Results of project 04-042

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A Tuber, bulb and root products

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1. INTRODUCTION

Sprouting of- and fungal attack on tuber, bulb and root products is a common problem to most countries.

Sprouting can be delayed by storage at low temperature, and partly prevented by a proper use of chemical sproutinhibitors.

Cooling is, however, energy consuming, expensive and not practicable everywhere. Chemicals are cheaper, but their application is not always reliable, especially at temperatures higher than 15'C. Moreover in some countries the application of chemical inhibitors are prohibited. From research it has proven that sproutinhibition can also be achieved by an irradiation treatment. However, this treatment can induce rot during storage, especially in (semi)tropical countries.

The appearance of rot in potatoes depends of different factors like, irradiation dose, postharvest irradiation time, woundhealing, dormancy period, storage temperature etc. To solve this rot problem these factors have to be studied.

2. RESEARCH

In relation to the above mentioned problem the following research was set up with the aim:

Study the effect of a postharvest and postponed irradiation treatment with different doses on sprouting, rot incidence, wound healing, chemical and sensory properties of potatoes.

In the framework of this project two experiments were started in September 1985 with the potato cultiva "Bintje". One experiment was focussed on the sprout inhibition and the other two on the control of rot. These experiments have been finished at July 1986.

3. EXPERIMENT ON SPROUTINHIBITION

The fresh harvested potatoes were transported immediately after harvest to the Pilot Plant for Food Irradiation in Wageningen and were irradiated with a Co-60 gamma source of 20 kCi.

The postharvest irradiation (PHI) took place after 0, 2, 4 and 6 weeks storage at 15'C and 85% relative humidity for woundhealing and estimation of the dormancy period. The irradiation doses amount to 0, 25, 50, 75 and 100 Gy.

After the irradiation treatment the potatoes were stored in storage rooms at 10'C and 20'C [(semi-) tropical conditions] at 85 and 80% RH respectively.

Every treatment was done in triplicate. Each sample, consisted of 50 potatoes, was packed in open wooden boxes. In total 2.5 tons of potatoes were treated.

With a 3 week's interval the product was evaluated on:

- loss of weight, rot incidence, sprouting, general appearance and wound healing.

During storage the commodity was also analysed in 5 fold of 10 potatoes on:

- Sugar content (sucrose, fructose and glucose).
- Total Vitamin C content [Ascorbic acid (AA) and dehydroascorbic acid(DHA)].

During storage the commodity was also analysed on sensory properties; taste and colour.

3.1. Results and discussion

To eliminate the large number of figures, only the most representative data are given in this report.

3.1.1. Loss of weight

It proved from figure 1 and 2 that the losses at 20'C were only a little bit higher than at 10'C. The relative humidity during storage was the most important factor by which the loss of weight was influenced. Differences between non-irradiated and irradiated potatoes were small in the first part of the storage period. On the end of the storage, however, the loss of weight in the objects 0 Gy (control) and 25 Gy was significant higher than in the objects treated with higher doses. Probably does the higher percentage of sprouts in the first mentioned objects stimulate the loss of weight.

3.1.2. Sproutinhibition

The length of the dormancy period of potatoes was estimated by the storage temperature after harvest. This period amounted to 6, 5 and 3 weeks of a storage temperature of 10, 15 and 20'C respectivily. The effect of an irradiation treatment was estimated by the following factors:

- The time interval of the treatment after harvest (postponed treatment)
- The irradiation dose
- The storage temperature

An irradiation treatment could most effectively be applied immediately after harvest. At 10'C an irradiation dose of about 50 Gy was sufficient for sproutinhibition, however, on the end of the dormancy period a dose over 75 Gy was neccessary. At 20'C a dose of 50 Gy was not effective, even of applied immediately after harvest. On the end of the dormancy period a dose of 100 Gy had to be given for complete sproutinhibition. A review of above mentioned results is given in figures 3 to 10.

3.1.3. Rot incidence

In figures 11 and 12 it is demonstrated that the percentage of rot was very small, even at 20'C. In the beginning of the storage period the damaged potatoes started to mould, but the rot incidence did not continue during storage. In this experiment an irradiation treatment did not induce extra decay with an increased dose. The effect of a woundhealing period before irradiation (postponed treatment) on the percentage of rot was not visble, because this percentage was too low and the spread too high for finding a significant difference.

3.1.4. General appearance

In general an irradiation treatment immediately applied after harvest with doses over 50 Gy gave the highest quality scores. Objects irradiated with 75 or 100 Gy, irradiated within 4 weeks after harvest and stored at 10'C and 20'C kept there initial quality during the whole storage period of 6 mounths. Non-irradiated objects could be stored at 10'C for 9 weeks only, while objects irradiated with 25 or 50 Gy could be stored 3 and 6 weeks longer respectively.
Non-irradiated objects stored at 20'C could be stored for 4 weeks only. An irradiation treatment with 25 and 50 Gy gave an extension of 2 and 3 weeks respectively.

3.2 Chemical analysis

3.2.1. Glucose

It proved from the results of analysis, that immidiately after irradiation treatment the glucose content in the potatoes stored at 10'C as well as at 20'C is increased. However, the glucose content of irradiated potatoes stored at 20'C decreased during storage to the same level as the control. The glucose content of the control remained rather constant during storage (see figures 13 and 14).

3.2.2. Fructose

The results of the fructose analysis are given in figures 15 and 16. These figures showed that the effect of irradiation on the fructose content was small. Only a dose of 25 and 50 Gy gave a slight increase at 10'C, maybe related to the start of sprouting. After 3 weeks the fructose content of the irradiated samples at 20'C was equal to that of the control samples.

3.2.3. Sucrose

It appeared from the results in figures 17 and 18 that immediately after irradiation the sucrose content increased with a rising dose. During storage the sucrose content of the irradiated samples decreased again, however, the decrease was at 20'C faster as compared with 10'C. The sucrose content of the control samples remainded stable at 10'C till 15 weeks after the harvest. After this 15 weeks the sucrose content of the control and with 25 Gy irradiated objects increased, probably related to the end of the shelf life period (senescence). In the objects stored at 20'C this increase started after 12 weeks of storage.

3.2.4 Vitamin C retention

The results of the dehydro ascorbic acid (DHA) and total Vitamin C (dehydroascorbic acid + ascorbic acid) retention are given in figures 19 to 22 respectively. The effect of irradiation on the DHA retention was hardly measurable, because the analysed value was very close to the detection level of the apparatus. There was a tendency that in the objects 0 Gy (control) and 25 Gy the DHA retention was higher than in the other objects, probably due to the larger number of sprouts. The total vitamin C retention was reduced by an irradiation treatment. Even with the dose of 25 Gy the reduction was measurable. The effect of irradiation on the reduction was at 10'C larger than at 20'C. It was also interesting to notice that the total vitamin C content of irradiated potatoes at 20'C was of a higher level than at 10'C, and also the decrease during storage was slower.

3.3 Sensory evaluation

Two aspects namely sweetness and greyness as an effect of the following three treatments have been tested by a panel of 20 persons

1. level of irradiation (0, 50 and 100 Gy)
2. storage temperature (10 and 20'C)
3. the time interval between harvesting and irradiation (0, 2, 4 and 6 weeks)

3.3.1 Sweetness

The first results were of the influence of the treatments on the sweetness of the potatoes.

Irradiation had a significant effect on sweetness(see table 1). The effect was already noticable at 50 Gy level of irradiation and even greater at a 100 Gy level. The storage temperature had a little or no effect on the sweetness (see table 2). Though it would seem that the sweetness of the potatoes stored at 20'C was slightly greater than of those stored at 10'C.

The overall effect of irradiation on sweetness was especially caused by a small (PHI 0) interval and a large (PHI 6) interval between harvest and irradiation (see table 3).

It was not possible to look at interactions between the three treatments, due to the fact that the method of paired comparison has been used. It seems likely that irradiation has a more dominant effect on sweetness than storage temperature and the time interval between harvesting and irradiation.

Table 1: The overall effect of irradiation on sweetness.

	total effect n = 459	more sweet
untreated - 50 Gy	**	50 Gy
untreated - 100 Gy	**	100 Gy
50 Gy - 100 Gy	**	100 Gy

** = significant level P <= 0.01

Table 2: The effect of irradiation on sweetness of potatoes stored at two temperatures.

	10'C n=226	20'C n=233	more sweet
untreated - 50 Gy	(*)	**	50 Gy
untreated - 100 Gy	*(*)	**	100 Gy
50 Gy - 100 Gy	**	*	100 Gy

(*) = significant level P = ca 0.05
* = significant level P <= 0.05
*(*) = significant level P = ca 0.01
** = significant level P <= 0.01

Table 3: The effect of irradiation on sweetness of potatoes in relation to post harvest irradiation.

	PHI 0 n=115	PHI 2 n=112	PHI 4 n=118	PHI 6 n=114	more sweet
untreated - 50 Gy	**	n.s.	n.s.	**	50 Gy
untreated - 100 Gy	*	n.s.	**	n.s.	100 Gy
50 Gy - 100 Gy	***	n.s.	n.s.	**	100 Gy

n.s. = not significant
* = significant level P <= 0.05
** = significant level P <= 0.01
*** = significant level P <= 0.001
PHI 0 = irradiation immediately after harvesting
PHI 2 = irradiation 2 weeks after harvesting
PHI 4 = irradiation 4 weeks after harvesting
PHI 6 = irradiation 6 weeks after harvesting

3.3.2 Greyness

The effect of irradiation on greyness was very dominant. This effect was so overruling that it was not possible to find a storagetemperature effect and/or an effect of the time interval between harvesting and irradiation, see table 4.

Table 4: The overall effect of irradiation on greyness.

	total effect n = 459	more
untreated - 50 Gy	***	50 Gy
untreated - 100 Gy	***	100 Gy
50 Gy - 100 Gy	***	100 Gy

*** = significant level P <= 0.001

3.3.3 Colour measurement

The colour of the boiled potatoes has been measured according to the L-a-b system, by means of an Elrephomat apparatus equipped with a D65 lamp. The measurement took place 5 to 6 hours after cooking. These results showed that there was no significant difference in colour among the non-irradiated and irradiated objects. The irraddiated objects, however, were less bright as compared with the control. The difference between control and 50 Gy was 2 units and between control and 100 Gy was 3 units. The correlation between the fysical brightness and the panel evaluation of greyness was significant.

4 EXPERIMENT ON ROT CONTROL

This experiment was carried out as follows: After harvest the potatoes were artificially infected with a 1000 spores/ml suspension of Fusarium solani. The postharvest irradiation took place after 0, 2, and 4 weeks storage at 15'C and 85% RH for woundhealing. The doses and storage conditions were equal to the experiment on sproutinhibition. During storage the commodity were evaluated on: weightloss, rot incidence, sprouting and general appearance.

The results runned parallel with the experiment on sproutinhibition, only the percentage of rot was higher due to the extra infection. The effect of irradiation dose and postponed treatment on the rot attack is given in figures 23 to 28. It proves from these figures that an irradiation treatment immediately after harvest increased the percentage of decay with a rising dose. The lowest percentage of decay was found after a woundhealing period of 2 weeks after harvest. After a woundhealing period of 4 weeks the percetage decay increased again, probably due to the high relative humidity during this period.

5 THE WOUNDHEALING

The results of the microscopical investigation of the effects of radiation on primary suberization are given in table 5 and on secundary suberization (periderm formation) in table 6.

table 5: Primary suberization after irradiation

storage [days]	irradiation dose [Gy] 0	25	50	75	100
3	+-	.	-	-	-
5	+	+-	+-	+-	+-
7	+	+	+	+	+
10	++	+-	+	+-	+
12	++	+	+	+-	+-
14	+	+	+	+	+-
17	++	+	.	+	+-
19	+	+	+	+	+
21	+	+	+	+-	+-

. = observation is missing
\- = no primary suberization observed
+- = slight traces of suberization
\+ = one cell suberized
++ = two cells suberized

Table 5 showes that suberization was delayed by irradiation, but not prevented. However, there was a tendency that primary suberization was limited by doses higher than 50 Gy.

table 6: Wound periderm formation (secundary suberization)

storage [days]	Irradiation dose [Gy] 0	25	50	75	100
3	0	.	0	0	0
5	0	0	0	0	0
7	0	1	0	0	0
10	3	1	1	2	1
12	3	2	1	0	1
14	3	2	1	1	1
17	4	2	.	1	1
19	5	2	1	0	0
21	7	2	1	1	1

. = observation is missing
1, 2, 3 etc number of cell layers formed

Table 6 showed that wound periderm formation (secundary suberization) was delayed or prevented by increasing radiation. With doses over 25 Gy no real wound periderm formation had taken place.

6 CONCLUSIONS

From the results of these experiments the following preliminary conclutions can be drawn:

- An irradiation treatment within two weeks after harvest gives the best results concerning sproutinhibition and rot incidence.
- In the beginning of the dormancy period a lower irradiation dose can be used.
- An irradiation treatment increases the sucrose content and reduces the vitamin C retention, related to the dose. These effects level off during storage.
- The sweetness and greyness of boiled potatoes increased significantly by an irradiation treatment, related to the dose.
- The effect of woundhealing and contamination with Fusarium on the results needs more study.

B INGREDIENTS

The effect of gamma irradiation and ethylene oxide fumigation on the microflora of dry slices of ginger and ground red pepper, and on the volatile oil content of ginger was investigated. Ginger as well as red pepper were produced in Vietnam.

Ginger and red pepper were highly contaminated. In both kind of spices the aerobic mesophilic colony count reached circa 10 to 8 cfu/g.
The predominant microflora of ginger consisted mainly of Enterobacter cloacae and Enterobacter agglomerans. The microflora of red pepper consisted mainly of aerobic spore-forming bacteria such as B. licheniformis, B. sublilis and B. pumilus.
For ginger, fumigation resulted in 4 log cycles reduction of the aerobic mesophilic colony count and a radiation dose of 6 and 10 kGy in 3, resp. c. 5 log cycles. For red pepper fumigation resulted in 3 log cycles reduction of the aerobic mesophilic colony count and a radiation dose of 6 and 10 kGy in approx. 4, resp. more than 7 log cycles reductions. Fumigation of red pepper did not reduce effectively the microbial population to an in the spice trade required final level of 10 to 4 cfu/g.
It was found that the microflora of fumigated ginger consisted mainly of Enterobacter agglomerans, followed by B. megaterium. Irradiated ginger compromised mostly of B. megaterium. The microflora of red pepper after fumigation consisted mainly of B. licheniformis and B. sublilis and after irradiation of B. licheniformis and B. pumilus, followed by B. firmus.
The irradiation treatment with a dose of 10 kGy as well as the fumigation treatment did not significantly change the volatile oil content of dry sliced ginger

C INTERNATIONAL COOPERATION

In the frame work of the International Facility of Food Irradiation Technology (IFFIT) project two scientific fellows from the Food Irradiation Department of the Centre des Sciences de la Technologie Nuclear (CSTN) in Algeria and one fellow from the Vietnam National Atomic Energy Institute join the potato project for training and to set up equal experiments under local conditions in their own countries.

D FIGURES

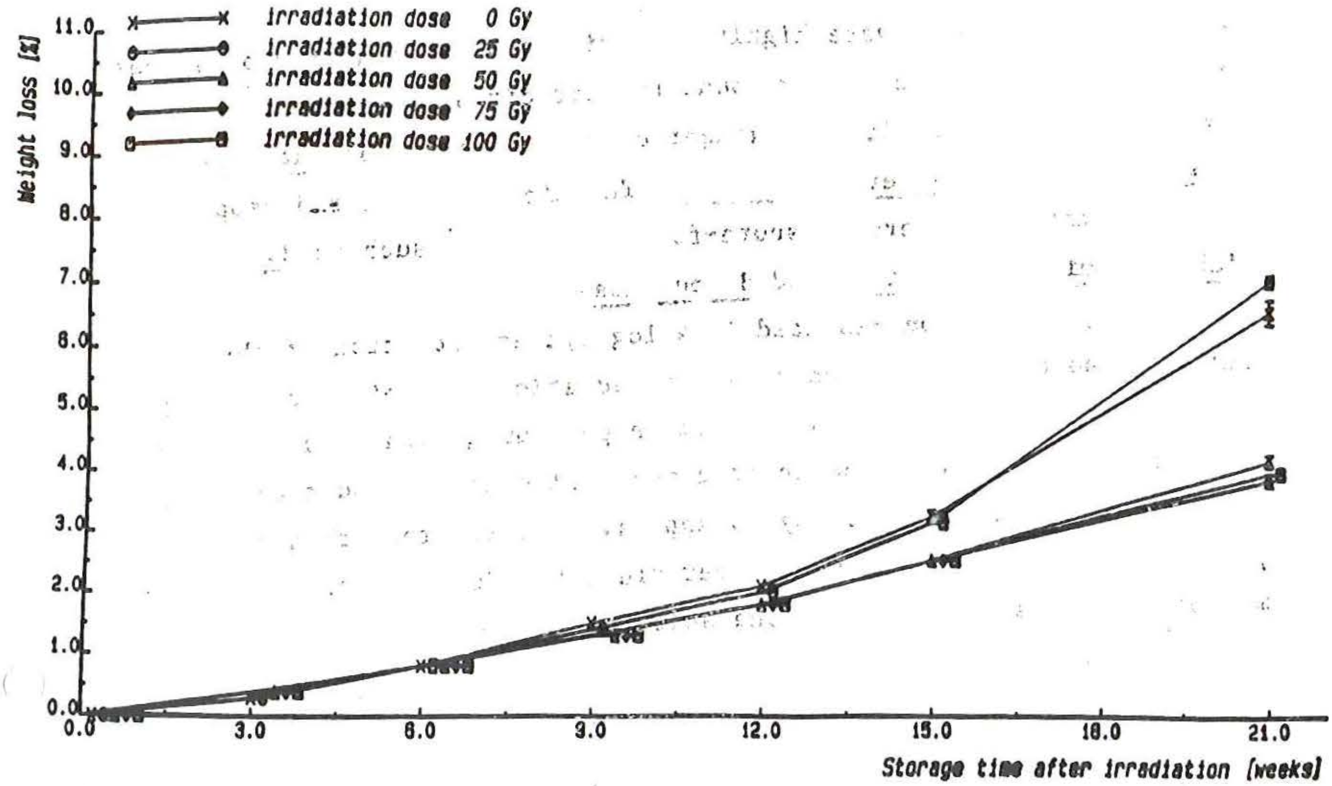

Figure 1 . Average weight loss +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

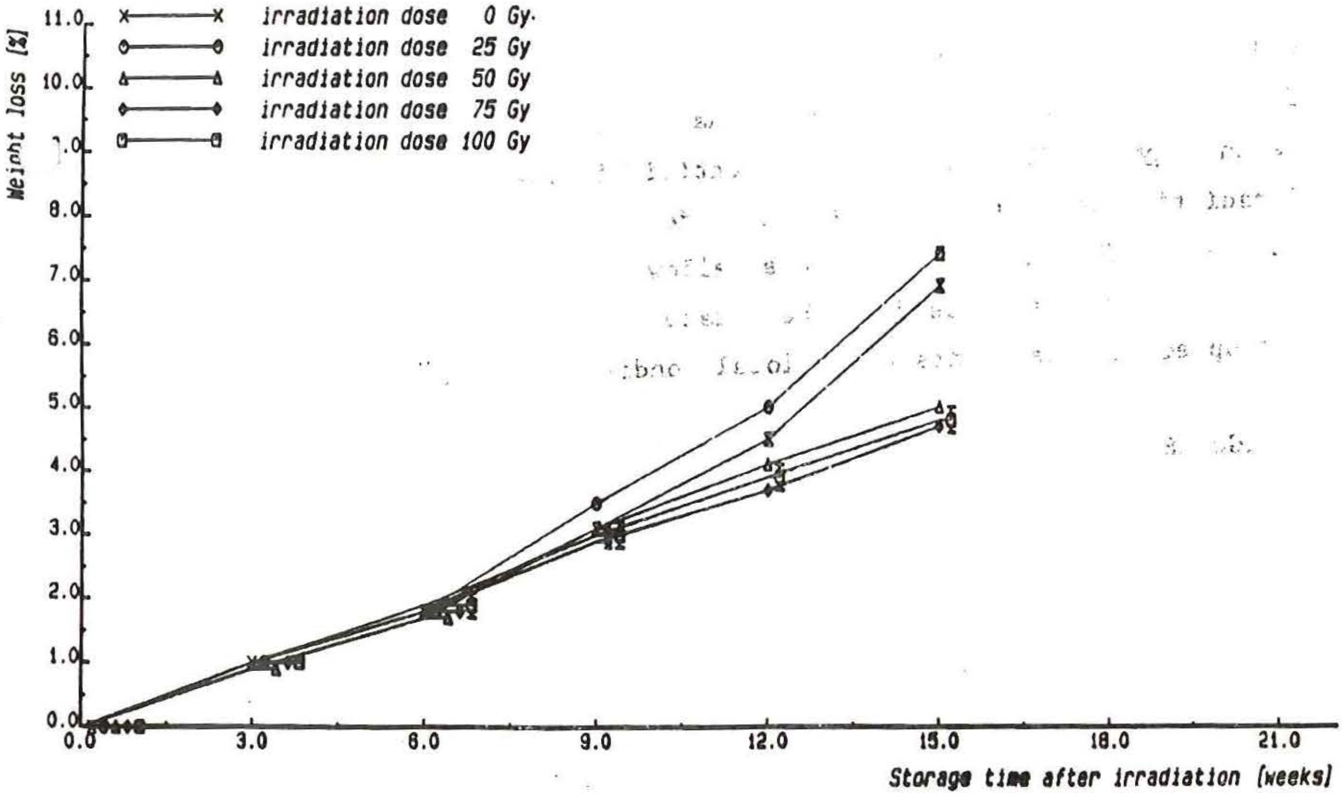

Figure 2 : Average weight loss +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

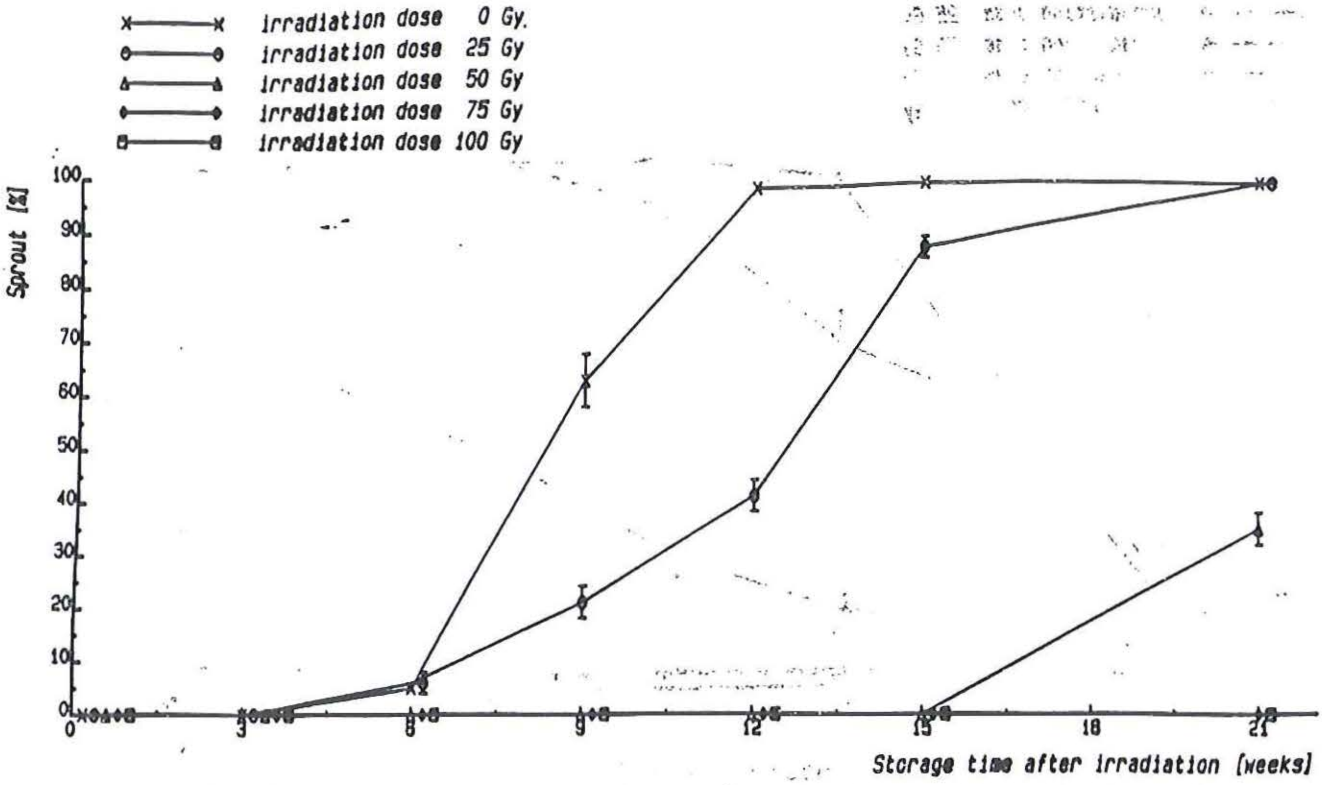

Figure 3 : Average sprout percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 0 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

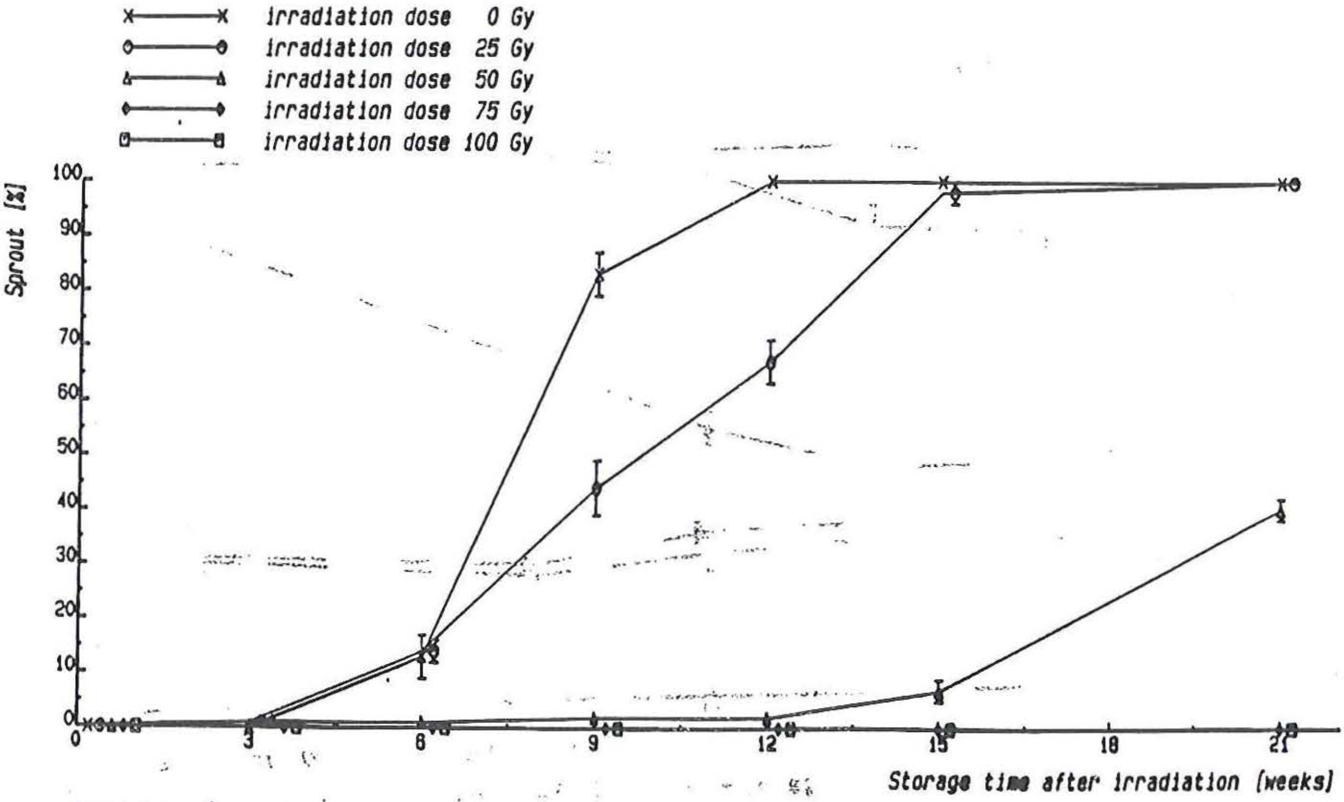

Figure 4 : Average sprout percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

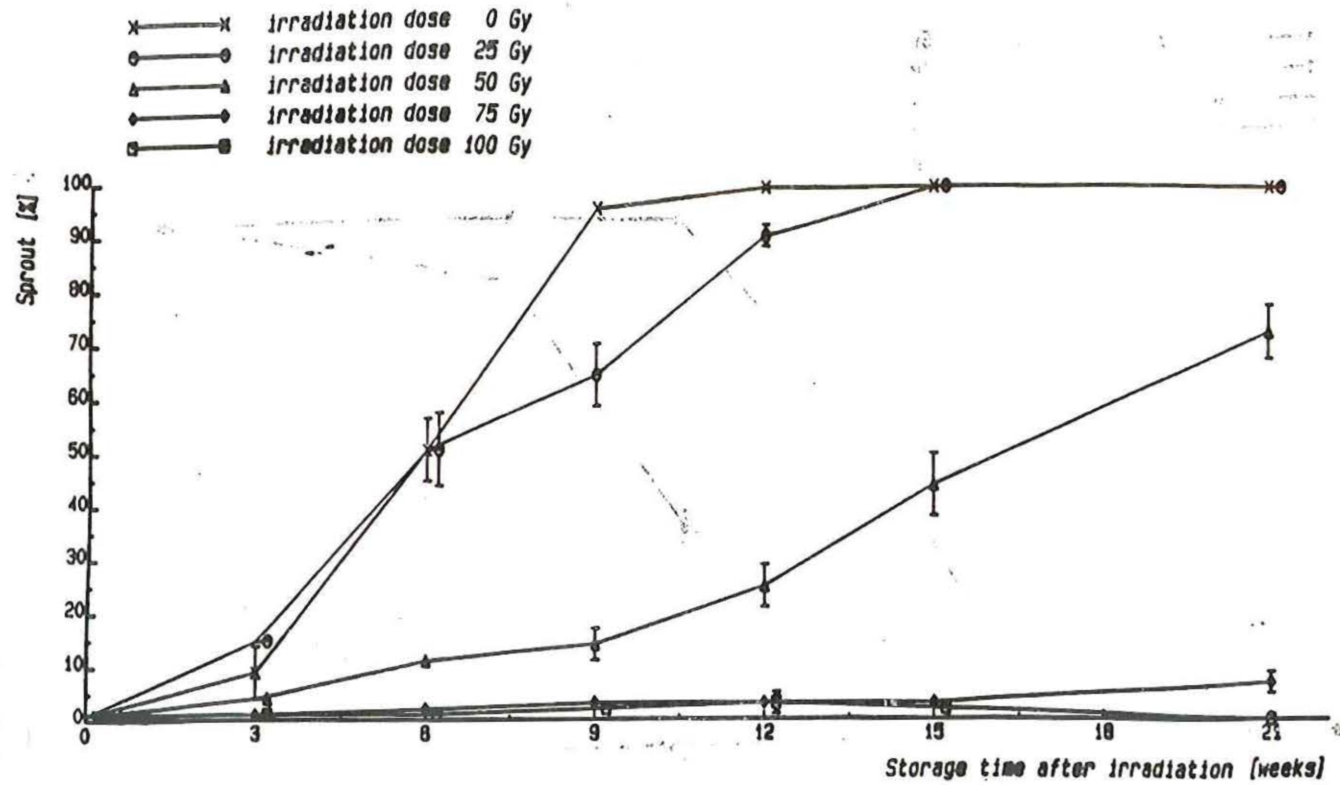

Figure 5 : Average sprout percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 4 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

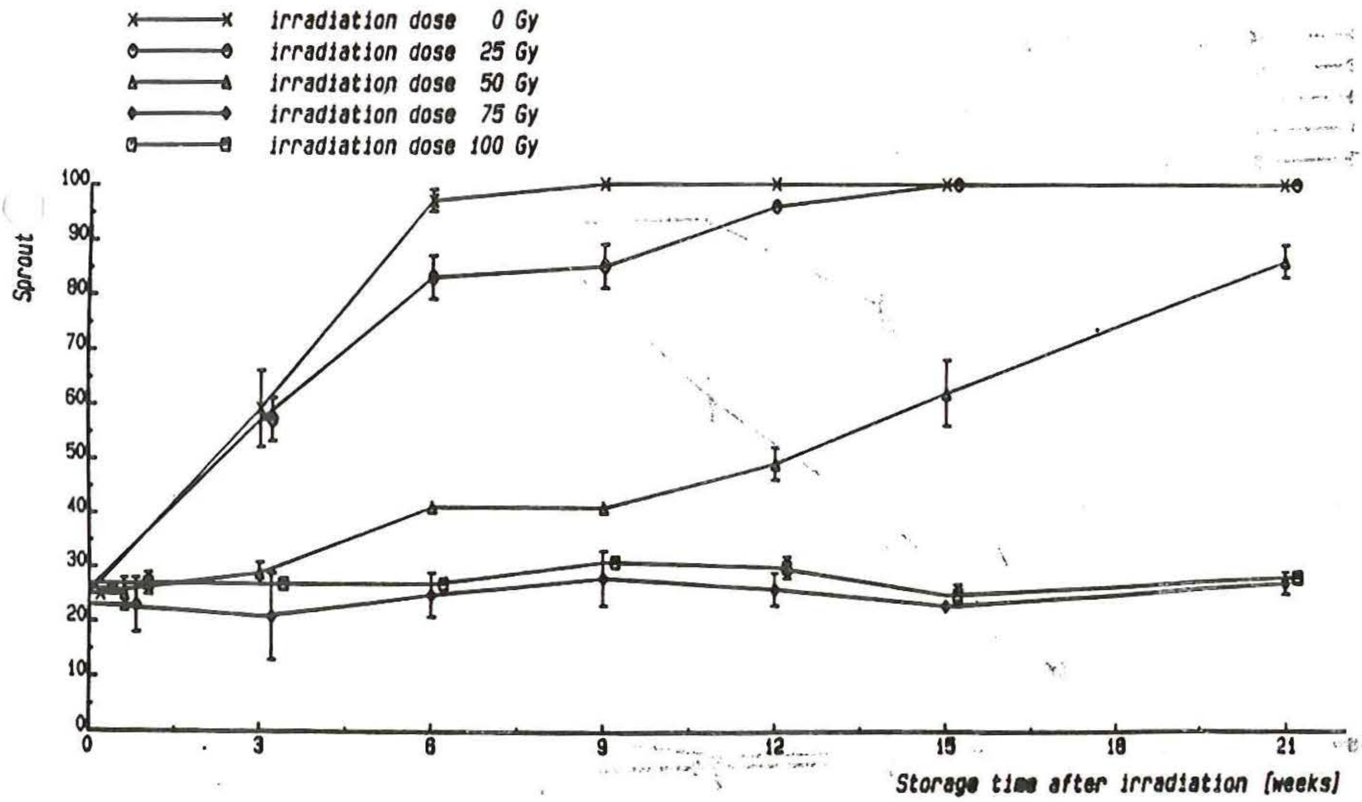

Figure 6 : Average sprout percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 8 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

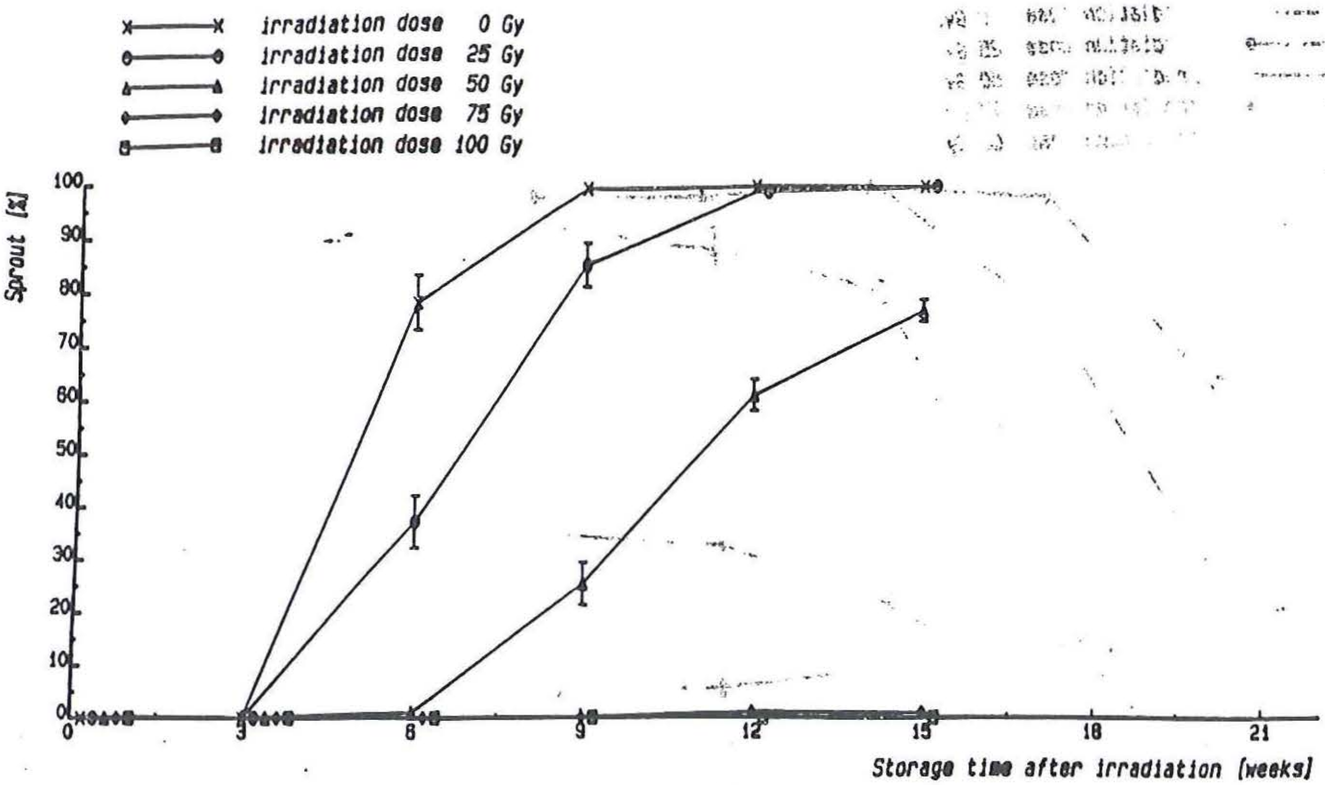

Figure 7: Average sprout percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 0 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

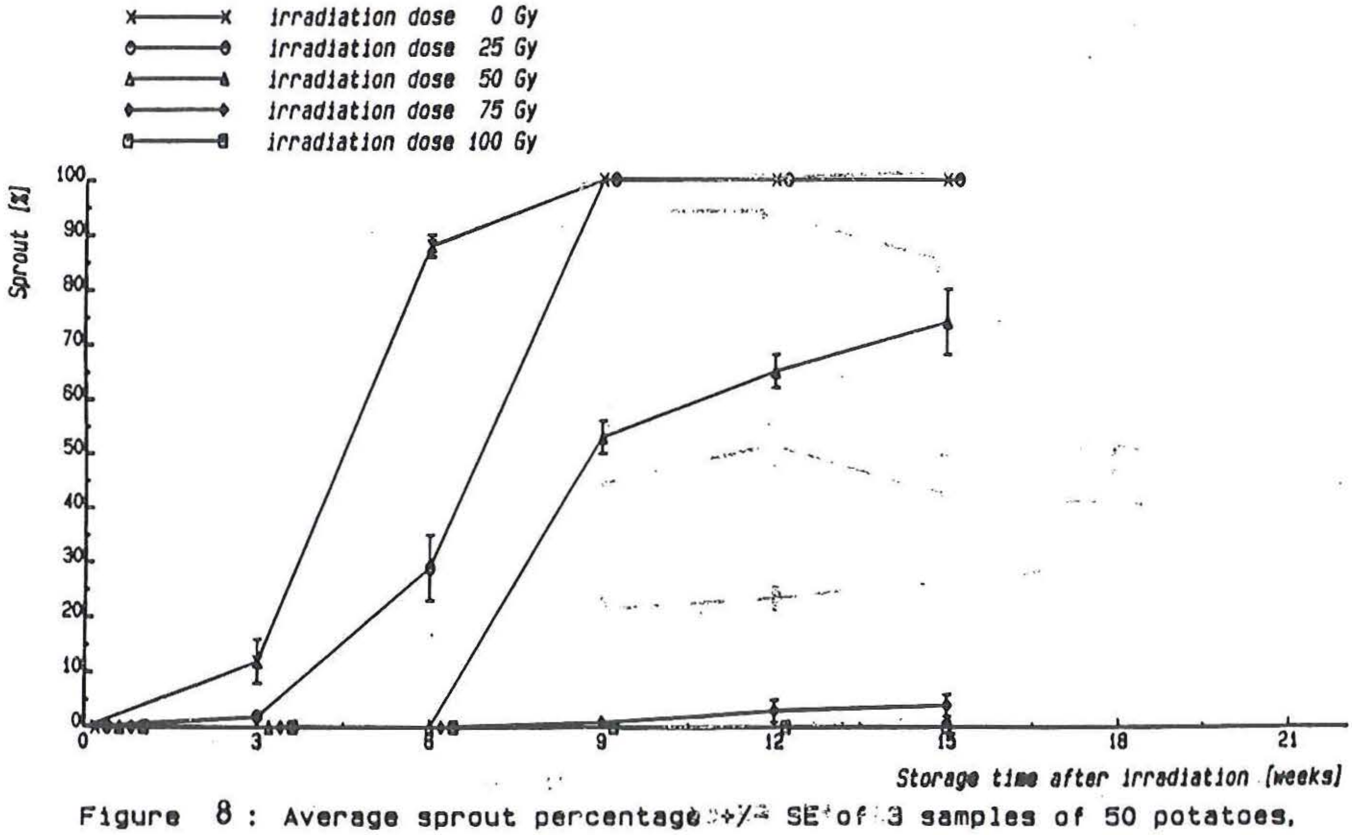

Figure 8 : Average sprout percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

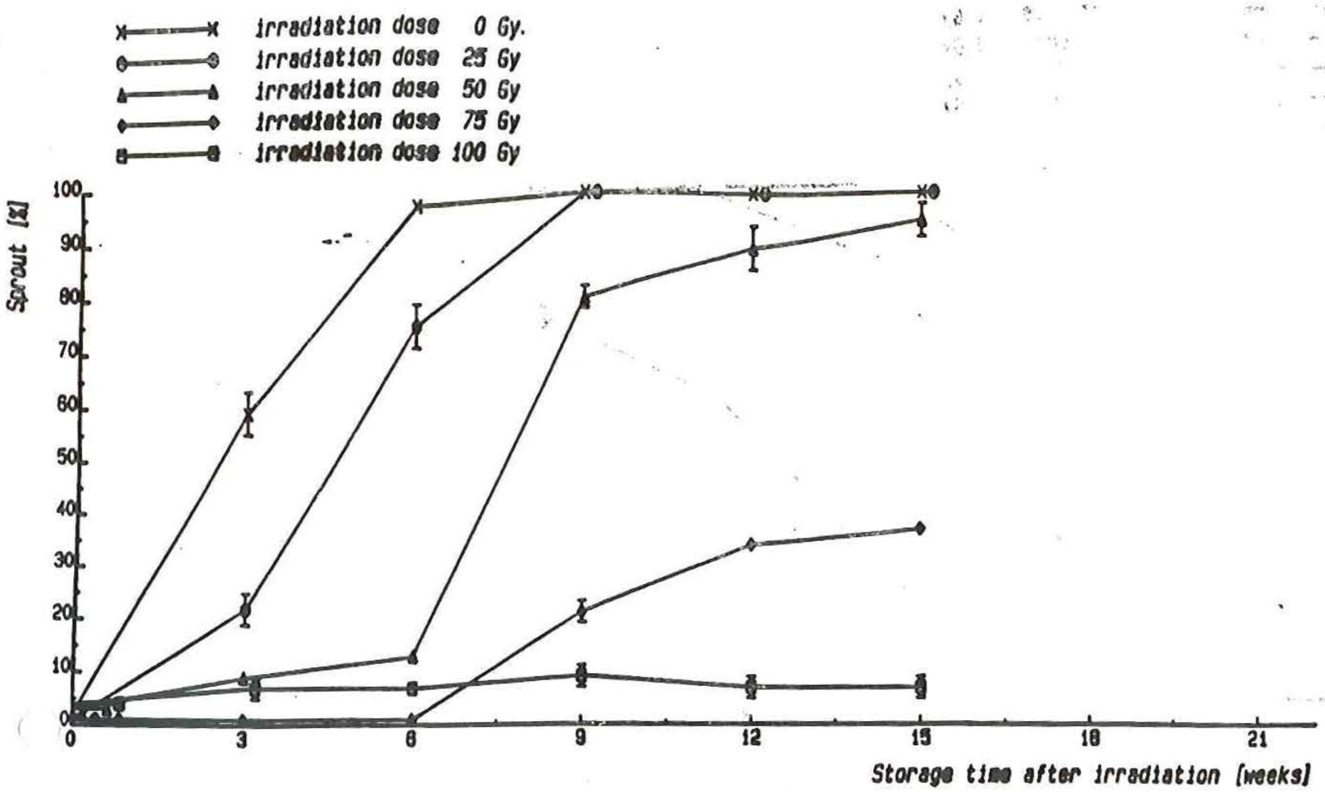

Figure 9 : Average sprout percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 4 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

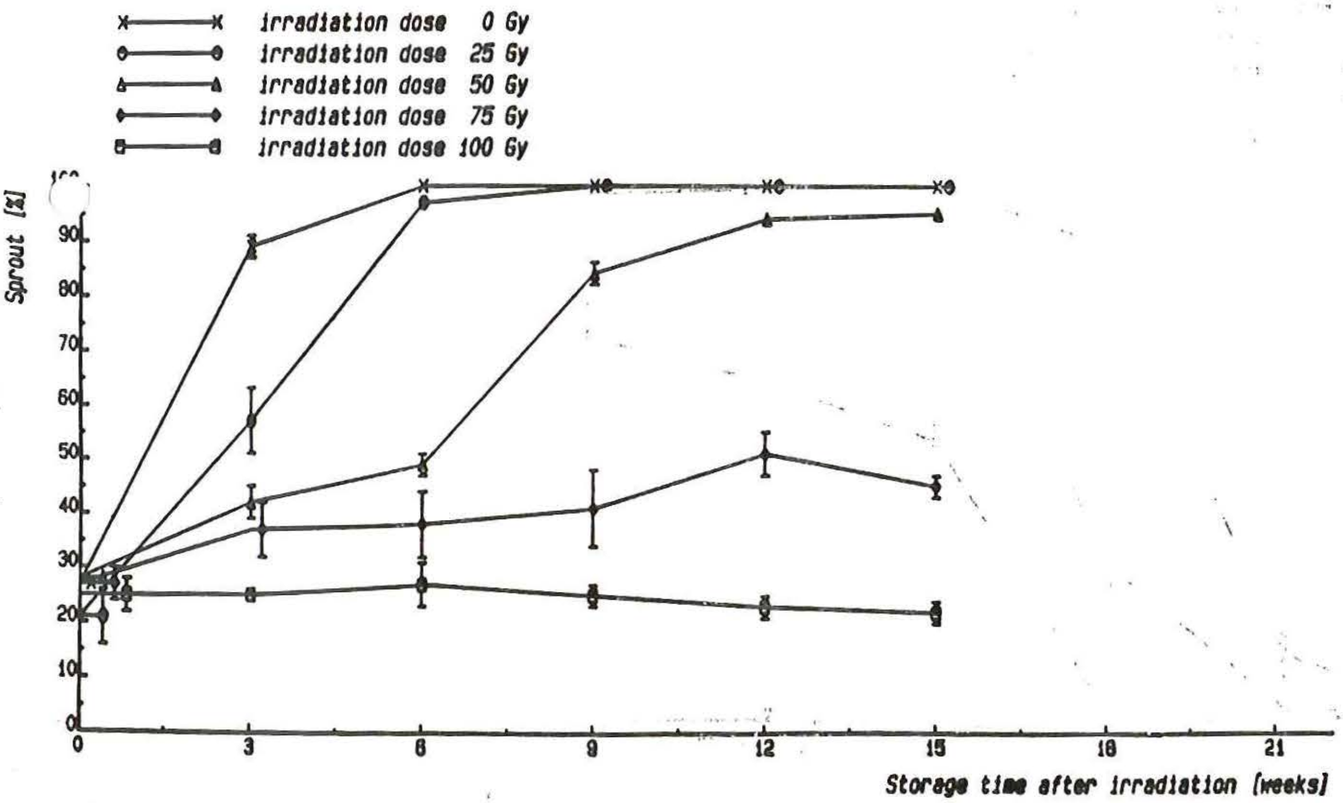

Figure 10 : Average sprout percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 6 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

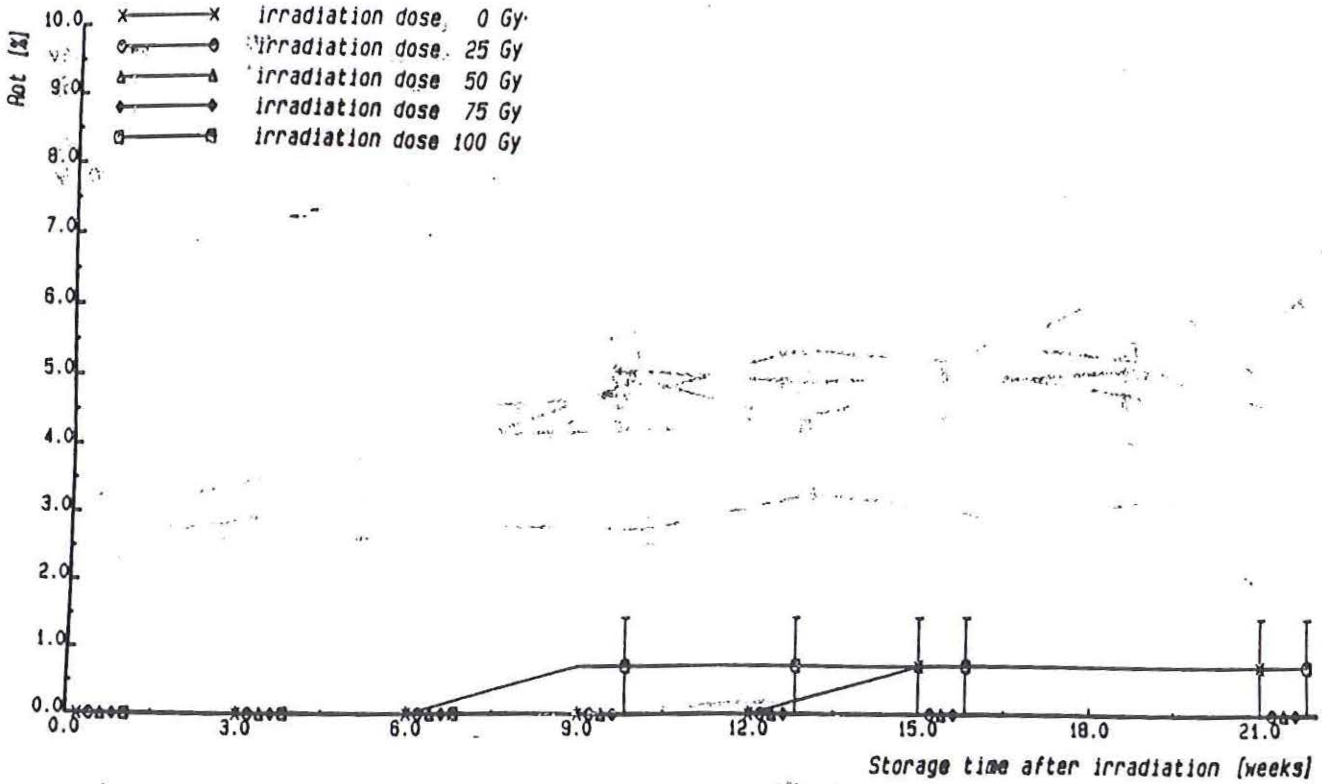

Figure 11 : Average rot percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

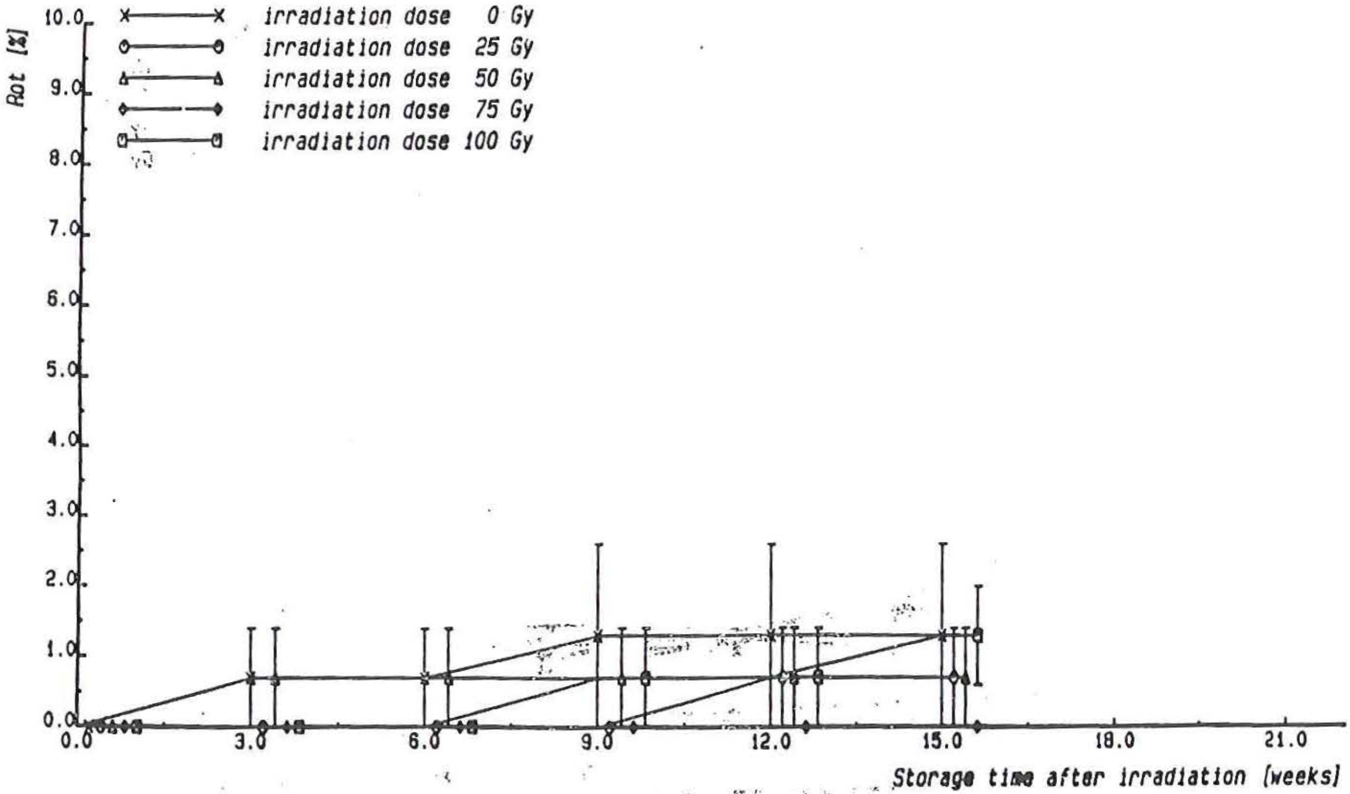

Figure 12 : Average rot percentage +/- SE of 3 samples of 50 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

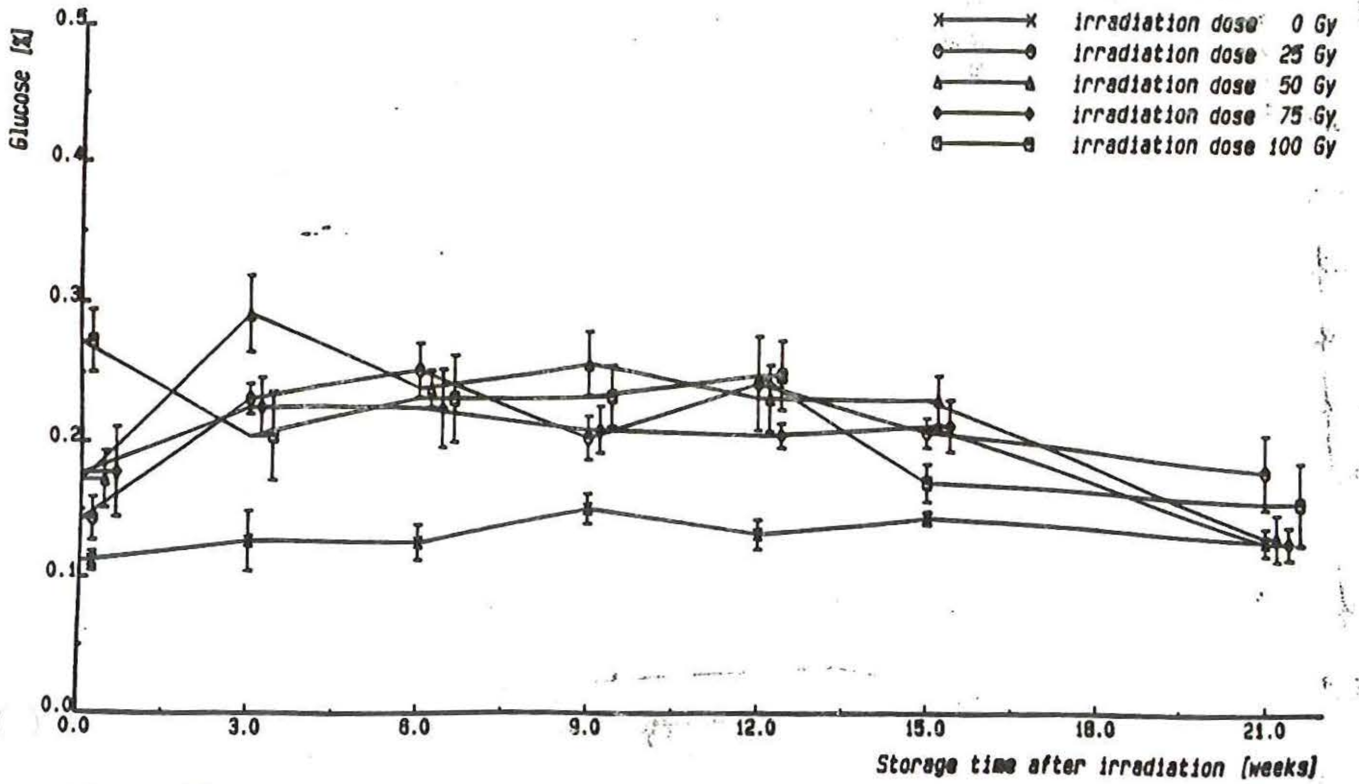

Figure 13 : Average glucose content +/- SE of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

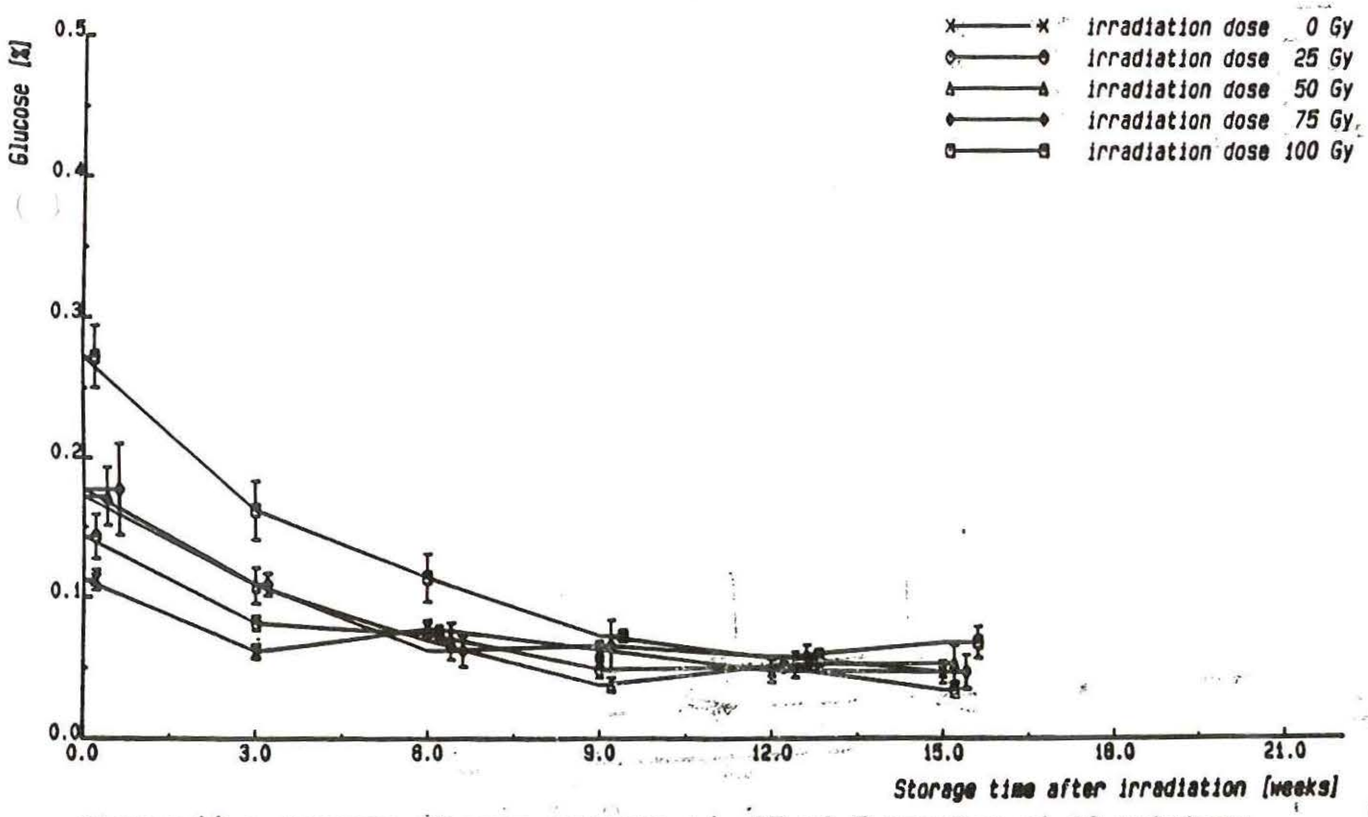

Figure 14 : Average glucose content +/- SE of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

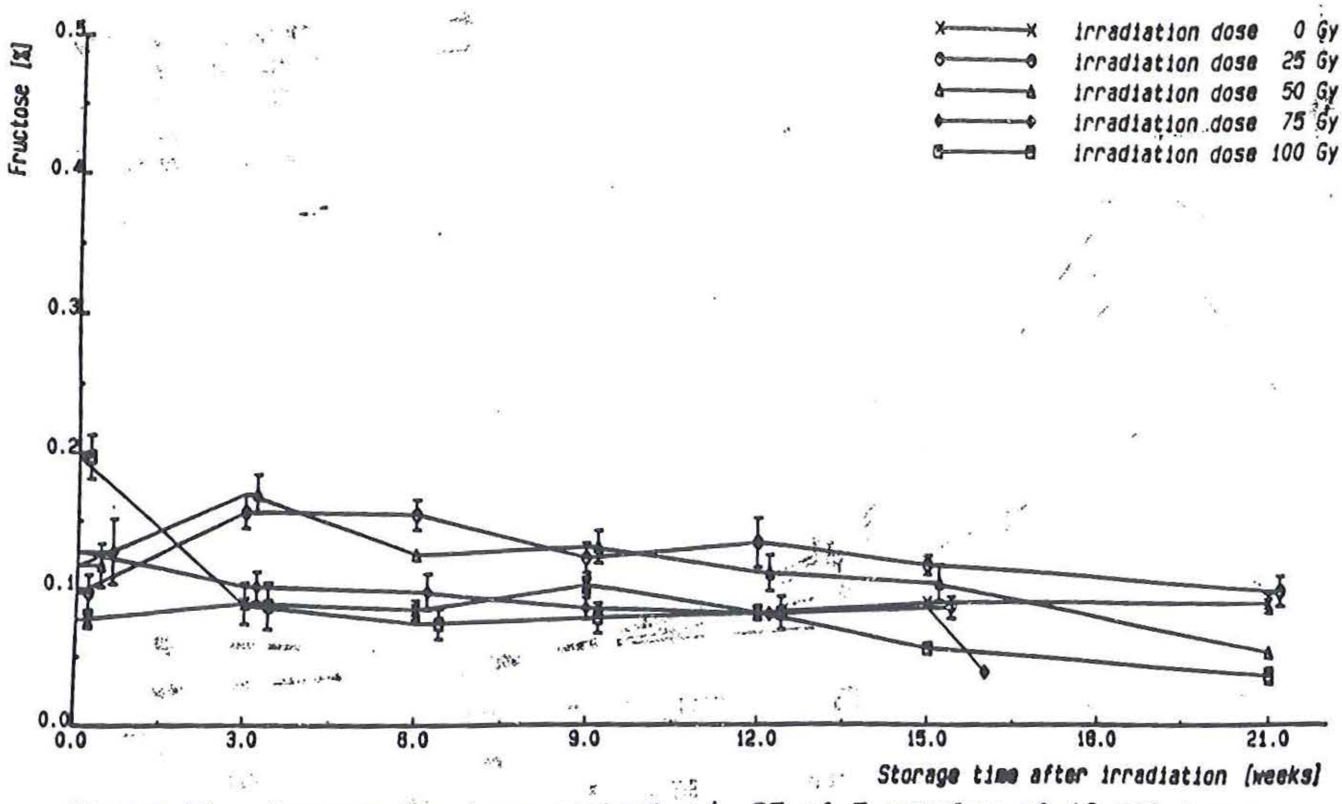

Figure 15 : Average fructose content +/- SE of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

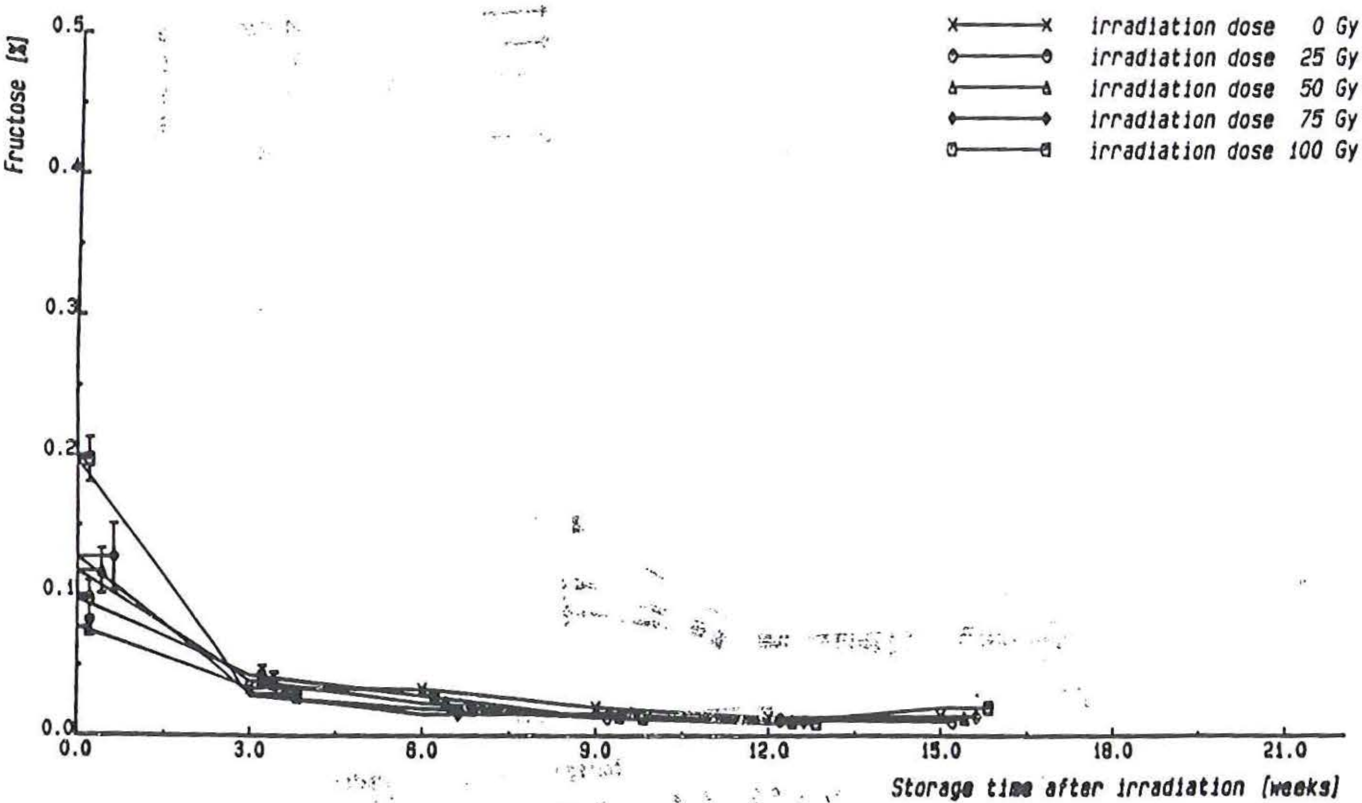

Figure 16 : Average fructose content +/- SE of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

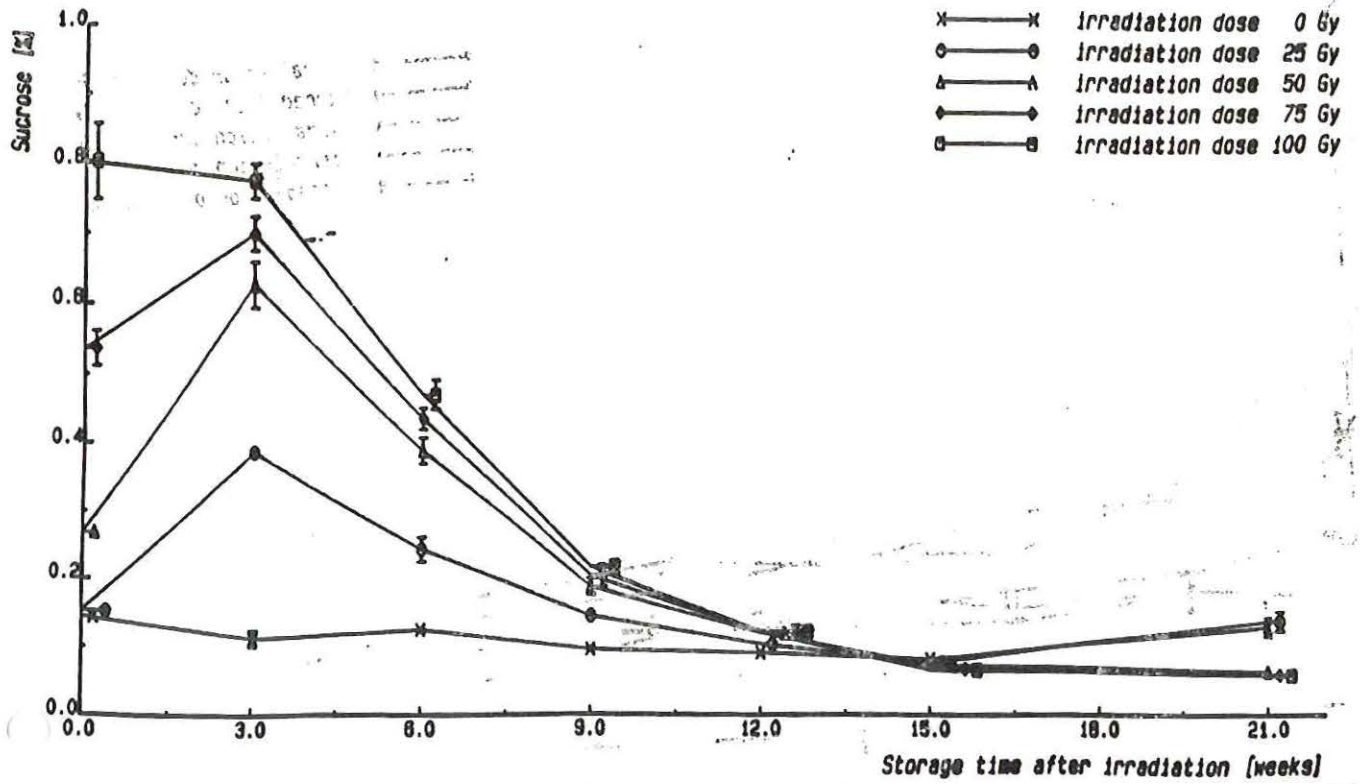

Figure 17 : Average sucrose content +/- SE of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

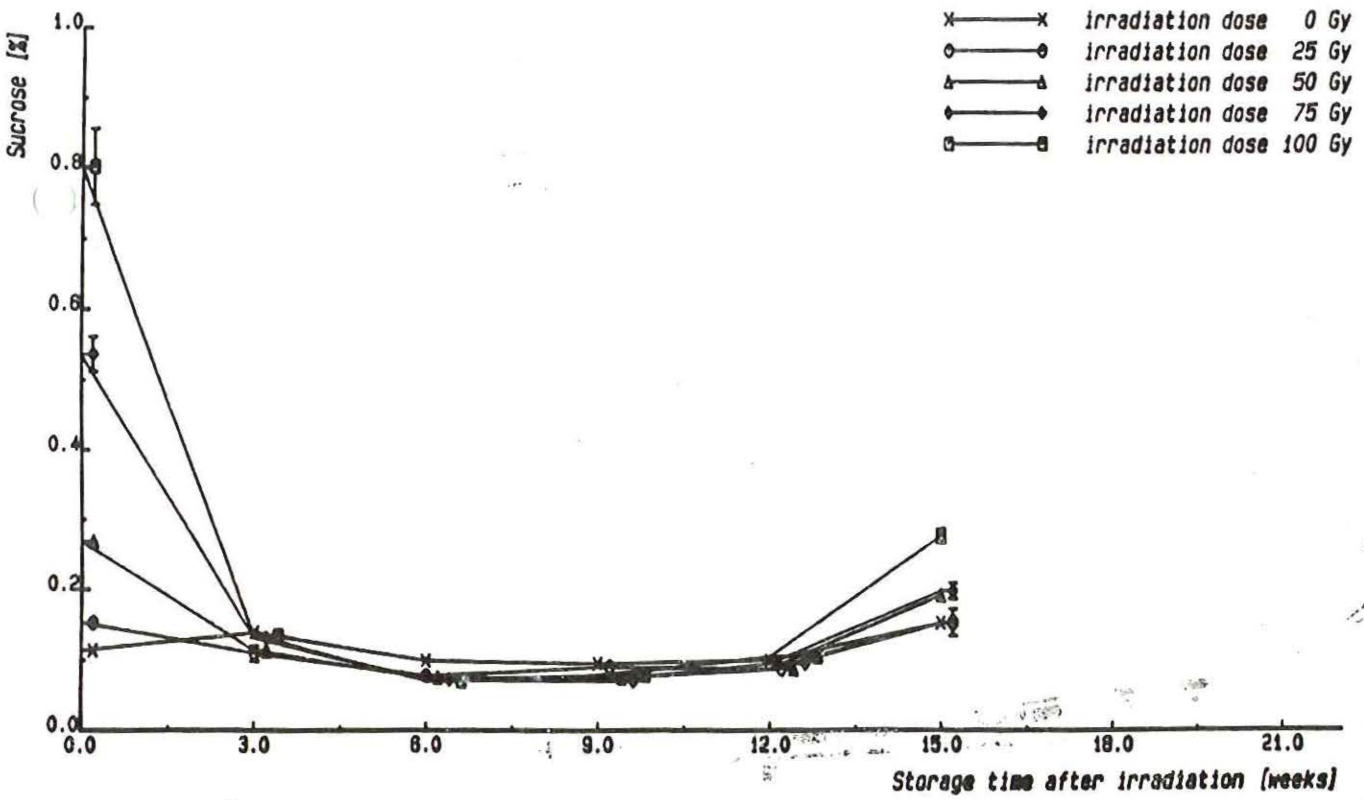

Figure 18: Average sucrose content +/- SE of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

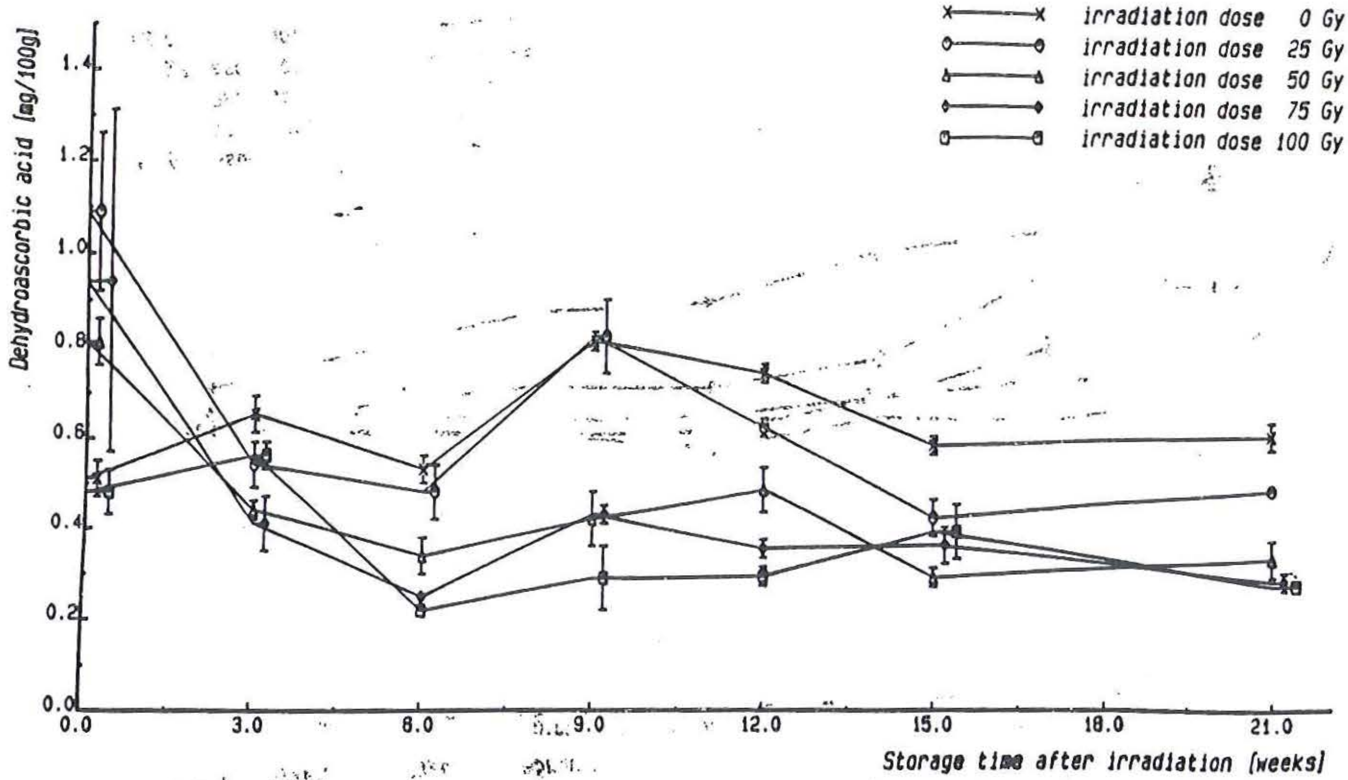

Figure 19 : Average dehydroascorbic acid content +/- SE of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

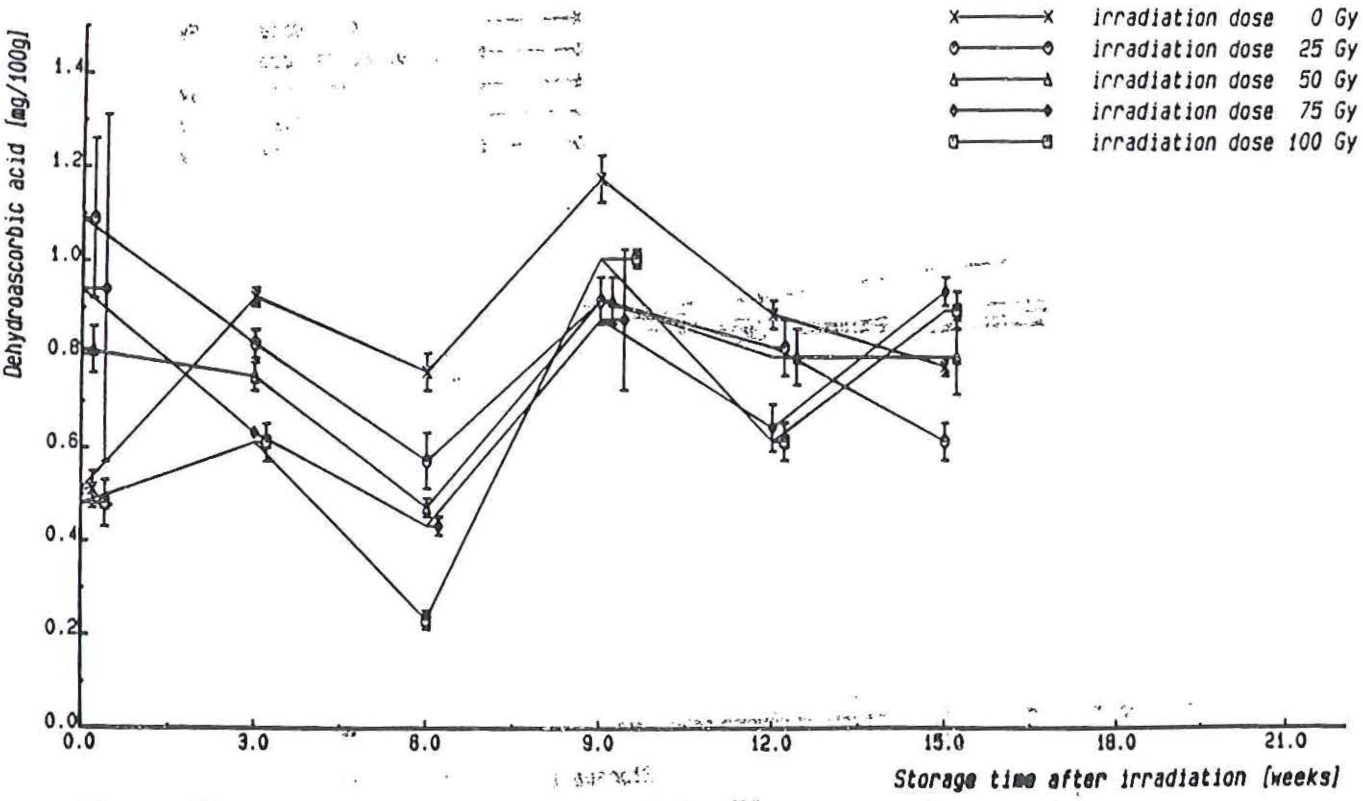

Figure 20 : Average dehydroascorbic acid content +/- SE, of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

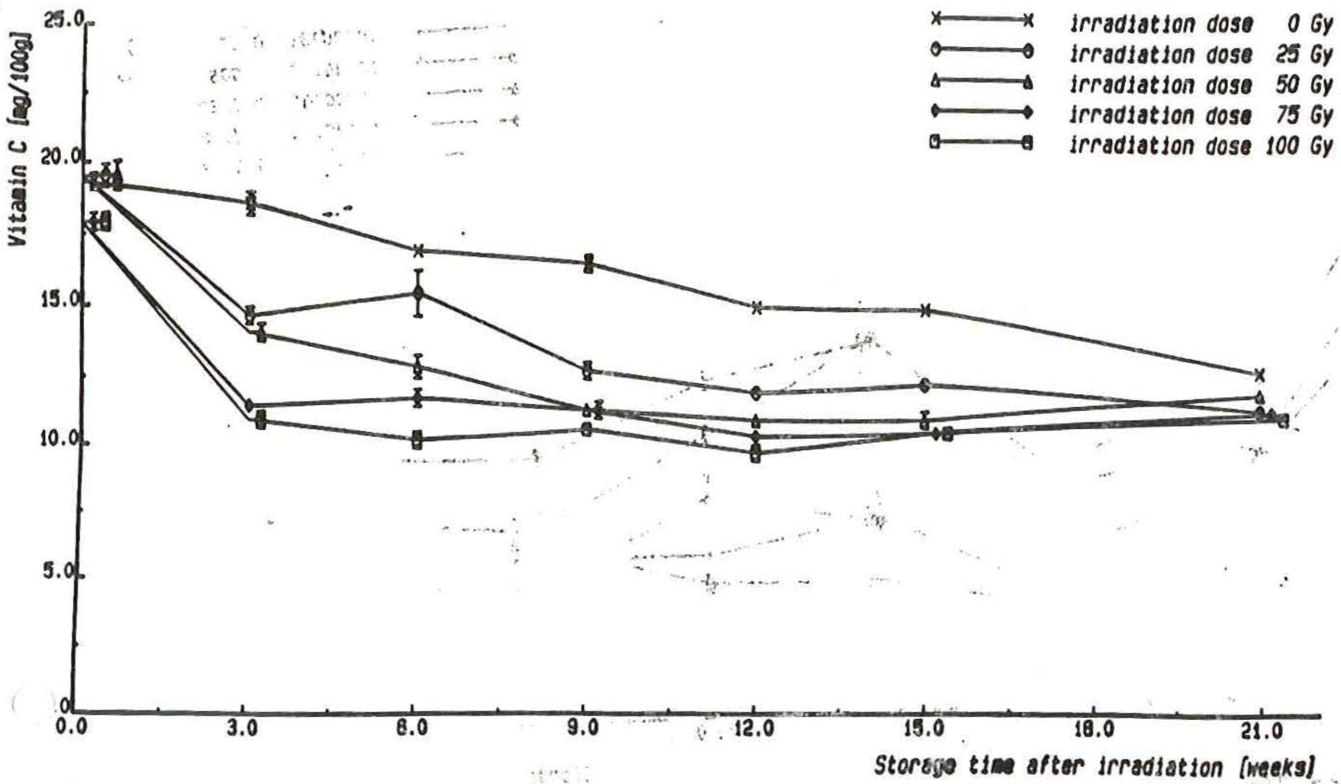

Figure 21 : Average vitamin C content +/- SE of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

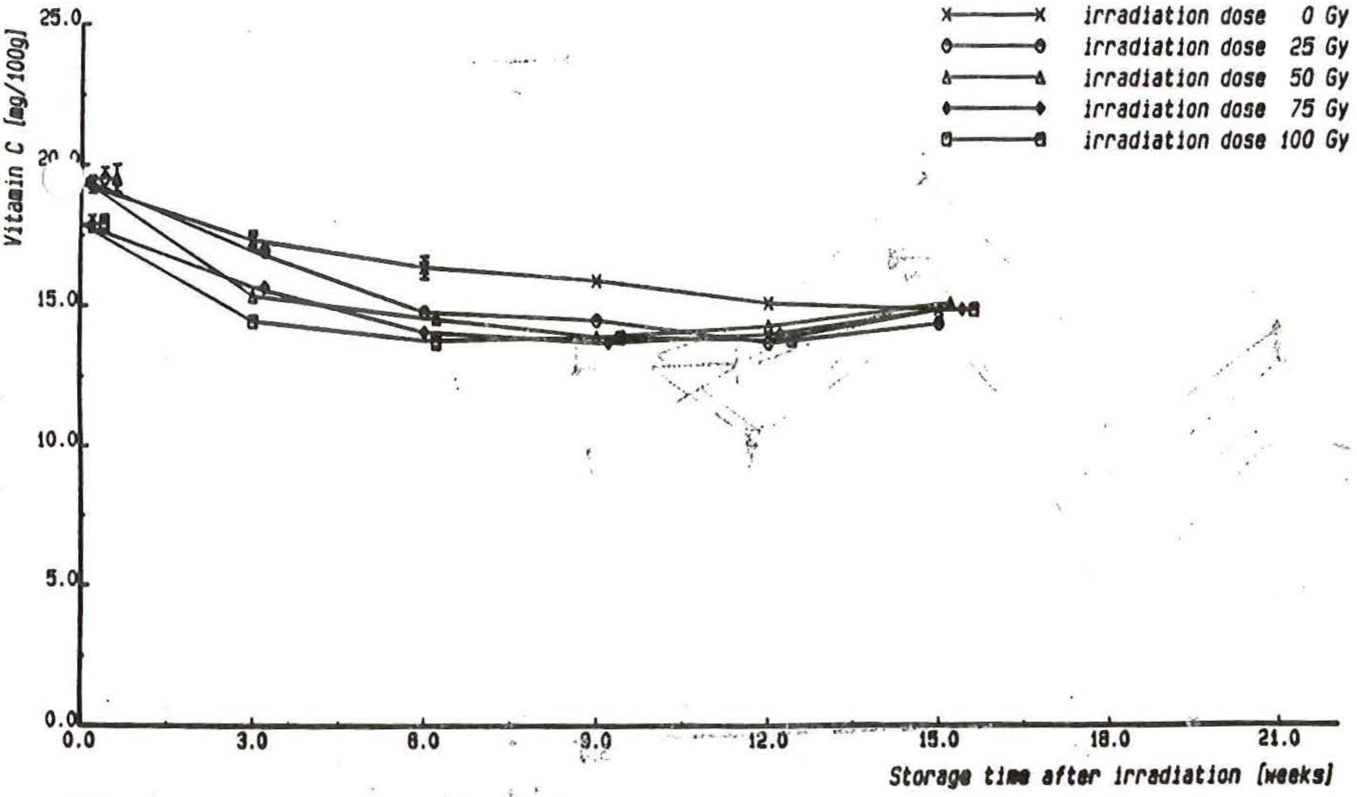

Figure 22 : Average vitamin C content +/- SE of 5 samples of 10 potatoes, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

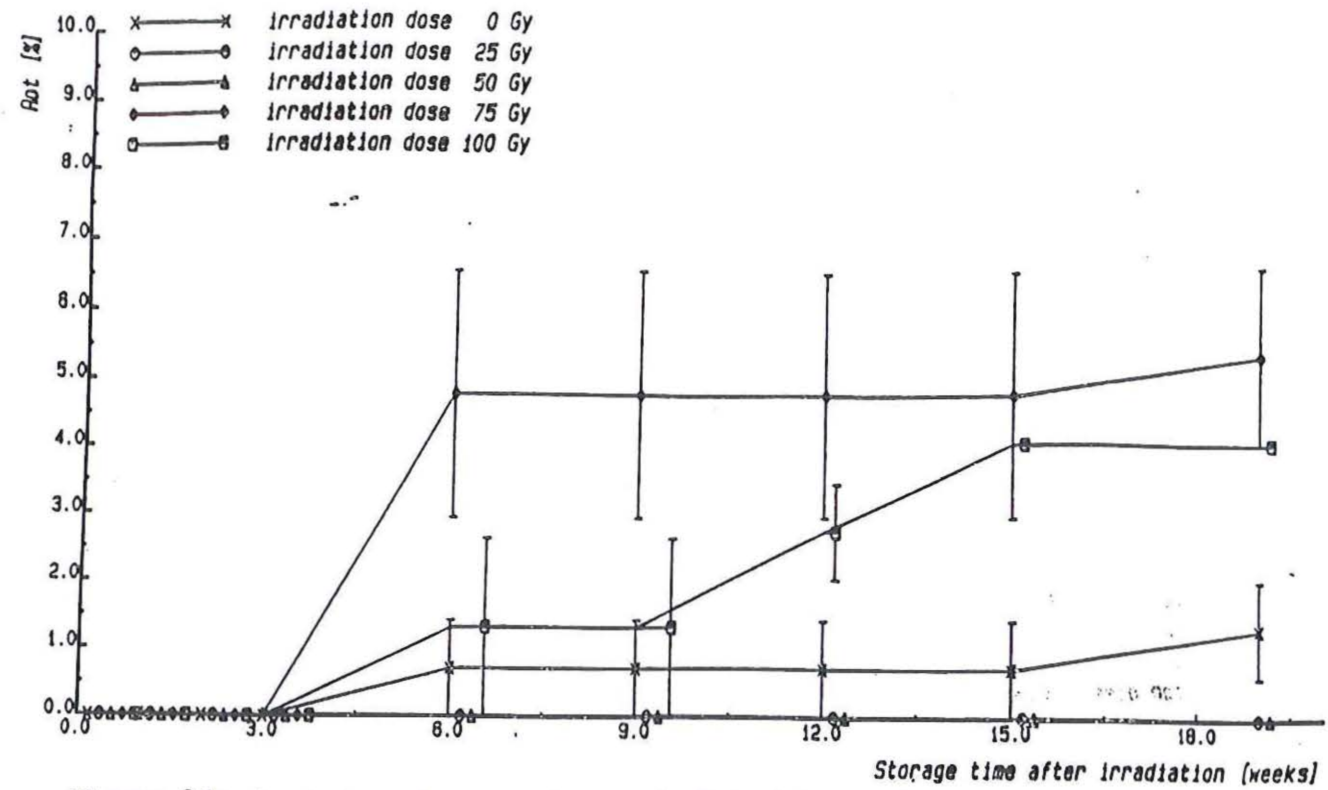

Figure 23: Average rot percentage +/- SE of 3 samples of 50 potatoes, infected with Fusarium Solani, post harvest irradiated after 0 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

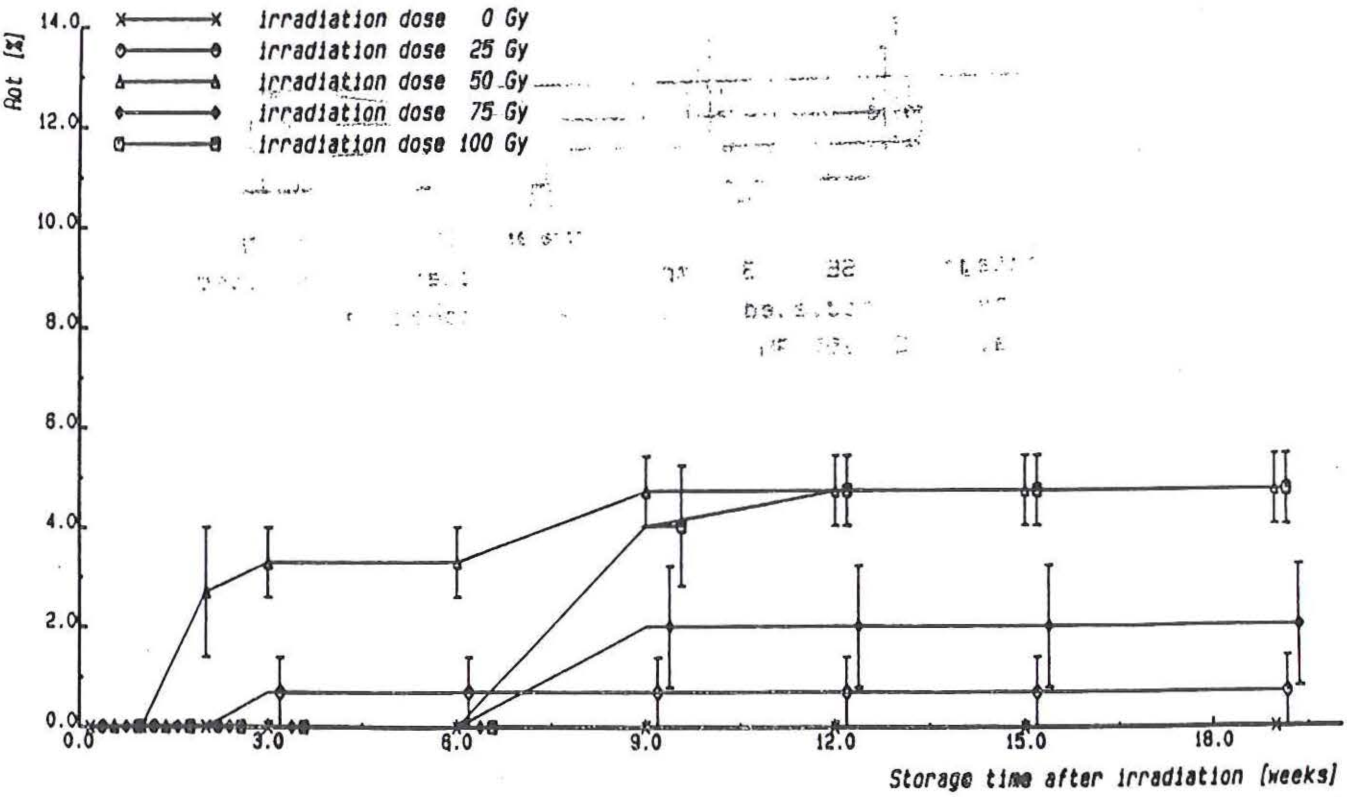

Figure 24: Average rot percentage +/- SE of 3 samples of 50 potatoes, infected with Fusarium Solani, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

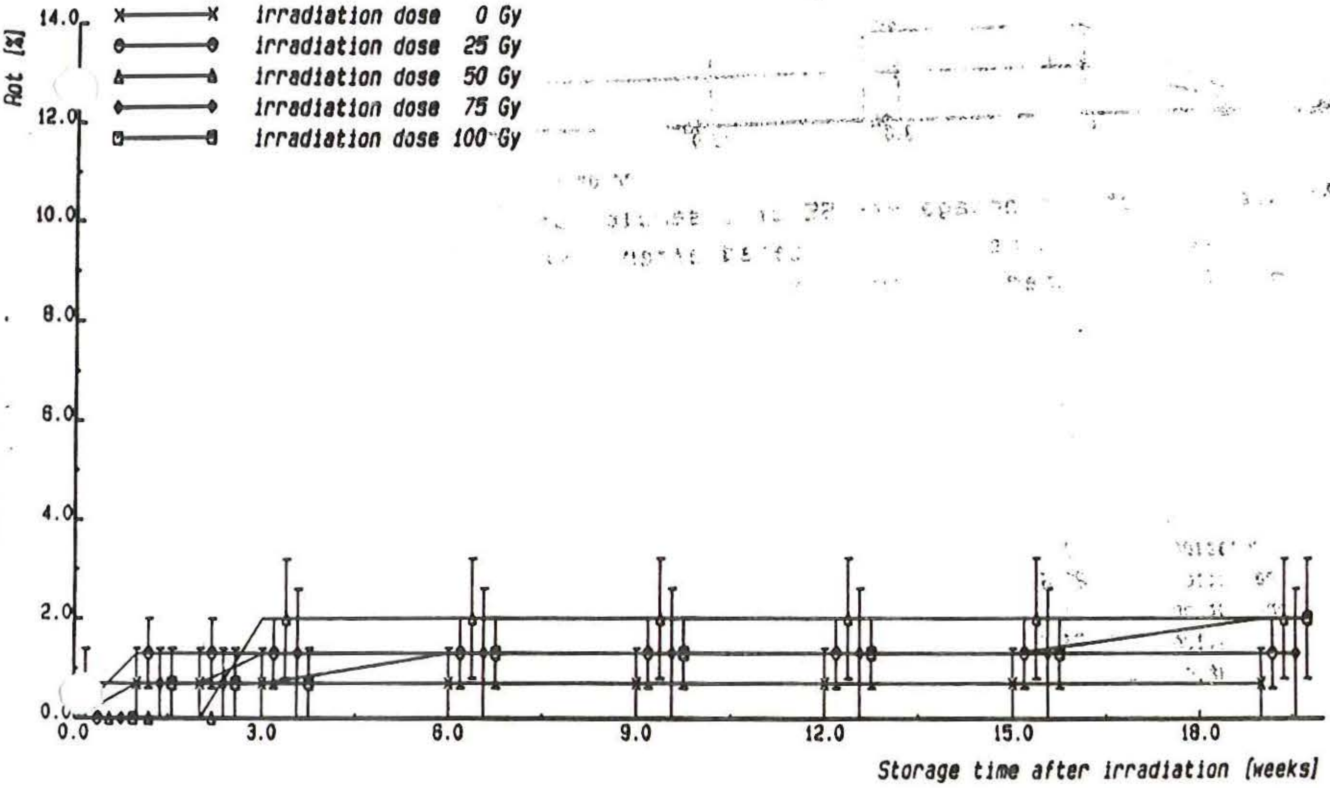

Figure25 : Average rot percentage +/- SE of 3 samples of 50 potatoes, infected with Fusarium Solani, post harvest irradiated after 4 weeks storage at 15'C, 85% RH and than stored at 10'C, 85% RH.

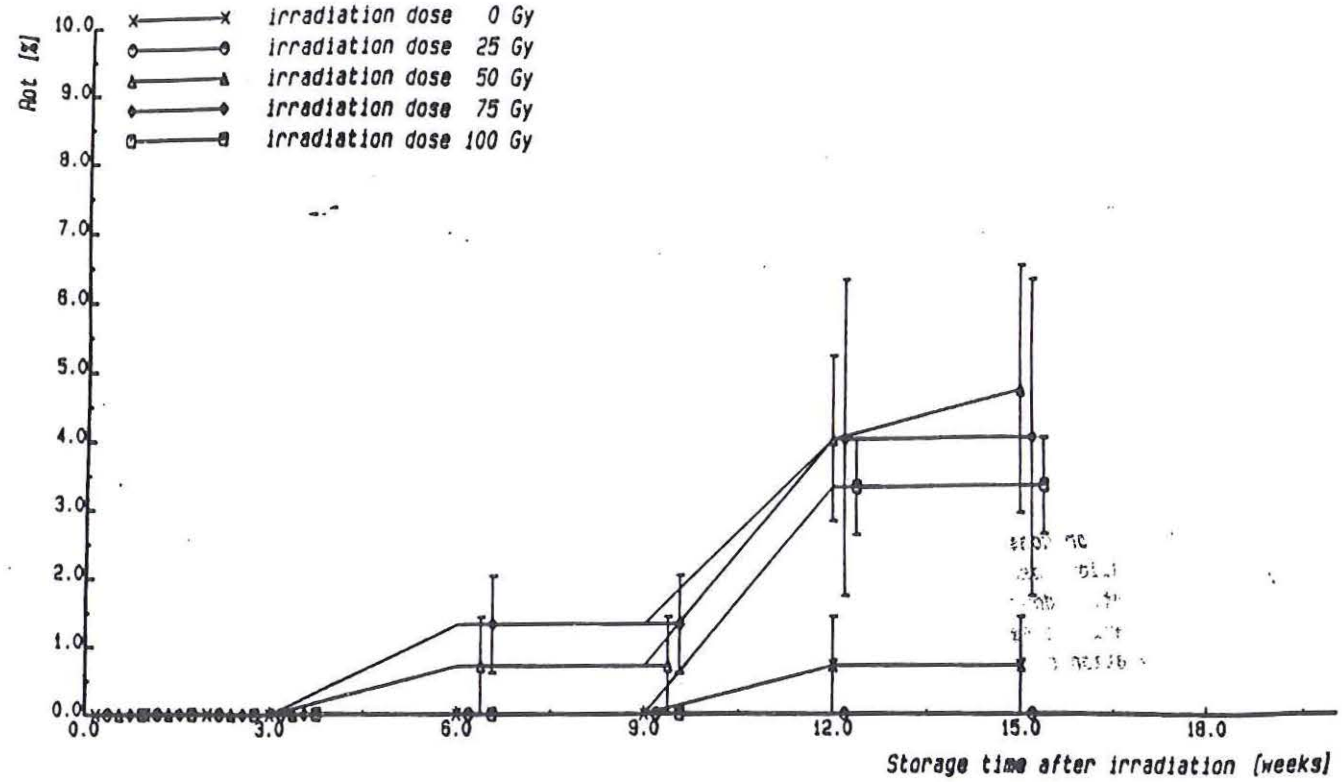

Figure 26 : Average rot percentage +/- SE of 3 samples of 50 potatoes, infected with Fusarium Solani, post harvest irradiated after 0 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

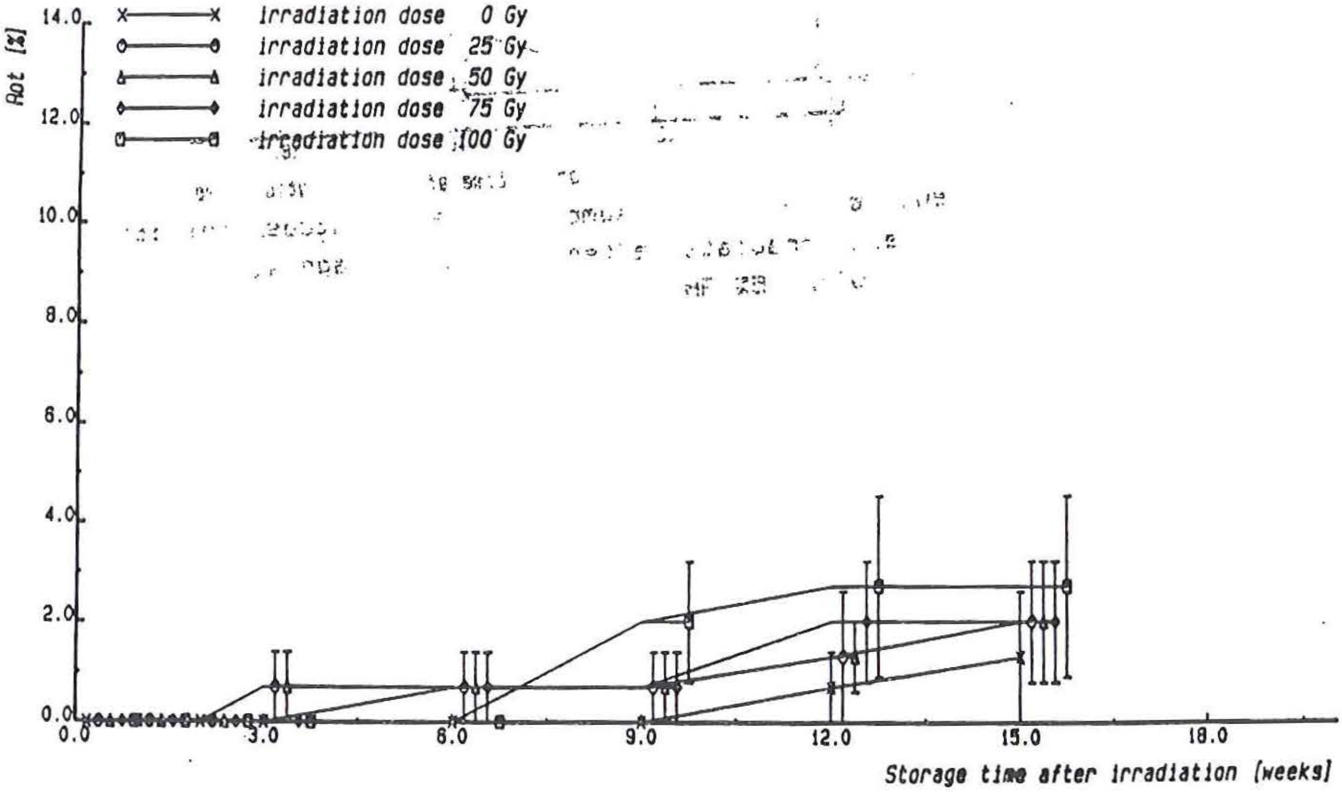

Figure 27 : Average rot percentage +/- SE of 3 samples of 50 potatoes, infected with Fusarium Solani, post harvest irradiated after 2 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.

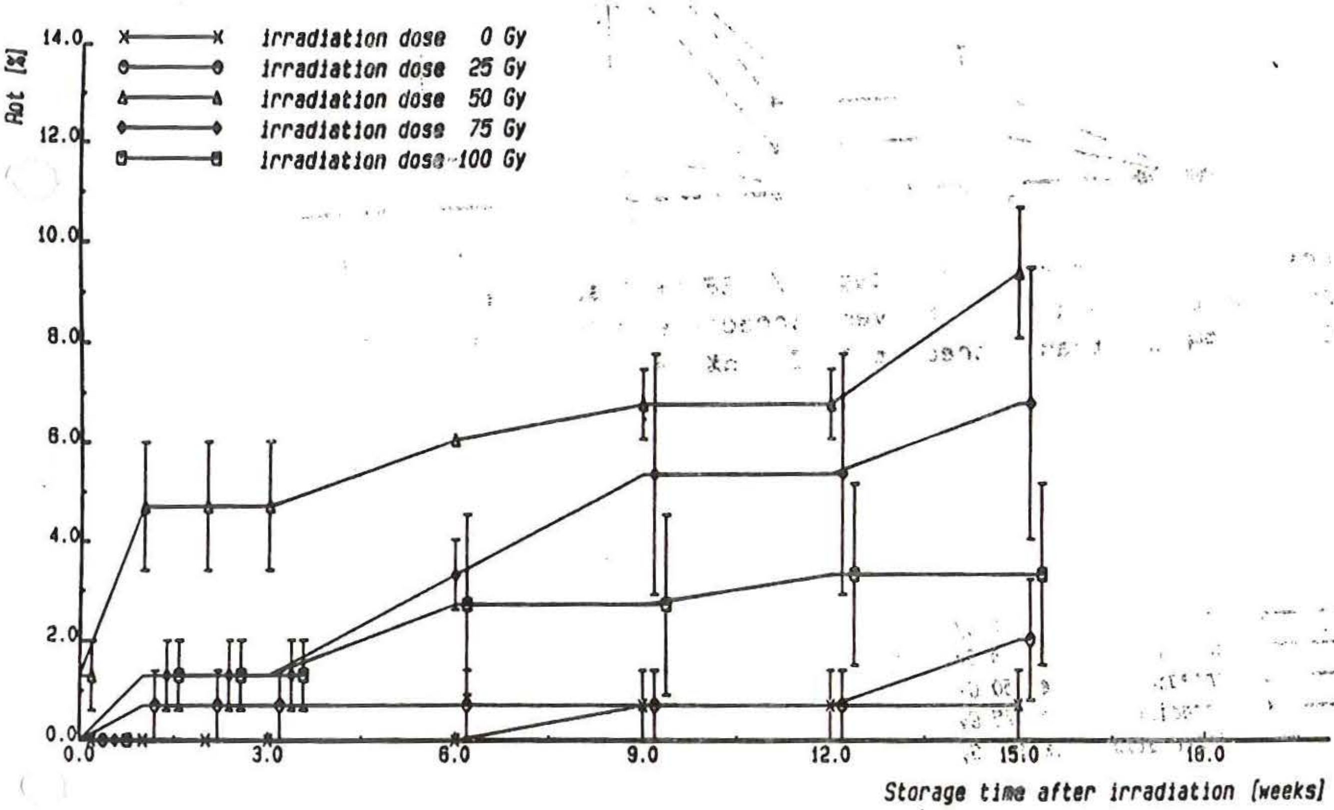

Figure 28 : Average rot percentage +/- SE of 3 samples of 50 potatoes, infected with Fusarium Solani, post harvest irradiated after 4 weeks storage at 15'C, 85% RH and than stored at 20'C, 85% RH.