Shelf-life Extension and Keeping Quality Improvement of Fresh and Cannde Mushrooms by Gamma Irradiation

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放射線照射에 依한 신선한 양송이의 貯藏壽命延長 및 통조림한 양송이의 品質改善

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SUMMARY

After irradiation the keeping quality of fresh and canned mushrooms were evaluated in terms of organoleptic test, shrinkage loss, color, storage test, pH, weight loss, together with general marketability.

The results of fresh mushroom were as follows.

1. On fresh mushrooms, irradiation at 2.5 kGy gave marked inhibitory effect on discoloration but not recommendable at low temperature storage.
2. Wrapping with polyethylene is beneficial for color preservation.
3. Precooling before irradiation is not recommendable due to the stimulation of brwoning although it delays cap opening.
4. Storage at 2℃ and 5℃ showed better result than 12℃ on color preservation, but humidity should be considered.
5. Wrapping gave effect of preventing cap opening and browing but stimulate the growth of stems.

With canned mushrooms, following results were obtained.

1. Shrinkage loss was reduced by precooling but no significant differences were detected between irradiation dose levels.
2. Precooling was detrimental on taste.
3. With precooling, harmful effect was given only on short time stored mushrooms.
4. Precooling gave higher weihgt loss than the unprecooled.
5. 16 minutes heat treatment gave better results than 35 minutes on color and weight loss.

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INTRODUCTION

Quality of fresh mushrooms deteriorates rather quickly due to cap opening, browning, stem growing, drying and tough texture when these are stored at room temperature. It could be stored only one day at 10℃ in prime quality as fresh mushroom (Wahid and Kovacs, 1980). Numerous attempts were made on the way of preservation. Among these attempts, irradiation seems to be one of the most promising method. Staden (1964) was the first to report on this new method of storage extension of mushrooms. Mumerous experiments have shown irradiation to inhibit the opening of pileus and changes in the sensory properties (Gill, 1968; Kovacs et al., 1968; Kovacs and Vas, 1970; Aoki et al., 1974; Skou et al., 1974).

Campbell et al. (1968) reported that growth of freshly harvested mushrooms subjected to 100 Krad of irradiation was markedly inhibited and significantly incresed the storage life of mushroom even under suboptimal conditions. Gill et al. (1969) demonstrated that irradiation at as low as 10 Krad retards the rate of cap opening during storage and 20-50 Krad is required for effective reduction in the shrinking of the stem diameter while 100 Krad or more is needed to prevent lengening of the stem.

Langerak (1971) also evaluated quality of freshly harvested mushrooms and found that deterioration comes through several factors such as stem growth, desiccation and browing and demonstrated that cooling coupled with closed wrapping may prevent the deterioration but these two techniques have been proved to be incompatible and suggested the combination of irradiation and closed wrapping.

In this study, for fresh cultivated mushroom experiment, combined treatments of medium dose irradiation (2.5 kGy and 5.0 kGy), low temperature storage (2℃, 5℃, and 12℃), wrapping and precooling before irradiation were tried. During one week storage, mushrooms were evaluated on color, cap opening, general marketability, and weight loss. For canned mushroom experiment, mushrooms were canned under normal processing conditions to see if there is any differences of product quality between irradiated and unirradiated samples. The products were evaluated on shrinkage loss, sensoric assessments such as visual color, odour, taste, and also light transmittance for color value, pH and weight loss.

MATERIALS AND METHODS

Raw material :

Agaricus bisporus Royal 21 A was obtained from a mushroom farm, Gebr. Vernooy Ltd, Bemmel, the Netherlands.

Radiation treatment :

Irradiation was carried out with a 50 kCi Cobalt-60 γ-irradiation source in the IFFIT pilot plant, Wageningen, the Netherlands. Applied dose level were 0 kGy, 2.5 kGy and 5.0 kGy at ambient temperature.

Precooling treatment :

For fresh mushroom experiment, mushrooms for precooled sample were stored at 2℃ for 24 hours before irradiation. For canned mushroom experiment, precooled samples were stored at 1 -4℃ for 3 days before canning process after irradiation.

Wrapping for fresh mushroom experiment :

Mushrooms for wrapped sample were covered

with single layer of polyethylene on top of carton boxes.

Storage :

For fresh mushroom experiment, 250g of sample were put into carton boxes and stored separately at 2℃, 5℃, and 12℃. For canned mushroom experiment, sample cans were divided into groups according to treatments (precooling before canning, irradiation dose level, and pasteurizing time) and stored separately at room temperature for 1 week, 50℃ for 3 weeks, and 30℃ for 8 weeks.

Processing procedure for canned mushroom experiment :

1. Blanching water was prepared by putting sodium metabisulphite into boiling water (1g/1).
2. Mushrooms were dipped into blanching water for approximately 6 minutes.
3. Cooled down and hardened by dipping into cold water.
4. Put onto plastic basket and kept for few minutes for dripping.
5. Filled up into cans with 250g each.
6. Filled up with brine (2% salt, 0.7g/1 citric acid) and the cans were sealed.
7. Pasteurize at 116℃ for either 35 minutes (control) or 16 minutes (treatment).

Evaluation of keeping quality of fresh mushrooms :

Color; Mushrooms were evaluated visually every day during stroage of one week for degree of browning.

Cap opening; Degree of cap opening, number of opened mushrooms, and ratio of opened ones to whole number in a box were checked.

Marketability; Overall marketability was judged on the basis of color, cap opening, driness, texture and degree of stem elongation.

Weight loss; Weight differences between initial weight of 250g and weight after one week were checked.

Evaluation of keeping quality of canned mushrooms :

Shrinkage loss (Steinbuch, 1978); Shrinkage loss was calculated as percentage of weight loss between initial weight of fresh mushroom and the weight after can-filling per batch of fresh mushroom.

Sensoric assessment; Products were evaluated by mushroom evaluating experts from canning industries and related institutes on color, odour, taste and texture.

Color value; Light transmittance of liquid portion was determined by spectrophotometer at 400 n.m.

pH; A digital pH meter was used.

Weight loss; Metal sieve (2.0㎜) was weighed, mushrooms were spread out on it. The sieve was tilted approximately 20° and waited for 2 minutes for dripping. The sieve with mushroom was weighed again to obtain the net weight of mushroom. Weight loss was obtained by subtracting the mushrooms weight from initial weight of 250g.

Storage test; Can opening practice and examinations of possible spoilage of long stored canned mushrooms were carried out following the method recommended by National Canners Association (National Canners Association, 1968). Can swelling by gas formation, browning of products, turbidness, and especially any occurrence of blackening were closely examined.

RESULTS AND DISCUSSIONS

Fresh Mushrooms

Color

Slight browning was observed from 3rd days storage on 2 boxes out of 12 mushroom samples, each irradiated at 2.5 kGy and 5.0 kGy, stored with precooled and unwrapped condition at the storage temperature of 12℃. All the other samples in lower temperature (2℃, 5℃), regardless of wrapping and precooling showed no sign of browning.

Table 1. Color gradings of irradiated mushrooms (after 4 days)

12℃		0 kGy	2.5 kGy	5.0 kGy
precooled	wrapped	white stem grown	2 (white)	3
	unwrapped	not browned cap opened	4 (browned)	5 (browned)
unprecooled	wrapped	white stem grown	1 (white)	3
	unwrapped	not browned cap opened	3	4 (slightly browned)
2℃				
precooled	wrapped	2	4	6 (stem grown)
	unwrapped	3	4	6
unprecooled	wrapped	1 (stem slightly grown)	2	4
	unwrapped	3	3	5

On the 4th day of storage, the color change was more noticeable especially among the samples of 12℃, unwrapped, 5.0 kGy irradiated and precooled boxes. In this temperature wrapped and precooled mushrooms were generally browner than unprecooled samples. In unprecooled and unwrapped boxes, the mushrooms irradiated at 5 kGy was browner than unirradiated and 2.5 kGy irradiated ones but no difference could be detected between the unirradiated and 2.5 kGy irradiated. Both on color and cap opening aspects, the mushrooms in irradiated at 2.5 kGy, unprecooled and wrapped boxes showed best result.

With the storage temperature of 2℃, wrapped mushrooms were also whiter than unwrapped one and among wrapped boxes the precooled

Table 2. Color gradings of irradiated mushrooms (after 1 week)

12℃		0 kGy	2.5 kGy	5.0 kGy
precooled	wrapped	3 (stem grown)	1	1
	unwrapped	cap opened	browned	browned
unprecooled	wrapped	3 (stem grown)	1	2
	unwrapped	cap opened)	browned	browned
precooled	wrapped	2	4	6 (stem grown)
	unwrapped	3	4	4
unprecooled	wrapped	1 (stem slightly grown)	2	4
	unwrapped	3	3	5
precooled	wrapped	stem grown	2	3
unprecooled	wrapped	stem grown	1	2

* unwrapped mushrooms were desiccated

showed as best quality in color and followed by the irradiated at 2.5 kGy and with the lowest quality with 5 kGy in both wrapped and unwrappped boxes although the differences were less noticeable than with 12℃ storage.

On the other hand, the samples stored at 5℃ were in general much whiter than 12℃ but could not see much differences between boxes except that the unwrapped mushrooms were little more browner than wrapped ones both in precooled and unprecooled boxes. However, this should be due to humidity conditions of storage rooms since the 5℃ storage was much drier than the other two although the degree of humidities were not checked.

On the 5th day, all the 12℃ stored, unwrapped mushrooms showed some degree of browning depending on irradiation dose rate, and precooling while all the wraped mushrooms still kept white color. Among the unwrapped, again precooled one were more brownish than unprecooled. In this temperature, unirradiated mushrooms were generally whiter than the irradiated but the best one could be found with the mushrooms in the irradiated at 2.5 kGy, unprecooled and wrapped box followed by irradiated (2.5 kGy) with precooled and wrapped one. The third quality mushroom in this experiment could be either the irradiated at 2.5 kGy with unprecooled, unwrapped one, or

5.0 kGy irradiated with precooled, wrapped one. Unwrapped, 5.0 kGy irradiated boxes were all browned in both precooled and unprecooled conditions. Among precooled ones, again wrapped mushrooms were generally whiter than unwrapped ones. This might be due to higher humidity, lack of carbon dioxide and producing of oxygen which activate the oxidation during storage. Therefore, wrapping was found to be advantageous for the protection of mushroom color while precooling gave adverse effect on color preservation of irradiated mushrooms. Unirradiated ones were unmarketable at this stage of storage regardless of its color quality.

In this 5th day of observation, the mushrooms stored at 2℃ and 5℃ cold storage were both still white although not so fresh. With 2℃ storage, the best in color could be obtained with the samples stored at unprecooled, unirradiated, and wrapped condition. The second quality was either 2.5 kGy irradiated, wrapped, unprecooled sample or unirradiatd, wrapped, precooled one. Unwrapped, unirradiated, both precooled and unprocooled mushrooms could be graded as 3rd and followed by 2.5 kGy irradiated, precooled, both wrapped and unwrapped samples. However in 2℃ storage, again high dose irradiated mushrooms showed poor color regardless of precooling and wrapping.

In 5℃ storage at this stage, mushrooms definitely showed the sign of drying although samples still maintain the initial white color. It was hard to compare between treatments.

On the final day, 8th since starting storage, the overall comparative look of mushrooms stord at the temperature of 12℃ and 2℃ was almost same as previous days observation, except few minor variations although the quality became much deteriorated.

With 12℃ storage, the irradiated (2.5 kGy), wrapped, both precooled and unprecooled were still rather white while the others were all either slightly browned or fully browned.

The color comparison of 2℃ stored mushrooms between boxes were exactly same as previous observations and final check on the color of 5℃ sample was also same as before. The unwrapped samples were all desiccated while both irradiated and wrapped ones were still good regardless of precooling. In general, the results of color evaluation on stored fresh mushroom showed that irradiation at low dose level and wrapping is definitely helpful for the preservation of color.

Cap opening

Caps of mushrooms started opening from 3rd day at storage of 12℃. Only the unirradiated samples in this temperature showed cap opening while the irradiatd ones remained closed. Out of 36 different treatment boxes (3 lots of temperature×3 lots of irradiation×2 lots of wrapping×2 lots of precooling), 3 boxes-precooled, unwrapped and unprecooled, unwrappped and unprecooled, unwraped with the ratio of the opened mushrooms to whole number in one box of 1/14 (7%), 11/17 (64%) and 3/15 (20%) respectively. On 4th day also cap openings were limited only on the above three boxes, but the ratios were increased to 14/14 (100%), 16/17 (94%), and 7/15 (47%) respectively. This again indicates the efficiency of wrapping and irradiation. However, one thing to be noticed was that unirradiated, 12℃ stored, unprecooled, wrapped mushrooms showed the stem elongation of all mushrooms in the box with some cap opened and some without cap opened. This elongation obviously indicates the growing of mushroom during storage. No opening was observed among the

irradiated mushrooms and those stord at low temperature of 2℃ and 5℃. Irradiated at 2.5 kGy, unprecooled, both wrapped and unwrapped mushrooms gave best quality as far as cap opening is concerned. As in the case of color, wrapping is obviously efficient in preventing cap opening when applied with irradiation. However, it stimulate the growth of stems of unirradiated mushrooms. It was observed that precooling also delays the opening of cap while give the ill-effect of faster browining of the irradiated mushrooms.

Marketability

Since customers reacted exclusively to the products external appearance (Heins, 1971), marketability depends mainly on color, degrees of cap opening, stem growth and desiccation.

On the 4th day, the 12℃ stored, unirradiated, unprecooled, and wrapped mushrooms stems were so much grown that its marketability was already lost while unwrapped, unirradiated, slightly cap opened two mushroom boxes were still marketable. All the rest of mushrooms were marketable up to 4th day of storage.

On the 5th day, 12℃ stored, unwrapped, unirradiated, both precooled and unprecooled samples became unmarketable since its cap opening and stem growth were already too big. On the other hand all wrapped samples except 12℃ stored, unirradiated, unprecooled one were still marketable although it allowed slight stem growing. Wrapping obviously prevent cap opening and browning but not elongation of stems. Among the 2℃ stored mushroosm, All the 5.0 kGy irradiated ones were unmarketable regardless of precooling and wrapping.

Although the mushrooms stored at the temperature of 5℃ were difficult to evaluate due to the dried condition of storage room, all wrapped ones were still marketable.

After 7 days of storage (8th day) at 12℃, 2.5 kGy irradiated, wrapped mushrooms were still marketable regardless of precooling. All the other mushrooms stored at the temperature of 12℃ were unacceptable. Among the samples stored at 2℃, both unirradiated and 2.5 kGy irradiated ones were still marketable while 5.0 kGy irradiated mushrooms were not, regardless of wrapping and cooling. Wrapped mushrooms in the 5℃ storage were still marketable despite of slight stem growth among unirradiated ones while all the unwrapped samples were highly desiccated and unmarketable.

Some of browned mushroom samples were cut in longitudinal section with knife to see if the discoloration was limited on the surface only. It was found that all the browning were fairly well distributed into the inside of mushroom cap and stem.

Weight loss

As shown on Table 3, weight loss of 12℃ and 5℃ were almost same while 2℃ stored sample was much lower. This is definitely due to the high driness of 5℃ storage as indicated earlier. In all storage temperatures, weight losses were naturally much higher in unwrapped mushrooms than wrapped ones but the differences between these two were comparatively smaller in low temperature storage. The weight loss differences between precooled and unprecooled were rather minimal except 5℃ storage.

Weight loss differences were not so great between two irradiated groups (2.5 kGy and 5.0 kGy) but some differences could be detected between the unirradiated and irradiated samples. 12℃ stored, precooled, unwrapped, unirradiated sample gave the weight loss of 56g while 2.5 kGy irradiated one showed only 50g, but unwrapped, unprecooled samples gave the

Table 3. Weight loss of fresh mushrooms

storage temp.	precooling	wrapping	0 kGy	2.5 kGy	5.0 kGy	mean
12℃	precooled	wrapped	26	26	26	26.0
		unwrapped	56	50	52	52.7
		mean	41.0	38.0	39.0	39.3
	unprecooled	wrapped	23	24	30	25.7
		unwrapped	58	56	47	53.7
		mean	40.5	40.0	38.5	39.7
	mean		40.8	39.0	38.8	39.5
5℃	precoled	wrapped	22	18	21	20.3
		unwrapped	49	56	55	53.3
		mean	35.5	37.0	38.0	36.8
	unprecooled	wrapped	23	21	21	21.7
		unwrapped	68	71	67	68.7
		mean	45.5	46.0	44.0	45.2
	mean		40.5	41.5	41.0	41.0
2℃	precooled	wrapped	25	21	16	20.7
		unwrapped	49	42	40	43.7
		mean	37.0	31.5	28.0	32.2
	unprecooled	wrapped	26	20	27	24.3
		unwrapped	47	43	43	44.3
		mean	36.5	31.5	35.0	34.3
	mean		36.8	31.5	31.5	33.3
mean			39.3	37.3	37.1	37.9

unit : gram

weight loss of 58*g* and 56*g* for unirradiated and 2.5 kGy irradiated respectively. However, at 5℃ storage in unwrapped group were generally larger in irradiated samples both precooled and unprecooled condition. In 2℃ storage, again the differences in weight loss between the two irradiatd samples in unwrapped group were minimal but the differences between the irradiated and unirradiated ones were much larger with the higher weight losses in unirradiated samples. In regard to weight loss, again 2.5 kGy irradiation showed some effect of preventing weight losses in unwrapped mushrooms both in high and low temperature storage. But at 5℃ storage which was in highly dry condition, the irradiation gave adverse

effect in the case of unwrapped mushrooms.

Canned Mushrooms

Evaluation of unstored canned mushrooms

Shrinkage loss

Shrinkage losses could be reduced by precooling mushrooms for 4 days before canning, but no significant differences were detected between irradiation dose levels.

Sensoric assessments

Before canning process, the color of fresh mushroom was visually examined twice, on the day after irradiation and 4 days after irradiation. On the day after irradiation, no color change was observed. However, three days later both 2.5 kGy and 5.0 kGy irradiated mushrooms were browned with the 5.0 kGy irradiated one more browned than the 2.5 kGy irradiated, while unirradiated sample remained unchanged.

Thble 4. Shrinkage losses of canned mushrooms (%)

Dose level	Canned 1 day after irrad.	Canned 4 days after irrad.
0 kGy	36	30
2.5 kGy	36	32
5.0 kGy	34	31

One week after canning, canned mushrooms were evaluated by mushroom evaluating experts on color, odour, taste and texture. The results are shown on Table 5 and 6.

In table 5, it was shown that the sensoric quality of mushrooms canned 1 day after irradiation was better than the 3 days old ones. This indicates as in the case of most other food products that for the canning of mushroom, always fresh mushrooms give better quality of finished products. With both samples canned 1 day after and 4 days after, 16 minutes heat treatment was as good (canned 4 days after) or even better (caned 1 day after) than 35 minutes.

With the mushrooms caned 1 day after, irradiated and heat treated for 35 minutes samples showed as lower quality products in the assessment of color, taste and texture. With the sample heat treated for 16 minutes, the quality assessment of 5.0 kGy irradiated sample showed similarly good results as in unirradiated one especially in color and texture and 35 minutes heat treated sample didn't give promising results in this regard.

In the mushrooms canned 4 days after irradiation, 2.5 kGy irradiated one was better than unirradiated ones, with 16 minutes heat treatment but not with 35 minutes. However, one thing to be noticed here is that in the mushrooms canned 4 days after irradiation, the irradiated samples in both doses showed some brown spots on the mushrooms which could not be found before canning process. This also indicated that 3 days storage gave detrimental effects on the quality of canned mushrooms.

The results of sensoric evaluation of mushrooms canned 1 day after irradiation showed generally higher assessment value than the 3 days old ones as in Table 5. In mushroom industry, evaluation of color was

Table 5. Sensoric asessment of irradiated canned mushrooms (by evaluation experts)

Treatment	Color	Odour	Taste	Texture	Remarks
Mushroom canned 1 day after irradiation					
0 kGy+16min.at 116℃	4	4	4	5	
2.5 kGy+16min.at 116℃	3	4	3	5	
5.0 kGy+16min.at 116℃	4	4	4	5	
0 kGy+35min.at 116℃	4	4	4	4	
2.5kGy+35min.at 116℃	2	4	2	3	(tough)
5.0kGy+35min.at 116℃	2	4	3	3	(tough)
Mishroom canned 4 days after irradiation					
0 kGy+16min.at 116℃	3	3	1	3	briny
2.5 kGy+16min.at 116℃	3	4	3	3	briny, brown spots
5.0 kGy+16min.at 116℃	3	3	3	3	briny, brown spots
0 kGy+35min.at 116℃	4	4	4	5	briny
2.5 kGy+35min.at 116℃	3	4	3	5	briny
5.0 kGy+min.at 116℃	4	4	4	5	byiny

1 : poor
2 : insufficient
3 : sufficient (limit of acceptability)
4 : good
5 : excellent

generally more critical than in the institute. According to industry evaluation in color as shown on Table 6, only two treatments of unirradiated mushrooms-canned 1 day after irradiation, heat treated for 35 minutes, and canned 4 days after irradiation, heat treated for 16minutes-were considered to be acceptable for marketing while all the others were not acceptable.

The reason for the poor color might be due to the failure of vacuum treatment application of the fresh mushroom before blanching and also due to the change of amount of citric acid from 1*g* per liter which is the amount of normal practice to 0.7*g* per liter.

Color value

Color of canned mushroom was evaluated further to confirm the results of previous visual assessment by determining light transmittance using spectrophotometer on liquid portion of mushroom cans. The scores which were marked by visual assessment were generally well in agreement with the light transmittance value. It showed again that the color of mushrooms canned 4 days after irradiation was

Table 6. Color evaluation of irradiated canned mushrooms (by a mushroom processing industry)

Treatment	Color	Remarks
Mushroom canned 1 day after irradiation		
0 kGy+16min.at 116℃	grey	not acceptable for
2.5 kGy+16min.at 116℃	more grey	first quality
5.0 kGy+16min.at 116℃	more grey	category
0 kGy+35min.at 116℃ tin	greyish yellow	acceptable for canning in tin not in glass jars
2.5 kGY+35min.at 116℃	greyish brown	not acceptable for
5.0 kGy+35min.at 116℃	greyish brown	first quality category
Mushroom canned 4 days after irradiation		
0 kGy+16min.at 116℃	grey	acceptable for second quality category only
2.5 kGy+16min.at 116℃	more grey	not acceptable
5.0 kGy+16min.at 116℃	more grey	not acceptable
0 kGy+35min.at 116℃	dark	not acceptable
2.5 kGy+35min.at 116℃	dark	not acceptable
5.0 kGy+35min.at 116℃	dark	not acceptable

darker than the one canned 1 day after irradiation. However, with the cans opened appoximately 2 weeks after processing the color differences between these two groups (canned 1 day after irradiation and canned 4 days after irradiation) seemed to be disappeard. The brown spots on the mushroom canned 4 days after irradiation, however, still remained. The ratio of brown spotted mushrooms to whole number in a can was shown on Table 8.

From Table 8 it was noticeable that the 5.0 kGy irradiated mushrooms with both heat treament of 16 minutes and 35 minutes gave much higher ratio than the unirradiated or the 2.5 kGy irradiated. The 2.5 kGy irradiated mushroom was the best in this regard.

pH

Since the taste of canned mushrooms depends greatly on the sourness of the finished proucts, pH of the liquid in cans were determined 1 week after processing and shown

Table 7. Light transmittance of the liquid of canned mushroom (at 40nm)

Treatment	cans opened 1 week after process		cans opened 2 weeks after process	
	canned 1 day after irrad.	canned 4 days after irrad.	1 day after irrad.	4 days after irrad.
0 kGy+16mon.at 116℃	16.4	6.2	14.9	15.6
2.5 kGy+16min.at 116℃	17.6	-	17.7	16.2
5.0 kGy+min.at 116℃	16.6	11.4	16.3	17.6
0 kGy+35min.at 116℃	7.3	12.6	7.6	10.7
2.5 kGy+35min.at 116℃	10.0	5.6	10.8	7.8
5.0 kGy+35min.at 116℃	8.7	-	9.3	8.9

Table 8. Ratio of brown spotted mushrooms

Treatment	ratio (%)
0 kGy+16min.at 116℃	8/53 (15.1)
2.5 kGy+16min.at 116℃	6/24 (13.6)
5.0 kGy+16min.at 116℃	9/44 (22.0)
0 kGy+35min.at 116℃	8/50 (16.0)
2.5 kGy+35min.at 116℃	7/55 (12.7)
5.0 kGy+35min.at 116℃	14/46 (30.0)

on Table 9.

Unlike to the results of color evaluation and brown spot ratio, no differences could be detected between treatments except that approximately 0.1 higher value with the mushrooms canned 1 day after irradiation than the one canned 4 days after irradiation. This indicates that pH remains fairly constant while other parameters show differences with various treatments.

Weight loss

The initial weight of filling and the one after processing with certain period of storage should normally be different due to the osmosis reaction of water absorbtion by brine. Canned mushrooms were stored 10 days at room temperature and weight losses were determined.

With every treatment, the mushrooms canned

Tablw 9. pH of canned mushrooms (stored 1 week)

Treatment	canned 1 day after irrad.	canned 4 days after irrad.
0 kGy+16min. at 116℃	5.58	5.42
2.5 kGy+16min. at 116℃	5.58	-
5.0 kGy+16min. at 116℃	5.58	5.44
0 kGy+35min. at 116℃	5.53	5.42
2.5 kGy+35min. at 116℃	5.52	5.41
5.0 kGy+35min. at 116℃	5.55	-

Table 10. Weight loss of canned mushroom (stored 10 days)

Treatment	Weight differences form 250g: canned 1 day after irrad.	canned 4 days after irrad.
0 kGy+16min. at 116℃	0	16.3(6.5)
2.5 kGy+16min. at 116℃	7.3(2.9)	9.8(3.9)
5.0 kGy+16min. at 116℃	8.4(3.9)	19.0(7.6)
0 kGy+35min. at 116℃	9.8(3.9)	21.5(8.6)
2.5 kGy+35min. at 116℃	13.6(5.4)	17.4(7.0)
5.0 kGy+35min. at 116℃	15.6(6.2)	19.4(7.8)

( ) : %

4 days after irradiation lost the weight more heavily than 1 day after irradiation. One thing to be noticed here is that the shrinkage loss of the mushrooms canned 4 days after irradiation was lower than canned 1 day after irradiation while the weight loss after 10 days showed entirely opposite way. With both mushrooms canned 1 day after irradiation and 4 days after irradiation, heat treatment of 35 minutes showed greater losses than 16 minutes treatment and among 16 minutes treatments, the unirradiated mushrooms showed no weight loss while 2.5 kGy and 5.0 kGy irradiation gave slight weight losses of 7.4g and 8.4g respectively.

Evaluation of high temperature short period stored canned mushrooms

Storage test

None of the 84 cans (6 treatment×7 cans in each treatment×2—one for "canned 1 day after irradiation" and another for "canned 4 days

after irradiation") showed either swell or leakage. No sign of spoilage was observed when the cans were opened. Taste was still good and flavor was rather fresh. However, some of the unirradiated, canned 4 days after irradiation showed the brown spots on cap while the irradiated mushrooms did not.

Assessment of visual color

No significant color differences could be observed between the two groups, mushrooms canned 1 days after irradiation and the one canned 4 days after irradiation. However, obvious color differences were noticed between two heat treatments, 16 minutes and 35 minutes regardless of irradiation doses. Color of 35 minutes heat treatment was darker than 16 minutes and the difference between these two was more obvious in the samples canned 4 days after irradiation than the sample of 1 day after. The samples canned 1 day after irradiation showed no significant color differences between the irradiated and unirradiated. With the mushrooms canned 4 days after irradiation, the 5.0 kGy irradiated one was somewhat darker than both the unirradiated and 2.5 kGy irradiated with 35 minutes heat treated samples, but not much differences could be observed between doses with 16 minutes heated samples.

pH

In order to evaluate the sourness of stored canned mushrooms more objectively, pH was determined on every sample can and the mean values were shown on Table 11. pH of the mushrom cans didn't show big variations between treatments and every can was within the acceptable range of 5.5—5.8

Table 11. pH of irradiated high temperature stored canned mushrooms (3 weeks at 50℃)

Treatment	canned 1 day after irrad.	canned 4 days after irrad.
0 kGy+16min.at 116℃	5.51	5.74
2.5 kGy+16min.at 116℃	5.74	5.64
5.0 kGy+16min.at 116℃	5.78	5.68
0 kGy+35min.at 116℃	5.77	5.70
2.5 kGy+35min.at 116℃	5.75	5.62
5.0 kGy+35min.at 116℃	5.78	5.63

Evaluation of low temperature long period stored canned mushrooms

Storage test and pH

All 102 cans (6 treatments×10 cans for "canned 1 day after irradiation", and 6 treatments×7 cans for "canned 4 days after irradiation") were examined and no spoiled can could be detected. As in the case of high temperature short period stored cans, some of the unirradiated, "canned 4 days after

Table 12. pH of irradiated canned mushroom (stored 8 weeks at 30℃)

Treatment		canned 1 day after irrad.	canned 4 days after irrad.
0 kGy+16min.	at 116℃	5.78	5.77
2.5 kGy+16min.	〃	5.78	5.66
5.0 kGy+16min.	〃	5.80	5.69
0 kGy+35min.	〃	5.77	5.74
2.5 kGy+35min.	〃	5.77	5.64
5.0 kGy+35min.	〃	5.79	5.67

irradiation" showed few brown spots on mushroom cap.

The mushroom cans gave rather constant pH value among all of the samples and was within the range between 5.6—5.8. However, it was noticeable that in every treatment, the samples of "4 days after irradiation" were all lower in pH value than "1 day after irradiation". Average pH values were shown on Table 12.

Assessment of visual color

Unlike to the case of high temperature stored cans, in low temperature long storage, mushrooms canned 1 day after irradiation obviously showed brighter color than the one canned 4 days after irradiation. However, as in the case of high temperature short storage, heat treatment of 16 minutes gave better color than 35 minutes. Among the samples of canned 1 day after irradiation with 16 minutes heat treatment, the unirradiated were the best and then 2.5 kGy irradiation followed by 5.0 kGy. Among the canned 4 days after irradiation with 16 minutes heat treatment, again the unirradiated were the best and followed by the order of the 5.0 kGy irradiated and the 2.5 kGy irradiated. Obviously, the irradiated with 35 minutes heat treatment gave worst color regardless of precooling before canning.

One thing to be noticed in mushroom canning was that brine should be filled right up to the top of can in order to obtain good color regardless of all treatments.

Weight loss

It was found that the results of weight loss examination and color assessment were quite similar. As in the case of color assessment, 16 minutes heat treatment showed better results in weight loss than 35 minutes heat treatment and also the canned 1 day after irradiation was in every treatment better than the canned 4 days after irradiation. The best result in weight loss was shown again with the unirradiated, 16 minutes heat treated with canned 1 day after irradiation while the worst was with the 35 minutes heat treated with canned 4 days after irradiation regardless of dose levels. These results were shown on Table 13.

Table 13. Weight loss of irradiated canned mushroom (stored 8 weeks at 30℃)

Treatment		Weight differences form 250g canned 1 day after irrad.	canned 4 days after irrad.
0 kGy+16min.	at 116℃	8.2(1.3)	15.0(6.0)
2.5 kGy+16min.	〃	10.7(4.3)	12.4(5.0)
5.0 kGy+16min.	〃	12.9(5.2)	13.9(5.6)
0 kGy+35min.	〃	9.7(3.9)	20.8(8.3)
2.5 kGy+35min.	〃	17.7(7.1)	20.5(8.2)
5.0 kGy+35min.	〃	19.4(7.8)	21.6(8.6)

( ) : % unit : gram

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摘　　要

신선한 양송이와 통조림한 양송이를 放射線 照射한 후, 이들의 품질을 관능검사, 수축율, 색갈, 저장중 변질여부, pH, 중량감소율 및 일반 판매가능성 여부등을 가지고 검사하였다.

신선한 양송이를 가지고 실험한 결과는 다음과 같다.

1. 2.5 kGy로 照射한 경우 색이 바래는 것을 억제하는 효과를 뚜렷하게 나타내었으나 저온저장에서는 별 효과가 없었다.
2. polyethylene 포장은 색갈보존에 효과가 있었다.
3. 照射前의 豫備冷却(precooling)은 cap opening을 지연시키는 효과는 있으나 褐變(browning)을 촉진시키므로 적합치 못한 것으로 나타났다.
4. 색갈보존에 있어서 12℃ 저장보다는 2℃나 5℃가 적합하나 적절한 습도를 유지하는 것이 중요하다.
5. 포장은 cap opening과 褐變을 방지하는 효과가 있으나 반면에 줄기의 성장을 촉진하였다.

한편 照射후 통조림한 양송이의 실험에서는 다음과 같은 결과를 보여주었다.

1. 豫備冷却에 의해서 수축율은 照射안한 것보다 완화시킬 수 있었으나 照射線量間에는 뚜렷한 차이가 없었다.
2. 豫備冷却은 관능검사상에 유해한 효과를 나타내었는데 이 逆効果는 단기간 저장한 양송이에서만 나타났다.
3. 豫備冷却은 이것을 하지 않은 것보다 더 큰 중량감소율을 보였다.
4. 16분간 열처리 한 것이 35분간 한것보다 색갈과 중량감소율에 있어서 더 좋은 결과를 보여 주었다.