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Effect of Irradiation and Edible Coating as Safe Environmental Treatments on The Quality and The Marketability of "*Anna*" Apples During Cold Storage

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The present study was carried out during two successive seasons of 2014 and 2015 on "*Anna*"apples. The effect of gamma irradiationof 0.5and 1.0 kGyin addition to edible coating with paraffin oil and glycerol on the shelf-life and quality of apples during cold storage at 0°C, 90-95% RH for 90 days was evaluated.Gamma irradiation of 0.5 and 1.0 kGycaused a reduction in blue mold incidence (%) caused by *Penicilliumexpansum*in from 20.2% to 10.0% and 6.5% after 90 days cold storage however, in artificial inoculated fruits blue mold incidence reduced from 40% to 20.2% and 18.7% after 30 days.At 60 days,this level was reduced from 85% to 36.1% and 30%. At the end of cold storage period,the blue mold was reduced from 100% to 55.7% and 42.1%, respectively.The results indicated that irradiation and edible coating greatly affectedthe storage quality of apples. Edible coating paraffin oil or glycerol as well as irradiation of 1.0 kGy were effective in increasing storability of apples during storage compared to 0.5 kGy irradiation doses.These treatments decreased discarded and weight loss percentage and increased firmness, shelf life and calcium flesh of apples content. It could be noticed thatuntreated apples could be stored for 60 days where the treated ones by irradiation of 0.5 kGy could be stored for 75 days.However edible coated apples or irradiationwith 1.0 kGy could increase the storage period tobe 90 days.

Keywords: Irradiation, Edible coating paraffin oil or glycerol, Fungal mold, Anna apples, treatment, shelf-life, Marketability

Introduction

Apples (***Malusdomestica Bork*** **)** is considered one of the most important fruits in the world .Like most of the other perishable fruits, apples contain large amounts of water which causes a number of physiological and pathological disorders, and consequently causes a reduction in storage and shelf life. Many attempts were made for increasing the storage life in apple fruits. Postharvest pathogens cause major losses in apple production. More than 90 fungal species have been described as causative agents of apple decay during storage (Pianzzola *et al*.,21). Blue mold caused by *Penicilliumexpansum* is the most important postharvest disease of apples(Gholamnejad *et al*.,11). This disease causes shortage of shelf-life andconsequentjy economic loss of apple. Cool storage is not enough to reduce the yield loss. Therefore, there is a need to search of alternative treatmentsto the commonly used fungicides in order to reduce the loss of yield(Mostafavi*et al*.,17).

Gamma irradiation offers a promising method in increasing the storage life and shelf life, since it has a destructive effect on microorganisms and insect.The extension of fruit shelf life is an important goal to be attained. Many storage techniques have been developed to extend the marketing distances and holding periods for

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commodities after harvest. Different preservation methodologies have been studied.

One method of extending post-harvest shelf life is the use of the edible coatings that provide a semipermeable barrier against oxygen, carbon dioxide (CO_2), moisture and solute movement; thereby reducing respiration, water loss and oxidation reaction rates (Park,18)**.**Proteins, lipids and polysaccharides are the main constituents of edible films and coatings. Among the studied proteins are wheat gluten, corn zein, soy protein, rice protein, egg albumin and milk proteins (Perez-Gago *et al*., 20); Falcão-Rodrigues *et al*.,10).Polysaccharide-based coatings, alginate, pectin's, cellulose and derivatives, starch and sucrose polyestershave been used to extend the shelf-life of fruits and vegetables (Rhim,23; Rojas-Grau *et al*.,24). Lipids also include waxes, acylglycerols and fatty acids have been used for extending the shelf-life of fruits and vegetables (Perez-Gago *et al*., 20); Falcão-Rodrigues *et al*.,10).The objectives of this research is to evaluate the potential ofgamma irradiationdoses,edible coatings with paraffin oilandglycerol on keeping quality of "Anna" apples

Materials and Methods

The experiment was carried out during 2014 and 2015 seasons on mature "Anna" apples. Fruits were picked when the total red color reached about 50%.Fruit firmness was about 12 lb./ inch^2 and T.S.S % was about 10.5 %(ADS ,1). Undamaged mature Anna apple (*MalusdomesticusBorkh*) fruits of uniform size, shape, weight and color, free of physical damage as well as fungal infection were harvested in 2014 and 2015 seasons at Nubaria city, Egypt and transported to the National Center for Radiation Research and technology (NCRRT), Atomic Energy Authority Cairo, Egypt .The fruits were cleaned and divided into five groups ; each group was 36 Kg of fresh and healthy fruits (5 treatments X 3 replicates X 2 boxes X6 Kg for each box = 180 Kg for each). Five different experiments were carried out as follows:

Treatment 1: control(untreated).
Treatment 2: irradiation at 0.5 kGy.
Treatment 3: irradiation at 1.0 kGy.
Treatment 4: Fruits were coated with thin layer of paraffin oil(99.0%).
Treatment 5: Fruits were coated with thin layer of Glycerol (99.0%).

Each replicate consisted of two boxes, one box for studying physical properties and the other for determining chemical constituents.Control fruits werekept in carton boxes in each boxwithout any treatment, and all treatments were stored at (0°C and 90-95% RH).

Irradiation treatments

The irradiation of apples were carried out at room temperature using ^{60}Co source at the NCRRT. The irradiation facility used was an Egypt's Mega Gamma- 1, of the type J-6500 supplied by the Atomic Energy of Canada Limited. The applied doses were 0.0, 0.5, 1.0kGy for Anna fruits.The dose rate delivered during the experimental duration was 1kGy/hr.,as monitored by radiochromic film (McLauchlin *et al*.,15).After irradiation treatment, the experimental materials(fruits) were transferred into a coldstorage room adjusted at 0°C, 90-95% RH.

Edible coatings film

Paraffin oil and glycerol (99.0%) were of reagent grade (Gomhoria Co., Amireya-Cairo, Egypt).The fruits were immersed in paraffin oil or glycerol (99.0%) film solutions for (2min.)then they were immediately towel- dried, placed in carton boxes and stored at 0 °C, 90-95% RH.

Fungal species

Penicilliumexpansum was isolated from apples showing blue mold.These fruits were kept in clean and sterile plastic bags at room temperature for isolation.Samples were sterilized with 1% sodium hypochlorite for 2 min then washed using sterilized distilled waterand dried using filter paper. Fungal isolation was carried out from the inner tissues neighboring the infected ones. Segments were separately transferred to Petri plates containing potato dextrose agar (PDA) media and incubated for 7 days at 27°C(Waller,27).The fungus was identified, according to the method reported by Raper and Thom (22). At Mycological Lab.2 (ML2),Faculty of Science, Zagazig University, Egypt.

The following measurements were done

A- Fruit physical properities

1- Discarded fruits%

The fruit did not show any sign of decay or visualdisorders during the storage time were counted and discarded every 15 days in apples, then the discarded %apples was calculated according to(Kabeel,12).Any treatment was terminated in case of having 50% discarded fruits.

2- Incidence percentage (%) caused by P. expansum

Apples were wounded on two opposite sides to a depth of 2 mm and were subsequently inoculated by immersion for 15 seconds in a conidial suspension ($1x10^5$ spores/ml) of a virulent isolate of *Pencilliumexpansum* isolated from decayed apples and identified as previously mentioned. One hour after the inoculation, seven of the eight groups of inoculated apples (48 apples/group) were placed in three tray packed boxes with perforated polyethylene bags.The control group (No. 8) was inoculated and placed withouttreatment.All boxes were immediately stored at0°C, 90-95%RH**,**fordifferent storage periods.The results were calculated according to the method described by (Morcos,16).

3- Fruit weight loss(WL%)

The percentage weight loss of fruits (WL)was calculated at zero time of storage, then the initial weight of appleswas recorded and the WL was calculated by weighing the same fruits at the cold storage durations and every 15 days (Kabeel,12).

4-Fruit firmness (Lb./inch²)

Fruit firmness was recorded before and after treatments and after storage as well as every 15 days for apples.Fleshfirmness was determinedaccording to (A.O.A.C,3).

5- Fruit shelf- life (in days)

A fruit sample from each replicate was taken out of the storage room and left at room temperature at (28–26°C).When 50 % of the fruits was scalded, the shelf- life was terminated and the number of days was calculated and considered as the shelf-life.

B- Fruit chemical analysis

1- Total soluble solids (T.S.S.%)

20 g of fruit tissues were homogenized in a blender. The homogenized tissues were filtered using Whatman No.1 filter paper.The clear juice was decanted and used for T.S.S and titralable acidity analysis. Using hand refractometer, TSS % was measured using drops of the above extracted juice according to(A.O.A.C,3). and the data was expressed as gm malice acid /100gm fresh.

2- Titratable acidity (TA%)

The TA% was detemined according to the official methods of Analysis (A.O.A.C.,2).

3-Calcium fruit contents (Ca%)

It was determined in fruits flesh sample of 0.2 oven-dried flesh was taken for Ca determination by ethylene diamine tetra acetate (Versenate method) according to (Barrows and Simpson,5)and the data was expressed as mg / 100 gm dry weight .

Experimental design and statistical analysis

All treatments in this study were arranged in a complete randomized block deign. The data were subjected to analysis of variance using the general linear module procedure of (SAS,26),where appropriate treatment means were separated using Duncan’s multiple range test(Duncan’s,9) and all percentages were transferred to angles before statistical analysis.

RESULTS AND DISCUSSION

A-Effect of irradiation, coating with paraffin oil and glycerol on

1-The physicalproperties of "Anna" apple fruits

Discarded fruits%

It was noticed that,the discarded fruits% increased with advancement in cold storage durations regardless of the used treatments.The primary mechanism of moisture loss from fresh fruits and vegetables is by vapor-phase diffusion driven by a gradient of water vapor pressure at different locations (Yaman and Bayoindirli,28).On the other hand, respiration causes a weight reduction because CO_2 is lost from the fruit in each cycle (Bhowmik and Pan,7).However, the coating process caused a significant decrease in weight loss percentages (WLPs) compared tothe control sample. It is clear that, in all treatments,apples had a long storage life compared to the control group apples

Table (1)shows the changes of decay**%** values of irradiated, coated and untreated apples during storage period. No decay signs were observed until 2 weeks after the beginning of the storage period.However, it could be seen that the fruit decay% was increased by increasing the time in cold storage as well as control increased regardless of the type of treatments. Fruit decay% increased from (2.40)after 30 days to (37.00)after 75 days of cold storage. However, all used treatments greatly decreased fruit decay % comparedto the control with significant differences between them.The great effect was shown with coating paraffin oil and glycerol during all cold storage periods with no significant differences between coating paraffin oil and glycerol.Irradiated apples showed a remarkable increase in the storage life for 90 days. This decrease in decay% of treated samples was probably due to the effects of these coatings on delaying senescence, which makes the commodity more vulnerable to pathogenic infection as a result of loss of cellular or tissue integrity (Patricia *et al*.,19).Data showed that it could be torrid apples for 75 – 90 days with high good storability after irradiation treatment and coatingwith paraffin oil or glycerol.The same trend of results was also found in the second seasons of the study.Finally, depending on discarding any treatment reached to 50% decay, it could be noticed that apples stored for 75 days for control,90 days for irradiationup to1.0 kGy,coating paraffin oil and glycerol treatments.

Table (1): Effect of irradiation,coating with paraffin oil and glycerol on Discarded fruits (%) of "Anna" apple fruits during cold storage at (0°C, 90-95% RH),during 2014 and 2015 seasons

Treatments	**2014 Seasons**					
	Days in cold storage					
	15	**30**	**45**	**60**	**75**	**90**
Control	00.00 A	2.40 A	4.31 A	17.74 A	37.00 A	*
Irradiation 0.5 kGy	00.00 A	1.37 C	2.64 C	7.97 B	20.01 C	41.12 B
Irradiation 1.0 kGy	00.00 A	1.81 B	3.01 BC	8.21 B	14.09 D	25.35 C
Paraffin oil	00.00 A	0.82 D	1.33 E	6.00 B	9.35 E	12.84 D
Glycerol	00.00 A	0.89 D	1.88 D	8.24 B	9.99 E	13.00 D
	2015 Seasons					
Control	00.00 A	2.38 A	4.18 B	18.51 B	47.81 A	*
Irradiation 0.5 kGy	00.00 A	1.65 B	2.15 CD	11.01 C	45.68 A	50.12 A
Irradiation 1.0 kGy	00.00 A	1.55 B	2.55 C	5.88 D	12.18 C	41.85A
Paraffin oil	00.00 A	0.91 C	1.58 D	4.28 E	8.45 D	12.25 B
Glycerol	00.00 A	0.68 C	1.68 D	3.68 E	8.68 D	12.38 B

-Means having the same letter(s) in each column are statistically insignificant at 5% level.
- 0.00 : Means no any discarded fruits at the beginning of the experiment.
-The experiment was terminated upon attaining 50% decay fruits.

Table (2):Effect of gamma irradiation on blue mold incidence in apple fruits caused bypenicilliumexpansum at different storage periods at 0°C, 90-95% RHin naturally and artificially infected fruits

Gamma Irradiation kGy	Disease incidence %							
	Days in cold storage							
	Naturally infected				Artificial infected (inoculated)			
	0	30	60	90	0	30	60	90
0.0	0.0	0.0	0.0	20.2	0.0	40	85	100
0.5	0.0	0.0	0.0	10.0	0.0	20.2	36.1	55.7
1.0	0.0	0.0	0.0	6.5	0.0	18.7	30	42.1

Means with the same letter are not significantly

Blue mold incidence
Table(2) shows that irradiation at doses of 0.5 and 1.0 kGy reduced the blue mold incidence from 40% to 20.2% and 18.7%,respectivelyafter 30 days but at 60 days reduced from 85% to 36.1% and 30%, while at the end of the cold storage period,the blue mold was reduced from 100 % to 55.7% to 42.1%,respectively.The best result was shownat 1.0 kGy at the end of cold storage periods.

Weight loss (%)
Table (3) shows the changes of WLPs of irradiated , coatedwith paraffin oil or glycerol and untreated apples during storage. Generally, the WLP increased gradually during storage period.The primary mechanism of moisture loss from fresh fruits and vegetables is by vapor-phase diffusion driven by a gradient of water vapor pressure at different locations (Yaman and Bayoindirli, 28).On the other hand, the respiration causes a weight reduction because CO_2 is lost from the fruit in each cycle (Bhowmilk, 7). However, WLPs of apples was gradually increased with advanced in storage periods where it increased from 2.38 % (after 15 days) to 7.85% (after 60 days) in untreated fruits. Regarding the irradiation effect, it could be noticed that paraffin oil and glycerol were effective in reducing WLP of apples during storage.It is also clear that paraffin oil apples treated lost their weight after 75 days storage.It could be considered that paraffin oil treatment is suitable refrigeration treatment for apples due to its great effect on reducing fruit decay and WLP. Also, the coating process caused a decrease in WLPs compared to control sample. Control samples had a significantly higher WLP (7.85%) for 60 days of the storage period, while apple samples coated with glycerol significantly have the lowest WLP -values (4.95 %). This reduction in weight loss was probably due to the effects of these coatings as a semi permeable barrier against oxygen, CO_2, moisture and solute movement, thereby reducing respiration, water loss and oxidation reaction rates. Similar data were reported by (Bai *et al*. ,4), studying Gala apple, coated with 10% zein (natural corn protein). (Cong *et al*. ,8). noted that Chitosan and polyethylene wax (PE) coatings also provide good protection for Hami melon.The same trend of results was also found in the second seasons of study.

Table (3): Effect of irradiation, coating with paraffin oil and glycerol on weight loss(%) of "Anna" apple fruits during cold storage at (0°C, 90-95% RH) , during 2014 and 2015 seasons

Treatments	2014 Seasons Days in cold storage 15	30	45	60	75	90
Control	2.38 A	3.95 A	5.15 A	7.85 A	*	*
Irradiation 0.5 k.Gy	2.12 B	3.28 B	4.71 B	6.05 AB	13.45 A	*
Irradiation 1.0 k.Gy	2.05 B	2.67 C	4.42 B	6.88 AB	12.25 B	13.08 A
Paraffin oil	1.68 D	2.08 D	3.51 C	6.48 AB	9.12 D	10.65 B
Glycerol	1.75 B	2.28 CD	3.65 C	4.95 B	10.71 C	10.92 B
			2015 Season			
control	2.11 AB	4.08 AB	5.41 B	7.85 B	*	*
Irradiation 0.5 k.Gy	2.28 A	4.51 A	6.38 A	10.65 A	13.45 A	*
Irradiation 1.0 k.Gy	1.78 B	3.21 C	5.25 B	7.68 B	9.05 B	13.08 A
Paraffin oil	1.80 B	2.28 D	3.58 C	5.85 C	8.12 B	9.05 B
Glycerol	1.75 B	2.48 D	4.01 C	5.65 C	7.38 C	9.31 B

Legends as Table (1)

Firmness

As shown in Table (4) the fruits firmness generally deceased with the increase in the storage periods regardless of the used treatment.No significant differences were noticed between different treatments in their effect on fruit firmness. This isbecause apples maturation is determined by 11.50 Lb./inch^{2}fruit firmness.Concerning the effect of different treatments, it could be noticed that differences between treatments appeared after 30 days of storage. Irradiation at 1.0 kGy and coating glycerol or paraffin oil treated fruit let to the higher fruit firmness values from 30 days till end of experiment compared with irradiation at 0.5 kGy.No significant different between coating glycerol or paraffin oil treated fruits in their firmness.At the end of storage, control samples clearly had the lowest firmness while apples coated with paraffin oil or glyceroland irradiationat 1.0 kGytreatment retained the highest firmness in both the first season and the second seasons. Nevertheless, this edible coating still largely reduce firmness losses in comparson withthe untreated fruits.The retention of firmness can be attributed to the retarded degradation of insoluble protopectins to the more soluble pectic acid and pectin. During fruit ripening, depolymerization or shortening of chain length of pectin substances occurs with an increase in pectinesterase and polygalactronase activities(Yaman and Bayoindirli, 28). Low oxygen and high CO_2concentrations reduce the activities of these enzymes and allows retention of the firmness during storage (Salunkhe *et al*.,25).

Hence, the present results reasonably agree with the findings of Yaman and Bayoindirli (28) for cherries coated with Semperfresh™. Furthermore, Patricia *et al*., (19)reported that refrigerated strawberry coated with wheat gluten-based films had a better firmness retention than control fruit.

Table (4):Effect of irradiation,coating with paraffin oil and glycerol on firmness (Ib/inch^2)of "Anna" apple fruits during cold storage at (0°C, 90-95% RH) ,during 2014 and 2015 seasons

treatments	2014 Seasons Days in cold storage 0	15	30	45	60	75	90
control	12.62A	11.62A	9.52A	9.95A	8.08BC	*	*
Irradiation 0.5 kGy	12.15A	10.71A	8.92A	5.85A	7.78AB	6.95C	*
Irradiation 1.0 kGy	12.35A	10.25A	9.98A	7.58A	8.25B	7.65B	5.72A
Paraffin oil	12.28A	10.42A	9.61A	9.02A	8.92A	8.52A	7.25A
Glycerol	12.12A	10.48A	9.95A	9.22A	8.82AB	8.18AB	6.62A
2015 Season							
control	11.51A	11.01A	9.15BC	9.48A	8.21BCD	*	*
Irradiation 0.5 kGy	11.65A	10.48A	8.41C	7.68A	7.61ED	7.10C	*
Irradiation 1.0 kGy	11.88A	11.81A	9.35ABC	9.15A	8.08CD	7.28C	5.72B
Paraffin oil	11.51A	11.81A	10.15A	9.51A	9.15A	8.05B	8.00A
Glycerol	11.85A	11.55A	10.25A	9.78A	8.81AB	8.35A	8.04A

Legends as Table (1)

Marketability shelf-life

Table (5) shows the effect of different supplementary refrigeration treatmentson the marketabilityshelf-life of apples,which indicates that it was gradually decreased with increasing days in storage regardless of the used treatments. The great effect on shelf life was observed with the fruit treated withglycerolor paraffin oil followed irradiation at 1.0 kGytreatment in both seasons. However, irradiated fruit especially at 0.5kGyhad a lower shelf-life than that irradiated at 1.0kGyafter 2 months of storage, whereas it decreases after 75 days of storage paraffin oil treated. In this concern (Kovacs *et al*.,13)**,** stated that other negative effects resulting from irradiation with 1.0 kGy, besides fruit softening, are dissolution of middle lamella, wrinkling of cell membrane and retention of starch by plastid of the skin.Differences between paraffin oil or glycerol were insignificant, so, paraffin oil could be recommended as supplementary refrigeration treatment for apples.The above mentioned results are in agreement with those reported by(Bhadra and Sen ,6).

2- Chemical analysisof “Anna” apple fruits

Table (6):Effect of irradiation,coating with paraffin oil and glycerol on Total Soluble Solids(TSS) of “Anna” apple fruits during cold storage at (0°C, 90-95% RH),during 2014 and 2015 seasons

Total soluble solids (TSS %)

Table(6) shows the changes of TSS values of irradiation doses, edible coating treatments and untreated apples during storage period. Control samples,without treatmentsand edible coating treatments showed an increase in the TSS after 45 days of storage and decreased after 60 days. The highest level of TSS value was observed after 75 days of storage at coating paraffin oil treatment and the lowest level of TSS was at0.5kGy. The same trend of results was also found in the second seasons of study. Similar effects were reported for strawberry coated with wheat gluten-based film by(Patricia *et al*.,19).

Titratable acidity

Table(7) shows that Titratable Acidity **(**TA)values were gradually and significantly decreased with increasing the storage period.Control samples had the lowest level of TA and the highest level of TA was paraffin oil after 60 days in storage. At the end of storage period TA of apples coated with glycerol,paraffin oil and irradiation at 1.0 kGy treated were approximately 0.42, 0.41 and 0.40 times higher than TA of control and irradiation at 0.5 kGy treatment ,respectively. Since, organic acids such as malic or citric acid are primary substrates for respiration, a reduction in acidity and, hence, an increase in pH are expected in highly respiring fruits. Coatings reduce respiration rates and delay the utilization of organic acids (Yaman and Bayoindirli, 28).Also,Patricia *et al*., (19), indicated that coating with PVC pack were effective in the retention of TA of strawberry fruit during the storage time.

Table (5):Effect of irradiation,coating with paraffin oil and glycerol on marketability shelf-life(in days)of “Anna” apple fruits during cold storage at (0°C,90-95% RH),during 2014 and 2015 seasons

treatments	2014 Seasons Days in cold storage						
	0	15	30	45	60	75	90
control	9.95A	9.28BC	8.95BC	6.28C	3.95B	*	*
Irradiation 0.5 kGy	10.28A	8.95C	6.62C	4.28D	3.28C	3.28B	*
Irradiation 1.0 kGy	9.95A	10.28AB	8.61B	7.62BC	5.95AB	4.95A	2.28A
Paraffin oil	10.61A	10.28AB	9.95A	8.95A	6.62A	5.28A	2.61A
Glycerol	10.28A	10.62A	9.61AB	8.62AB	6.62A	5.28A	2.95A
2015 Season							
control	9.95 C	9.28 CD	7.95 BC	7.95 BC	6.28 BC	*	*
Irradiation 0.5 kGy	10.95AB	8.61 D	5.61 D	5.61 D	4.61 D	3.23 B	*
Irradiation 1.0 kGy	10.61AB	9.95 BC	8.61 B	8.61 B	7.28 B	6.95 A	5.80AB
Paraffin oil	10.61AB	10.1 AB	10.28 A	10.28 A	9.28 A	7.28 A	5.95AB
Glycerol	11.28 A	10.95 A	9.95 A	9.95 A	9.28 A	7.28 A	6.25 A

Legends as Table (1)

Table (6):Effect of irradiation,coating with paraffin oil and glycerol on Total Soluble Solids(TSS) of "Anna" apple fruits during cold storage at (0°C, 90-95% RH),during 2014 and 2015 seasons

treatments	2014 Season						
	Days in cold storage						
	0	15	30	45	60	75	90
control	11.08A	11.88A	12.15A	12.75A	11.22A	*	*
Irradiation 0.5 kGy	11.38A	11.55A	12.82A	12.82A	11.75A	10.59A	*
Irradiation 1.0k.Gy	10.95A	11.48A	12.65A	12.61A	11.62A	10.62A	10.42A
Paraffin oil	10.82A	11.55A	12.48A	12.75A	11.28A	10.81A	10.55A
Glycerol	10.95A	11.88A	12.55A	12.22A	11.28A	10.95A	10.62A
2015 Season							
control	12.81A	13.38AB	13.38 AB	13.85 A	13.91 A	*	*
Irradiation 0.5 kGy	12.31A	13.55 AB	13.81 A	13.75 A	13.45 A	12.00 AB	*
Irradiation 1.0 kGy	12.41A	12.68 AB	14.15 A	13.55 A	13.61 A	12.25 AB	12.25 A
Paraffin oil	12.38A	14.25 A	13.15 AB	13.21 A	13.38 A	12.81A	12.35A
Glycerol	12.75A	13.11 AB	14.18 A	13.85 A	13.78 A	12.95A	12.41A

Legends as Table 1

Table (7):Effect of irradiation,coating with paraffin oil and glycerol on Titratable acidity(gm malice acid /100gm fresh) of "Anna" apple fruits during cold storage at(0°C, 90-95% RH),during 2014 and 2015 seasons

treatments	2014 Season						
	Days in cold storage						
	0	15	30	45	60	75	90
control	0.60AB	0.55A	0.52A	0.48A	0.41A	*	*
Irradiation 0.5 kGy	0.56A	0.55A	0.49A	0.44A	0.44A	0.36A	*
Irradiation 1.0kGy	0.57A	0.55A	0.49A	0.48A	0.44A	0.40A	0.40A
Paraffin oil	0.56A	0.54A	0.50A	0.48A	0.45A	0.42A	0.41A
Glycerol	0.59A	0.54A	0.50A	0.49A	0.44A	0.42A	0.42A
2015 Season							
control	0.61A	0.60 A	0.50 A	0.45 A	0.42 A	*	*
Irradiation 0.5 kGy	0.61A	0.61 A	0.49 A	0.39 A	0.41 A	0.36 A	*
Irradiation 1.0 kGy	0.59AB	0.54 A	0.53 A	0.43 A	0.41 A	0.37 A	0.30 A
Paraffin oil	0.62A	0.58 A	0.50 A	0.43 A	0.40 A	0.36 A	0.34 A
Glycerol	*0.65A*	*0.61 A*	*0.48 A*	*0.43 A*	*0.41 A*	*0.37 A*	*0.36 A*

Legends as Table 1

Calcium flesh content

Table(8)showsthat the Ca flesh content decreases with increasing storage duration in all groupsat30 days of storage and the treated fruits with paraffin oil or glycerol showed the highest values of Ca flesh content compared tothe control or irradiation treatments up to 1.0 kGy. The great effect of edible coatings with paraffin oil and glycerol on reducing the rate of Ca flesh content losses continued with all cold storage periods. In this concern (Lurie *et al.*,14).confermid that there was less wax on the surface of the heated fruits than the unheated fruits. It is suggested that during heat treatment the wax softens and fills in the cracks while water loss pull

Table (8):Effect of irradiation,coating with paraffin oil and glycerol on Calcium flesh content (mg/100g dry weight) of "Anna" apple fruits during cold storage at (0°C, 90-95% RH),during 2014 and 2015 seasons

Treatments	Days in cold storage						
	0	15	30	45	60	75	90
2014 Season							
Control	14.87B	13.40B	13.00B	11.70B	11.10AB	*	*
Irradiation 0.5 kGy	15.10B	12.44B	12.80B	11.74B	10.90B	10.60A	*
Irradiation 1.0kGy	15.34B	12.90B	13.00B	11.90B	11.47AB	9.93B	9.42AB
Paraffin oil	16.90A	15.60A	14.67A	13.67AB	11.87AB	10.60AB	10.34A
Glycerol	16.54A	15.07A	14.14A	13.77A	12.04A	11.10A	10.40A
2015 Season							
control	14.43C	13.43 C	12.97 B	12.37 B	11.80 C	*	*
Irradiation 0.5 kGy	16.17B	14.50BC	13.47 B	12.70 B	11.90BC	10.60 B	*
Irradiation 1.0 kGy	14.97BC	13.87 C	13.40 B	12.63 B	12.13BC	11.17 A	10.17AB
Paraffin oil	16.77A	15.53 A	15.07 A	13.97 A	12.97AB	11.20 A	10.93 A
Glycerol	17.23A	15.10AB	14.70 A	13.80 A	13.15 A	11.43 A	11.00 A

Legends as Table 1

the fruit calcium towards the fruit surface. This continuos wax layer on heated fruits decreases the ability of external calcium to move into the fruit.After 60 days of storage Ca flesh content of apples was ranged from 11.10 for control to 12.04,11.87, 11.47 and 10.90(mg/100g dry weight) for glycerol, paraffin oil, Iirradiation at 1.0 k.Gy and 0.5 kGy, respectively.These values could be an indicator for determining the storage ability of apples and reduction of Ca flesh content than this value caused many disorders and shortened shelf life of the fruits .

Conclusion

The results indicated that irradiation and edible coating as supplementary refrigeration treatments greatly affected the keeping quality of apples. Edible coating paraffin oil or glycerol and irradiation at 1.0 kGy were effective than 0.5 kGy in increasing storability of apples during cold storage at 0°C, 90-95% RH .These treatments decreased discarded fruits and weight loss % and increased fruit firmness , shelf life and fruit calcium flesh content compared with 0.5 kGy or control fruits. A slight effect was noticed on chemical constituents of the fruits during cold storage duration. It could be noticed that untreated apples could be stored for 60 days where the treated fruits are by the irradiation at 0.5 kGy stored for 75 days but edible coated apples with (paraffin oil or glycerol) or irradiation at 1.0 kGy could be stored for 90 days.

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