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Studies on the Preservation of Korean Rice by Gamma-irradiation(I)

by

Hyong Soo Kim and Young Rack Choi

Food Tech. Div., Radiation Research Institute in Agriculture, Office of Atomic Energy, Seoul

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감마선 조사(照射)에 의한 쌀 저장에 관한 연구(제1보)

원자력청 방사선농학연구소 식품공학연구실

김 형 수 · 최 영 락

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요 약

쌀 저장중 곤충과 미생물에 의한 손실을 방지하기 위하여 팔달, 농광 두 품종을 현미와 백미로 도정하고 Polyethylene bag에 포장후 6—400 K rad의 Co^{60} γ선을 조사하여 8개월간 실온에 저장하면서 곤충, 미생물의 발생상태와 방사선 조사에 의한 쌀중 수분과 Amylose, reducing Sugar, Rancidity의 변화를 검토하여 다음과 같은 결과를 얻었다.

1) Polyethylene bag에 저장된 쌀은 대조구도 곤충의 발생이 없었으나 가마니에 저장된 것은 5월달부터 곤충이 발생되었다.
2) 400 K rad 조사로는 쌀중 Yeast와 곰팡이의 살균에 부족하였고 Yeast는 쌀 표면에, 곰팡이는 균사가 쌀입자에 깊이 뿌리박고 있었다.
3) 저장중 쌀의 수분은 방사선의 영향을 받지 않았다.
4) 선량증가와 저장기간에 따라 전분중 Amylose의 함량은 증가하는 경향이있다.
5) Free reducing Sugar의 함량은 방사선에 의해 영향을 받지 않았고 저장중 감소하였다.
6) Rancidity는 선량과 저장기간에 따라 증가하였다.

Introduction

In Korea, about 3,750,000 M/T of rice were produced in 1967, and the loss by insects and harmful microbes has been estimated to be more than 5% of the yearly crop. Especially damage by insects (*Sitophilus oryzae*) is very serious[2,3] and infection of microbes is responsible for loss of nutrients and production of toxic materials harmful to human body.[5] For example, *Penicillium citrinum*, one kind of rice microbes, produces toxic materials such as citrinin during the growth in rice.

Changes of rice quality during storage, such as development of rancid odour and lowering of viscosity, have given unfavarable effects on rice taste, and as a result, rice quality becomes progressively poorer the longer the storage period.[1]

Many countries have made a effort to protect rice from insects and microbes, and the common practice for preserving rice quality has almost been dependent upon the chemical treatments and fumigation.[4] The fumigation method, however, has many defects in that various chemicals have to be used for disinfestation and disinfection. On the other hand the above

defects can be easily removed and large amount of rice can be treated by applying the radiation. [6]

Norman and Tape, [7] reported that the irradiation of Pakistani rice at 30 K rad appeared to control insects and this dosage did not have any effect on rice quality in terms of flavor, texture or color. They also appeared that irradiation at a level of 2 to 4 times the doses required to control insects have very limited effect on rice quality. In the dose range of 15-60 K rad, there was no apparent difference between the control and irradiated rice. Viscosity of rice at the varied temperatures or storage time employed was not significantly different from each other, but the viscosity decreased with increasing radiation dose on the amylograph data. However, a sensory test failed to reveal any difference in texture.

Iuzka[8] reported that the dose required to control the microbes was 200-600 K rad and the dose to inhibit the microbes varied with the moisture content of rice. High moisture content stimulated the inhibition of microbes. Irradiation at the dose range resulted in a blackening of the rice surface, lowering the viscosity significantly.

Hukuba[9] reviewed the changes in taste, starch, sugar and flavor of unirradiated rice of Japanese variety during the storage.

The amylose and sugar content were increased with storage. He identified several carbonyl compounds from the rice flavor.

A few investigators have studied on the preservation of rice by radiation and particularly the effect of radiation on rice components. Wholesomeness[10] must be considered in the food preservation by radiation because of the possible polymerization and depolymerization of organic compenents of food stuffs.

This study was initiated to obtain some information on disinfestation and disinfecion, and the changes in the contents of amylose in starch, reducing sugar, rancidity of Korean rice during storage.

Materials and Methods

1. Sampling and Packing

Sample rice, harvested in 1967 at Su-Won area, was used for this study. Two varieties, Paldal and Nongkwang were collected in January 1968 and hulled into two kinds: polished rice and unpolished rice by commercial Rice Inspection Station.

One kilogram of the sample rice was put into a polyethylene bag (dia. 10cm, thickness 0.1mm, length 60cm) and both ends were heat-sealed hermetically.

Table 1. Varieties of Sample

Variety	Scientific name	Type	Remark
Paldal	Oryza Sativa L.	Japonica	B; unpolished rice C; polished 〃
Nongkwang	〃	〃	A; unpolished rice D; polished 〃

2. Irradiation and Storage of Samples

The samples were lain around source and following dosages were given to the polyethylene packaged rice samples at room temperature, 10-20°C, using an irradiation facility of Co^{60} source (770 ci).

Low dosage : 6 K rad, 10 K rad, 15 K rad, 25 K rad, 35 K rad. High dosage : 80 K rad, 200 K rad, 400 K rad

The irradiated rice samples have been stored under the room temperature since last January and the experiments have been carried out.

The other samples packaged in straw sacks without irradiation were also stored under the same condition.

Table 2. Changes of Temperature in Storage Room

Month	Mar.	Apr.	May	June	July
Average temperature, °C	15±1	18±2	22±2	24±2	29±2

Month	Aug.	Sept.	Oct.	Nov.
Average temperature, °C	29±1	27±1	23±2	17±2

3. Disinfestation and Disinfection

1) Disinfestation

Number of insects (larva and adult) occurring naturally in each polyethylene bag was counted monthly by the naked eye to determine the optimum dosage.

2) Disinfection

A. Preparation of medium

One kilogram of malt was put into 3-4*l* of tap water and stirred vigorously. The soaked malt was digested on a water bath of 60°C for about 6-9 hours until iodine reaction was nega-

tive. It was then filtered through a cheese cloth and the sugar concentration and pH of filtrate were adjusted to 18 Brix and 5.6-5.8 respectively. 300g of agar-agar were added into 1 *l* of malt extract and sterilized in an autoclave at the pressure of 15 lbs for 15 minutes.

Twenty ml of the sterilized medium were poured into a petridish and allowed to solidify at the room temperature (25°C).

B. Separation of spore and mycellium

(1) Spore

Approximately two hundred grains of rice taken from the sample package were suspended in 100 ml of sterile water and shaken vigorously for 2 minutes 0.5 ml out of it were spread on the surface of medium and the plates were incubated at 30°C for 2 days.

The number of colony on the surface was compared in each sample.

(2) Separation of mycellium

Approximately two hundred grains were suspended in an Erlenmeyer flask containing 50 ml of sterile water and shaken vigorously as before, then the liquid was decanted. Another 50 ml of sterile water were poured into the flask containing the rice grain and shaken as before. This washing procedure was repeated 20 times. Then 3-4 grains were picked up and placed on the surface of medium and the plates incubated at 30°C for 6 days.

The growth of mold in each samples was compared by the naked eye.

4. Changes of Components

Each rice sample was ground to powder in the size about 30 mesh by an ordinary crusher before analyzing.

1) Analysis of general components[11]

a) Moisture……by A. O. A. C. official method

b) Fat ……by Soxhlet extraction method

c) Protein ……by micro kjeldahl method

d) Ash……A. O. A. C. method

2) Deterimination of amylose contents

A. Preparation of standard starch[12,13]

About 150g of rice powder was transferred into 2 *l* flask. About 300 ml of 0.2% NaOH was added to this. After mixing, it was kept for one day, and then the liquid was decanted. Starch residues at the bottom of flask were washed with 300 ml of 0.2% NaOH solution and the liquid decanted again. Such procedure was repeated until the decanting liquid gave negative Biuret test. The starch residues were then washed 5 times with 200 ml of 95% EtOH to remove fats and lipids by heating the mixture to boiling followed by centrifugation at 2500r. p. m. for 20 minutes.

Ethanol in the starch preparation was evaporated in vacuum oven.

B. Separation of amylose and amylopectin[14,15]

After 15 ml of H_2O and 150 ml of butanol were added to 30g of above refined starch and dextrinized by heating, pH of this solution was adjusted to 6.2 with 0.1N-NaOH. And then this solution was heated for 20 minutes in an autoclave (pressure: 20 lbs) to disperse the starch. 75 ml of butanol and isoamyl alcohol were added to it while it is warm. After mixing well, the flask was covered with a cheese cloth and kept it cool at the room temperature.

The precipitate was separated from dispersed solution by centrifuging. And then one sheet of filter paper was put into the above solution and kept it cool in a refrigerator after paper absorbed remained amylose.

Five hundred ml. of methanol were added to the solution and amylopectin was precipitated. The precipitate was washed 3 times with absolute methanol followed by centrifuging at 2500 r. p. m. for 20 minutes methanol in amylopectin was evaporated in a vacuum oven. Pure amylopectin was obtained.

Precipitate obtained from former procedure was dissolved in 300 ml of hot 5% butanol, Insoluble substance was removed by centrifuging while this solution was warm. And the solution was kept cool and stirred for 3 hours. The precipitate was washed 3 times with absolute methanol followed by centrifuging. Methanol was evaporated in a vacuum oven and the pure amylose was obtained.

C. Identification of amylose and amylopectin[16]

The identification of amylose and amylopectin

thus separated was performed by employing the paper chromatography technique.

In order to remove the coloring substance in paper by iodine, whatman No. 1 paper (4×30 cm) was washed with 15% KOH by the descending method, and then washed by tap water until the alkali was removed and the paper was dried. Fifty miligrams of amylose and amylopectin were dissolved in 10 ml of 0.5N KOH respectively and kept in a refrgerator for one day.

Three μl from its was taken and spotted on a strip paper (2×25cm). After developing with 1N KOH by the ascending method at the room temperature, paper strip was taken out from the chamber and submerged in 10% acetic acid solution to neutralize alkali. Immediately it was submerged in an iodine solution (dissolve 200 mg of iodine in 50 ml of 90% ethanol and add 50 ml of water). And blue spots appeared on the strip.

Amylopectin did not move from the spotting place, and showed a red-violet cycle shape, but amylose moved from spotting line to the distance of Rf 0.3 and showed a blue V-shape.

From this result, we recognized that the seperated amylose and amylopectin were very pure.

D. Ouantitative analysis of amylose and amylopectin in starch[17]

Amylose and amylopectin obtained from the above mentioned procedure were mixed in the following ratio.

Amylose	0	10	20	30	40	50	60	70	80	90
Amylopectin	100	90	80	70	60	50	40	30	20	10

After adding constant quantities of iodine solution to the mixture, the optical density was measured using Beckmen DU spectrophotometer at 660 mμ, and the standard curve of amylose was plotted for each sample. One ml of EtOH and H_2O were added to sample starch solution respectively. And then 2 ml of 10% NaOH were added to it and heated to dissolve on the water bath. The solution was diluted to 100 ml with H_2O. Five ml from it were pipetted into 100 ml flask and diluted to 100 ml with H_2O and added 3 drops of 6 N-HCl.

And then this was transferred to the 250 ml flask to this 5 ml of iodine reagent solution was added and the resulting solution diluted to 250 ml of water. Three ml from it was pippeted to a cell and the optical density was measured at 660 mu by spectrophotometer.

3) Glucose determination[18]

A. Reagents

(1) Glucose standard solution (0.06 μmole/ml). Stored cold.

(2) Nelson's reagent A; 12.5g Na_2CO_3 (anhydrous), 12.5g sodium potassium tartarate, 10 g $NaHCO_3$ and 100g Na_2SO_4 (anhydrous) dissolved in 350 ml H_2O diluted to 500 ml.

(3) Nelson's Reagent B; 7.5g $CuSO_4 \cdot 5H_2O$ in 50ml H_2O plus one drop conc. H_2SO_4.

(4) Arsenomolybdate Reagent; 25g $(NH_4)_6 Mo_7 O_{24} \cdot 4H_2O$ dissolved in 450 ml H_2O. 21 ml conc. H_2SO_4 added. Solution of 3.0g $Na_2HAsO_4 \cdot 7H_2O$ in 25 ml H_2O added to above acidic molybdats solution. Stored in a brown bottle (with clean dry plastic screw cap unlined) for 24 hrs. at 37°C. Reagent should be yellow but not green.

B) Procedure

(1) Preparation of standard curve

A series of sugar solutions using the stock solution (containing 0.60 μmoel glucose/ml) were prepared as follows:

Volumes in ml.

Tube	1	2	3	4	5	6
H_2O	1.0	0.8	0.6	0.4	0.2	···
Stock	···	0.2	0.4	0.6	0.8	1.0

After mixing 10 ml of Nelson's reagent A with 0.4 ml of Nelson's reagent B, 1 ml of this reagent solution was added to each of the above tubes.

The contents were mixed well and placed in a boiling water bath for 20 minutes. The tubes well cooled in a beaker of cold water. One ml arsenomolybdate reagent was added to each tube and the tube shaken to dissolve Cu_2O. Seven ml of distilled H_2O were added

to tube. Remove stains and water droplets from it and transfer it to the cell and read the optical density in the Coleman colorimeter at 540 mμ against the blank.

In order to determine the amount of glucose of sample solutions we can take 1.0ml of the sample solution (contains 0.1 to 0.6 μmole of glucoss) instead of standard solution and follow the above procedures.

4) Rancidity[31]

About 5 grams af crushed rice were taken in a distillating flask and added 50 ml of distilled water, added HCI to adjust pH to 1.2. Steam distillation was carried out and 50 ml of distillate was received in a graduated flask.

Optical density was measured according to the following procedure.

A) Preparation of reagent

T. B. A. sol'n……Dissolve thiobarbituric acid in 90% glacial acetic acid solution, and adjust its concentration to approximately 0.02M. If T. B. A. dissolved sparingly at the room temp. heated until completely dissolved on water bath of 80°C.

B) Procedure

Distillate was mixed well, and transferred 1ml of it to test tube with cap. 5 ml of T. B. A. reagent was added and mixed well. The tube was heated in a boiling water bath for 35 minutes and cooled in tap water. Absorbance was measured at 538 mμ by spectrophotometer DU.

Result and discussion

1. Disinfestation

It is known that most of insects to be infestated during storage of rice belong to *Sitophillus oryzae*, *Oryzaphillus surinamensis*, *Triborium ferugineum Fabricus*, and *Sitotrogen cerealla olive*.[19] Though the dose required to kill above insects have been investigated, this dose was different according to the investigators.

Therefore, the authors investigated the minimum dose requried to inhibit the growth of the above insects when rice was packaged in the polyethylene bag and the straw sack. But there was no any infestation in the non-irradiated rice as well as the irradiated rice packaged in polyethylene. As showed in B of Fig. 1.

But several kinds of insects which were not identified in this experiment occurred in rice packaging in the straw sack.

In the early part of July, such insects began to occur in the straw sack and the maximum population was found in August. Infestated rice sticked together and formed small mass as shown in of Fig. 1. All sample irradiated and non-irradiated that were packaged in polyethylene tube were satisfactory. Infestation in the straw sack may come from straw itself or the atmosphere, and there have been many reports that straw is best media for insect to tide over winter, also the clearance of the straw sack is loose enough to allow the infestation from the atmosphere.

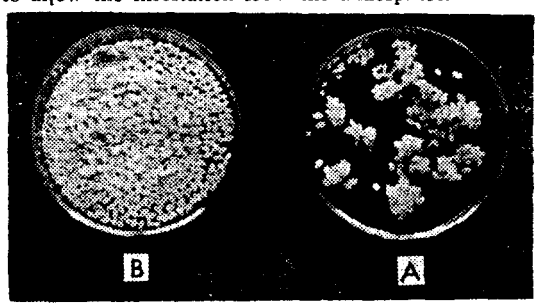

Fig. 1. Comparison of infected rice in straw sack and non-infected rice in polyethylene tube on August

2. Disinfection

Concerning the microorganisms occurring in rice during storage, Kawano[20], Kondo[21], and Harukawa[22], have done much research works, and on the denatured rice, Kakuda[23] reported their research works, and Yosidaet al[23], asserted that *Penicillium toxicarium*, *Penicillium isolandicum* & *P. citrinum* caused yellow coloration of rice. Kim et al[25], studied on the yellow coloration of Korean rice and reported that some microorganisms of to the*Panicillium* and *Aspergilus* genus excreted toxic substance and its LD_{50}=0.022g/100gr.

In this experiment, we isolated microorganisms monthly from March to November, but we are going to deal with the results of August portion when optimum condition for the growth of microorganisms was realized.

Fig. 2 illustrates the microorganisms isolated from

the surface of non-irradiated rice with sterile water and lots of microorganisms were isolated from brown rice, A & B, but no microorganisms was isolated from polished rice, C & D.

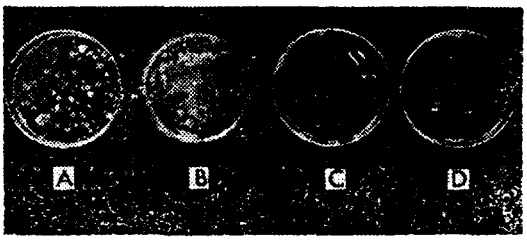

Fig. 2. Occurrence of microorganisms on surface of unirradiated rice on August

Fig. 3 illustrates microorganisms isolated from the surface of 400 Krad irradiated rice. There was no microorganism in the polished rice, C & D, while in brown rice A_8 and B_8 which were stored at the same condition there existed radiation resistant microorganisms but the number was less than the control. Judging from this, the surface of brown rice carried more microorganism than that of polished rice and complete sterilization of rice surface microorganisms was not done with 400 Krad irradiation. Most of the microorganisms isolated were found to be yeasts by the microscopic examination.

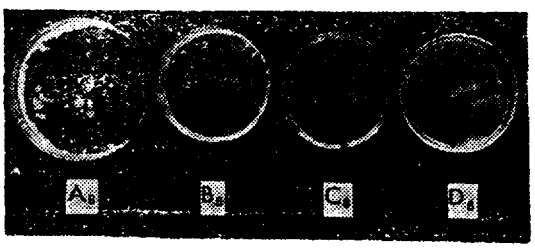

Fig. 3. Occurrence of microorganisms on surface of rice being irradiated 400 k rad on August

The pH 5.2 of the medium, which is a good condition for the growth of yeast seemed to be responsible for this, but also, bacteria have neither connection with the denaturaton of rice nor were isolated. [26]

Fig. 4 illustrates the results of the examination of mycelium rooted in the non-irradiated rice which were washed 20 times with distilled water and completely removed spores, we could notice the presence of mold in both brown rice and polished rice, and from the fact that more mold were isolated from the polished rice than brown rice, we can tell the damaged by mold is more severe during storage in the polished rice than brown rice.

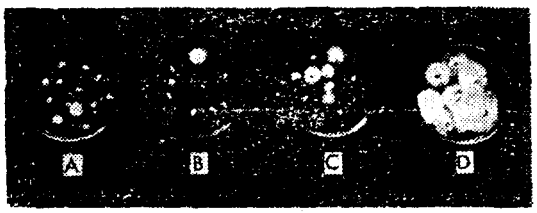

Fig. 4. Isolation of mold mycellium from unirradited rice

Fig. 5 illustrates that 400 Krad dose is not sufficient for sterilization of mycelium rooted in rice. These molds by microscopic examination were supposed to belong to genus, *Aspergillus* and *Penicillium* and these results coincide with those of Prodo, Christensen.

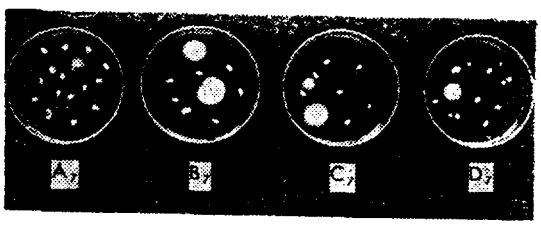

Fig. 5. Isolation of mold mycelium from rice being irradiated doses of 200 Krad

3. Changes of Chemical Componets

General components are shown in Table 3.

Table 3. Chemical Composition of Sample Rice*

	Moisture %	Fat, %	Protein, %	Ash, %	Free nitrogen extract, %
A	13.14	1.11	7.63	1.18	76.94
B	11.45	1.52	6.84	1.09	79.10
C	12.41	0.88	6.12	0.55	80.04
D	13.51	0.53	7.23	0.59	78.08

*Korean rice A: Nongkwang unpolshed
B: Paldal unpolished
C: Paldal polished
D: Nongkwang polished

1) Change in moisture

This Fig. 6 illustrates the change in moisture of brown rice Nongkwang during storage, right after hulling, the moisture content was high having 15.3%, and decreased during the dry season, viz upto

May and began to increase with the onset of rainy season, viz upto June—July. There was no notable increase after rainy season, upto November, but the irradiated lot absorped more moisture than the control lot after May, and the moisture content was not affected by the increase in doses.

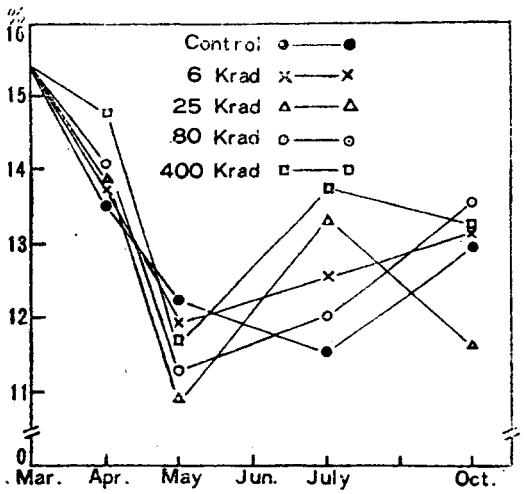

Fig. 6. Changes of moisture contents in unpolished rice (Nongkwang) by irradiation

Fig. 7 illustrates the change in moisture of brown rice, Paldal; the moisture content was not affected by the increase in doses, and on the whole, the irradiated lot showed less decrease in moisture than the control lot and showed much absorption of moisture during rainy season and this might be attributable to the softening of tissue by irradiation.

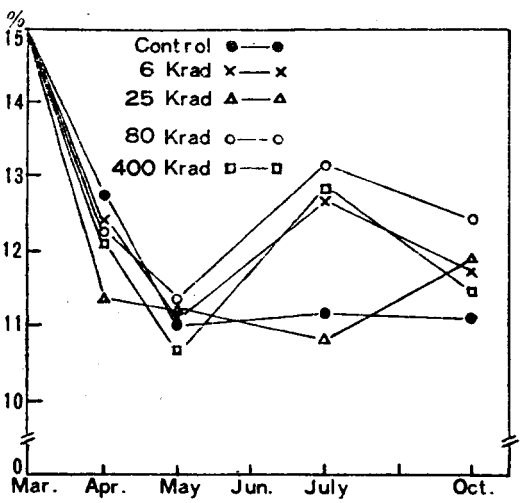

Fig. 7. Changes of moisture contents in unpolished rice (Paldal) by irradiation

2) The change of amylose in rice starch

It is well-known fact that amylose of rice starch varies according to the variety of rice, culture method, soil, and climatic condition[28], and in this experiment, the difference between varieties was not much, and Paldal contained somewhat higher amount than Nongkwang.

It is already established that iodine reaction of starch depends rather upon the amylose content than the differance in the length of amylose chain, Hukuba[9] asserted that when the sum of the total chain length of amylose and the end chain length of amylopectin was big, little amount of amylose dissolved into water resulting in reduced viscosity, Dakaoka[29] reported that if average polymerization of the end chain of amylopectin was large, starch formed strong micelle to produce reduction in viscosity.

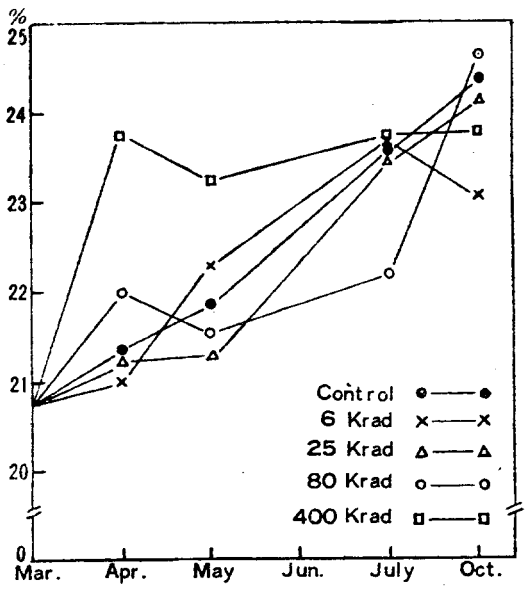

Fig. 8. Changes of amylose contents in unpolished rice (Nongkwang) by irradiation

As illustrated in Fig. 8 amylose content in A lot showed the tendency of increase according to the extension of storage period and increase in doses, 25 Krad irradiated lot showed less increase than control lot, but the increase in the other irradiated lots were notable, especially there was much change in the first month of storage. This didn't mean that amylose in starch was newly formed by the polymerization but either the micelle of amylose and

amylopectin was broken down or the total chain of amylose broke down to increase the dissolution of amylose, so the amylose ratio was considered to increased in the amylose : amylopection ratio. We must try further to find out whether amylose content ratio was risen due to the break down of amylopectin by irradiation. Tape et al[7] reported that irradiation reduced the viscosity of rice, but it is difficult to know whether it came from the increase of amylose, viz decrease in amylopectin.

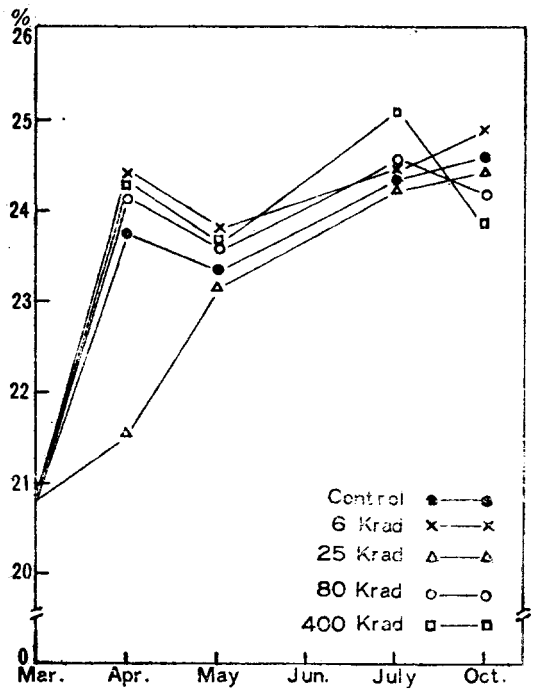

Fig. 9. Changes of amylose contents in unpolished rice (Paldal) by irradiation.

B lot (Fig. 9) has similar results to A lot, and toward the end of storage, amylose of Paldal increased more than that of Nongkwang and this seems to arise from the micelle sturcture and the extent of break down.

In C lot (Fig. 10), in general amylose increased more in irradiated lot than non-irradiated one, and there was no significant difference between higher dose and lower dose irradiated lot.

In D lot (Fig. 11), in the middle of storage, amylose showed the tendency of increase in irradiated lot compared with that of control lot, and at the end of storage, there was no difference, and in the main, D lot showed the similar tendence as

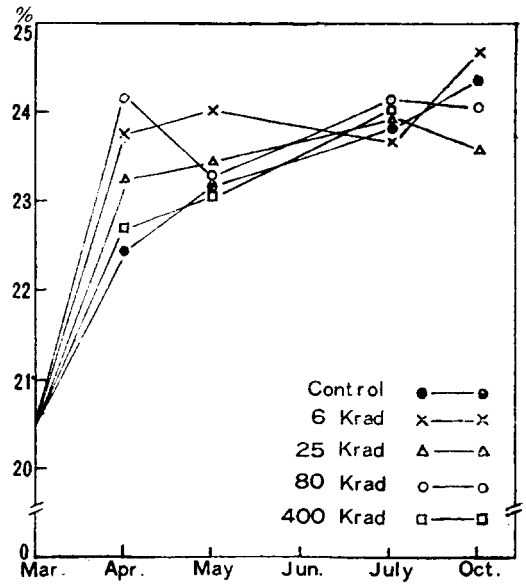

Fig. 10. Changes of amylose contents in polished rice (Paldal) by irradiation.

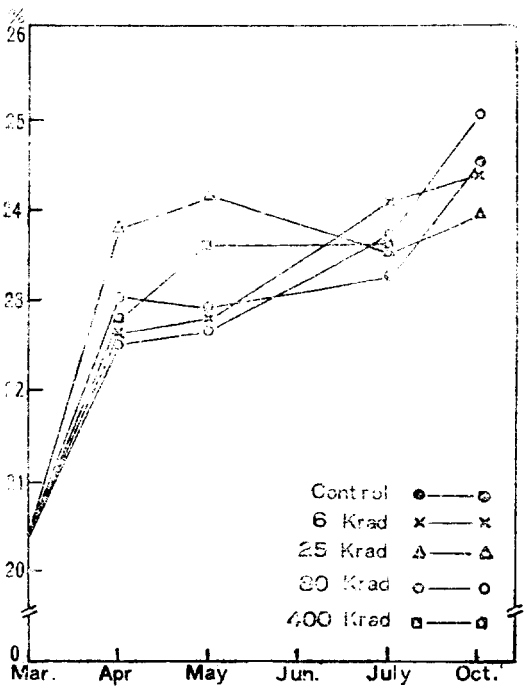

Fig. 11. Changes of amylose contents in polished rice (Nong kwang) by irradiation.

A. B. C. lot.

3) Changes of free reducing sugar

The changes of free reducing sugar, during storage are shown in Fig. 12, 13, 14, 15 respectively.

Nelson's method is one of the determination methods of free reducing sugar except sucrose which is nonreducing sugar. Free reducing sugar contents appe ared to be decreased with prolongation of storage time regardless of the radiation doses.

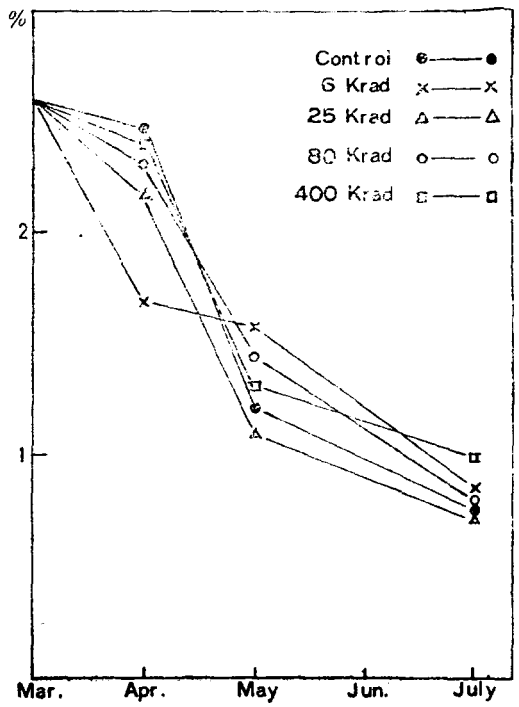

Fig. 12. Changes of free sugar contents in unpolished rice (Nongkwang) by irradiation

There was somewhat more free reducing sugar contents in Nongkwang (Fig. 12) than Paldal (Fig. 14), but the decreasing ratio according to storage time showed a similar pattern in the polished rice and the unpolished rice. (Fig. 13, 15)

This result suggested that rice starch was not converted to free sugar by 400 Krad radiation which is highest does and decrease of free sugar depended on respiration and oxidation of rice.

Kim et al[28], reported that the water soluble sugar in rice were sucrose, raffinose, glucose, and fructose and most of free sugar was sucrose and fructose was little. In this experiment, sucrose was not dealt with because our attention was concentrated on the change of monosaccharide, glucose which might be converted from maltose and be produced from starch by radiation. Okamura[30], reported

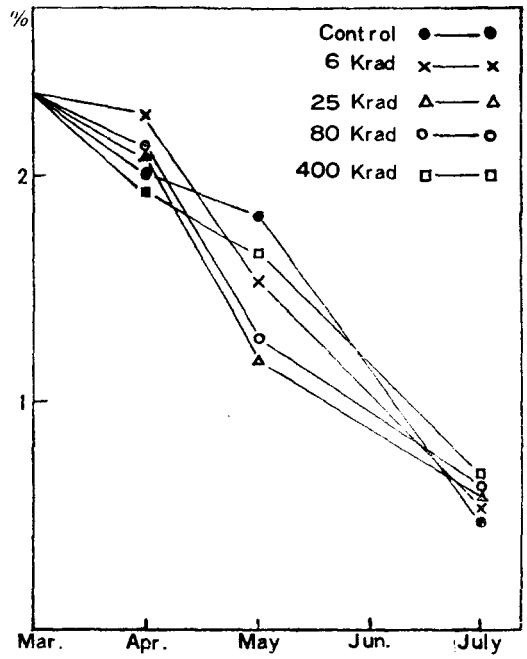

Fig. 13. Changes of free sugar contents in polished rice (Nongkwang) by irradiation.

that the unpolished rice contained much more quantity of reducing sugar than the polished rice, but

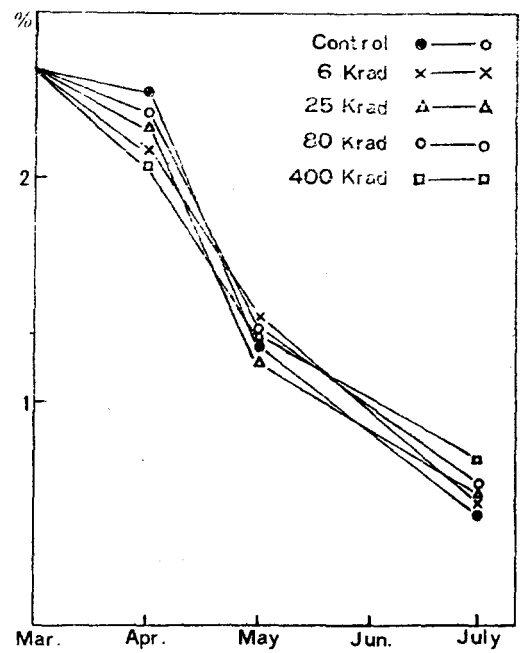

Fig. 14. Changes of free sugar contents in unpolished rice (Paldal) by irradiation.

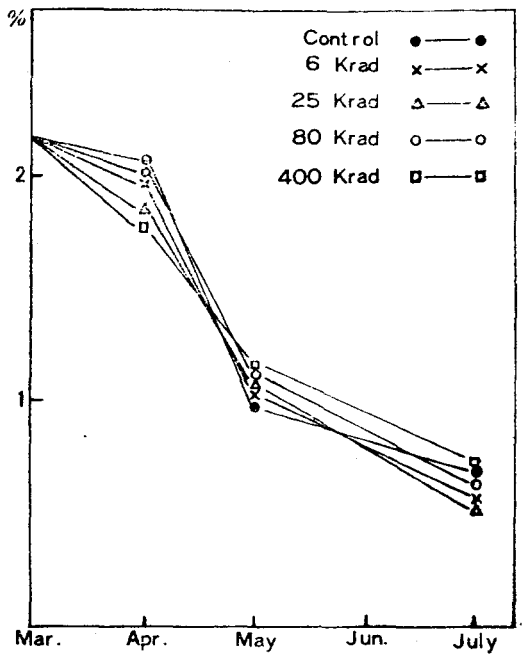

Fig. 15. Changes of free sugar contents in polished rice (Paldal) by irradiation.

the difference of reducing sugar contents between unpolished rice and polished rice was not large in this experiment.

4) Rancidity

Deteriorative changes in fat present in grains may be hydrolytic, resulting in the production of free fatty acids, and oxidative, resulting in the development of peroxides and malonaldehyde. Rao, et al, [32] reported that rancid odour was noticeable in husked rice and highly milled rice was developed low rancidity. The other rancidity was caused by a lipolytic enzyme present in rice.

The 2-thiobarbituric acid method is one of methods to allow the quantitative determination of malonaldehyds in rancid foods and Watts. B. M. [33] considered the malonaldehyde contents of food as a sensitive index of rancidity.

Rancidity increased with the storage period and the irradiation dose such as in Fig. 16 and Fig. 17.

This phenomenon may be came from that irradiation stimulates the oxidation of fat and a lipolytic enzyme activity. Especially the decreasing in first stage (Fig. 16) may depend upon that free fatty acid of rice is oxidized by irradiation.

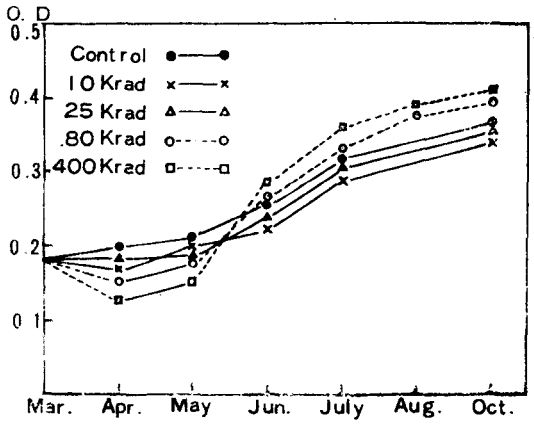

Fig. 16. Changes of rancidity in unpolished rice.
Variety: Nongkwang

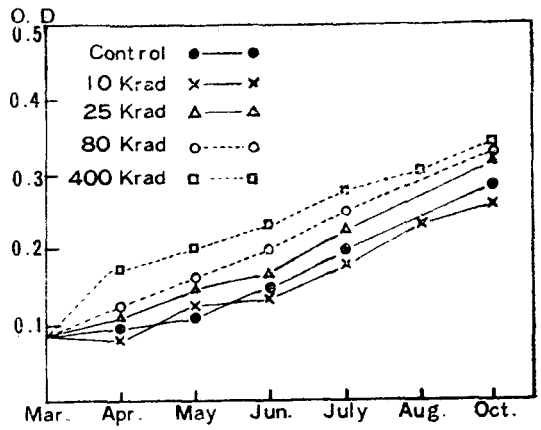

Fig. 17. Changes of rancidity in polished rice.
Variety: Nongkwang

Summary

In order to eliminate the considerable loss of rice by insects, to protect the human body from toxin excreted by some microbes, and to promote the storage efficiency of rice by employing the irradiation, the following experiments were carried out.

Two varieties of rice, Paldal and Nongkwang polished and unpolished by the conventional methods and were packaged in polyethylene bags. After irradiating to the doses of 6—400 Krad of gamma-radiation from a Co^{60} source the samples were stored at the room temperature 20°C for 8 months.

The effects of radiation in terms of the removal of insects and microbes and the changes of chemical components (such as moisture, amylose , free sugar, and rancidity) were determined monthly from march

to October during the storage.

1) Infestation of insects was greatly influeneed by the packaging materials used. There was no infestation in rice being packaged in a polyethylene bag, while as the rice packaged in a straw sack was infested in two months of the storage.
2) Some yeast and molds survived 400 K rad of radiation.

Sterilizing dose to inhibit reproduction and growth of microbes was presumed to be higher than 400 K rad.

Yeast mainly were found on the surface of rice, but mold were embeded into rice kernels by mycelium.

3) Changes of moisture contents during storage was not affected by radiation but was by humidity of the storage room.
4) Amylose content in starch increased with increasing dose of radiation and with the length of storage time, indicating possible depolymerization of starch molecules.
5) Free reducing sugar content was not affected by radiation and decreased with storage time.
6) Rancidity also increased with does and storage time.

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