慶北大農學誌(Agric. Res. Bull. Kyungpook Natl. Univ.) 8 (1990. 12) 89~94

전리에너지가 버섯의 호흡과 당에 미치는 영향

윤형식 · 권중호*

경북대학교 농과대학 식품공학과 *한국원자력연구소

Monitoring of Respiration and Soluble Carbohydrate Changes in Mushrooms Following γ−Irradiation

Yoon, Hyung Sik · Kwon, Joong Ho*

Dept. of Food Sci. & Tech., Coll. of Agric., Kyungpook Natl. Univ.

* Korean Atomic Energy Research Institute

Summary

Respiration and soluble carbohydrates of stored mushrooms (*Agaricus bisporus*) were determined to be associated with physiological and biochemical changes induced by ionizing radiation treatment which was applied for extending the shelf−life. Immediately after gamma irradiation at 1 to 3 kGy, the respiratory rate of mushrooms increased linearly with increasing doses of irradiation, and then it normarized after 2 days of storage at 9±1℃ and 80±7% RH. In the nonirradiated mushrooms, the respiratory peak was observed at around 5 to 6 days after storage, while irradiation treatment not only reduced respiratory activities of stored mushrooms, but prolonged the peak development. Moisture content and dry matter of mushrooms packaged in a paper box and polyethylene film were relatively constant during the storage for 20 days and the reducing sugar contents decreased significantly after 5 days of storage($p<0.01$). Free sugars of mushroom pilei, which consisted of mannitol, trehalose and glucose, also markedly decreased at the earlier part of the storage period and thereafter, 2 kGy irradiation resulted in the reduction of their changes.

Introduction

Mushrooms belong to the group of organisms known as filamentous fungi. They must get their nutrients from waste products or other living things because all fungi lack the chlorophylls required for obtaining their energy directly from the sun. Only about 25 species of more than 2000 edible fungi are widely accepted as human food. And only a few of these are commercially cultivated or grown in halfculture processes or grown under controlled conditions.[4]

Cultured mushrooms are highly perishable vegetables, and can be kept in prime condition for only 3 to 5 days at commercial storage conditions of 13℃.[2, 13, 14] Several factors contribute to post−harvest quality of fresh mushrooms. As with all raw agricultural commodities, harvesting does not terminate metabolic activities; cell division continues after harvest and the pileus and stipe expand during storage, along with discoloration and textural changes of the mushroom flesh.

Even though consumer acceptance has not been favorable, domestically we have twelve irradiated food items including fresh mushrooms approved for human consumption and also have a commercial irradiation facility for treating them.[9] The practical utilization of food irradiation technology is increasingly recognized in the food industry as a viable technology not only to solve or complement the limitations of conventional methods like chemicals or refrigeration but also to meet stiff standards of quality and quarantine which are confronted in the ever-increasing international trade of food products.[9, 11]

The shelf-life extension of mushrooms is one of the most promising fields in food irradiation and recently irradiation technology has been proposed as a new technique for mushroom preservation thoughout the world.[1, 5, 16]

This work was intended to determine the influence of gamma irradiation on physiological activities of fresh mushrooms associated with quality changes during post-irradiation storage.

Materials and Methods

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

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

The respiratory rate of mushrooms was determined by placing the sample in a desiccator, and then the evolved CO_2 was absorbed in a normalized KOH solution prepared at a bottom. The remaining potassium hydroxide concentration was titrated with hydrochloric acid solution for expression as CO_2 mg/kg sample/hr at a given temperature.

Determination of some physicochemical attributes was performed at a given interval during storage. Moisture content of mushrooms was determined by a 105℃ oven method and dry weights were measured after drying of the sample at 80℃.[7] The amount of reducing sugar was determined according to the modified Somogyi method[8] and calculated as glucose content.

Analyses of free sugar contents in the samples were carried out according to the high performance liquid chromatography (HPLC) method described by Choi et al.[5] The pilei of mushroom bodies were first extracted three times with 80% ethyl alcohol at 80℃. The solvent was removed in a rotary evaporator and the residue was dissolved in water. The aqueous solution was extracted with diethyl ether to remove the residual lipid components. The aqueous layer was concentrated and then deproteinized by centrifugation at 8,000 rpm in 80% ethanolic solution.

HPLC was performed on a Bio-Rad 402 system equipped with a refractive index detector and a Lichrosorb NH_2 column (5 micron stainless steel, 20cm). A mobile phase made up of acetonitrile:water (43:8, V:V) was used as eluant. The flow rate and attenuation were set at 1.8mℓ/min and 16 X, respectively.

The significance of each factor in various observations on the stored mushrooms following irradiation was determined according to the T-test and ANOVA test. All figures reported here represent the mean of triplicate determination.

Results and Discussion

The respiratory rate was measured to evaluate post-harvest metabolic response induced by ionizing radiation. Changes in respiratory activities of stored mushrooms following irradiation are presented in Fig.1.

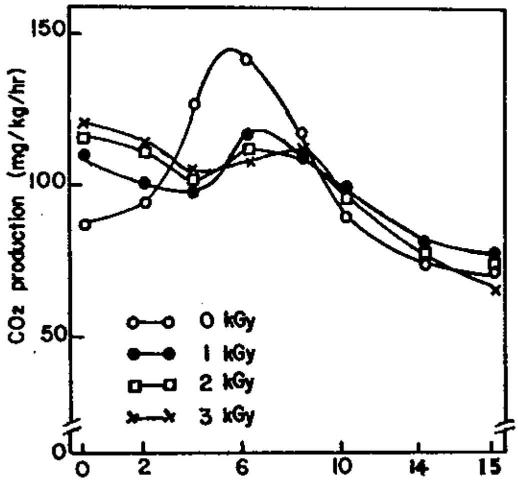


Fig.1. Respiratory patterns of gamma−irradiated mushrooms(*Agaricus bisp orus*) during storage at 9±℃ and 80 ±7% RH.

Immediately after irradiation the respiratory rate of mushrooms was found to increase with increasing doses of irradiation, and then it decreased with the lapse of storage time. In the nonirradiated mushrooms, remarkable increase was observed in the respiratory activities up to around 5 to 6 days after storage. This peak in respiratory activities coincided with the maximium growth of the pileus and stipe and with the rapid development of the gills, as was previously reported.[10)]

The magnitude of the increase in respiratory rate induced by irradiation is correlated with the degree of tolerance of the fruit and vegetables to irradiattion.[1)] The pattern of post-harveat respiration was known to be dependent on the maturity of the sporophore at harvest.[3)]

The harvested sporophore of the cultured mushrooms undergoes a course of developm-ent and senescence. The morphological chan-ges, which involve exposure of the gills, cap expansion and stalk elongation, are supported by substrates which are present in the sporophore at harvest, rather than substrates of mycelial origins as is the case in growing sporophore.[7)] Previous reports indicated that the respiration rate increased along with the rapid development of mushroom gills and that the overall decline in respiratory activity observed after harvest was due to the exhaustion of substrates and senescence of the mushroom tissues.[3, 6, 12)] Our obtained results agree well with this statement.

This work shows that irradiation treatment not only reduced respiratory activities of stored mushrooms but also prolonged their respiratory peak develoment especially in the 3 kGy−irradiated group, thereby extending the storage life of fresh mushrooms.

Fresh mushrooms are high−moisture vegetables and thus the freshness of stored mushrooms is easily influenced by both the packaging materials and storage conditions. Table 1 and 2 show the changes in the conte nts of moisture and dry matter of stored mushrooms after irradiation. During the whole storage period, the contents of moisture and dry matter of irradiated mushrooms range from 92.3 to 93.8% and from 7.50 to 7.70% respectively, and showed no significant no significant changes among the treated groups. This phenomenon is explained as being due to the packaging method and storage condition used in this experiment.

Table1. Changes in moisture content of gamma−irradiated mushrooms (*Agaricus bisporus*) during storage[a]

Storage period (days)	Irradiation dose(kGy)			
	0	1	2	3
0	92.80	92.90	92.90	93.20
5	92.80	93.20	93.30	93.20
10	93.80	92.90	93.10	93.20
15	92.30	93.50	92.90	93.00
20	93.80	92.80	92.90	93.20

[a] Sample was stored at 9±1℃ and 80±7% RH
Each value is the mean of triplicate determinations and expressed as percentage

Table2. Changes in dry matter content of gamma—irradiatd mushrooms (*Agaricus bisporus*) during storage[a]

Storage period (days)	Irradiation dose(kGy)			
	0	1	2	3
0	7.70	7.65	7.67	7.65
5	7.65	7.62	7.65	7.62
10	7.60	7.58	7.64	7.59
15	7.58	7.60	7.66	7.65
20	7.50	7.61	7.65	7.70

[a] Sample was stored at 9±1℃ and 80±7% RH Each value is the mean of triplicate determinations and expressed as percentage

Table3. Change in reducing sugar conternt of gamma—irradiated mushrooms (*Agaricus bisporus*) during storage[a]

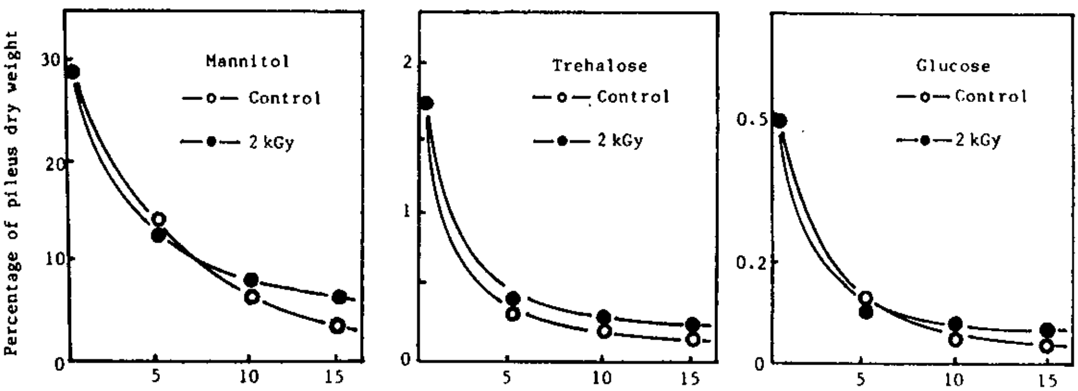
Storage period (days)	Irradiation dose(kGy)			
	0	1	2	3
0	5.57	5.54	5.52	5.57
5	4.71[b]	4.69[b]	4.70[b]	4.68[b]
10	3.48	3.76	3.66	3.60
15	3.12	3.52	3.50	3.48
20	3.10	3.32	3.34	3.34

[a] Sample was stored at 9±1℃ and 80±7% RH Each value is the mean of triplicate determinations and expressed glucose(%) on the basis of dry weight

[b] Significantly different from initial values($p<0.01$)

These results are consistent with the reports of Campbell et al.[3] regarding the radiation influence on the nutritional quality of mushrooms.

Immediately after irradiation, there were no changes in the content of reducing sugar of mushrooms, as given in Table3. But the amounts for all stored mushrooms significantly decreased



Storage period(days)

Fig.2. Changes in soluble carbohydrates of mushroom pileus (*Agaricus bisporus*) during postirradiation storage at 9 ±1℃ and 80±7% RH

from the 5th day of storage period ($p<0.01$), with no significant difference evident among irradiated groups. The disappearance of significant quantities of reducing sugar from the stored major respiratory substrates in stored mushrooms, although it is evident that other substrates are utilized.

It is well known that the change of storage reserves is primarily dependent not only on the storage conditions but on the physiological states of the commodities. The changes in soluble carbohydrate levels of mushroom pilei are illustrated in Fig.2 as functions of 2 kGy irradiation and subsequent storage at 9±1℃ and 80±7% RH. The contents of free sugars, which consisted mainly of mannitol(29%), trehalose (1.7%) and glucose(ca 0.5%), sharply decreased until 5 days of storage and thereafter showed a gradual decreasing tendency. This phenomenon was similarly observed in two samples, the control and 2 kGy-irradiated ones.

Immediately follwing treatment, ionizing radiation at 2 kGy had no influence on the contents of free sugars. As the storage time was prolonged, however, there was indication of some difference in the changes of sugar contents between the control and irradiated samples, showing that the irradiated samples contained higher amounts of free sugars than the nonirradiated control.

This result can be correlated with the changes in respiratory activities of stored mushrooms. And it is reasonable to assume that the reduced changes in free sugar contents of the irradiated samples are principally due to the irradiation effects on retarding the physiological activities of stored mushrooms, as compared to the nonirradiated control. The changes in respiration and soluble carbohydrates during post-harvest storage of mushrooms were well discussed by Hammond and Nichols.[6]

This study confirms that mushroom pileus has a high soluble carbohydrate content and this appears to be utilized as the obvious source of respiratory substrate. In addition, it seems evident that ionizing irradiation reduces the changes in soluble carbohydrate content and decreases the respiratory activities of stored mushrooms. However, considering the short shelf-life of fresh mushrooms and immediate changes in their physiological and biochemical aspects after picking, detailed studies are needed during the earlier stage of post-harvest to obtain more definite information.

적 요

양송이 버섯의 신선도 연장을 위한 전리에너지 처리가 저장중 버섯의 생리적, 생화학적 변화에 미치는 영향을 검토하기 위하여 호흡활성과 가용성 당류의 변화를 조사하였다. 1~3kGy의 감마선은 선량에 비례하여 조사직후 버섯의 호흡활성을 자극하였으나, 저장(9±1℃, 80±7% RH) 2일경에는 다시 안정된 호흡량을 보였다. 버섯의 정장중 물리적 생장이 왕성한 5일경에는 호흡량이 최대치를 보였으나 감마선 조사시료에서는 호흡량의 감소와 peak의 발현이 지연되었다. 종이상자와 폴리에틸렌으로 포장된 버섯의 수분함량과 건물량은 저장중 비교적 안정하였고 환원당함량은 저장 5일부터 모든 시료에서 유의적으로 감소되었다($p<0.01$). 버섯갓(pileus)부위의 유리당은 mannitol이 대부분이었고 trehalose와 glucose는 소량 함유되어 있었으며, 저장후 5일까지는 급격히 감소하다가 그 이후에는 완만한 변화를 보였다. 2 kGy 조사시료는 대조시료보다 다소 높은 유리당 함량을 유지하였고, 저장중 버섯의 당함량과 호흡활성의 변화에는 뚜렷한 연관성이 나타났다.

References

1. Akamine, E.K.and T. Goo, 1971, J. Food Sci., 36, 1074.
2. Bush, P. and D. J. Cook, 1976, Mushroom J., 39, 76.
3. Campbell, J. D., Stothers, S., Vaisey, M. and B. Berck, 1968. J. Food Sci., 33, 540.

4. Chang, S. T. 1980. Bioscience, 30, 399.
5. Choi, J. H., Jang, J. G., Park, K.D., Park, M. H., and S.K. Oh, 1981. Korean J. Food Sci. Technol., 13, 107.
6. Gill, W. J., Nicholas, R. C., and P. Markakis, 1969. Food Technol., 23, Ⅲ.
7. Hammond, J. B. W. and R. Nichols, 1975. J. Sci. Food Agric., 26, 835.
8. Kobayashi. T. and T. Tabuchi, 1954. J. Agric. chem. Soc. Japan., 28, 171.
9. Kwon, J. H. 1989. Food Sci. Ind. (Korean Soc. Food Sci. Technol.), 22, 74.
10. Kwon, J. H., Cho, H. O., Byun, M.W., Yang, J. S. and S. W. Kim, 1988. Approach to Radiation Preseration of Mushrooms, KAERI/RR-768/88, p. 164.
11. Loaharanu, P. 1989. Food Technol., 43. 80.
12. Murr, D. P. and L. L. Morris, 1975. J. Amer. Soc. Hort. Sci., 100, 16.
13. Nichols, R. and J. B. W. Hammond, 1974. Mushroom J., 24, 473.
14. Refrigeration Research Foundation. 1980. Mushrooms:Storage, Freezing, Canning and Dehydration, The Community Storage Manual (USA).
15. Roy, M. K. and N. Bahl, 1984. Mushroom J., 136. 124.
16. Urbain, W. M. 1989. Food Technol., 43. 76.