EFFECT OF GAMMA IRRADIATION ON THE SHELF-LIFE OF ONION (*Allium cepa* L)

BY

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D E C L A R A T I O N

This work is solely the work of the author and has not been presented elsewhere for the award of a degree.

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DEDICATION

This thesis is dedicated to the Creator of onion who knows exactly what happens when gamma rays pass through it.

A C K N O W L E D G E M E N T S

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ABSTRACT

The effect of gamma irradiation on the shelf-life of onion was investigated. Onions of variety DS x WS'78 and DS'79 harvested 14 days prior to the experiment were treated at about 25°C with 5,8 and 15 krad doses of gamma irradiation. Bulbs were stored in a well ventilated room (temperature 20-25°C and RH 20-82%) in vegetable mesh bags on wooden shelves for 7 months. Onions were weekly investigated for sprouting and rotting- Chemical analyses were carried out monthly for ascorbic acid, fl -our, protein, dry matter, lipid, ash and reducing sugar.

Irradiation dose of 5-15 krad completely inhibited sprouting throughout the whole storage period but irradiated bulbs showed a higher tendency to rot. In comparison with the control, irradiation did not have any significant effect on ascorbic acid, dry matter, flavour and lipid but the protein content was siginificantly lower in the irradiated bulbs. Irradiation had significant effect on the ash and reducing sugar. The compositional differences found between irradiated and untreated onion seem to be of no nutritional or organoleptic significance - Almost 100% loss was recorded for local storage trial.

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"The ability to preserve food is a prerequisite for civilization".

Dr. Ari Brynjolfsson

1977

CHAPTER ONE

I N T R O D U C T I O N

Onion has been known and cultivated as an article of food from the earliest period of History. Records from as early as the 5th century B.C. showed that workers engaged in building the cheops pyramid consumed large quantities of onion (Greig and Lockwood, 1969). The demand for onion is world-wide. Their use is not limited to any nationality, and they are probably as widely grown as any cultivated crop (Jones and Mann, 1963a).

Traditionally, onions have been regarded as being consumed mainly for their flavour. In Nigeria, it probably constitutes an ingredient of at least one meal per day in most house holds depending on whether supplies are available. Apart from its use as flavour, onion plays some roles in Medicine (Irvine, 1930; Dalziel, 1937; Stoll and Seeback, 1951; Jones and Mann, 1963b). In Nigeria onion has been used to cure diseases such as fever and to relieve earache (Ikram, 1971).

Nigeria exports onion to the neighbouring West African countries of which Ghana is one (Sinnadurai and Abu, 1977). During storage serious losses of onions occur. Reduction of post harvest losses would significantly increase the

total availability for consumption and exports. Improving the conditions of preservation is therefore very important economically for the country.

Onion Production and Marketing in Nigeria.

Production - Onions are produced mainly in the Northern states of Nigeria under intensive systems of agriculture. The main commercial crop is grown during the dry season. Estimated onion production in the country increased from 68,000 metric tons in 1958/60 to 86,000 metric tons in 1969/70 (Olayide et al, 1972). The average annual output of onions in Nigeria is 77,000 tons with an average increase in production of 2.6% (Federal MANR, 1974).

Marketing - Part of the harvested crop is transported to the South by road or rail mainly by Hausa traders. The nation wide demand however, is not successfully met at every time of the year.

The price of onion is low when the bulb of the dry season crop is harvested (Feb-April) because of large quantities of wet, immature bulbs rushed into the market. At this time, the price of onion per bag (about 100kg) is as low as ₦3.00. At the time of scarcity (October-Dec.) the onion price may increase by as much as 600%. Thus, the

market price continue to fluctuate throughout the year.

Marketing of onion in Nigeria has never been organised (Green, 1971). Onions bought in some parts of the Northern states when transported to the South can yield about 500% profit. The retail system of selling bulbs appear to be haphazard but in the actual sense, the price per kg is fairly constant (Green, 1971).

There appears to be no quality demand by the consumer but there exist preferences for bulb size and in all areas traders prefer red bulbs and will never accept other colours. The reason for this being that yellow bulb varieties usually store only for a short period.

L I T E R A T U R E R E V I E W

Onion storage

Under all storage conditions, onions frequently suffer from sprouting, loss of water and dry matter, rooting and undesirable post harvest chemical and biochemical changes, (Roushdy et al, 1973). Among the factors affecting storage losses are: Choice of cultivar, agronomic practices, harvesting and curing, temperature and humidity and design of storage structures. Several workers have described the differences in storage life of different cultivars (Wheeler and Finch, 1962).

Woodman and Barnell, (1937) reported that poor keeping cultivars generally have a low dry matter content, high relative rates of water loss and a high total water loss, mainly in the period immediately following harvest. This results in softening, shrivelling and loss in weight. Such cultivars are frequently more susceptible to storage rots and sprout more easily (Foskett and Peterson, 1950). Pungent onions have a better keeping quality than less pungent ones (Jones and Mann, 1963b).

The effect of agronomic practices on the storage qualities of onions is far from being clear. Studies on the effect of fertilizer rates and irrigation on the storage quality of onion have been carried out (Vaughan, 1960). It was shown (Pande, 1969), that there was increased incidence of disease, particularly neck rot, following excessive nitrogen fertilisation and late irrigation. Celestino (1961) also showed that weight loss during storage was more in irrigated plots. Contrary to the above, Wayse (1967), reported that nitrogen application (45kg/ hectacre) significantly reduced weight loss in storage and had a variable effect on sprouting. He further noted that the addition of potassium and phosphorus had no effect on the keeping qualities of onions.

Jones and Mann (1963d), concluded that excessive application of nitrogen late in the growing season will produce bulbs with thick necks and because these thick necks do not shrink easily on drying such bulbs do not keep well on storage.

Onions stored with tops particularly those with shorter topping kept better than those stored with tops removed (Hoyle, 1947). There is however a danger of excessive neck rot developing in onions stored with tops. It is also important to note that where large quantities of tops are placed in storage, this may affect the airflow between bulbs and increase wastage (Green, 1972).

Effect of harvest date upon the keeping qualities of onion is controversial. Wallace and Hickman, (1945) reported a decrease in storage losses due to neck rot when bulbs were harvested prior to the tops falling over. They also observed a delay in sprouting following early lifting. Hoyle, (1947) on the other hand found that rots and total losses were always lowest for bulbs harvested with tops down and dry, and highest for bulbs harvested with tops either down and green or up and green. Romanowski, (1962) also noted a marked reduction in the percentage of diseased bulbs with a delay in harvest.

The state of maturity has pronounced effect on the weight loss of storage above 30°C but no significant effect in storage at 0°C. It is suggested in conclusion that in a season when a high incidence of neck rot is expected, early harvest is advantageous whereas in other season, late harvest might gain advantage (Thompson et al, 1972).

Bulbs properly cured kept better than non-cured bulbs(Hoyle, 1948). The method of handling has some effects on the storage of onions. Damaged bulbs have increased weight loss. They also are more exposed to spoilage micro-organism (Thompson et al, 1972).

The size of onion bulbs have been shown to affect both sprouting and water loss during storage (Karmarkar and Joshi, 1941). Karmarkar and Joshi, (1941) and Kapur et al, (1953) reported that in storage at 11°C, large bulbs sprouted at a faster rate than small ones but loss due to rot was more in small bulbs. Kunkel, (1947), however noted that there was no statistically significant differences in storage loss due to the size of the stored bulbs. Bolting seems to increase rot in onions (Van Amstel, personal communication).

Temperature and Relative humidity (RH) have been shown to affect sprouting, rooting, rotting, respiratory

rate, the incidence and severity of rots and nutritional qualities of stored onions (Ang, 1963). At maturity onion bulbs are dormant and the length of this period depends on the cultivar and the condition under which the bulbs are grown and stored (Thompson et al, 1972).

The effect of storage temperature and humidity on the keeping qualities of onions have been investigated (Wright et al, 1935). Wright et al, (1935) in their study concluded that the amount of sprouting in stored onion was influenced little by humidity but significantly increased with increase in temperature (over the range 0-10°C). Rooting increased with increase in relative humidity but not increase in temperature. Wright et al, (1935) further reported that the amount of disease, largely neck rot, showed general slight tendency to increase as both relative humidity and temperature increased. It was suggested (Wright et al, 1935) that the best storage conditions were a temperature of 0°C and a low relative humidity of about 64%.

Karmarkar and Joshi,(1941) showed a linear relationship between increase in temperature and weight loss of onion bulbs from 0-10°C. This was due to increased sprouting and root growth.

The feasibility of high temperature storage of onion bulbs has been demonstrated by Yamaguchi et al, (1957). High temperature prevents sprouting but encourages high water loss. Water loss however, can be reduced by maintaining a high humidity but root growth is enhanced (Thompson et al, 1972). As there is only a comparatively small increase in loss in bulbs stored at high temperature compared with those kept in cold storage it would therefore appear that high temperature storage of onion could be an economically viable proposition in the tropics (Thompson et al, 1972).

It is well documented that sprouting is a major source of spoilage of stored onion (Solanas and Darder, 1968). In recent years many growth regulating substances have been used to prevent or delay sprouting in stored onions. Some of these chemicals include Isopropyl phenyl carbamate (IPC) plus methylnaphthalene acetate (MNA) (Dallyn and Smith, 1952); 2-chloroethyl-trimethylammonium chloride (Thomas, 1969); Maleic hydrazide (Wittiwer and Sharma, 1950). Of the many chemicals tested, Maleic hydrazide has been shown to be the most effective in preventing sprouting and rooting of onion bulbs (Wittiwer et al, 1950). Maleic hydrazide does not produce any unde sirable flavour or

off-colour in the bulb. It has also been reported (Thompson et al, 1972) that Maleic hydrazide has no effect on total reducing sugars, ascorbic acid or dry matter content of bulbs.

Storage Structures.

Storage structures vary from simple shelters that do no more than protect from rain and sun, to well-insulated houses with heaters to prevent freezing and cold-storage rooms that provide constant low temperatures, to completely controlled atmosphere stores.

In India, special storage houses are built with grass-thatched roofs, and with sides made of bamboos that are suitably spaced to allow good air ventilation (Jones and Mann, 1963c).

In areas, where bulbs are harvested with their tops on, onions are tied together into bundles which are then hung up on bamboo poles in well ventilated shelters. This is commonly practised in Japan.

In the Western United States, much of the onion is stored in crates or bags in well ventilated and insulated houses. Crates, which are much preferred, are stacked on slatted floors in storage houses that are build so that

air circulates from below the floor, upwards through the crates, and out through vents in the roof. Alternatively, dry air can be forced up through the crates periodically by fans (Jones and Mann, 1963c).

In Northern United states, Canada and United Kingdom, onions are commonly stored piled in bulk in well insulated and well ventilated houses. The onions are piled on slatted floors with air tunnels below, through which air can be forced up through the bulbs. Refrigeration keeps the temperature of these ware-houses at about $0^{o}C$ throughout the storage period. Ventilated bulk storage of onion is considered cheap and also provides a satisfactory method of storing bulbs (Jones and Mann, 1963c).

The most recent development in storage structures is the use of controlled atmosphere stores in which the level of carbon dioxide, oxygen, and other gases can be regulated. Onions stored in this condition appeared superior to those stored in air at the same temperature but the use of such stores is very unlikely to be economical (Thompson et al, 1972).

Storage conditions and method in Nigeria.

Harvesting of dry season crop commences from late December and finishes at the end of March - the beginning

of April. If the prices are low in the market, the farmers may decide to store the bulbs. The local method of storage is often unsatisfactory, losses up to 75% have been recorded in a storage time of seven months- (Porter, 1976).

Onions are stored in different ways. One method is storing in specially constructed huts. These huts are raised 2-3 feet above the ground and have slatted floors usually made of guinea corn stalks. Walls are made of mud with a small door at one end. These walls are generally about 3 feet high and may or may not have ventilation holes. The hut is about 6 feet square which has a thatched roof made of grass which is about 6 feet high at the apex and protrudes about a foot over the sides of the wall.

Onions to be stored are heaped on the floor of the hut. In many cases no attempt is made to select damaged or slightly diseased onions, all are packed together. However, the very obvious bad onions are removed. The small door is then closed using a locally woven mat and the onions are checked at regular intervals. Up to 2 tons of onions can be stored in one hut by this method.

The storage time ranges from 3-8 months depending on:-

(i) The state of onions

(ii) The financial position of the farmer or trader

(iii) The prevailing market price for onions.

The lack of space between heaped onions restricts air circulation, allows the R.H. to rise, encourages disease-spread to adjacent bulbs and favours bulb sprouting and rooting. At this time of the year when the temperature is always above 20°C, the growth of both onions and pathogen is enhanced.

IRRADIATION OF ONION BULBS.

Food irradiation has become increasingly important over the last few years as a complementary food preservation technique.

The vegetables whose irradiation have attracted the most wide-spread attention have been potatoes and onions. Radiation of onions in particular has almost developed into an established technique (Sekhavat et al, 1978). Results gained in different countries are adaptable only to a certain extent to other conditions. This has therefore led to investigation of the effects of radiation treatment on specific varieties under local storage conditions in several countries (Sudarsan, 1972; Rahman et al, 1972; Cohen 1967; Farkas, 1975).

Radiation has proved to be a useful tool for the extension of the shelf-life of onions (Dallyn and Sawyer, 1959; Kahan and Temkin Gorodeiski, 1968; Kalman and Kiss, 1971; Nair et al, 1973; Kalman, 1975; Szell, 1976). Results obtained so far are promising. Much attention has been devoted to wholesomeness studies of food irradiation. Although irradiated onions has received clearance for human consumption in certain countries since 1958, (IAEA 1977), acceptability and wholesomeness is not yet completely elucidated. However, a provisional acceptance of irradiated onions has been given (Report of Joint FAO/IAEA/WHO, 1976).

Increasing interests by many investigators have been in the possibility of controlling sprouting and decay in onion by radiation. The optimum radiation dose that can fulfil the preservation requirement is not conclusive, but a maximum dose of 15 krad has been suggested (Roushdy et al, 1973). Efficiency of sprout inhibition of onion by irradiation treatment has been shown to depend very much on the period between the harvest and the irradiation treatment (Mullins and Burr, 1961; Nair et al, 1973; Takano et al, 1974; Thomas et al, 1975; Umeda, 1975). Effect on sprout-inhibition was relatively less if radiation takes place after the break of dormancy.

Some chemical changes in Onion bulbs as affected by gamma-radiation and Storage.

Assessment of the wholesomeness of irradiated onions through conventional animal feeding experiments has posed some difficulties as onions are not acceptable to Laboratory animals except in very small quantities (Bandyopadhyay et al, 1973). Information can however be inferred from analysis of changes in the chemical constituents of onions as a result of irradiation.

The reducing sugar content of onions under various physiological studies have been shown to increase during storage particularly under cold condition (Karmarkar and Joshi 1941; Yamaguchi et al, 1957; Mahmoud et al, 1978). There is no significant difference in the vitamin C content between the non-irradiated and irradiated onion bulbs (Mahmoud et al, 1978). Mahmoud et al (1978) also reported that the Vitamin C content of irradiated onion seemed to be independent of the date of irradiation treatment.

No major difference was observed between the amino acid composition of the untreated and irradiated samples (Mahmoud et al, 1978). Radiation up to dose level of 50 krad has been shown to have no effect on the volatile components of onion bulbs and flavour precursors (Bandyopadhyay et al, 1973).

'. Research Objective.

Since onion production in Nigeria is seasonal and main harvest is once in a year, it requires storage for prolonged availability. The post-harvest problems of onions, even under temperate conditions are little understood and very little information is available in connection with the possibilities of their successful storage under tropical conditions. The storage period so far reported is not long enough to stabilize the price of onions for the market. Thus, the need for the improvement of knowledge and of storage techniques particularly in tropical countries (Nigeria for example) is obvious.

The objective of this study therefore is to:-

1. Prolong the storage life of onions by the use of gamma irradiation
2. Determine the optimal dosage suitable and economical for onion cultivars in Nigeria.
3. To study post-irradiation behaviour of irradiated onions with regard to (a) storage quality and (b) changes in volatile and non-volatile components.
4. Attempt to improve on local storage method which will be economically viable for the local onion farmer.

CHAPTER TWO

MATERIALS AND METHODS

Effect of gamma irradiation on Storage.

Sample (Onion cultivars).

Fully matured onion bulbs of two varieties Ws'79 and DS x Ws'78, harvested 14 days prior to the experiment. were obtained from the Horticultural section of Institute of Agricultural Research Samaru, Zaria. Only healthy and undamaged bulbs of medium size (5-7cm) were used.

Radiation treatment.

Part of the bulbs were transported to Biochemistry Department, University of Ibadan for irradiation. Irradiation was carried out in a Co^{60} gamma 3500 irradiation unit (Noratom Norcontrol AS, Vinderen Oslo3 Norway) at ambient temperature and atmospheric pressure. Absorption of radiation was checked with ferrous sulphate and ceric sulphate dosimetry (Weiss, 1952). The bulbs were irradiated 16 days after harvest with doses of 5, 8 and 15 krad. After the irradiation, the bulbs were packed into the vegetable mesh bags (mesh size of 5mm) ready for storage. These onion bulbs were transported by road to and from Ibadan and for the duration of the

experiment, they were kept in vegetable mesh bags on wire mesh with wooden stands.

Experiment 1: Four different treatments were given to bulbs of Ws'79: 5 krad, 8 krad, 15 krad and an untreated control. Each treatment had 9 replications, each replicate contained 50 bulbs.

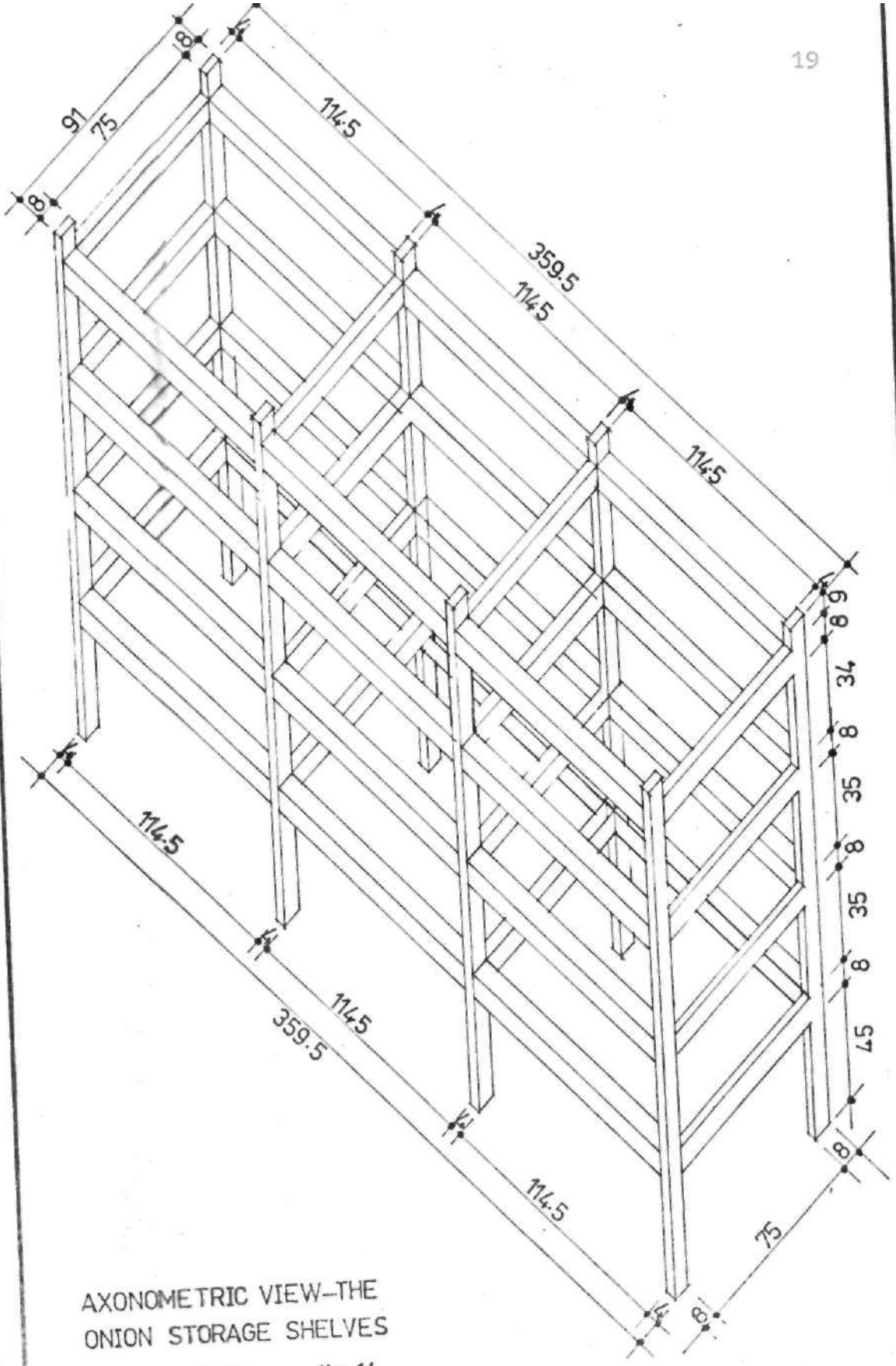
Experiment 2: Bulbs of Ws'79 were given only three different treatments: 8 krad, 15 krad and an untreated control. Each treatment had 5 replications, each replicate contained 90 bulbs.

Storage. Two days after irradiation, the bulbs were stored in a well ventilated room (RH 20-82%, temp. 20-25°C) on wooden shelves covered with a wire gauze (see fig 14 for dimension). Units (mesh bags) were arranged in randomised blocks design with 9 replications for experiment 1 and 5 replications for experiment 2.

Observations. In experiment 1, weekly counts were made of rotten and sprouted bulbs (external sprouting). In experiment 2, samples were selected monthly from the healthy non-sprouted bulbs for the chemical analyses and in addition, bulbs were weekly observed for rotting and sprouting.



PLATE 1. Onions on storage shelves



AXONOMETRIC VIEW–THE
ONION STORAGE SHELVES

scale 1:20 fig. 14

all dimensions are in centimetres.

Criteria for Spoilage: Bulbs were considered rotten when they became very soft and distinct smelly liquid started flowing out of the bulbs. Sometimes some larvae were found in the rotten bulbs. The criterium for sprouting was the appearance of external green foliage leaves.

Sampling: Two bulbs were randomly selected from each mesh bag for the chemical analyses. One of the bulbs was used for flavour determination while part of the other bulb was used for determining ascorbic acid and the other part for determining dry matter content. Other chemical analyses were carried out on the dry matter obtained.

LOCAL STORAGE TRIAL.

Construction of the mud houses.

Four small mud houses were constructed (courtesy to IAR labourers, Horticulture section). These huts were round 1.1m high, resting on sticks and a central core of mud, 30cm above the ground with slatted floor made of branches of trees. Three small ventilation openings (10 x 10cm) in the wall at half the height were constructed in each hut. In addition a window of 30 x 30cm at about



PLATE 2. Mud huts for local storage experiment.

one-third of the height from the base was also made. This was closed with a wooden shutter. Thatched roof, projecting about 60 cm over the side of the hut and leaving a space of about 10cm between roof and top of the wall(mainly for ventilation) was used to cover the wall (see plate 2).

Experiment

Onions used were bought from a local market, Wudil in Kano State. Before storing, rotten ones were discarded.

On 28/5/79, the mud huts were filled with onions 400kg per hut. In two huts, onions were simply piled on top of each other, the other two huts were filled by alternating layers of wheat straw and bulbs. The huts were left until after 3 months when they were opened. The onion bulbs were taken out (each hut at a time) and the sprouted and the rotten ones discarded. The remaining healthy bulbs were weighed and put back in the mud houses. The next observation was made after 7 months of storage. The remaining marketable bulbs were weighed.

Chemical analyses

Chemicals: Analytical reagent grade chemicals, unless other wise stated, were used without further purification. Silical gel G-HR for thin layer chromatography was obtained from Camlab Ltd, Cambridge, England. The rest of the chemicals used were supplied by BDH (British Drug Housing), England and Hopkins and Williams, Chadwell Health Essex, England.

Proximate composition: The standard methods of the Association of Official Analytical chemists (A.O.A.C. 1975) were used in the determinations.

Determination of dry matter content

The method of A.O.A.C. (1975a) was adopted.

Apparatus:

1) Porcelain dishes
2) Oven (Laboratory thermal Equipment, A Searle company, England)

Method

About three quarter of a bulb was sliced and weighed into a porcelain crucible. This was dried to a constant weight in an oven maintained at a temperature of

65-70°C for about 36 hours. The dry matter obtained was cooled and weighed. The weight was expressed as a percentage of the fresh weight. Each treatment was replicated 5 times.

Calculation.

$$\text{Dry matter (\%)} = \frac{\text{wt of dry matter (g)} \times 100}{\text{wt of fresh onion (g)}}$$

Determination of total ash content.

The ash content was determined by the method of A.O.A.C. (1975b).

Apparatus.

1) Porcelain crucibles
2) Muffle furnace
3) Air tight desiccator with activated silica as the drying agent.

Method.

1-1.5g of dry powdered onion sample was accurately weighed into an already weighed porcelain crucible. The porcelain crucible and its contents was ignited in a muffle furnace for 24 hours at a temperature of 550°C. This temperature was high enough to allow all the organic

matter to be burnt off but with the assumption that no appreciable decomposition of the ash constituent was occurring. At the end of 24 hours, the crucible plus the contents was removed from the furnace and cooled at room temperature in a desiccator. The weight of the ash was then recorded.

Calculation

$$\text{Ash (\% dry wt)} = \frac{\text{wt of ash (g)} \times 100}{\text{wt of sample (g)}}.$$

Determination of crude protein content.

The protein content was determined using micro-kjeldahl method (A.O.A.C. 1975c). In principle, the protein of plant material is usually estimated from the total nitrogen after conversion of the protein nitrogen to ammonium salt by digestion involving acid hydrolysis. Crude protein is obtained by multiplying the total nitrogen by the factor 6.25.

Apparatus.

1) Heating mantles
2) Micro-kjeldahl digestion apparatus
3) Digestion flasks, $50cm^3$
4) Burette $25cm^3$
5) $50cm^3$ conical flasks.

Reagents.

a) Concentrated sulphuric acid
b) Potassium sulphate.
c) Mercuric Oxide.
d) 60% sodium hydroxide solution:
prepared by dissolving 60g of sodium hydroxide in $100cm^3$ of distilled water.
e) 0.01M Hydrochloric acid (from ampoules)
f) 2% Boric acid with 0.1% bromocresol green indicator:
prepared by dissolving 20g of boric acid plus 1g of bromocresol green in $1dm^3$ flask with distilled water.

Method.

About 0.5g of the dry powdered onion was accurately weighed into a digestion flask containing 1.9g of potassium sulphate, 40mg of mercuric oxide and anti-bumping granules. $10cm^3$ of concentrated sulphuric acid was slowly added after which the flasks were set up in the digestion rack placed in the fume cupboard. The flasks were initially heated slowly to avoid vigorous charing then heated strongly for 24 hours until the digests were colourless.

The flasks were allowed to cool to room temperature after the digestion and the content of each flask was poured into $100cm^3$ volumetric flask.

Each flask was rinsed 3 times with distilled water. The volume was made up to the mark with distilled water.

$10cm^3$ of the solution was pipetted into the distilling apparatus followed by the addition of $10cm^3$ of 60% sodium hydroxide solution. The mixture was distilled into $10cm^3$ of boric acid-indicator solution which trapped the ammonia liberated. Distillation was continued until about $20cm^3$ of the distillate was collected. The distilate was titrated with 0.01M hydrochloric acid to dark red endpoint. A blank determination in which the sample was omitted was also carried out exactly as described above.

Calculation

$1cm^3$ of 0.1NHCl ≡ 14 mg N

Total protein = Nitrogen X 6.25

Determination of crude petroleum ether extract (Lipid).

The method of A.O.A.C (1975) was used. The procedure is based on the extraction of lipid from plant material using a suitable solvent. The weight of the lipid obtained after distilling off the solvent from the extract gives the amount of lipid present.

Apparatus.

1) Soxhlet extractors
2) Fat-free thimbles
3) Heating mantle
4) 500cm^3 round-bottom flasks
5) Anti-bumping granules.
6) Flash rotary vacuum evaporator (Bucher Instruments pat. 2,865, 445. Fortles N.I. U.S.A.).

Reagent

Petroleum-ether (b.p 60-80^{o}C).

Method

5-7g of the dry powdered onion sample was weighed accurately into a weighed fat-free thimble. 250 cm^3 of petroleum ether (b.p 60-80^{o}C) was poured into a previously weighed 500cm^3 round bottom flask containing anti-bumping granules. The Soxhlet extractor containing the thimble with its content was them fitted into the round bottom flask and the extraction continued for 8 hours.

The petroleum ether in the round bottom flask was distilled off using a flash vacuum rotary evaporator. The last traces of the solvent were removed by drying the flask in an oven at 50^{o}C. The flask was cooled, weighed and the amount of lipid extracted was obtained from

the difference between the weight of the flask before and after extraction.

Calculation

$$\text{Lipid (\% dry wt)} = \frac{\text{wt of lipid (g) X 100}}{\text{wt of dry sample (g)}}.$$

Thin Layer chromatography of the Onion lipid.

The method of Kates (1972) was adopted.

Apparatus

1) Chromatographic tank
2) Silica gel plates
3) Capillary tubes.

Reagents.

a) Hexane: diethyl ether: acetic acid (80:20:1 v/v): prepared by mixing $80cm^3$, $20cm^3$ and $1cm^3$ of hexane, diethyl ether and acetic acid respectively in a $250cm^3$ flask.

b) Chloroform.

Method.

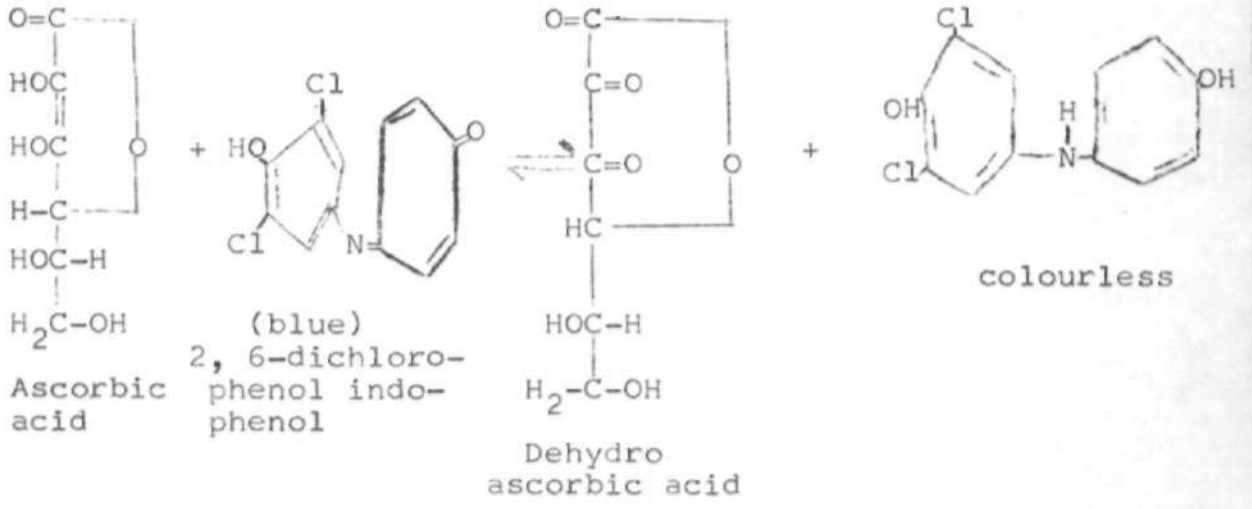
The lipid extract was dissolved in $1cm^3$ of chloroform. Using capillary tubes, silica gel plates were spotted with lipid extracts of both the control and irradiated samples.

Solvent mixture of Hexane:diethyl ether: acetic acid (80:20:1 v/v) was used as the developing solvent. Chromatograms were allowed to run for 20-30 minutes at room temperature in the chromatographic tank.

The chromatograms were dried in air and kept in iodine vapour tank for 5 minutes. The position of different spots were marked out. The distance between the centre of each spot and the origin was measured.

Determination of Ascorbic acid.

The ascorbic acid content was determined by the 2, 6- dichlorophenol indophenol visual titration method as modified by Bassir (1971). This procedure measure only the reduced form of ascorbic acid.



To prevent the oxidation of ascorbic acid, glacial acetic acid was used in the extraction of the vitamin. Glacial acetic acid also precipitates interfering substances such as proteins.

Apparatus

1) 50 cm^3 conical flasks
2) 100 cm^3 volumetric flasks
3) 1 dm^3 volumetric flasks
4) 1 cm^3 pipette
5) 50 cm^3 burette.

Reagents

a) Standard ascorbic acid: prepared by dissolving 1mg ascorbic acid in 100 cm^3 of 5% acetic acid.

b) 2:6 - Dichlorophenol Indophenol Solution: prepared by dissolving 0.01g of dye in boiling distilled water and solution made up to 100 cm^3 with freshly boiled distilled water.

c) Glacial acetic acid.

d) 5% acetic acid: prepared by diluting 5 cm^3 of acetic acid to 100 cm^3 with distilled water.

Method

A bulb was randomly selected from each mesh bag with each treatment of 5 replicates. For each one, a piece of fresh onion was cut out longitudinally, weighed, transferred into a mortar and ground with 2 cm^3 glacial acetic acid. The whole content was transferred quantitatively with distilled water into a 50 cm^3 conical flask and solution made up to the mark with distilled water. This was well shaken and filtered rapidly through a layer of glass wool.

The filtrate was titrated against 1cm^3 of the dye, 2:6-Dichlorophenol-indophenol which contained one drop of 5% acetic acid. The volume of the extract required to decolorize the dye was recorded. The titration was repeated using standard ascorbic (1mg/100cm^3) acid in place of the extract.

Calculation

$\frac{V \times T \times 100}{W}$ = mg ascorbic acid/100g fresh onion

V = cm^3 aliquot of dye titrated

T = Ascorbic acid equivalent of dye solution, expressed as mg/cm^3 of dye.

W = Weight in grams of sample in volume of extract used for titration.

Determination of Thiopropanal S-Oxide content (Flavour).

A rapid spectrophotometric method originally developed by Freeman and Whenham (1975) was used in the study. The method is based on the extraction of thiopropanal S-Oxide (a lachrymatory factor produced on disintegration of fresh onion tissue) into hexane and observation of the absorbance of the extract at 254 nm.

The major flavour precursor of intact onion tissue is S-(1-propenyl)-L-cysteine sulphoxide (Schwimmer et al, 1960). On disintegration of the tissue, S-(1-propenyl)-L-cysteine sulphoxide undergoes fission by the enzyme allinase with production of equimolecular amount of pyruvate and ammonia.

$CH_3CH{=}CHS(O)\ CH_2CH\ (NH_2)\ COOH \xrightarrow{\text{allinase}}$

$CH_3CH{=}CHSH + CH_3COCOOH + NH_3$

1-propenyl- sulphenic acid — pyruvic acid — Ammonia

$\downarrow$

$CH_3CH_2CH{=}S{=}O$

Thiopropanal S-oxide

Apparatus

1) A sharp knife
2) pestle and mortar
3) 50 cm^3 conical flasks
4) 5 cm^3 volumetric pipettes
5) Glass wool
6) Funnel
7) Separating funnels
8) CE 505 Double beam ultraviolet spectrophotometer with CE 500 control-Record module (CECIL Instrument)

Reagent

Hexane - "fraction from petroleum special for spectroscopy".

Method.

Fresh bulb was cooled to $0^{\circ}C$ in a deep freezer for about one hour which was then rapidly sliced with a knife and ground with a pestle and mortar (precooled to $4^{\circ}C$). A portion of the juice was diluted 1:10 with distilled water at $4^{\circ}C$. 5 cm^3 of the diluted solution was shaken with 10cm^3 of hexane. The hexane layer was separated and the absorption spectrum, in the range 190-350nm,

observed in a double beam U.V sspectrophotometer. The maximum absorbance at 254 nm was read.

Calculation.

Conversion of the observed absorbance values at 254nm to concentration of thiopropanal S-Oxide equivalent in the onion sample was based on the observed absorbance value of a solution of the synthetic compound in hexane containing 10 $\mu g/cm^3$ ≡ 0.111 $\mu mole/cm^3$

(Freeman and Whenham, 1975).

10 $\mu g/cm^3$ gave absorbance of 0.57 units

∴ 1 unit ≡ 17.54 $\mu g/cm^3$ ≡ 0.195 $\mu mole/cm^3$

The original concentration in the aqueous solution (before hexane extraction) is given by $C(\alpha + 1)$.

Where C = concentration in hexane solution after partition.

α = partition coefficient of the compound between water (1 volume) and hexane (2 volumes).

α = 2.99.

∴ concentration = 0.195 x 3.99 = 0.778 $\mu mole/cm^3$

Concentration = 0.778 x Absorbance.

Reducing Sugars.

The reducing sugar content was determined colorimetrically by the Dinitrosalicylate (DNS) method (Clark and Switzer, 1964). At alkaline pH (pH> 8) and at a temperature of 100°C, DNS is reduced to 3-amino-5-nitro salicylate by reducing sugars. The reduced DNS has maximum absorbance at 540 nm.

Extraction of Sugar.

A modified method of Bell (1955) was used for the extraction. The extraction was carried out at 84 ± 2°C for 6 hours with 80% ethanol.

Apparatus

1) 500 cm^3 round bottom flask
2) Reflux set
3) Rotary vacuum evaporator (Busher Instruments pat. 2, 865, 445. Fortlee, N.J. U.S.A.).
4) 100 cm^3 measuring cylinder
5) Heating mantle
6) Auto bench centrifuge (Gallenkamp juniour centrifuge, England).
7) 1 dm^3 flasks.

Reagent

80% ethanol: prepared by diluting 80 cm^3 of ethanol to 100 cm^3 with distilled water.

Method.

2g of dry onion powder was weighed into a 500 cm^3 round bottom flask. 200 cm^3 of 80% ethanol was poured into the flask and the resulting mixture was refluxed for 6 hours at 84 $\pm$ 2^{o}C. The flask with its contents was cooled and the mixture centrifuged at 400 r.p.m. for 20 minutes. This was to remove the solid particles and precipitated protein. The extract was concentrated in vacuo with rotary evaporator at about 50^{o}C. The final solution was diluted with distilled water to a total volume of 1 dm^3.

Identification

The method of Hough (1954) was used.

Apparatus

1) 250 cm^3 volumetric flask
2) 250 cm^3 separating funnel
3) 50 cm^3 volumetric flasks
4) capillary tubes

5) Whatman No. 1 chromatography paper, 30 x 10 cm

6) 100 cm^3 and 25 cm^3 measuring cylinders

7) Chromatographic tank

Reagents

a) Butanol: acetic acid: distilled water (4:1:5, v/v)

b) Ethyl acetate: pyridine: distilled water (2:1:2, v/v)

c) Aniline/diphenylamine reagent: prepared fresh by the addition of the following in 250 cm^3 flask

1) 4 cm^3 aniline
2) 4g diphenylamine
3) 20 cm^3 phosphoric acid (H_3PO_4)
4) 200 cm^3 acetone

d) 1% Fructose, 1% glucose and 1% sucrose: Each prepared by dissolving 1g in 100 cm^3 of distilled water.

Method

Using capillary tubes, spots of the extract plus the standard sugars were carefully placed on the chromatographic paper. Each spot was allowed to dry in air. The end of the paper near the spots was dipped into a non-aqueous layer of butanol: acetic acid: distilled water

(4:1:5, v/v) and ethyl acetate: pyridine: distilled water (2:1:2, v/v) mixture which was used as the developing solvent. Chromatograms were allowed to run for 16 hours at room temperature (26 $\pm$ 1^{o}C) in the chromatographic tank.

The chromatograms were air dried at room temperature, sprayed with the aniline/diphenylamine reagent and placed in an oven maintained at 80^{o}C for 5 minutes for colour developments. The position of the spots were marked out and the distance between the origin (where the samples were applied) and the centre of each spot was measured. Using the standard sugars as the reference and ^{R}glucose, the sugars in the extract were identified.

Determination of reducing sugars.

Apparatus

1) Water bath
2) CE 505 double beam U.V spectrophotometer.
3) Flasks and pipettes.

Reagents.

a) 2M-sodium hydroxide: prepared by dissolving 80g of sodium hydroxide pellets and making up to 1dm^{3} with distilled water.

b) 3:5 - Dinitrosalicylate (DNS) reagent: 1g of 3:5-DNS dissolved in 20cm^3 of warmed sodium hydroxide. 30g of potassium sodium tartrate (laboratory reagent grade) dissolved in 50cm^3 distilled water. The two solutions mixed with stirring and made up to 100cm^3 with distilled water.

c) Standard glucose + Fructose (5mM-glucose and 5mM fructose = 5 µmoles glucose + 5 µmoles fructose per cm^3): prepared by dissolving 900mg of glucose + 900mg of fructose and making up to 1dm^3 with distilled water.

Method.

The following table was used in the preparation of standard calibration curve.

	TUBE NUMBER					
	1 Blank	2	3	4	5	6
5mM glucose/ 5mM Fructose (cm^3)	0.0	0,2	0.4	0.8	1.0	1.2
µmoles of sugar present	0.0	1µmole G* 1µmole F*	2µmoles G* 2µmoles F*	4µmoles G* 4µmoles F*	5µmoles G* 5µmoles F*	6µmoles G* 6µmoles F*
Distilled water (cm^3)	2,5	2.3	2.1	1.7	1.5	1.3
DNS (cm^3)	2.0	2.0	2,0	2.0	2.0	2.0

G* Glucose F* Fructose

The tubes with their contents were thoroughly shaken, heated for 5 minutes in a water bath maintained at about 100°C and cooled under tap water. The content of each tube was diluted to 20cm^3 with distilled water and the absorbance of the solution was taken at 540nm on a CE double beam U.V. spectrophotometer. The calibration curve of absorbance against μmoles of glucose + Fructose was plotted.

For the extract, 1cm^3 was pipetted into each test-tube containing 1.5cm^3 distilled water and 2cm^3 DNS. These tubes were exactly treated in the same way as the standard and the absorbance read at 540nm. The equivalent μmoles of glucose + Fructose was read off from the standard curve. Each treatment had 4 replications.

Calculations.

The equivalent μmoles of glucose + fructose from the standard curve was per cm^3 of the extract. Say μmoles glucose + fructose = y μmoles/cm^3 extract.

∴ In 1dm^3 = 1000y μmoles. But molecular weight of glucose or fructose = 180.

∴ mg reducing sugar = $\frac{180 \times 1000y}{1000}$ mg

But wt of onion used = 2g.

∴ % reducing sugar = $\frac{180 \times 1000y \times 100}{2 \times 1000 \times 100}$ = 9y %

CHAPTER THREE

RESULTS

Sprouting

The accumulated percentage sprouted onions in the control and irradiated bulbs for variety DS x Ws'78 and Ws'79 are shown in Tables 1 and 2 respectively. Sprouting was completely inhibited by a dose of 5 - 15 krads. There was no incidence of external sprouting in DS x Ws'78 in the first month of storage, however, sprouting started in the control in the 2nd month. Unlike variety DS x Ws'78, bulbs of WS'79 started sprouting in the first month of storage.

The pattern of loss due to sprouting in both varieties are shown in Figures 1 and 2. In both cases, sprouting increased with storage time in the first 4 months. A sharp decrease was observed in Ws'79 at the end of the 5th and the 6th month followed by an increase in the 7th month. DS x Ws'78 on the other hand showed a decrease only at the end of the 7th month.

TABLE 1.

Cummulative percentage sprouting of irradiated onions (variety DS x WS'78) stored at room temperature (20 -25°C) and RH 20-82% .

Month	Control	5krad	8krad	15krad
1	0.00	0.00	0.00	0.00
2	0.76	0.00	0.00	0.00
3	2.54	0.00	0.00	0.00
4	4.06	0.00	0.00	0.00
5	11.17	0.00	0.00	0.00
6	16.75	0.00	0.00	0.00
7	19.54	0.00	0.00	0.00

TABLE 2.

Cummulative percentage sprouting of irradiated onion (variety WS'79) stored at room temperature (20-25°C) and RH 20-82%.

Month	Control	8krad	15krad
1	2.69	0.00	0.00
2	8.16	0.00	0.00
3	20.19	0.00	0.00
4	31.82	0.00	0.00
5	39.15	0.00	0.00
6	44.03	0.00	0.00
7	52.72	0.00	0.00

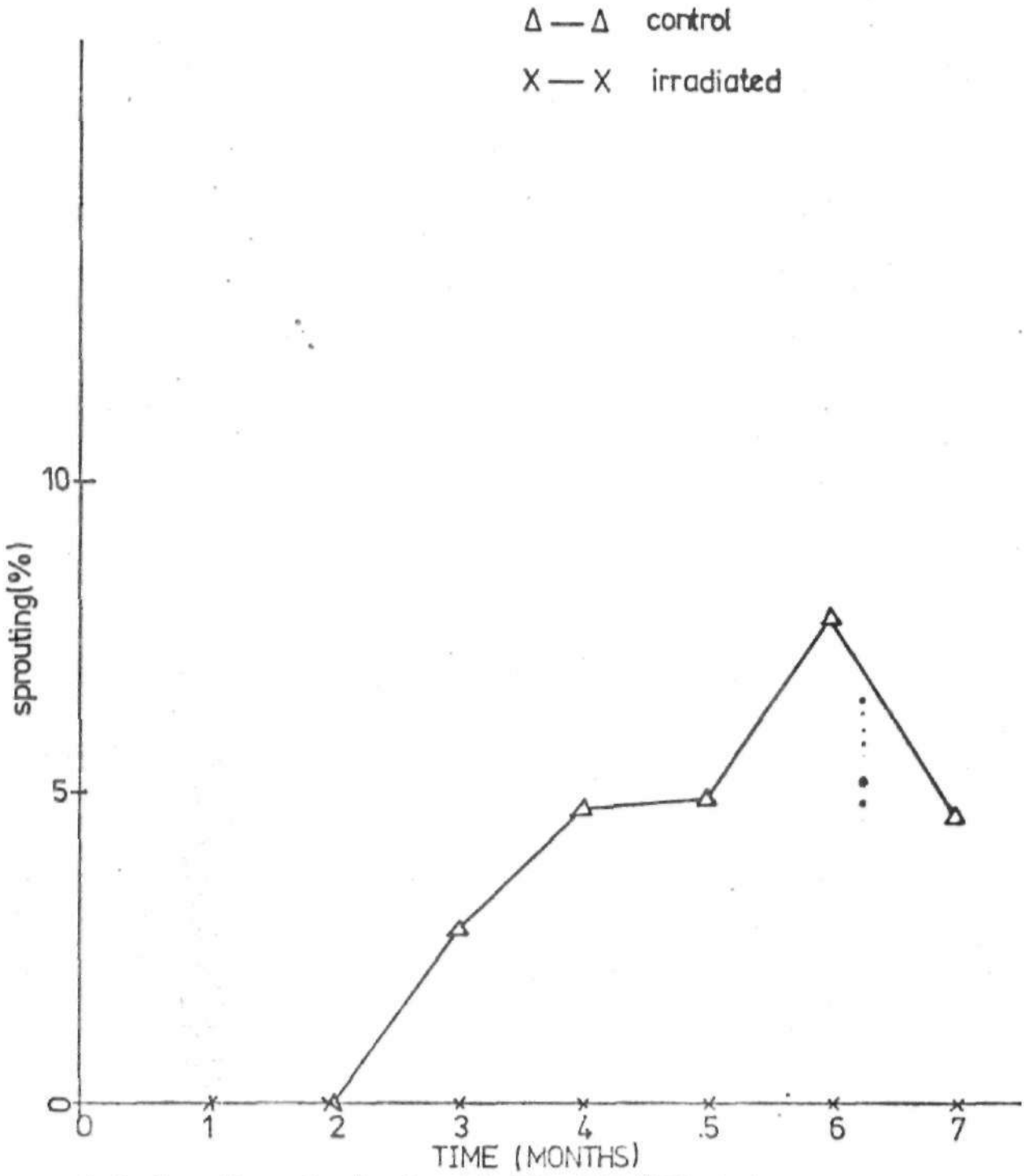


fig 1 Sprouting of onion (variety DS × WS '78) during storage (RH 20-82%, temp 20-25°C)

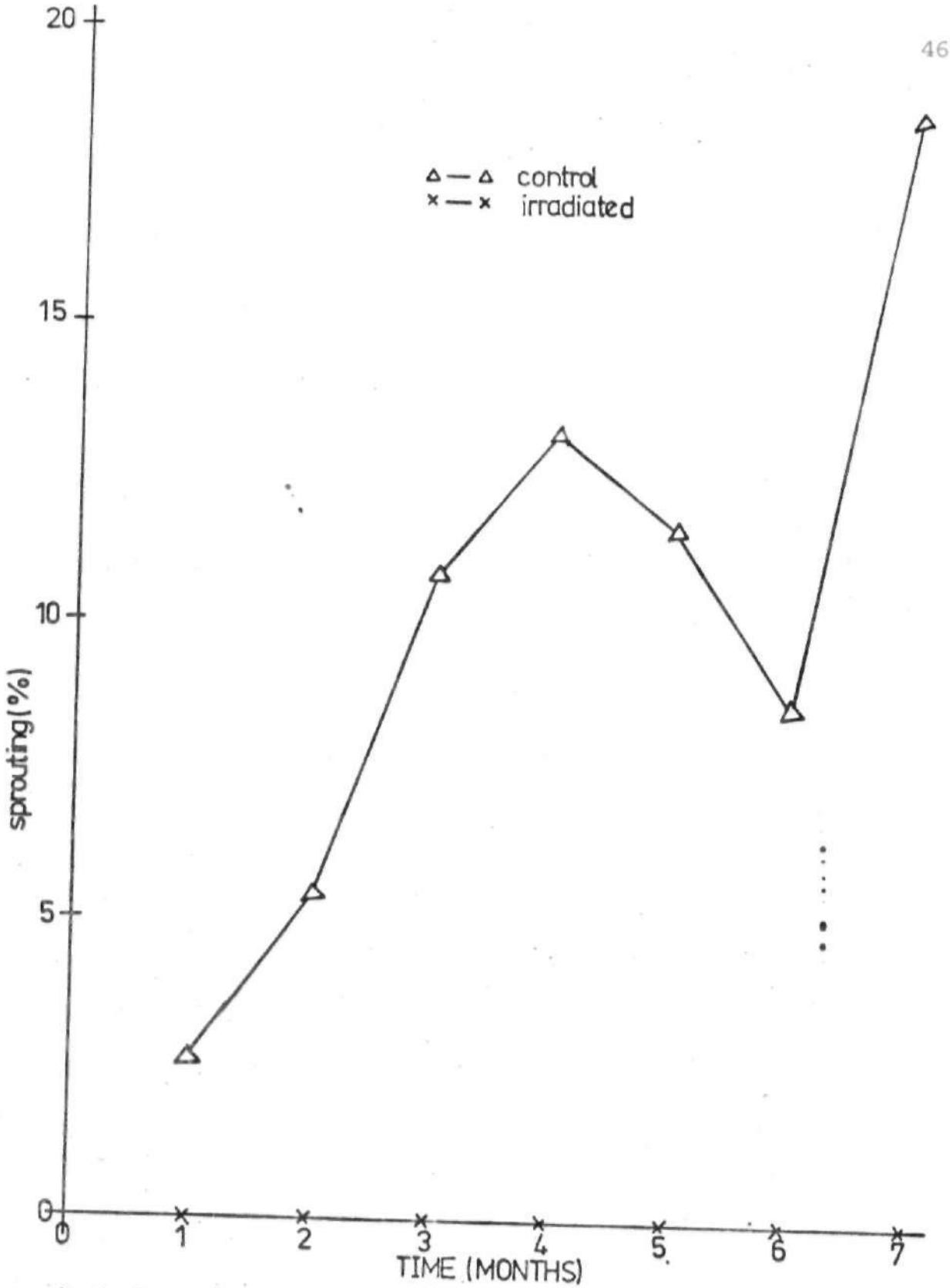


fig 2 Sprouting of onion (variety WS '79) during storage RH 20-82% temp 20-25 °C

Rotting

The accumulated percentage loss due to rotting in DS x WS'78 and WS'79 are shown in Tables 3 and 4 respectively. The difference between the control and all treatment levels (variety DS x WS'78) was not significant ($p > 0.05$) after 3 months. However, the difference was significant ($p < 0.05$) after 7 months. Unlike variety DS x WS'78, WS'79 showed a significant difference ($p < 0.05$) in percentage loss due to rot between the control and the irradiated both at the end of 3 and 7 months of storage. In both varieties, t-test showed that there was no significant difference ($p > 0.05$) in percentage loss due to rot between the treatment levels either after 3 months or 7 months. In general, irradiated onions showed an increase tendency to rot during storage. A higher percentage loss was observed in the treated WS'79 than in the treated DS x WS'78. The control of DS x WS'78 however showed a higher percentage rot than WS'79.

The pattern of loss due to rotting in both varieties are shown in Figure 3 and 4. The rate of rotting generally increased with storage time up to the 6th month.

TABLE 3.

Cummulative percentage rotting of irradiated onion (variety DS x WS'78) stored at room temperature (20-25°C) and RH 20-82% .

Month	Control	5krad	8krad	15krad
1	5.58	3.51	4.74	2.97
2	10.66	7.16	9.44	6.64
3	12.44	11.98	13.73	9.89
4	15.49	18.33	16.46	13.48
5	18.03	24.69	24.15	19.15
6	23.11	36.68	36.19	33.60
7	26.66	42.05	41.63	39.22

TABLE 4.

Cummulative percentage rotting of irradiated onion (variety WS'79) stored at room temperature (20-25°C) and RH 20-82%.

Month	Control	8krad	15krad
1	1.07	3.00	3.90
2	2.27	9.02	7.82
3	4.69	18.59	17.45
4	7.09	32.90	31.69
5	11.57	43.68	43.72
6	16.05	57.09	57.46
7	17.47	58.75	60.48

TABLE 5

Total percentage rotting and sprouting (For 7 months storage).

Variety	Control	5krad	8krad	15krad
DS x WS'78	46.20	42.05	41.63	39.22
WS'79	70.19	*	58.75	60.48

* NOT DETERMINED

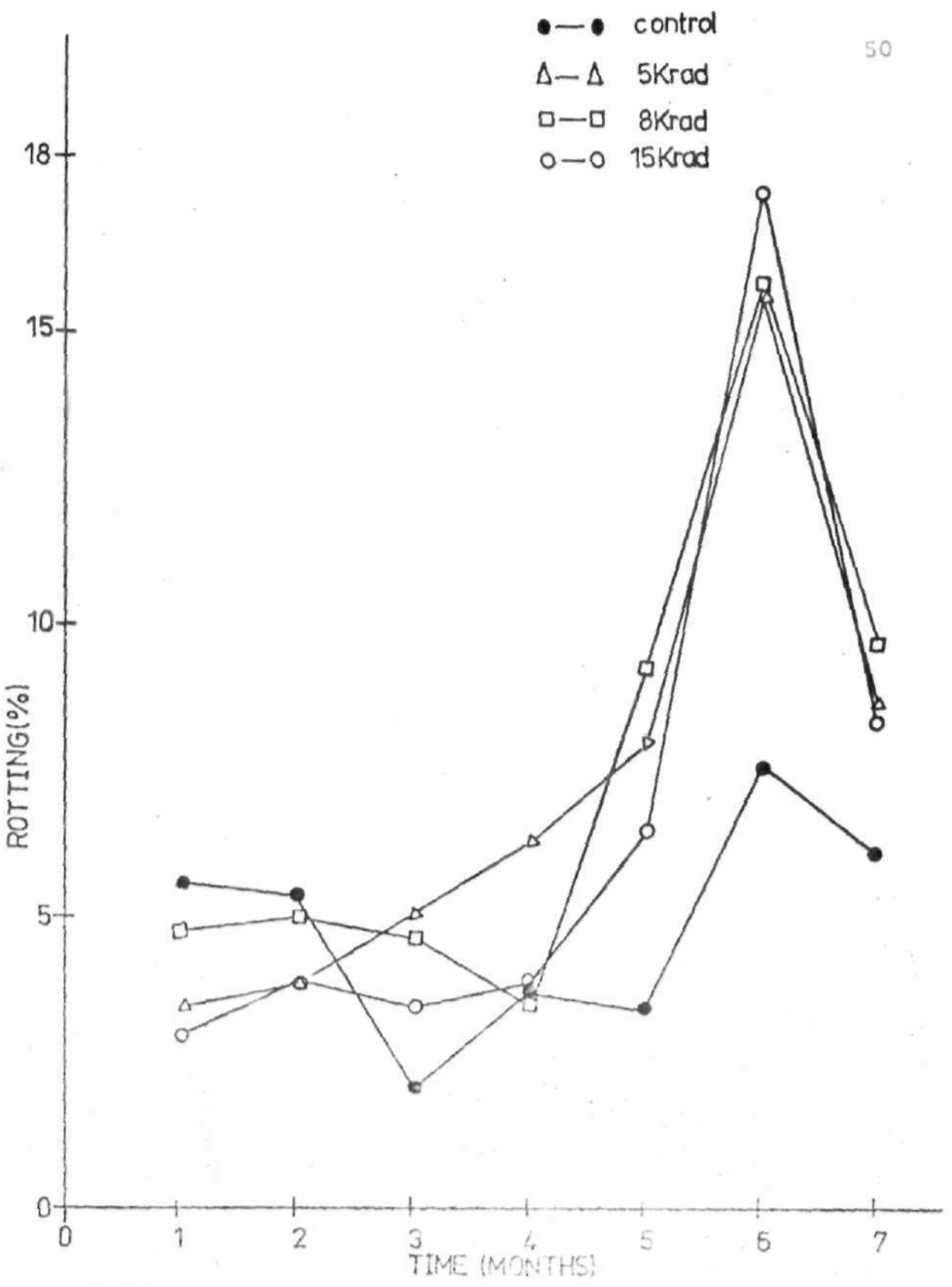


fig 3 Effect of irradiation and storage time on rotting of onion (variety DSx WS'78) RH 20-82% temp 20 - 25°C

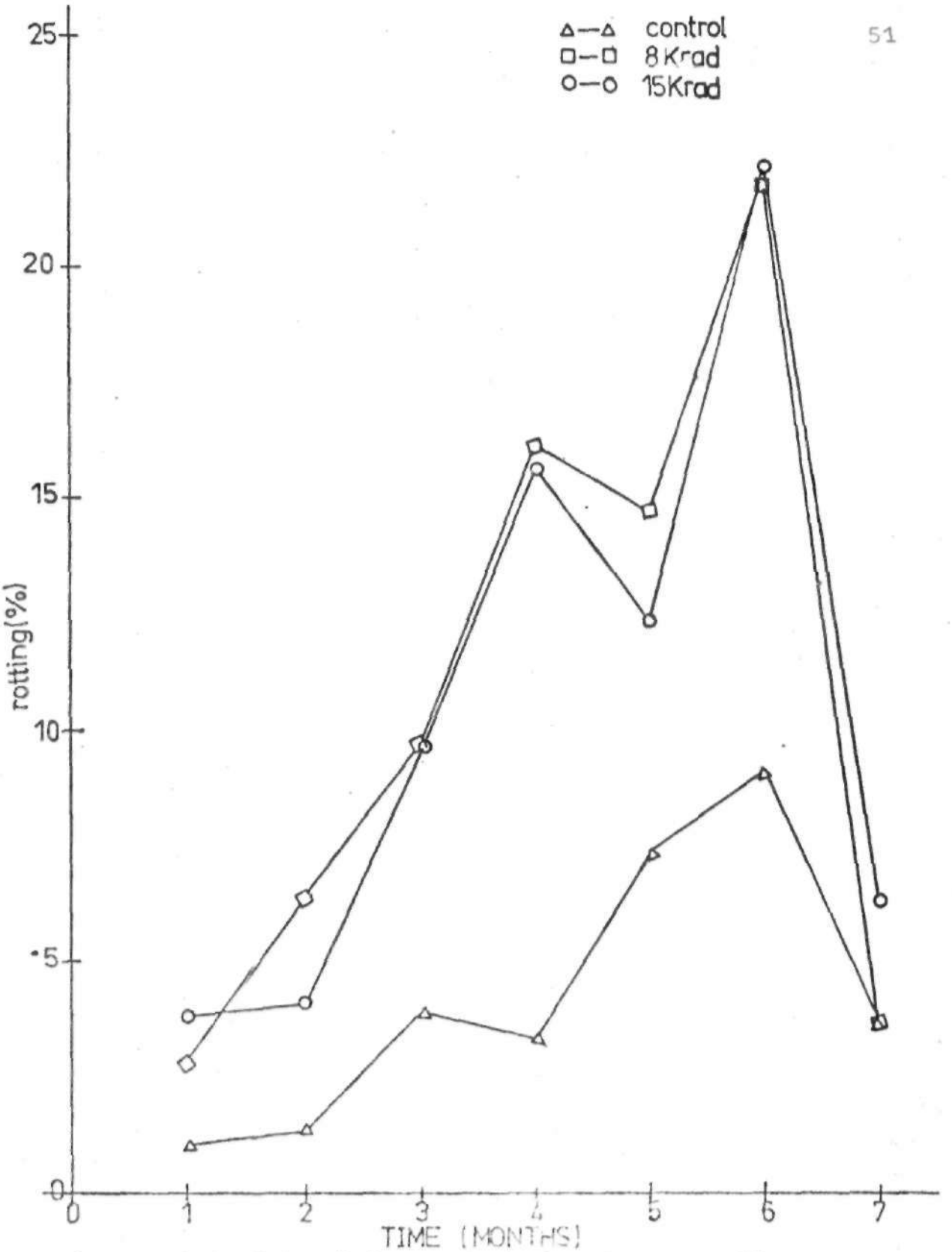
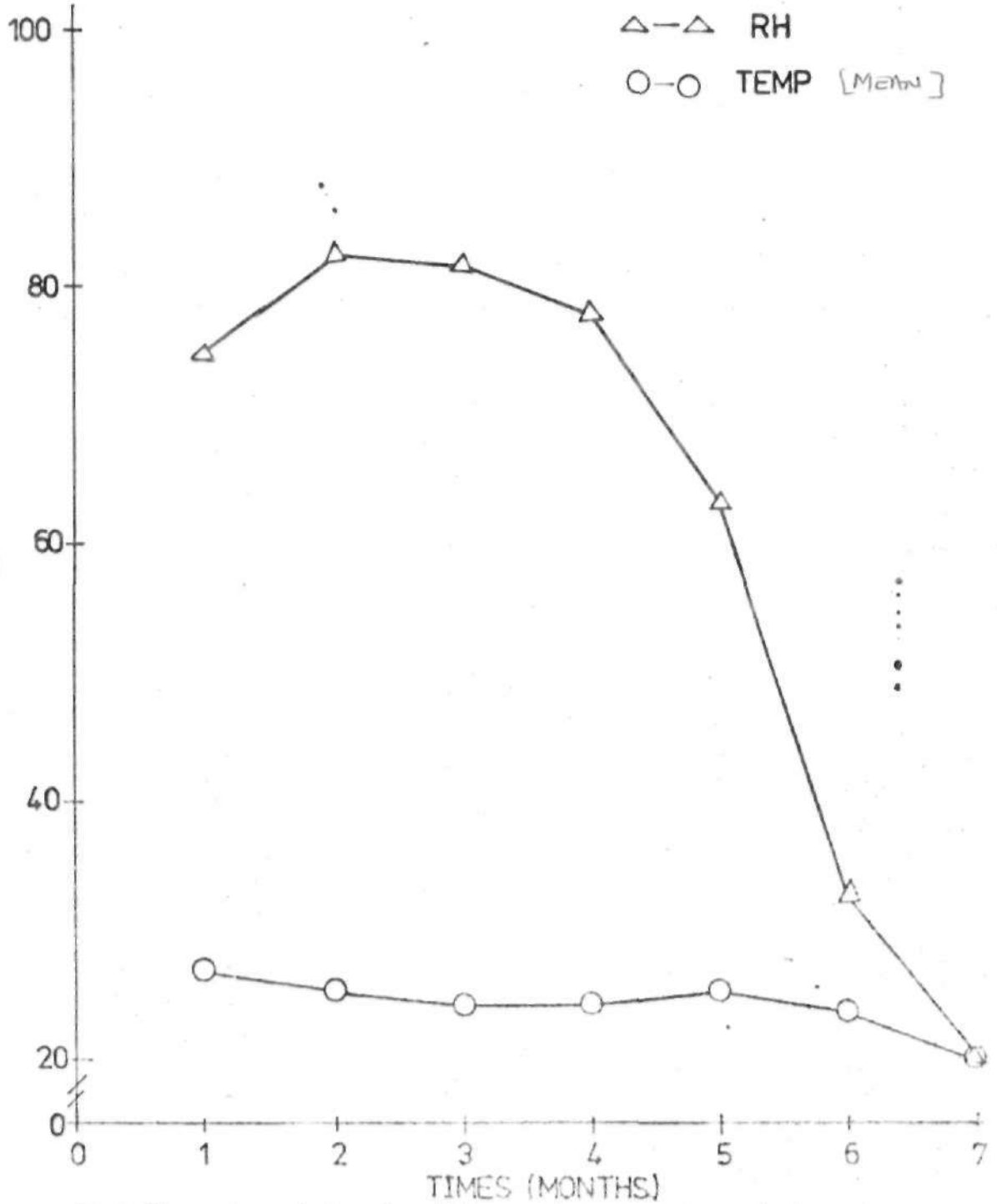


fig 4 Effect of irradiation and storage time on rotting of onion (variety WS '78) RH 20-82% temp 20 - 25°C



Variations in relative humidity and temperature during storage

fig 5



PLATE 3. Sprouted bulbs from the control group.
[VARIETY DS x WS '78]

The highest rate was recorded at the end of the 6th month in both varieties after which there was a significant decrease ($p < 0.05$). There was a decrease in 8 and 15 krad treated samples at the end of the 5th month in variety WS'79.

Local storage trial.

The percentage losses due to sprouting and rotting in the local storage trial are shown in Table 6. The mean percentage loss at the end of 3 months storage was 66.84% and 78% for huts with straw in between layers and without straw in between layers respectively. At the end of 7 months storage, the mean percentage loss in huts with straw and without straw was 98.08 and 98.20 respectively. Hut number 4 collapsed after 3 months due to excessive rotting of the bulbs.

A similar experiment in which the bulbs (from the same batch as used in local storage) were stored in single layers on wire gauze shelves in a well ventilated store was carried out. The results are shown in Table 7.

TABLE 6.

Percentage rotting and sprouting of onions stored in locally constructed mud huts. (Local storage method).

Hut No.	Total Loss (%)	
	After 3 months	After 7 months
1 (No straw in between) layers.	73.50	98.20
2 (Straw in between layers).	65.57	97.97
3 (Straw in between layers)	68.10	98.19
4 (No Straw in between) layers.	82.50	Hut collapsed

TABLE 7.

Percentage rotting and sprouting of onions stored in single layers on wire gauze in a well ventilated store.

Replicates	Total Loss (%)	
	After 3 months	After 7 months
1	39	76
2	39	80
3	39	78
4	38	83
Mean	38.75 ± 0.25	79.25 ± 1.49

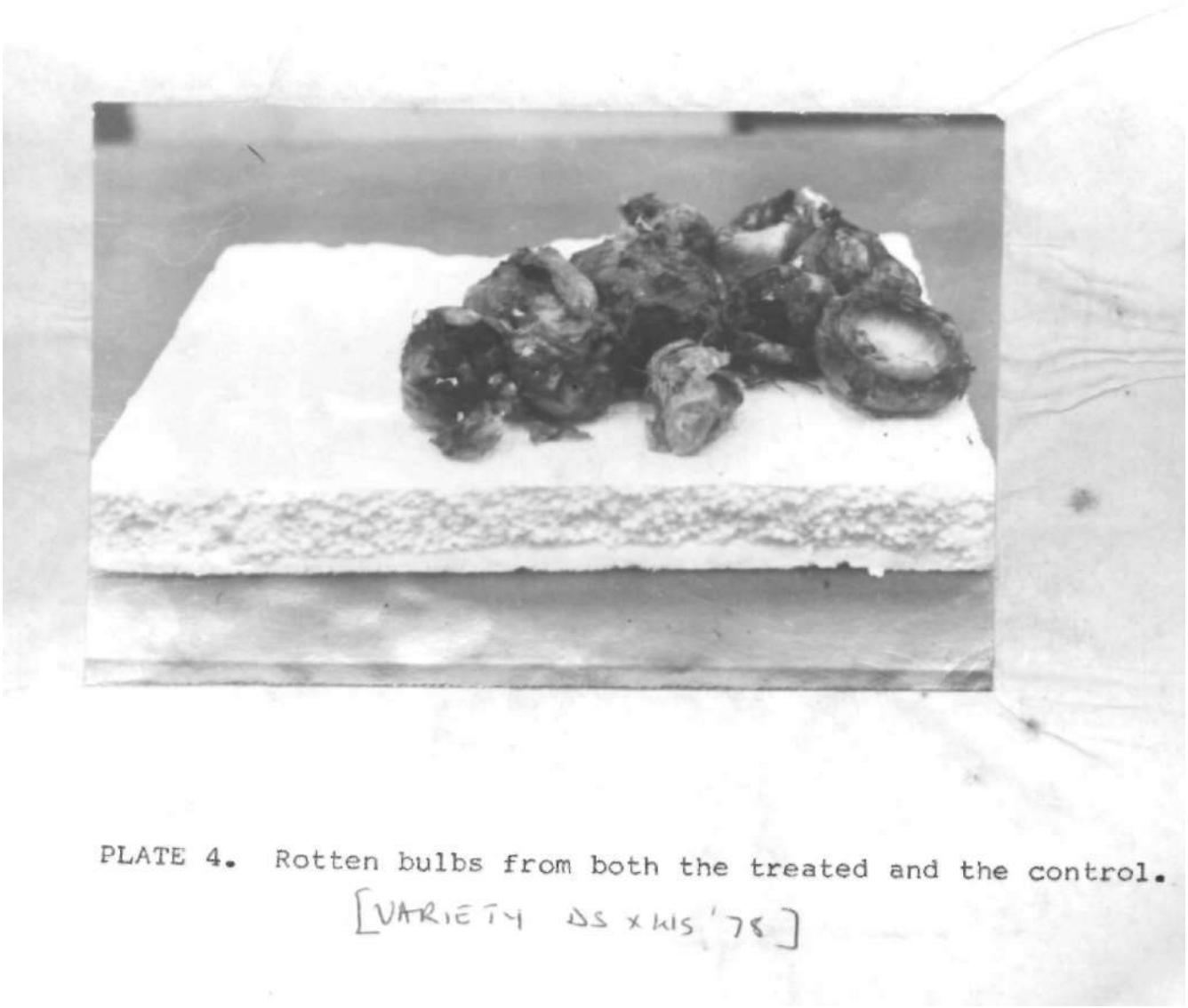


PLATE 4. Rotten bulbs from both the treated and the control.
[VARIETY DS x WIS '78]

Chemical Changes.

Flavour (Thiopropanal S-oxide).

The effects of gamma irradiation and storage on the flavour (thiopropanal S-oxide) are shown in Figure 7. There was an initial decrease in the flavour component in the irradiated bulbs. The decrease though not significant was more apparent in the 15 krad treated samples. No decrease was observed in the control for the first 2 months. However, there was a slight decrease at the end of the 3rd month. The flavour component in 8 krad treated sample varied irregularly in the first 3 months of storage.

There was an increase in both the treated and the control at the end of the 4th month followed by a sharp decrease at the end of the 5th month. A slight increase was observed at the end of 6 months storage. In general, both the irradiated and the control varied irregularly with storage. The U.V spectra of the flavour extract are shown in Figure 6.

Irradiation had no effect on the flavour component of onion ($p > 0.1$). Flavour component however, varied significantly with storage time ($p < 0.001$). Interraction between dose and storage time was equally not significant ($p > 0.25$).

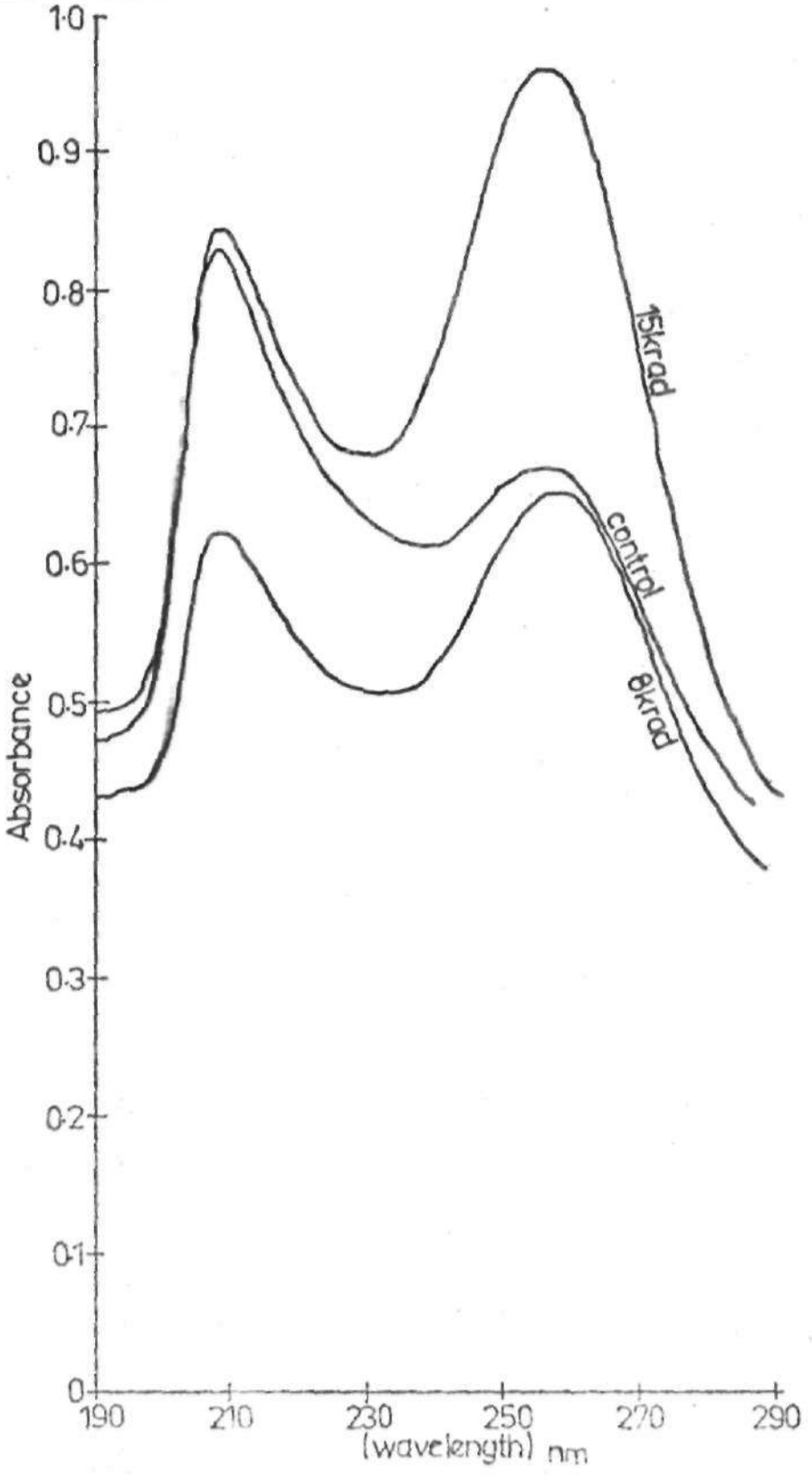


fig 6 U.V. Spectra of onion flavour extract.

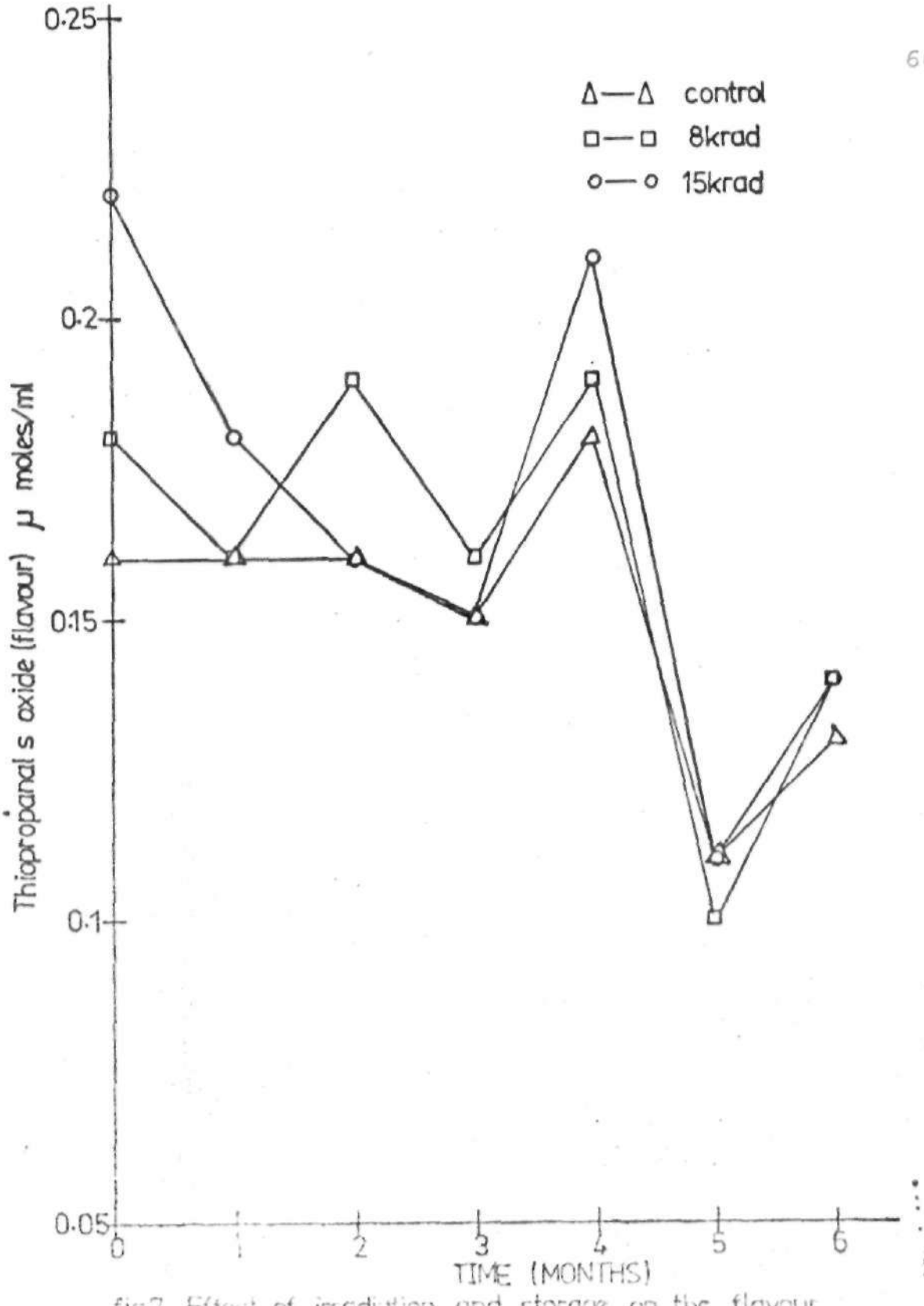


fig7 Effect of irradiation and storage on the flavour (Thiopropanal s oxide) componenk of onion.

Ascorbic acid.

The changes in ascorbic acid content during storage of both the control and irradiated onions are shown in Figure 8. Ascorbic acid increased in the first 3 months of storage. There was a decrease at the end of the 4th month after which there was an increase. Ascorbic acid content of 15krad treated sample however showed a slight decrease at the end of the 2nd month. Irradiation had no significant effect ($p > 0.25$) on ascorbic acid. Storage time, however, had significant effect ($p < 0.001$). Interraction between storage time and irradiation was not significant ($p > 0.05$).

Dry matter content

The effects of irradiation and storage on the dry matter content are shown in Figure 9. There was a decrease in dry matter content in both the irradiated and the control in the first 3 months of storage. A slight increase was observed at the end of the 4th month after which there was a decrease.

It can be seen that at the end of the 6th month, the dry matter content of 15 krad treated sample increased.

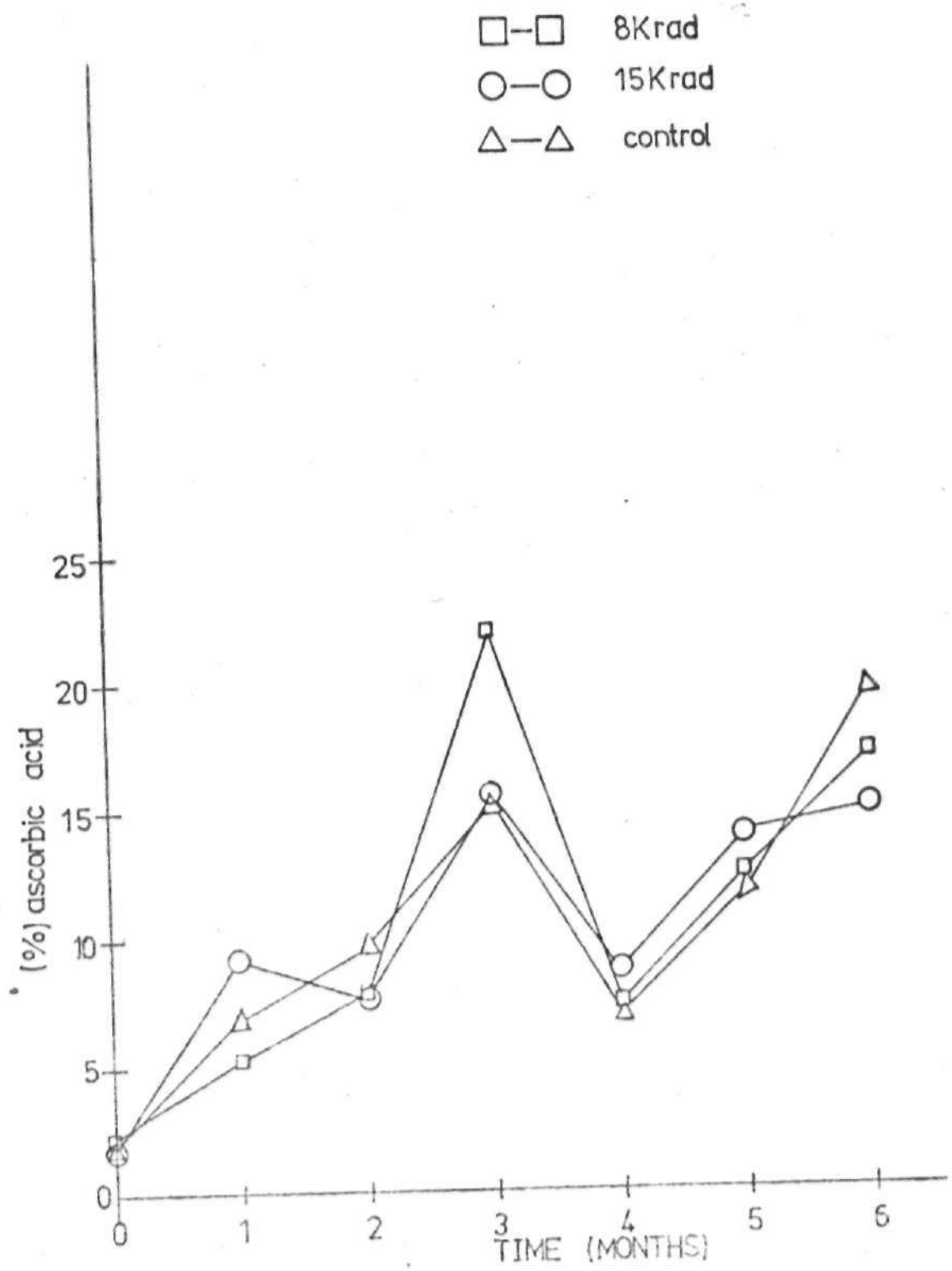


fig 8 Effect of irradiation and storage on the ascorbic acid content of onion.

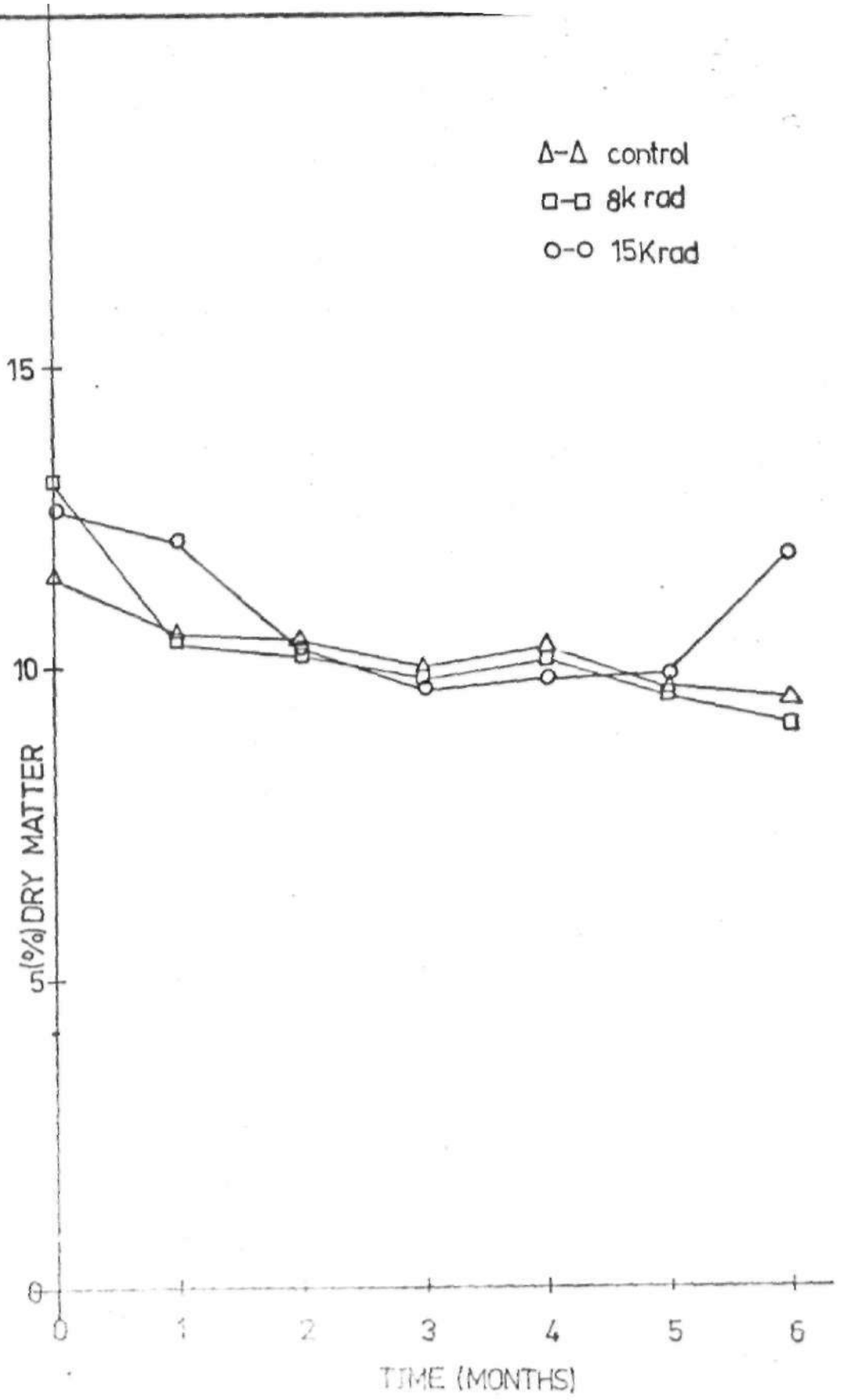


fig.9 Effect of irradiation and storage on the dry matter content of onion.

Irradiation did not affect the dry matter content. Storage time however had a significant effect ($p < 0.001$). Interraction between the dose and storage time was not significant ($p > 0.05$).

Ash content.

Changes in ash content of both the control and the irradiated samples as a function of storage time are shown in Figure 10. The ash content in general seemed to increase with storage time. There was a slight decrease in the ash content of the irradiated samples at the end of the 6th month.

Irradiation had a significant effect ($p < 0.05$) on the ash content. While higher values of ash content were recorded for the 8krad treatment, lower values were recorded for 15 krad with intermediate values for the control. Interraction between time and radiation dose was not significant ($p > 0.25$).

Protein content

Figure 11 shows the effect of storage and irradiation on the protein content. A general decrease in protein content

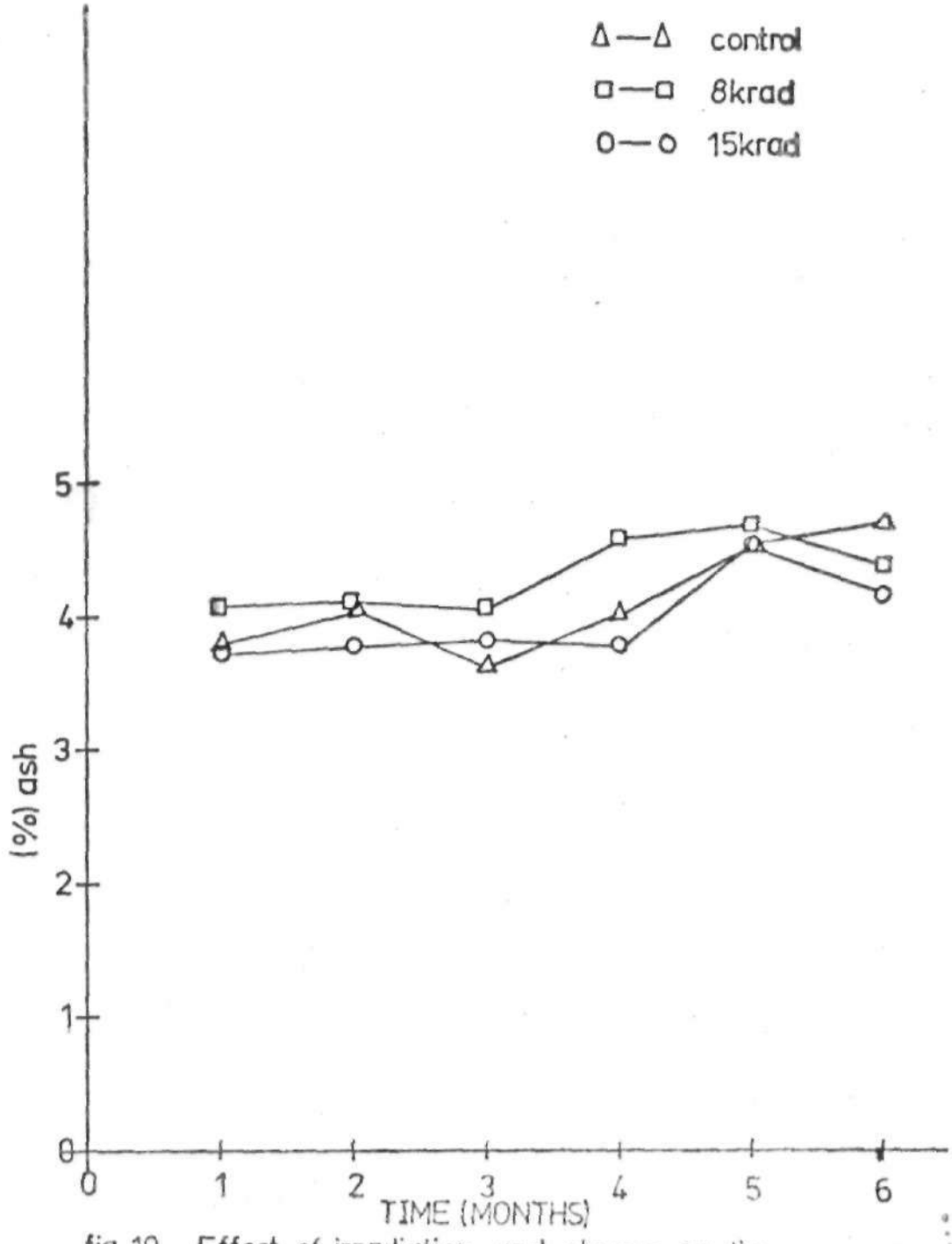


fig 10 Effect of irradiation and storage on the ash content of onion.

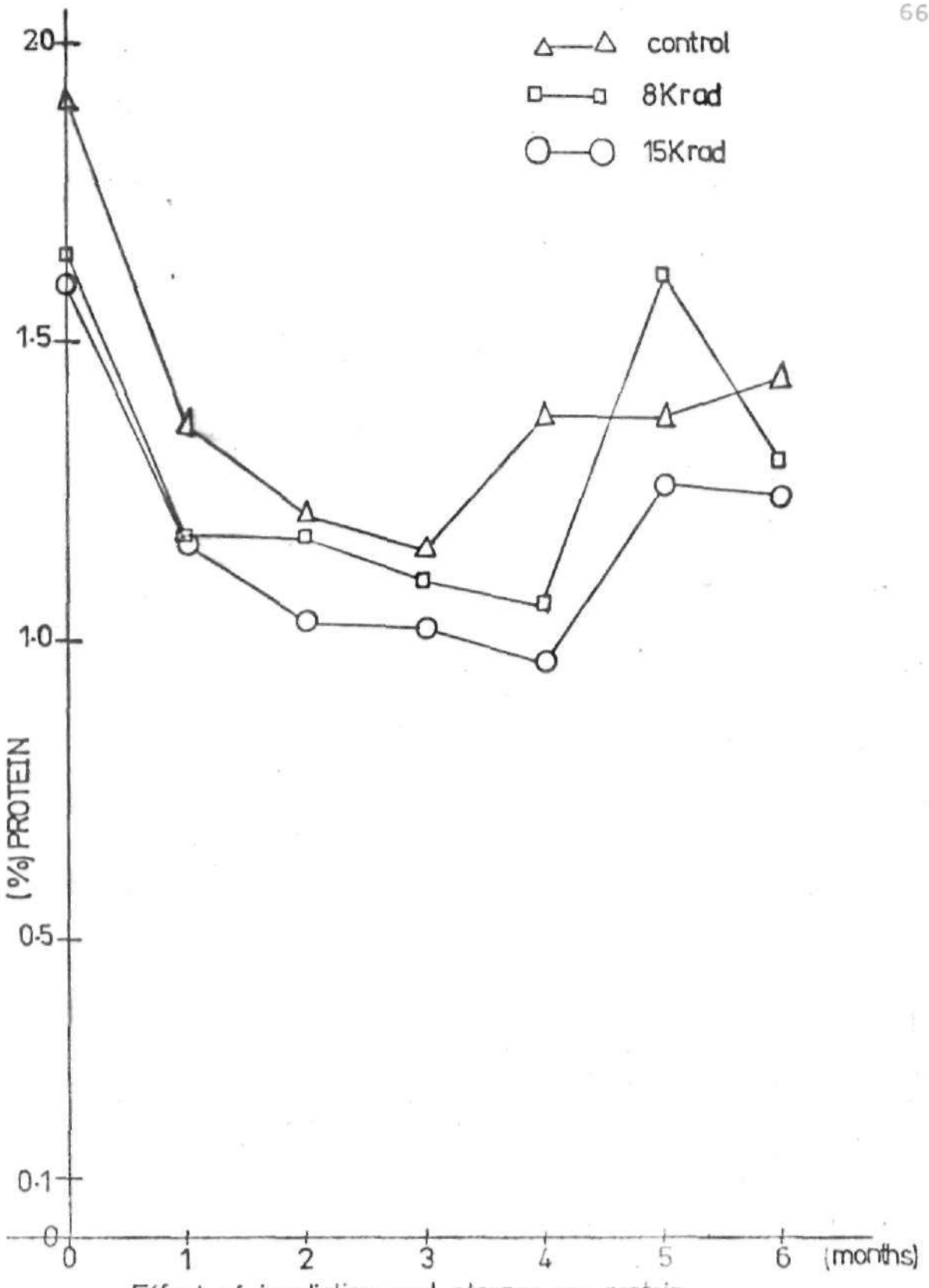


fig 11 Effect of irradiation and storage on protein content of onion.

was observed in the first 4 months. There was an increase in the irradiated samples at the end of the 5th month but decreased in the 6th month. Contrary to the irradiated samples, the non-irradiated ones showed a gradual increase in protein content from the end of the 4th month till the 6th month. The effect of irradiation on protein content was significant ($p < 0.001$). The protein content decreased with increase in dose level. Interraction between time and dose was also significant ($p < 0.05$).

Lipid.

The effects of irradiation and storage on the lipid content are shown in Figure 12. An increase in lipid content was observed up till the end of the 2nd month in both the control and the treated samples. This was followed by a gradual decrease throughout the storage period. There was no noticeable difference in variation of lipid content between the control and the irradiated samples during storage. Analysis of variance also showed that irradiation had no significant effect on the lipid content ($p > 0.25$).

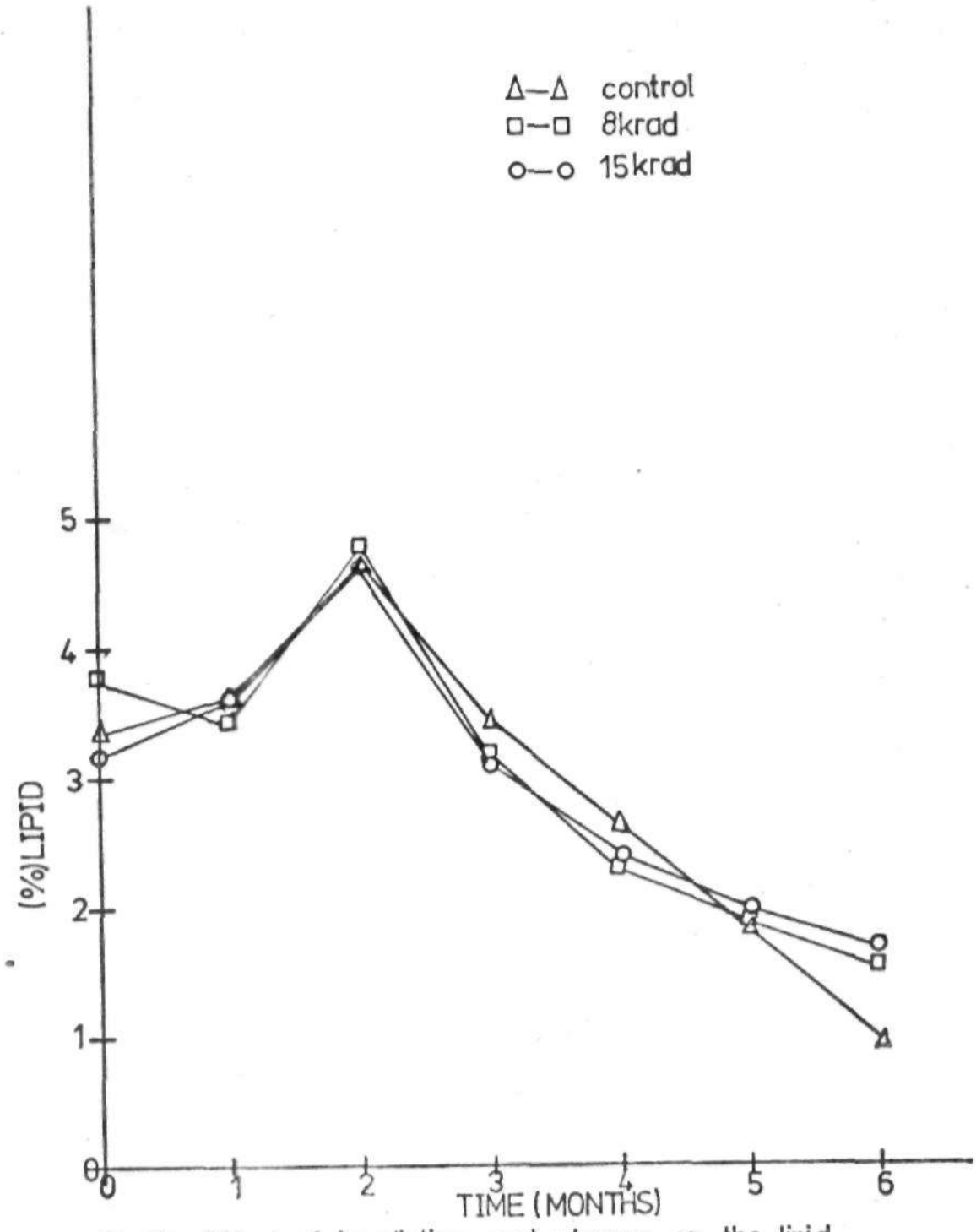


fig 12 Effect of irradiation and storage on the lipid content of onion.

Thin layer chromatography.

Plate 5 represents the thin layer chromatographic separation of onion lipid from control and irradiated samples. Similar patterns of separation and identical chromatograms were observed in both the control and the irradiated. Seven distinct spots, numbered consecutively (1-7) from the base were obtained. Their R_f values are shown in Table 8. No marked difference could be seen in the R_f values of both the control and the treated samples.

Reducing Sugar

The variation in reducing sugar content during storage period is shown in Figure 13. Reducing sugar content in both irradiated and control increased in the first 2 months of storage. There was a decrease at the end of the 3rd month followed by an increase in the 4th month. A decrease at the end of the 6th month was also observed. Analysis of variance showed that gamma irradiation has significant effect ($p < 0.001$) on the reducing sugar content. The effect of time was also significant.

TABLE 8.

Rf values of the lipids extracted from irradiated onions.

Component	Rf values		
	Control	8krad	15krad
1	0.11	0.11	0.11
2	0.16	0.14	0.14
3	0.19	0.18	0.18
4	0.25	0.23	0.22
5	0.55	0.53	0.53
6	0.94	0.93	0.93
7	0.97	0.97	0.97

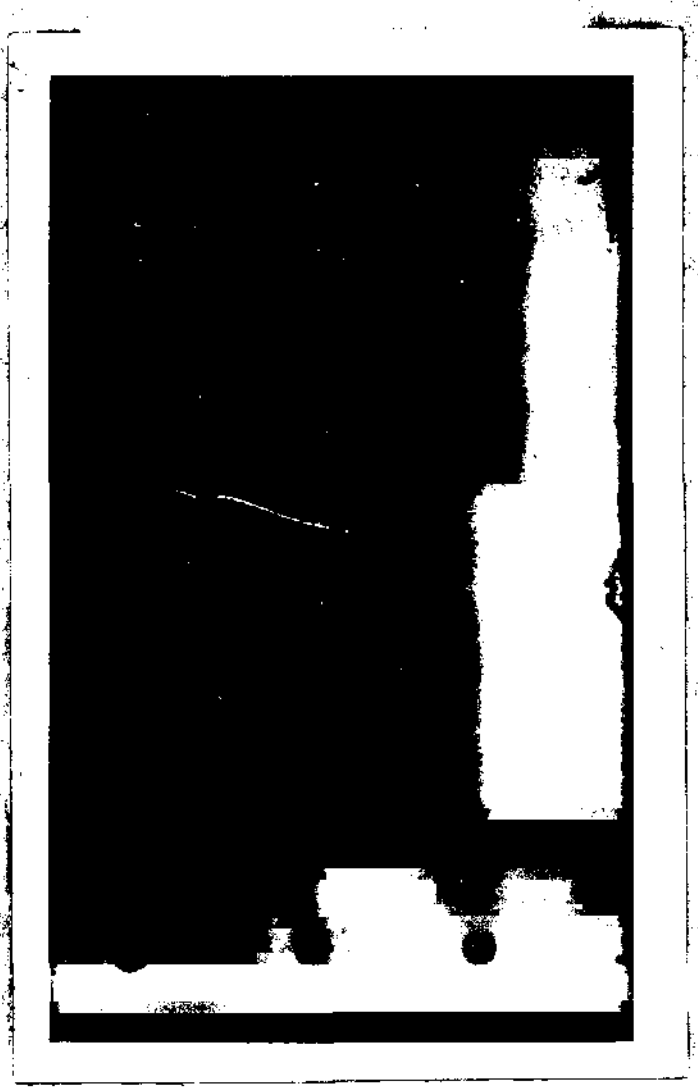


PLATE 5. Thin layer chromatogram of onion lipid.

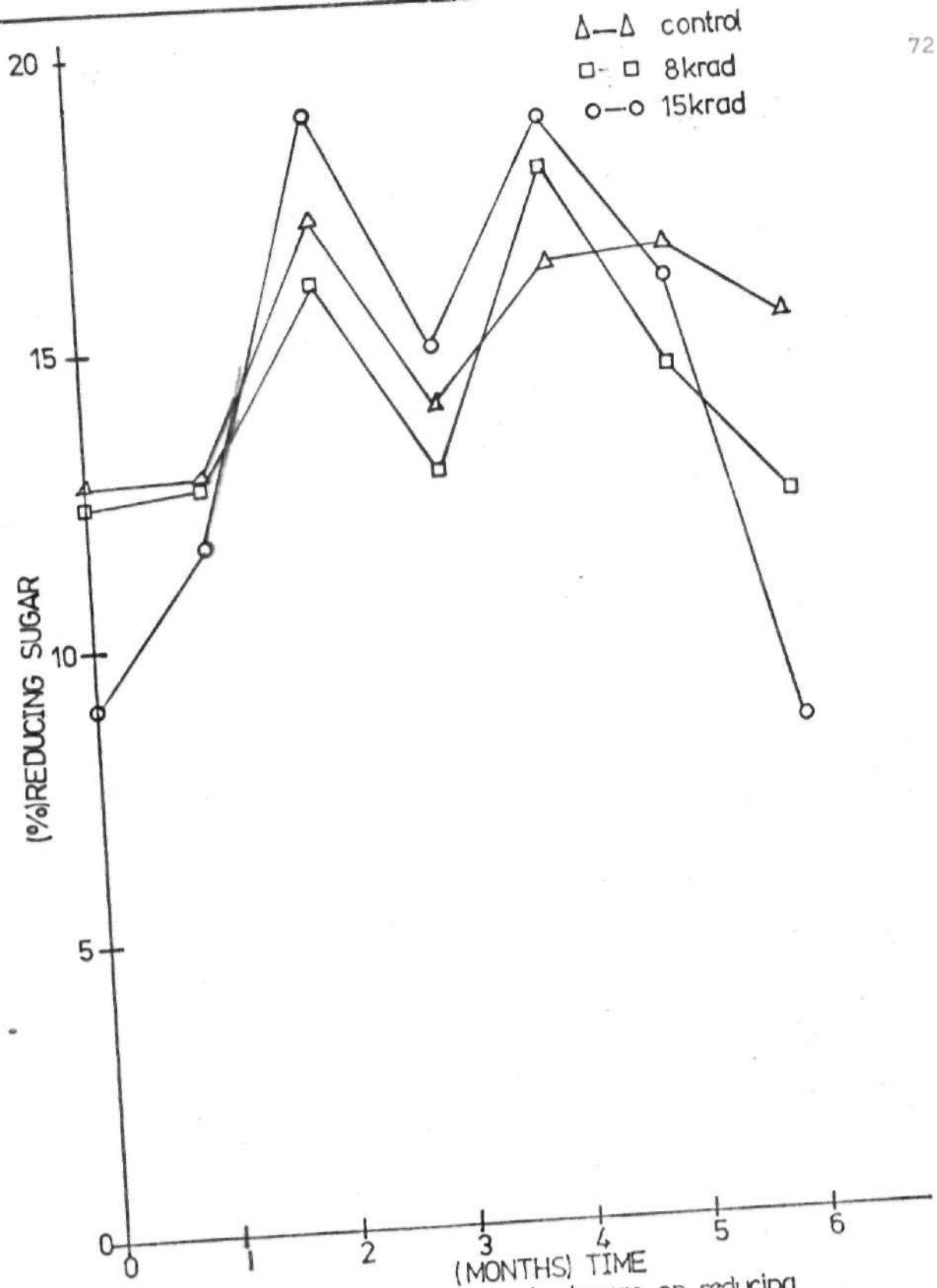


fig 13 Effect of irradiation and storage on reducing sugar of onion.

CHAPTER FOUR

DISCUSSION

Sprouting

The results (Tables 1 and 2) have shown that a dose as low as 5krad inhibited sprouting completely. This is in agreement with the report of Khan and Wahid (1978); de Zeeuw, (1975) that a dose of 5-15krad used shortly after harvest showed complete sprout inhibition. However, the results do not agree with the findings of Nair et al, (1973). They reported that irradiation dose levels of 6-15krad did not completely inhibit sprouting in onions. This contradiction may be explained by the assumption that these workers irradiated the bulbs after the break of dormancy. Varietal differences may also account for this discrepancy.

Sprouting in variety WS'79 was significantly higher ($p < 0.05$) than in variety DS x WS'78. The difference may be attributed in part to the difference in variety. Also, many bulbs of WS'79 were harvested while still immature. This may account for the higher incidence of sprouting in WS'79. Immature bulbs sprout more easily (Karmarkar and Joshi, 1941). In addition, bulbs of WS'79 were

bigger than those of variety DS x WS 78. This is similar to the findings of Kapur et al (1953). The effect of relative humidity and temperature on sprouting was not apparent.

Maleic hydrazide (MH) has been widely used to suppress sprouting in onion bulbs. This method when compared with the use of gamma irradiation is less effective. A dose as low as 5krad inhibited sprouting completely whereas complete inhibition of sprouting in onion by MH has not been reported.

The target of gamma irradiation is not completely known. However, it was reported (Nair et al, 1973) that one of the causes for gamma irradiation induced growth inhibition is a derangement of the synthesis of growth hormones.

Rotting.

Irradiated onions showed an increased tendency to rot during storage. The results in terms of accumulated percentage loss due to rot are not in agreement with the observations reported by Salem, (1974); Khan and Wahid, (1978); Dallyn and Sawyer, (1959a); Sawyer and Dallyn, (1956),

that there was no higher incidence of rotting in irradiated onions. Ogbadu, (1979), also observed a decrease in rot in irradiated onions during storage. Khan and Wahid, (1978) however, showed that there was a slight increased tendency of irradiated potatoes to rot than the control. The probable reason for the higher incidence of rot in irradiated bulbs in this study may be due to pre-harvest infection of bulbs used. The resistance of the bulbs might have also been lowered by irradiation. In addition, mechanical injuries received by the bulbs during transportation to and from Ibadan probably made the irradiated bulbs more susceptible to rot pathogens. The control bulbs were not transported to Ibadan due to limited space in the vehicle used.

The effect of relative humidity and temperature on rotting is rather difficult to conclude. One will expect that the percentage rotting will increase with increase in relative humidity, but in this study, the percentage rotting increased with decrease in relative humidity (compare Figs. 3, 4 and 5). The possible explanation is that the bulbs might have been infected in the first 4 months (June - September) when the relative humidity was high but that there was a time lag before the manifestation

of the disease. The sharp decrease at the end of the 7th month may be due to onset of harmattan when the relative humidity was low.

The higher incidence of rot in the treated bulbs of WS'79 compared with that of DS x WS'78 may be due (in addition to the difference in variety) to variety WS'79 being infected on the field before harvest. (Van Amstel, Personal communication). Despite heavier infection levels in the field of variety WS'79, the control of variety DS x WS'78 showed more rot than the control of WS'79. The possible explanation might be that DS x WS'78 grown at Kadawa were packed in bags after harvest for some days before they were transported by road to Samaru. These were left for some days before being spread out. Probably, this might have caused damage to the bulbs and increased rotting.

Periodic examination of the irradiated and the control onion bulbs during storage showed signs of discoloration (changing to yellowish brown) of the growth centre in several irradiated bulbs. This increased during storage. In several cases the discoloration was accompanied by rotting of the growth centre. Similar discoloration of the growth centre has been reported by many workers (Dallyn and

Sawyer, 1959b; Nutall et al, 1961; Kahan and Temkin-Gorodeiski, 1968, Nair et al, 1973). It was suggested (Nair et al, 1973) that the discoloration of the growth centre may be due to death of the meristem tissues which became more susceptible to microbial attack. Adesuyi and Mackenzie (1973) reported similar observations in irradiated yam tubers. Discoloration however, does not cause a serious problem during domestic cooking as this part can easily be removed, but when processing into powder or flakes, it may give a poor product.

Rotting and Sprouting (total loss).

The results show that the major loss factor in variety DS x WS'78 onion during storage is rotting. In WS'79 however, the major loss factor appears to be sprouting. It is interesting to note that a random examination of the bulbs at the end of storage experiment showed almost 70% internal sprouting in the control bulbs as against 0% in the irradiated ones. Irradiation will be more effective in preserving onion when the bulbs to be treated are healthy and show low susceptibility to storage rots.

Local Storage trial:

There was no significant ($p > 0.05$) difference between the total percentage loss in the two sets of huts. However, the huts with straw in between layers of onion seem to be a better method.

Comparing the mud huts experiment with the single layer experiment, there was a marked difference between the total loss at the end of the 3rd month. The total loss in the mud huts was almost twice that in the single layer experiment. However, at the end of the 7th month, not much difference was observed between them.

The excessive loss in the mud huts experiment may be due to: (1) Lack of enough ventilation holes in the huts. This restricted air circulation, allowed relative humidity to rise in the huts and disease spread to adjacent bulbs was enhanced. It was observed also that heat built up in the huts was high. This favoured disease spread. The evidence in support of this fact is that very few bulbs sprouted while the bulk of the bulbs rotted. (2) Bulbs used were already badly infected as shown by high percentage rot when bought. (3) Lack of inspection of huts at regular intervals.

Comparing the results obtained in this local storage

with the irradiation experiment, it is clear that local storage method is not favourable.

Chemical Changes.

Flavour (Thiopropanal S-oxide)

A dose as high as 15krad did not affect the flavour component of onion. This agrees with the report of Bandyopadhyay et al, (1973) that there was no difference between the control and the irradiated onions in terms of flavour component. Losses in flavour volatiles and lachrymator observed during slicing were not likely to be significant since onion tissues were disinte grated at low temperature (4°C).

Arguments (Greig and Lock Wood, 1969) have been presented that since a high percentage of onion is lost through decay and sprouting, an alternative is to produce dehydrated onions. This is being done on commercial scale. But onions have been traditionally consumed mainly for their flavour. The effects of post harvest processes have been studied by Freeman and Whenham (1974). They reported that about 90% of the flavour was lost during processing. In view of the above facts, dehydrated onions

may not be able to replace fresh ones to a large extent. Moreover, onion to be processed have to be stored for some time since all bulbs cannot be processed at the same time.

Ascorbic acid.

The changes in ascorbic acid during storage in this investigation is quite contradictory to what has been reported by earlier workers (Salem, 1974; Sawyer and Dallyn, 1956). They reported that ascorbic acid decreased with storage. The reason for this difference may be due to the fact that most of their works were carried out at a controlled relative humidity and temperature which was not the case in this study. It was also reported that gamma irradiation of fresh onion bulbs resulted in reduction of ascorbic acid (Salem, 1974). This was however not the case in this work. The pattern of change in the treated and the control were the same (Fig. 8). Moreover, the values of ascorbic acid recorded for the control throughout the storage period were never higher than that of the irradiated bulbs.

The sharp increase of ascorbic acid at the end of the 3rd month may be due to increase in the rate of synthesis

L-gulonolactone oxidase

of ascorbic acid. There was a corresponding decrease in the percentage reducing sugar at the end of the 3rd month (Fig. 13). Glucose might have been used up in the synthesis of ascorbic acid. On the other hand, the sharp decrease at the end of the 4th month may be due to a decrease in the synthesis. This led to accumulation of reducing sugar at the end of the 4th month (Fig. 13). The reason for this variation may be enviromental.

Dry matter content.

Dry matter content generally decreased with storage. Irradition did not affect the dry matter content. The reason for the increase in dry matter content of the 15krad treated sample at the end of the 6th month is not known. Equally, the reason for the slight increase in both the control and the treated at the end of the 4th month is not very obvious.

In stored onions, as in all living tissues, respiration results in the continual loss of stored food (dry matter) and in the production of heat.

Although the respiration rate of onion bulbs is much lower than that of most vegetable crops (Jones and Mann, 1963c), the loss of dry matter can be important because onions are often stored for long periods. This loss is especially important in onions that are used for dehydration, as dry matter is the end product.

Ash content.

Ash content gives a rough idea of the amount of mineral elements present in food sample. The major mineral elements as analysed by Ketiku (1976) are phosphorus, calcium, magnessium, potassium and sodium. Potassium when compared to sodium is relatively high. This relatively high potassium and low sodium content of onions make them a useful diet suppliment in some cardiac disorders (Falase, 1975).

The ash content is known to vary between individual food material and it is often difficult to obtain satisfactory duplicate ash determinations (Joslyn, 1970). The variation in the ash content (Fig. 10) may be in addition to irradiation due to changes in weight caused by progressive decomposition of carbonates, or losses of

relatively volatile constituents such as chlorides. It may also be due to difficulty of weighing alkaline ashes quickly enough to avoid weight changes owing to hydration during the necessary exposure to humid atmosphere outside of desiccators and on balance pans.

Protein content.

Gamma irradiation of onion bulbs resulted in a decrease in protein content. Results obtained in this study partially agree with those of other workers (Sawyer and Dallyn, 1956; Salem, 1974).

The gradual decrease in protein during storage may probably be due to metabolic changes that occur in onions. The protein was gradually being utilized in the building up of new tissues. The decrease in protein could also be due to utilization of the protein as nutrient by the micro-organism for growth which resulted into formation of spoilage metabolites (Eskin et al, 1971a). Increase in percentage rot during storage may be an additional evidence in support of the above reason. Protein has been implicated in the browning process in plants (Eskin et al, 1971b). This could account at least

in part for the decrease in protein during storage. The lower values of protein content in the treated samples compared with the control may be attibuted to the deamination of the free amino acids, polypeptides.

The increase in protein in the control as from the 4th month suggests a break in dormancy and the bulbs were synthesizing new protein. The increase in protein content in the irradiated samples at the end of the 5th month followed by the decrease in the 6th month cannot easily be accounted for.

Lipid content.

The lipid content of both the control and the irradiated samples gradually decreased (except at the end of the 2nd month) throughout the storage period. The decrease may be due to degradation in the biochemical reaction involving lipase and lipo oxidase activities (Eskin et al, 1971c).

The increase at the end of the 2nd month was mainly due to petroleum ether used in the extraction. Petroleum ether (b.p. 80-100^{o}C) was used due to lack of one with b.p 60-80^{o}C at this time.

Petroleum ether (80-100°C) must have extracted some other ether soluble components which have accounted for this high value. It was observed that when petroleum ether (b.p 80-100°C) was used, decomposition of onion lipid was occuring as black substance which was suspected to be acrolein was produced. This observation also has given a clue as to the size of lipid component in onion. It is suggested that the lipid components probably have low molecular weights and thus low boiling points.

Reducing sugar.

The initial increase in the reducing Sugar is similar to what has been previously reported (Salem, 1974; Mahmoud et al, 1978). The increase in reducing sugars may be due to enzymatic breakdown of the cell wall to oligo and monosaccharides (Godwin and Mercer, 1972). The stored starch may become converted into sugars, mainly sucrose, glucose and fructose due to activities of amylase (Nordin and Kirk Wood, 1965; Whelan, 1961). Contrary to what has been reported by Mahmoud et al, 1978, the reducing sugar content of irradiated bulbs

increased faster at the initial stage of storage than the control. Infact, the difference between 15krad and the control was significant. The high accumulation of reducing sugar in 15krad treated onions in most cases may be due to a relatively high rate of enzyme activity compared with the rate of utilization in respiration.

A decrease in reducing sugar at anytime during storage has not been reported. In this study, a decrease in reducing sugar in both the control and irradiated has been observed. Referring to Figs 8 and 13, it could be seen that there is a negative correlation (r=-0.60) between the pattern of changes in ascorbic acid content and that of reducing sugar as from 3rd month. The reason for this has already been discussed.

CONCLUSION

Irradiation with a dose of 5-15krad completely inhibited sprouting throughout the whole storage period of 7 months.

The resistance of onion to rot disease seemed to be

lowered by irradiation.

The optimum dose could not be effectively determined as the percentage rot recorded for all the treated were about the same. However, since the cost of irradiation depends very much on the dose required, a dose of 5krad (for inhibition of sprouting) is suggested for large scale application.

After 7 months storage, irradiated bulbs were found to have better appearances. The chemical and nutritive qualities of onion regarding ascorbic acid, flavour, protein, lipid were not adversely affected by irradiation dose up to 15krad.

It is clear from the results that local storage method is not suitable as almost 100% of onions were lost at the end of 7 months storage.

The use of irradiation in onion preservation is still in the experimental stage. Harmful effects due to ingestion of irradiated onion are beyond the scope of the present study. However, a provisional acceptance of irradiated onion has been given (W.H.O/FAO, IAEA 1976). In addition, it was reported that the toxicological data available do not indicate any health hazard arising from ingestion of irradiated onions.

Inspite of the considerable research already carried out in the irradiation of food and the encouraging results which have emerged, much remains to be accomplished before irradiation can take its place along with the conventional food preservation processes.

Suggestion for further Studies

1. Since losses in irradiated onions were mainly due to rotting during storage, a prior treatment of the bulbs with fungicides before irradiation may reduce the percentage loss due to rotting in irradiated bulbs. Either the onion field is sprayed before the harvest or bulbs are sprayed immediately after harvest. In this way, the loss due to sprouting and rotting in onions may be reduced to insignificant level.

2. In the local storage method, more ventilation windows should be created and the height of the huts above the ground should be raised. More importantly, very good quality bulbs should be used for storage trials.

3. Foods, generally are irradiated in the raw state and then stored for a period of time before they are cooked and consumed. Cooking is known to result in loss of nutrients, depending on the method of cooking. The extent to which irradiation may contribute to these losses needs looking into. Thus nutritional evaluation of irradiated onion should be carried out on bulbs as they are actually consumed (either raw in salad, or cooked as in soup).

4. Toxicity studies should be carried out which involve animal feeding experiments and taking note of the growth rate, reproduction performance and some haematological tests.

5. The word 'radiation' conjures up thoughts of atomic bombs, fallouts, cancer and genetic defects. The public (including many scientists) are more concerned about the hazards of radiation and this is reflected in a distrust of irradiated foods. It is therefore necessary to educate and reassure the public as to the safety of irradiation as a food preservation process.

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APPENDIX

Percentage loss due to rotting and sprouting per month of irradiated onions

Variety DS x WS'78

Month	Control		5krad		8krad		15krad	
	S*	D*	D*	S*	D*	S*	D*	S*
1	0.00	5.58	3.51	0	4.74	0	2.97	0
2	0.008	5.36	3.80	0	4.97	0	3.85	0
3	2.83	2.04	5.08	0	4.68	0	3.43	0
4	4.76	3.75	6.25	0	3.47	0	3.85	0
5	4.87	3.41	7.94	0	9.28	0	6.46	0
6	7.77	7.66	15.52	0	15.84	0	17.43	0
7	4.56	6.09	8.57	0	9.78	0	8.37	0

S* Sprouted onions

D* Decayed onions

Variety WS'79

Month	Control		8krad		15krad	
	S*	D*	D*	S*	D*	S*
1	2.64	1.02	3.00	0	3.90	0
2	5.47	1.30	6.33	0	4.02	0
3	10.82	3.85	9.73	0	9.69	0
4	13.22	3.33	16.22	0	15.64	0
5	11.60	7.29	14.71	0	12.39	0
6	8.67	9.12	21.76	0	22.22	0
7	18.61	3.72	3.55	0	6.25	0

S* Sprouted onions

D* Decayed onions

CHEMICAL ANALYSES.

FLAVOUR (THIOPROPANAL S-OXIDE)

(Measured in μ moles/ml of onion juice)

MONTH	CONTROL	8KRAD	15KRAD
0	0.16 ± 0.02	0.18 ± 0.01	0.22 ± 0.02
1	0.16 ± 0.00	0.16 ± 0.01	0.18 ± 0.01
2	0.16 ± 0.02	0.19 ± 0.01	0.16 ± 0.02
3	0.15 ± 0.02	0.16 ± 0.01	0.15 ± 0.03
4	0.18 ± 0.03	0.19 ± 0.03	0.21 ± 0.02
5	0.11 ± 0.01	0.10 ± 0.00	0.11 ± 0.01
6	0.13 ± 0.01	0.14 ± 0.01	0.14 ± 0.01

ASCORBIC ACID

Results expressed as mg/100gm of fresh onion.

MONTH	CONTROL	8KRAD	15KRAD
0	1.92 ± 0.29	2.22 ± 0.09	1.64 ± 0.01
1	6.84 ± 0.65	5.19 ± 0.47	9.18 ± 1.38
2	9.56 ± 1.00	7.90 ± 0.69	7.72 ± 1.01
3	15.08 ± 0.88	21.93 ± 3.11	15.47 ± 0.77
4	6.92 ± 0.46	7.42 ± 0.72	8.58 ± 0.66
5	12.44 ± 0.55	12.44 ± 0.62	13.95 ± 0.71
6	19.49 ± 1.34	16.96 ± 0.87	14.98 ± 1.33

DRY MATTER CONTENT (in percent).

MONTH	CONTROL	8KRAD	15KRAD
0	11.56 ± 0.08	13.08 ± 0.69	12.58 ± 0.40
1	10.69 ± 0.52	10.51 ± 0.08	12.11 ± 1.00
2	10.55 ± 0.33	10.30 ± 0.42	10.46 ± 0.22
3	10.09 ± 0.17	9.93 ± 0.39	9.77 ± 0.25
4	10.49 ± 0.68	10.23 ± 0.96	9.89 ± 0.44
5	9.76 ± 0.51	9.68 ± 0.65	10.00 ± 0.62
6	9.62 ± 0.27	9.13 ± 0.60	11.99 ± 0.93

PROTEIN CONTENT (in percent).

MONTH	CONTROL	8KRAD	15KRAD
0	1.91 ± 0.04	1.64 ± 0.03	1.59 ± 0.05
1	1.35 ± 0.11	1.18 ± 0.06	1.16 ± 0.07
2	1.21 ± 0.05	1.17 ± 0.05	1.03 ± 0.03
3	1.15 ± 0.05	1.11 ± 0.05	1.02 ± 0.03
4	1.37 ± 0.04	1.06 ± 0.08	0.96 ± 0.06
5	1.37 ± 0.07	1.61 ± 0.16	1.26 ± 0.05
6	1.44 ± 0.04	1.30 ± 0.06	1.24 ± 0.11

LIPID CONTENT (in percent).

MONTH	CONTROL	8KRAD	15KRAD
0	3.37 ± 0.07	3.79 ± 0.07	3.17 ± 0.07
1	3.64 ± 0.34	3.44 ± 0.24	3.64 ± 0.28
2	4.66 ± 0.37	4.75 ± 0.42	4.71 ± 0.21
3	3.42 ± 0.16	3.17 ± 0.12	3.10 ± 0.12
4	2.61 ± 0.27	2.26 ± 0.26	2.36 ± 0.37
5	1.80 ± 0.26	1.83 ± 0.23	1.96 ± 0.26
6	0.92 ± 0.03	1.53 ± 0.26	1.69 ± 0.56

ASH CONTENT (in percent).

MONTH	CONTROL	8KRAD	15KRAD
0			
1	3.81 ± 0.14	4.09 ± 0.10	3.73 ± 0.09
2	4.06 ± 0.21	4.09 ± 0.15	3.78 ± 0.15
3	3.61 ± 0.17	4.07 ± 0.23	3.82 ± 0.18
4	4.02 ± 0.27	4.56 ± 0.35	3.77 ± 0.24
5	4.58 ± 0.13	4.67 ± 0.16	4.54 ± 0.15
6	4.70 ± 0.20	4.37 ± 0.30	4.05 ± 0.17

REDUCING SUGAR.

MONTH	CONTROL	8KRAD	15KRAD
0	12.75 ± 0.09	12.38 ± 0.09	9.00 ± 0.34
1	12 [illegible] ± 0.13	12.60 ± 0.23	11.66 ± 0.43
2	17.10 ± 0.93	15.98 ± 0.24	18.90 ± 0.48
3	13.86 ± 0.35	12.74 ± 0.25	14.85 ± 0.67
4	16.20 ± 1.15	17.82 ± 0.08	18.68 ± 0.16
5	16.47 ± 0.11	14.40 ± 0.06	15.90 ± 0.21
6	15.21 ± 0.23	12.15 ± 0.43	8.37 ± 0.23