maturation and senescence of fresh mushrooms, and so irradiated mushrooms were acceptable more than 20 days storage. The texture of irradiated samples was superior to that of nonirradiated samples, even though softening of the tissue occurred during storage. Weight loss was greatest in the nonirradiated sample due to evaporation from an increased surface area resulting from expansion and ripending, which were retarded in the 2 to 3 kGy irradiated samples after 5 days of storage. These results suggest that the irradiation dose of 2 to 3 kGy is apparently effective to extend the shelf life of fresh mushrooms stored at the above-mentioned condition.

key words: fresh mushroom, gamma irradiation, shelf life, physiological characteristics

Introduction

Fresh mushrooms (*Agaricus bisporus* L.) are a highly perishable vegetable. The fresh mushrooms market is limited by an extremely short shelf life under commercial storage conditions. Recommended condition for storage (0 to 1 °C, 90% RH) can maintain mushrooms in salable condition for only 3 to 5 days and more realistic temperatures of 10 to 13 °C for only 1 to 3 days[1,2].

Quality criteria of fresh mushrooms are white or light buff, without marks on either cap(pileus) or stem(stipe). The veil is closed and gills(lamellae) are not visible. The upper surface of the caps should be strongly convex and stems should be plump, rather than elongated. Cell division continues after harvest. Within 1 to 3 days following harvest mushrooms undergo a number of adverse changes which decrease their attractiveness to consumers; growth (stipe elongation, cap opening), discoloration (cap, stipe and gills darkening), changes in texture (shrivelling, softening, toughening)[3,4].

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For extending the shelf life of fresh mushrooms have been suggested the methods of low storage temperature[3], pre-packaging[5,6], C.A. & M.A. storage[7,8] and antioxidants[9]. But all of these methods have only been moderately successful.

Recently new intrest in irradiation processing has arisen by the result of the rule proposed by the FDA on Feb. 14, 1984, permitting irradiation of fresh fruits and vegetables at levels of below 1 kGy[10]. This proposal was suggested based on the conclusion of the 1980 joint FAO/IAEA/WHO expert committee that foods irradiated at levels up to 10 kGy presented no toxicological hazard. In korea, the first Co-60 industrial food irradiation facility was completed in June 1987, and the Ministry of Health and Social Affairs approved radiation processing for foods such as potato, onion, chestnut, garlic, fresh and dried mushrooms in 1987; such as red pepper, black pepper, onion powder, garlic powder, ginger powder, welsh onion in 1988[31].

Research on irradiation of mushrooms has been conducted with the intend of delaying cap opening and stipe elongation as well as other aspects of mushroom senescence. Staden[12] was suggested that gamma irradiation was the first investigated as a new method for improvement the keeping quality of mushroom and some workers[13,20] coincided with that results. A current list of the approved uses of radiation throughout the world states that mushroom irradiation at levels of low dose (1 to 3 kGy) is allowed in Hungary, China, Czechoslovakia, Netherlands, U.S.A. and Korea[21].

Therefore, this study was intended to assess the efficacy of gamma-irradiation for extending shelf life of fresh mushrooms particulary on the physiological parameters.

Materials and Methods

Mushrooms

White strains of cultivated mushroom (*Agaricus bisporus* L.) was used in this research. The fresh mushroom were harvested at stage of 45 days after cultivation of a pileus diameter of 3.5 to 4.0 cm.

Gamma Irradiation and Storage

Mushrooms weighed from 250 to 270g were aerobically packed, put into corrugated paper box (18 x 11 x 7 cm) and convered with polyethylene film (0.06 mm).

The packaged mushrooms were exposed to a Co-60 gamma ray source (activity: 7.4nBq) at ambient temperature of 22 to 23 °C. The dose levels applied were 0, 1, 2 and 3kGy. Absorption of ionzing radiation was checked with ferrous sulfate and ceric sulfate dosimetry[32]. The variation in exposure was estimated to be within 3% of the average dose desired. Irradiated and nonirradiated mushroom were stored at 9 ± 1 °C, and 80 ± 7% RH as commerical storage conditions and checked 0, 1, 3, 5, 10, 15 and 20 days for parameters of different quality. Day zero evaluations were conducted immediately upon arrival in our laboratory (within five hours after harvest).

Quality Parameters

Maturity of each mushroom was evaluated for degree of cap opening described as "maturity index" used by Guthrie[22] as modified from Schmidt[23].

Maturity Index	Stage of Development
1	Veil intact (tight)
2	Veil intact (stretched)
3	Veil partially broken (less than half)
4	Veil partially broken (greater than half)
5	Veil completely broken
6	Cap open, gills well exposed
7	Cap open, gill surface flat

Mushroom stipes were broken away from the botton of the caps by grasping the stipe and gently pulling it away from the cap. The length of that portion of the upper stipe from the end broken from the cap to the veil was recorded as stipe growth.

Changes in pileus and stipe diameter (in mm) during storage measured using vernier caliper.

Texture of mushroom was measured by using the Rheometer (M-1101, I&TCo., Japan). Texture was measured with mushroom cap and stipe portions separately. Firmness of cap was recorded as resistance to 10 mm peneturation from the upper caps (kg/10 mm). Toughness of stipe was recorded as resistance to shear from 4 mm thickness stipe (kg/4 mm).

Mushrooms of each group were weighed daily, difference in weight was calculated and weight loss was expressed as percentage of the original values.

Results and Discussion

Maturity Index, Pileus Expansion and Stipe Elongation

The state of the veil breakage (maturity index), pileus expansion and stipe elongation have been considered as the critical quality parameters of mushrooms(3).

Fig. 1. shows the effect of gamma irradiation on maturity index of mushrooms. Freshly mushroom samples harvested had completely closed veils. The results showed that the nonirradiated mushrooms deteriorated most rapidly. It was observed that the veils were partially broken on 3 days storage and were completely broken veils exposing the dark colored gills during 5 days storage.

On the other hand, mushroom irradiated with 1 kGy dose could retarded the maturation of mushrooms over 2 times which compared with the nonirradiated mushrooms. Also in 2 to 3 kGy irradiated groups, maturation was completly inhibited for 20 days storage.

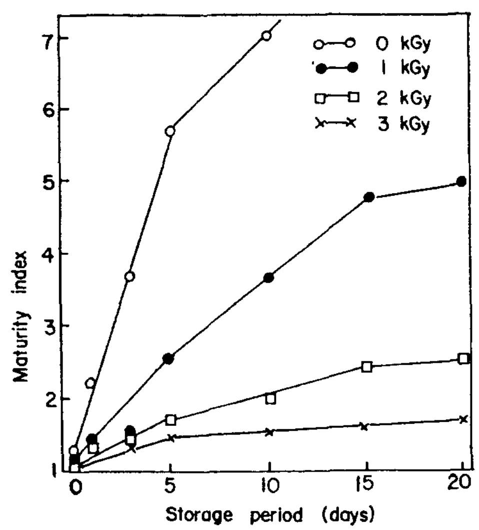

Fig. 1. Efect of gamma irradiation on maturity index of mushroom (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH.

Maturity index: 1, veil intact(tight); 2, veil intact (stretched); 3, veil partially broken (less than half); 4, veil partially broken (greater than half); 5, veil completely broken; 6, cap open (gills well exposed); 7, cap open (gill surface flat).

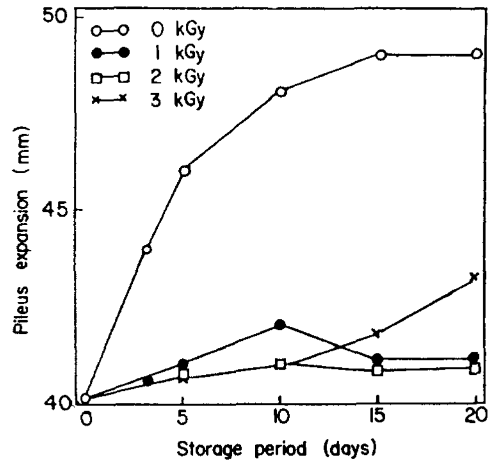

Fig. 2. Effect of gamma irradiation on pileus expansion of mushrooms (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH.

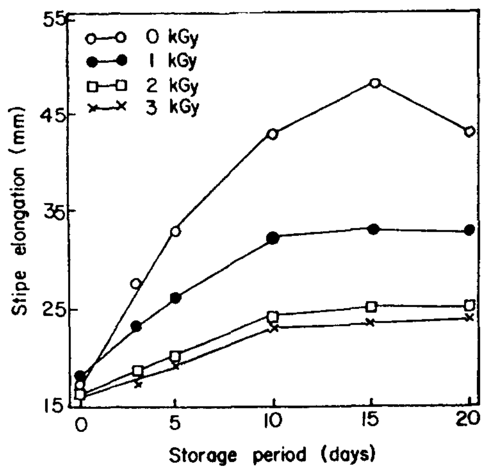

Fig. 3. Effect of gamma irradiation on stipe elongation of mushrooms (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH.

Fig. 2, 3 shows the effect of gamma irradiation on pileus expansion and stipe elongation of mushrooms. The first state (0 time of storage) was a button stage where the caps were about 40 mm in diameter and the stipes were about 17 mm in length. In nonirradiated group, pileus expansion and stipe elongation were promoted upto 46 mm

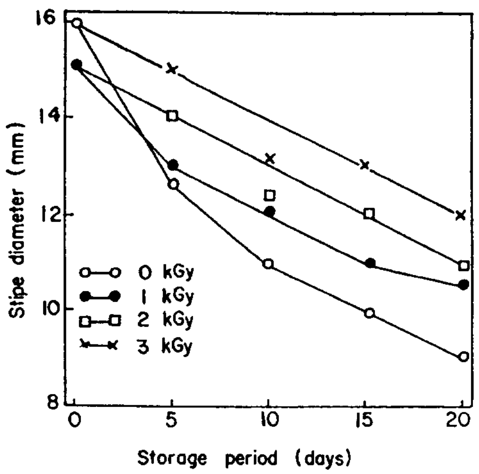

Fig. 4. Effect of gamma irradiation on stipe diameter of mushrooms (*Agaricus bisporus*) during storage at 9±1 °C and 80±7% RH.

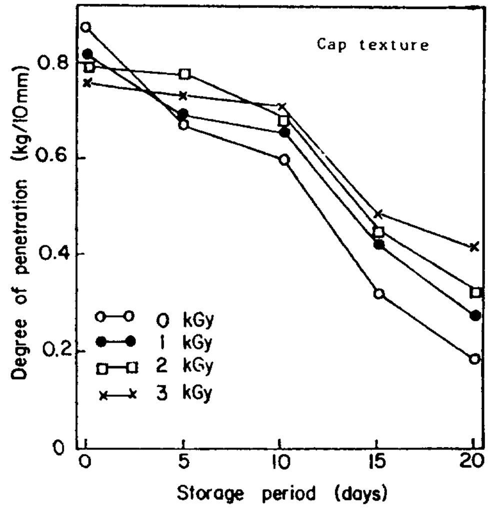

Fig. 5. Effect of gamma irradiation on firmness of mushrooms (*Agaricus bisporus*) during storage at 9±1 °C and 80±7% RH.

and 33 mm for 5 days storage, and 48 mm and 43 mm for 10 days storage, while 2 to 3 kGy groups irradiated were significantly retarded for 20 days storage. 1 kGy irradiated group was found intermediate between nonirradiated and 2 to 3 kGy irradiated groups. The initial diameter of stipes was about 16 mm. The nonirradiated group was continuously thinned during storage and led to less than 11 mm at 10 days after storage, and the changes in 2 to 3 kGy irradiated groups were observed slowly compared to that in the nonirradiated group (Fig. 4).

From these results, gamma irradiation can markedly retard the maturation of mushrooms. The higher dose levels of at least 2 to 3 kGy were especially efficient in retarding or stopping the natural maturation and senescence of mushrooms at 9±1 °C and 80±7% RH.

Since the note of Staden[12] about the beneficial effects of gamma irradiation on fresh mushrooms, similar results were described by many different workers[13-20]. The irradiation doses which were used by them varied considerably. The 0.1 kGy was the lowest limit[13], followed by 0.25 to 1.0 kGy[12,18], between 1.0 to 3.0 kGy[19,20,24,25] and 2.0 to 3.0 kGy[15,16]. It has been agreed by all investigators that all irradiation doses inhibit the maturation of mushrooms and this effect is improved on higher doses. Generally the irradiation doses depends on the strains and ripeness of mushrooms, the temperature and environmental condition of the storage[15,17]. Also the beneficial effects of gamma irradiation depend on keeping the time between picking and irradiation short, and with a strong penetrating irradiation, shorter irradiation times are required and that there is less risk of injury or impairment of flavor and color[12,17].

Texture

Softening, an undesirable characteristic of senescence which occurs during storage, was observed a decreased Rheometer penetration values for all mushrooms over storage period (Fig. 5). Immediately after gamma irradiation, cap firmness of irradiated mushrooms were found to be softer than that of nonirradiated mushrooms. However the effect of irradiation slowed the natural softening due to senescence during storage period, irradiated mushrooms were better (firmer) in cap firmness than nonirradiated mushrooms. The texture of mushrooms becomes tough with ageing of

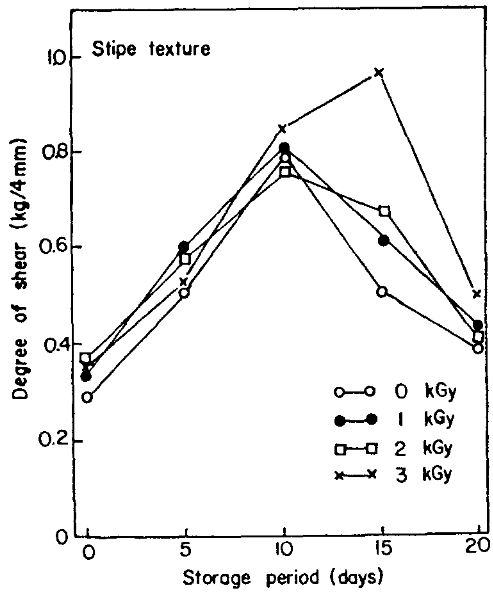

Fig. 6. Effect of gamma irradiation on toughness of mushrooms (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH.

the tissues. Several authors(15,18,20,28) reported that irradiation causes a temporary softening which, however, disappears during further storage. There can be two reasons responsible for softening of mushrooms; The differences in texture during the storage are due to changes in cell wall structure. Cell autolysis the rate of which increases during senescense, causes a decrease in firmness, and it is well known that most of the fungi undergo a certain degree of autolysis(20,29).

Toughness of stips measured by resistance to shear revealed little effect of gamma irradiation (Fig. 6). All groups displayed obvious increases in toughness during the first few days storage with the highest toughness readings for all groups being recorded at 10 days storage, lower values were observed thereafter. 3 kGy irradiated mushrooms had more resistance to shear than those nonirradiated or 1 kGy and 2 kGy irradiated mushrooms after 10 days storage. At later storage periods lower toughness values probably indicated structural losses which were not desirable. Nonirradiated controls displayed this late storage in toughness to a much greater extent than did irradiated groups.

Contrary to the general opinion about softening effect induced by gamma irradiation, the findings of the present investigation indicated that 2 to 3 kGy irradiated mushrooms were better in texture than their nonirradiated mushrooms. The probable reason is that already low irradiation doses had a favourible influence on the physiological state, preventing the impairment of cell wall elements, the slowing down of life functions may also have contributed to the preservation of texture.

Weight losses

Mushrooms have porous sponge-like structure. They are very sensitive to practically any level of relative humidity below 100% and thus also to packing and an eventual airflow during storage. This susceptibility might be at least partially responsible for the discrepancies reported in the literature. Some authors note an increased weight loss after irradiation(13,30), while others obtained

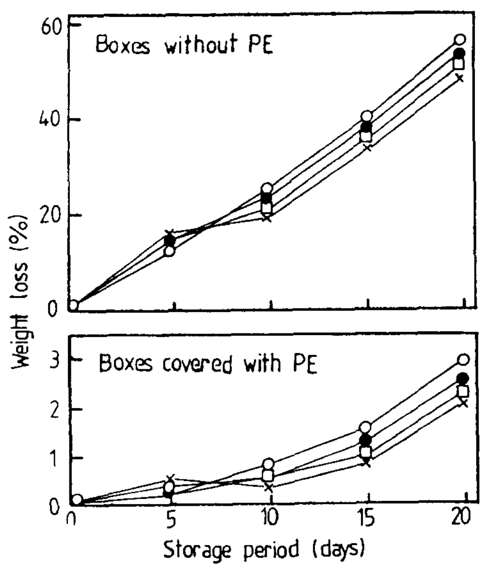

Fig. 7. Flesh weight loss of gamma-irradiated mushrooms (*Agaricus bisporus*) during storage at 9 ± 1 °C and 80 ± 7% RH.
○—○, 0 kGy; ●—●, 1 kGy; □—□, 2 kGy; ×—×, 3 kGy.

the opposite result[14] or found weight uneffected by irradiation[15,17,19,20,25]

As shown in Fig. 7, 10 days after storage, mushrooms weight were found to be decreased up to 0.5% in boxes covered with polyethylene (PE) film and about 20% in boxes without polyethylene film. There was a significantly greater weight loss in the uncovered, also nonirradiated groups stored for more than 5 days than in those treated with 2 and 3 kGy. This seems quite natural since the nonirradiated mushrooms will expand and ripen, thus resulting in greater evaporation from the increased surface area, while impairment of these processes as the result of irradiation would preclude such evaporation. Therefore weight loss was only indirectly affected since it was directly related to the retarding effect of irradiation on growth and ripening.

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(Received May 23, 1989)

양송이 버섯의 생리적 특성에 대한 감마선 조사 영향

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감마선 조사(0, 1, 2, 3 kGy)에 의한 생양송이 버섯의 저장성 연장에 관한 연구결과는 다음과 같다. 9±1℃, 80±7% RH 저장조건에서 비조사구는 저장 3일 경부터 갓핌과 줄기가 크게 신장하고 노후현상을 보여 상품가치를 상실한데 반해 감마선 조사구는 자연적 숙성의 지연으로 1kGy 조사구는 10일 정도, 2-3kGy 조사구는 20일까지도 신선도를 유지하였다. 양송이의 조직은 저장기간 동안 모든 시험구에서 연화를 보였으나 감마선 조사구가 비조사구에 비해 양호하였다. 중량변화는 골판지 상자에 양송이를 담고 polyethylene 필름으로 겉씌우기를 한 것이 골판지 단독 포장구보다 중량감소 억제효과가 매우 현저하였고, 저장 5일 이후부터는 2-3kGy 조사구가 비조사구에 비해 중량 감소율이 낮았다. 이러한 결과는 생양송이에 2-3kGy의 감마선 조사 후 9±1℃, 80±7% RH의 저장조건에서 숙도지연에 따른 고려할 만한 저장성 연장효과를 나타내었다.