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RESEARCH ARTICLE

Sprouting Suppression and Quality Attributes of Potato Tubers as Affected by Post-Harvest UV-C Treatment under Cold Storage.

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Abstract

Potato (solanum tuberosum, L.) is one of the most important vegetable crops in Egypt, it is considered as a source of national income since the potato crop is exported abroad because it has high quality specification. As a result of its cheap price and different prepared ways, potato is the most consuming crop by domestic consumer. So, the need to maintain the potato quality and preserve the crop without losses, providing good storage conditions after harvest is an important process for inhibiting sprouting, reduce the loss of weight and keeping the quality. The aim of this study is to investigate the effect of different doses of ultraviolet light (0, 1.42, 2.14 and 2.85 J/cm^2) and different storage conditions (ambient air 45 ± 2^{o}C with 50-60% RH, two cold dark storages, at 8^{o}C±1with 75-82% RH and13^{o}C±1 with 85-92% RH) on inhibition the sprouting of small tubers (60-90g) and big tubers (120-220g) after four months of storage. The analysis of variance(ANOVA) with three replicates ($P < 0.05$) based on Randomized Complete Block Design(RCBD) was conducted for the statistical analysis. It was concluded that increasing irradiation doses and decreasing storage temperature is good combination for sprouting suppression, reducing weight loss percentage, reducing the increment of soluble solids content, increasing firmness and remaining on the dry matter content almost constant. Only the tubers of non-irradiated treatment under ambient air storage showed percentage of damage. While,10 min irradiation treatment was very low to be effective in sprouting suppression or maintain other quality attributes at all storage temperatures. Exposure of 15 min UV-C is recommended as post-harvest treatment when small tubers are stored at 8^{o}C. Storing tubers at 13^{o}C after high irradiation doses showed very low sprouting weight for small and big tubers.

Introduction: -

In year 2014,Egypt produced 4,800,000 tons of potato crop with yield production 269.663 Hg/Ha. In Egypt, potato ranked the second crop for export after orange, since, the total export quantity was 427.907 tons with price 481 $/ton. (FAO, 2015).In addition to theimportance of the potatocropas a sourceofnational income for the country, but its importancealsolies inthe growing domestic demand or beingan important source ofenergy as it includes aproportion ofcarbohydratenot less than 85% of thedry matter contentasit is richin protein, vitamins, minerals and fiber.(Kolasa, 1993; Neiderhauser, 1992).Egypt'spotato cropis growninthreeseasons ofspring, fall and winter.According to the recommendations of (Ministry of Agriculture and land Reclamation) the spring season is planted using imported European seeds. Tubers grown in spring are stored during summer months for planting in the fall and winter seasons to reduce the high cost of imported seeds. Small tubers (60-90g) are preferred in planting than big tubers to reduce the chance of rotting of seeds in the soil and the spread of viruses and bacteriain the case of cutting the tuber. Also the local consumption during summer period is depend on the tubers which are stored until the new production. Therefore, storage process and the appropriate circumstances to preserve the potato tubers specifications of high quality for a long time is a very important process. Since, the losses in potatoes during storage is an approximately 50% of the crop production which is due to the sprouting, loss in weight, rotting, greening and sweetening in the presence of inappropriate storage conditions (Rezaee et al., 2011; Karanja et al., 2013; ELbashir et al., 2011).Sprouting is a major problem causing a high weight losses from the surface of the tuber and diminish the nutritional quality of the potato, these in turn affect the marketing, consumption and processing (Frazier et al., 2004; Shetty et al., 1998). Chemicals treatments, low temperature storage and ionizing irradiations are considered as an alternative method to inhibit sprouting. Chemicals such as maleic hydrazide (MH), isopropyl-N-3-chlorophenylcarbamate (CIPC), isopropyl-N-phenylcarbamate (IPC) and tetrachloro nitrobenzene (TCNB) are used as effective sprout inhibitors but at the same time with a negative impact on the quality of tubers where its use would lead to prevent the development of wound periderm in potato tubers which cause an increase in microbial rots in storage (Mehta and Kaul, 1991) and induces an increase in reducing sugar causing darker fry color (Gichohi and Pritchard, 1995). Moreover, the residues of this chemical is a vital concern about the safety of food because its carcinogenic effects on consumers (Burton, 1992;Walsh,1995). The problem of low temperature sweetening is the main problem of storage at 2-4^{o}C which is the recommended temperature for inhibiting sprouts and respiration rate (Prange et al., 1997; Kleinkopf, 1995). Whereas, the consumption of reducing sugars becomes low and their content accumulates in the tubers which develop dark color when exposed to high cooking temperatures as a result of Maillard reaction and formation of acrylamide. Acrylamide compound has been included in the list of potentially toxic chemicals.(Matsuura-Endo et al., 2004; Brandt et al., 2003; Kumar et al., 2004). Risk of freezing or chilling injury, forming rots or decay and the high cost price are vital reasons to continuing search for alternative ways of mechanical refrigeration. (Chourasia and Goswami, 2001).Although the ionizing radiations have been shown to be effective in controlling disease and sprouting at low doses (Frazier et al., 2006; Todoriki and Hayashi, 2004; Rezaee et al., 2011) but, these technologies are expensive and may result in deleterious effects on the tuber quality, such as a degradation of constituent polymers and faster discoloration after cooking as a result of increase reducing sugars. However, the potential for using this technique in potatoes industry is still complicated and refused by consumer.(Ranganna, 1996; Joshi et al.,1990; Daniels-Lake et al., 1996). The germicidal range of ultraviolet radiation UV-C (200–280nm) is effective in food industry to disinfect containers, tools, and work areas. Also it used in inactivates bacteria and viruses as it has damage effect on DNA molecules. (Vecchia et al., 2007; Koutchma et al., 2009;Corry et al., 1995).There are no concerns about residues with UV treatment because the permeability of ultraviolet is low so that the sterilizing effect influences only the surface (Tazawa, 1998; Hidaka and Kubota, 2006). It has been reported that UV-C irradiation for 20 min reduced decay, maintained quality and prolonged storage life of fresh figs (Bal, 2012). Also the low dose of UV-C (3.7×10^{3} Jm^{-2}) delayed ripening and senescence of tomato, while the higher dose 24.4×10^{3} Jm^{-2} impaired ripening and caused abnormal browning(Maharaj et al., 1999). Vicente et al. (2005) treated red peppers with UV-C (7×10^{3} $J\ m^{-2}$) after storage they found that the sugar content does not change and chilling injury incidence and severity could be reduced. The results indicated that UVC delayed ripening of peaches and apples, and extend the shelf life (Lu et al., 1991).Few researches investigated the effect of UV-C on inhibition sprouting of potato tubers after postharvest and storage at different conditions. The aim of this study is to find out the effectiveness and the proper doses of UV-C light on sprouting suppression and preserve the quality of "Spunta" potato tubers under cold storage for four months.

Materials and methods:-

Preparation of Potato Tubers:-

The experiment of this research was carried out at the laboratory of Ag. Eng. Research Institute (AEnRI), Dokki, Giza, ARE. During summer season of year 2015. After curing period sound potato tubers "Spunta" variety were procured from a local grower(Qaliubiya governorate). The tubers were cleaned gently by tap water and were left in the air to dry. A digital balance with maximum capacity 500g and 0.01g accuracy (Chyo balance /Crop Kyoto JAPAN/ serial No 84237) was used to weight the tubers one by one and separate them in two piles. One of this piles was the tubers in range (60-90g) and defined as small tubers and the other was (120-220g) and defined as big tubers. A randomized sample from small and big fresh potatoes was taken for some measurements: weight(g), firmness (kg/cm^2), specific gravity and total soluble solids content (Brix %).

Ultraviolet irradiation procedure:-

The ultraviolet chamber that was used for this investigation was totally fabricated in the manufacturing workshop at the Agricultural Researches Center (ARC), Giza, Egypt. The chamber was a box from Aluminum metal in dimensions of($90\times45\times45$ cm^3)with a top hinged door to fit two germicidal lamps (HRA 4384-Germany) with 2.5 cm tube diameter, 60 cm length and output power of 18 Watt emitted at 253.7nm for each one. Inside the box was totally covered with a highly reflective material to increase the UV-C intensity and to minimize any shadowing effect on irregular shaped samples (Yaun, 2002). A UVA, UVC light meter model YK-37UVSD was used to measure the UV radiation intensity at 254 nm with mw/cm^2 and the UV-C dose was calculated according to Bachmann (1975) as shown in the equation (1):

$$D = L\ (T) \ldots\ldots\ldots\ldots (1)$$

D = applied dosage (mJ/cm^2), L = applied intensity (mW/cm^2) and T = exposure time (Sec).

For exposure durations of 0, 10, 15 and 20 minute and intensity of 2.38 mW/cm^2,the applied doses are 0, 1.42×10^3, 2.14×10^3 and 2.85×10^3 mJ/cm^2 respectively. on- irradiated UV-C treatment was used as control. To insure a full exposure on the entire surface of the tubers, the position of the tubers was reversed upside down and were exposed to the same duration of UV light again. Three replicates for each treatment of UV-C are applied

Storage treatments: -

Three kilogram of tubers for each replicate were placed in a plastic string bag and the bags were stored for four months in two cold dark refrigeration, one at 8^{o}C±1with75-82% RH, and the other at 13^{o}C±1 with 85-92% RH. Ambient air storage at 45 ± 2^{o}C with 50-60% RH was used as a control treatment of storage conditions. A digital hygro-thermometer was used for measuring the storage temperature and relative humidity.

Quality attributes:-

Weight loss percentage and sprout weight:-

At the end of the storage period, the bags were removed from storage rooms, weighed using a digital balance with maximum capacity of 5000 grams and 0.01gram accuracy. The bag was opened and sprouts from sprouted tubers were removed, weighed and expressed in g/3kg. the relative weight loss was calculated according to Rezaee et al. (2011) as shown in the equations (2),(3).

Final weight of the tubers after storage =
(The bulk weight of the bag after storage period - Sprouts weight)…............... (2)

Weight loss percentage of each bag =
(The initial weight before storage – Final weight)/Initial weight ×100.……… (3)

Specific gravity and dry matter content:-

Specific gravity determination was conducted according to (Mohsenin, 1986),the selected tuber was weighed in air and re-weighed suspended with a string as shown in equation (4).

Specific gravity = weight in air / (weight in air - weight in water)………. (4)

The means of the measurements were recorded as an average of specific gravity for each treatment. The dry matter content percentage of the tubers was calculated according to (Kleinkopf et al., 1987) as shown in equation (5).

$$\text{Dry matter \%} = -214.9206 + 218.1852\times\text{specific gravity} \ldots\ldots (5)$$

Firmness:-

The firmness of the tubers was measured by using a digital penetrometer (ST 308 -TECNO TEST- made in Italy) with 10 mm diameter of flat end plunger and expressed in kg/cm^2. The average of two readings for the two opposite sides in each tuber was taken and the average for the tubers at each treatment was calculated.

Soluble solids content percentage (SSC):-

The total soluble solids content was measured and expressed by °Brix using refractometer (with accuracy 0.5 Brix No). Two longitudinal slices from each tuber were blended in juicer mixer and several drops from the juice were placed onto the refractometer prism and the reading was taken. After storage the average of 5 readings for each treatment was determined and the change of soluble solids content as percentage from initial value was calculated.

The percentage of damaged tubers %:-

The percentage of damaged tubers is calculated as the number of rotten/decayed tubers over the total number of tubers in each bag multiplied by 100 (Ranganna, 1996).

The statistical analysis:-

Two different weights of "Spunta" potato variety(small and big tubers) were irradiated with four irradiation doses 0, 1.42, 2.14 and 2.85 J/cm^2 of UV-C and stored at three different storage conditions (8^{o}C±1 with 75-82% RH, 13^{o}C±1 with 85-92% RH and ambient air). The three way interactions ANOVA (2×3×4, $p < 0.05$) based on Randomized Complete Block Design(RCBD) with three replicates was conducted for the statistical analysis using SPSS statistics 20 program and the least significant difference (LSD)was determined for pair wise comparisons.

results and discussions:-

Sprouting weight:-

The effect of UV-C irradiation on sprouting suppression are shown in figure (1) and the interaction between the factors are presented in table (1). For sprouting, the analysis of variance yielded a significant interaction between tubers weights, irradiation doses and storage conditions. The sprouting was totally suppressed for small and big tubers which we restored at 8^{o}C after 15 and 20 min irradiation dose. There was minimum sprouting when the two different weights of tubers stored at 13^{o}C after irradiated with 20 min dose (3.22and 4.95g/3kg).The greatest value of sprouting (21.85g/3kg)was observed at non irradiated big tubers which were stored at ambient air. The results showed that the sprouting decreased significantly ($P<0.05$, $LSD_{0.05}=2.5$) with decreasing storage temperature and increasing the time of irradiation. However, small tubers stored at ambient air showed a different manner, since the sprouting weight of the small tubers after irradiated with 20 min dose (12.16g/3kg) was significantly higher than sprouting weight of non-irradiated tubers (6.86g/3kg). With the remarkable drought and the shrinkage which appeared on the tubers after storage, these results may be due to that the small tubers do not endure the storage at high temperature and lost its dry matter content and vitality, while higher doses of UV-C light may have enhanced its quality and the ability to sprout with time under poor storage condition. No significant difference in sprouting weight was noticed between small and big tubers when the tubers stored at 13^{o}C after irradiated with 15 min and 20 min, since, the sprouts weight were (3 and 4.32 g/3kg) of small and big tubers respectively at 15 min, and (3.22 and 4.95g/3kg) of small and big tubers respectively at 20 min. 10 min dose was not an effective irradiation treatment for sprouting suppression at all storage temperatures.

Table 1: Effect of different irradiation doses of UV-C light and different storage conditions on sprout weight (g/3kg) for two different weights of Spunta potato after four months of storage.

Storage Temperature (^{o}C)	**Tubers weight**	**Irradiation time (min)**			
		0	**10**	**15**	**20**
Ambient air	**Small**	6.86ij	10.27ef	9.84eh	12.16de
	Big	21.85a	18.10b	8.50fghi	9.64fgh
13	**Small**	13.87cd	15.82bc	3.00mnop	3.22mnop
	Big	15.10c	9.93eg	4.32klp	4.95jkln
8	**Small**	5.22jklm	4.65jklo	0.00q	0.00q
	Big	6.40il	6.80ik	0.00q	0.00q

Means in columns and rows not sharing the common letter(s) are significantly different ($P<0.05$, $LSD_{0.05}=2.5$).

Weight loss percentage:-

Weight loss percentage results are shown in figure (2). The differences of weight loss percentage were significant ($P<0.05$, $LSD_{0.05}=1.51$) and the means comparisons are represented in table (2).The least significant decrease in weight of small tubers stored at 8^{o}C was 3.42% when the tubers exposed to UV-C for 15 min while this percentage significantly increased to become 5.1% when the tubers exposed to 20 min of irradiation. In the other side, the big tubers which were exposed for 20 min of UV-C and stored at the same conditions lost only 2.31% of its initial weight which means that the higher irradiation doses at cold storage may leads to adverse results in case of small seeds but it was good treatment for maintaining excessive weight loss in big tubers. Irradiation doses, 15 and 20 min of UV-C reduced the loss percentage of weight to its lower value (1.97 and 2.7%) when small tubers stored at 13^{o}C. Also there was no significant difference between weight loss percentage at 10 and 15 min doses in case of big tubers stored at 8^{o}Csince, the weight loss percentages were 6.29% and 4.9%. So, it can be concluded that low dose of irradiation (10min) may leads to improvement in reducing the weight loss when big tubers stored at low temperature. It was observed that there were no significant differences of weight loss percentage between big tubers stored at either (13^{o}C or 8^{o}C) at each irradiation dose even control treatment (0 min). This may be due to the higher value of relative humidity at 13^{o}C than relative humidity at 8^{o}C which was important factor to decrease the weight loss at 13°C. On the other side, small tubers which stored at 13°C and 8°C showed significant difference of weight loss percentage at control and 20 min treatments so, this may lead to that the small tubers needs specific irradiation dose to preserve its quality. Weight loss percentage of small tubers was significantly higher than weight loss percentage of big tubers when the tubers stored at ambient air. This may be due to that the small tubers are faster affected by poor conditions of storage. This problem was fixed by increasing the irradiation dose to 15 min which reduced this difference to be 2.07% while irradiance of 20 min led to disappearance of the difference since, weight loss percentage of small tubers was 10.02% while it was 9.17% at big tubers.

Table 2: Weight loss percentage of two different weights of Spunta potato tubers after four months as affected by different irradiation doses of UV-C light and different storage temperatures.

Storage Temperature (C°)	Tubers weight	Irradiation time (min)			
		0	**10**	**15**	**20**
Ambient air	**Small**	15.52a	14.2ab	12.63cd	10.02gh
	Big	13.5bc	11.82df	10.56fg	9.17gi
13	**Small**	8.8hi	6.81j	1.97r	2.7qr
	Big	7.23jk	6klmn	3.91opq	3.2qr
8	**Small**	6.58jm	7.69ij	3.42pr	5.1mno
	Big	6.87jl	6.29jn	4.9np	2.31r

Means in columns and rows not sharing the common letter(s) are significantly different ($P<0.05$, $LSD_{0.05}=1.51$).

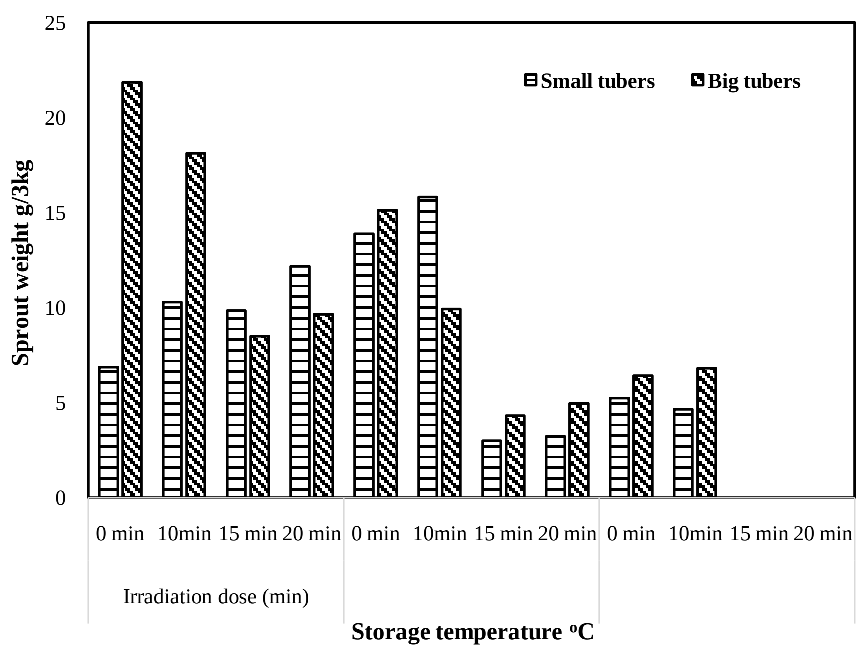


Figure 1: The sprout weight for two different weights of Spunta potato tubers after four months as affected by different irradiation doses of UV-C light and different storage temperatures.

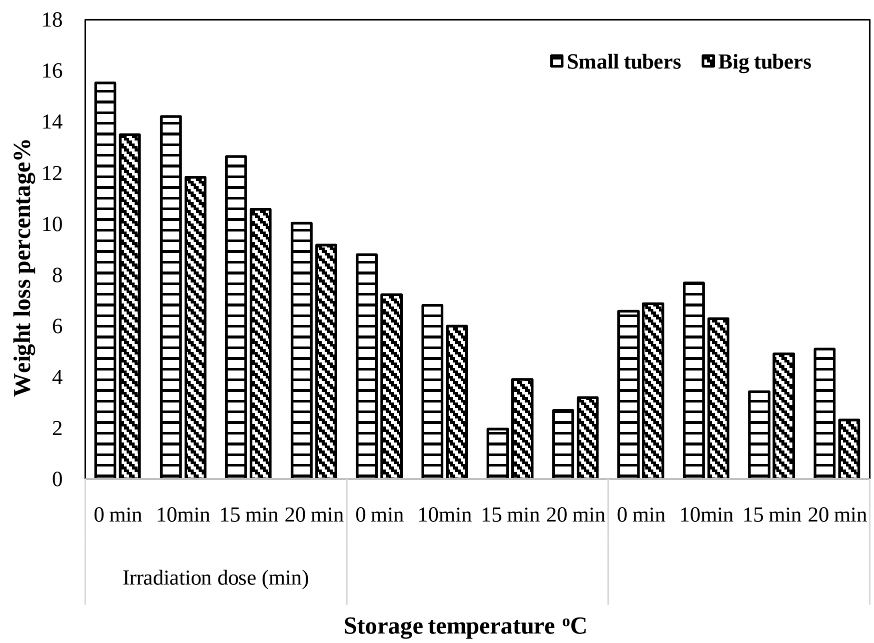


Figure 2: Weight loss percentage of small and big Spunta potato tubers after irradiated with UV-C different doses and stored at different storage conditions for four months.

Firmness of potato tubers:-

Firmness of fresh tubers before storage was 2.84kg/cm^2.ANOVA analysis yielded two first order interactions of firmness means, the first interaction was between irradiation doses and storage conditions as shown in table (3a) and the other interaction was between the tubers weight and storage conditions as presented in table(3b). Generally, at the end of the storage period, the firmness significantly increased ($P<0.05$, LSD=0.233) for all treatments as compared to the average firmness of fresh tubers. This is may be due to increasing the elasticity as a result of evaporation (water loss) during storage. The tubers stored at 8 and13^{o}C had higher significant firmness than tubers stored at ambient air. This may be because of the breakdown of dry matter content as a result of high respiration rate and excessive weight loss of potato tubers which stored at ambient air (Karanja et al., 2013).The firmness of small and big tubers stored at 13^{o}C after 20 min of UV-C irradiation was (5.25 and 5.4kg/cm^2)without significant differences shown in figure (3).On the contrary, 20 min dose significantly decrease the firmness of small tubers (4.98 kg/cm^2) than big tubers (5.47kg/cm^2) after the potatoes stored at 8^{o}C. This is may be due to the excessive weight loss of small tubers when irradiated with 20 min and stored at 8^{o}C.Figure (3a) show the interaction between irradiation doses and storage conditions and its effect on the means of firmness (kg/cm^2) for the two weights (small and big tubers). It is obviously that 20 min exposure of UV-C rays significantly increased the firmness of small and big tubers at ambient air and 13^{o}C storage to be (4.04 and 5.325 kg/cm^2).Figure (3b) show the effect of tubers weight and storage temperature on firmness means of irradiation doses. Big tubers had the highest significant firmness means (5.283 and5.365kg/cm^2) of all irradiation doses when stored at 13^{o}C and 8^{o}C, which means that irradiation of UV-C improved the firmness of big tubers while, the small tubers needs higher doses for better appearance at the same storage conditions.

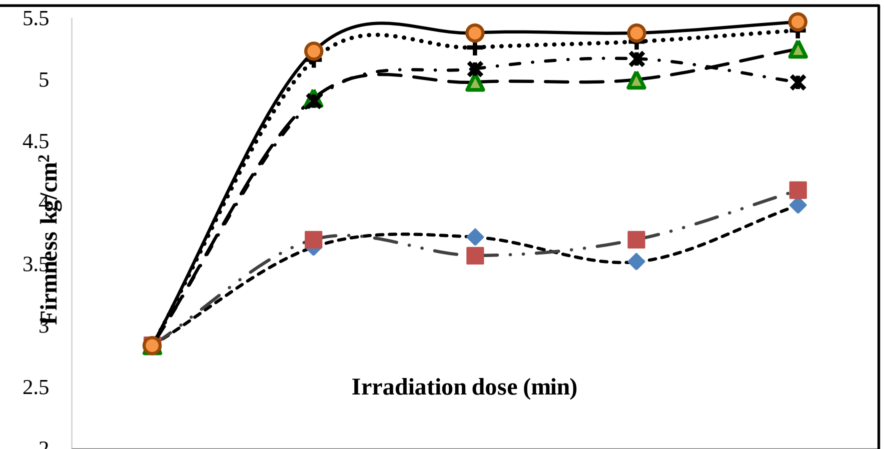
Table (3a): The effect of storage temperature and irradiation doses on firmness means ($LSD_{0.05}$=0.165).

Storage temperature °C	Irradiation doses (min)			
	0	10	15	20
Ambient air	3.67b	3.645b	3.61b	4.04b
13	5.005a	5.12a	5.155a	5.325a
8	5.03a	5.235a	5.275a	5.225a

Table (3b): The effect of tubers weight and storage temperature on firmness means($LSD_{0.05}$=0.117).

Tuber weight	Storage temperature °C		
	Ambient air	13	8
Small	3.715a	5.02b	5.017b
Big	3.768a	5.283a	5.365a

Means in the same columns not sharing the same letters are significantly different (p<0.05)



	Initial reading	0 min.	10 min.	15 min.	20 min.
ambient air	2.84	3.64	3.72	3.52	3.98
ambient air	2.84	3.70	3.57	3.70	4.10
13	2.84	4.85	4.98	5.00	5.25
13	2.84	5.16	5.26	5.31	5.40
8	2.84	4.83	5.09	5.17	4.98
8	2.84	5.23	5.38	5.38	5.47

Figure(3): The firmness of small and big (Spunta) potato tubers after different post-harvest treatments of UV-C light and different storage conditions for four months.

Dry matter content(DMC) of potato tubers:-

Specific gravity of small tubers (60-90g) and big tubers (120-220g) for fresh Spunta potato before storage were (1.069 and 1.11) respectively, so the dry matter content was 18.44% for small tubers and 26.35% for big tubers. For statistical analysis, two way interactions ANOVA with two factors (storage conditions and irradiation,3×4 with three replications) at each weight (small and big tubers) was done. Figure 4a shows the dry matter content of small tubers after different irradiation doses and different storage conditions. The statistical analysis showed an interaction between UV-C irradiation treatments and storage conditions ($p<0.05$) as shown in Table (4a).Dry mater content of small tubers stored at ambient air was significantly decrease (LSD=0.435) for all irradiation treatments. This may be because of starch degradation as a result of breathing at high temperature. However, tubers irradiated with20 min UV-C maintained the decreased of DMC to be 17.34 % as compared with control which was 16.62%.On the other side, storage at 8°C significantly raised DMC at non-irradiated, 10 and 20 min, this was a result of evaporation of the moisture at cold temperature which caused DMC increased (Ratovski, 1981).But tubers irradiated with 15min dose and stored at 8°C kept the value of DMC (18.82%) without change, this may be because 15 min UV-C reduced the weight loss and maintained the excessive evaporation as compared with other doses. At the same time tubers stored at a temperature of 13°C after UV-C exposure of 15 and 20 min showed stability in DMC without significant difference (18.74, 18.84%).

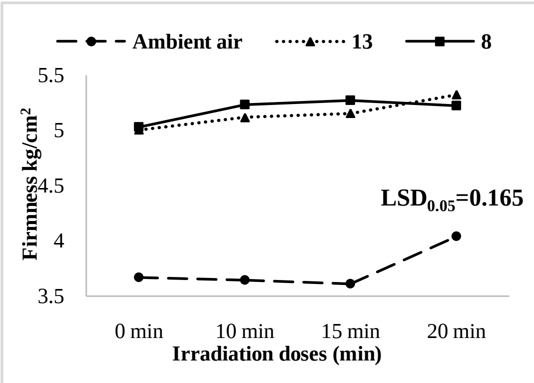


Figure (3a): The effect of interaction between different irradiation doses and storage conditions on firmness (kg/cm^2) (LSD$_{0.05}$=0.165).

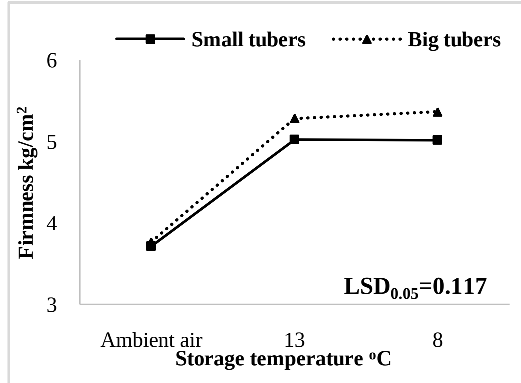


Figure (3b): The effect of interaction between different tuber weights and storage conditions on firmness (kg/cm^2) (LSD$_{0.05}$=0.117).

Tables (4a): Effects of irradiation doses and storage conditions on dry matter content of small tubers.

Irradiation doses (min)	Storage temperature°C		
	Ambient air	13	8
0	16.62b	17.67b	19.2ab
10	16.9b	17.82b	19.05a
15	17.02ab	18.74a	18.82b
20	17.34a	18.84a	19.44a

Means in the same columns not sharing a common letter (s) are significantly different (LSD$_{0.05}$=0.435)

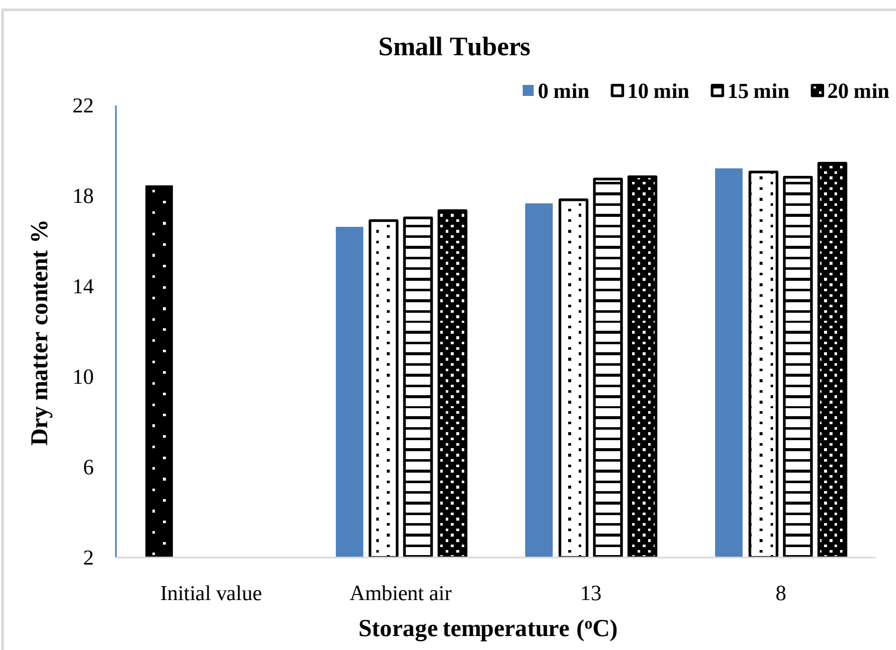
Figure (4b) shows the effects of UV-C irradiation doses and storage conditions on dry matter content of big tubers. Big tubers which were irradiated by 20 min UV-C and stored at 13 or 8°C kept the DMC as initial value without significant change (26.57, 26.75%). while, the 15min of exposure to UV-C significantly increase the DMC as compared to initial value after storage at 13 or 8°C since the increment was 1.5% after storage at 13°C and 2.27% after storage at 8°C. Dry matter content of non-irradiated tubers and 10 min UV-C treatment significantly increased after storage at each of cold temperature (13 and 8°C) as the evaporation of moisture was high due to sprouting. The results showed that the storage at ambient air significantly decreased the DMC because of starch degradation at high temperature but 20 min of UV-C decreased the reduction to be 3.98% instead of 16.5% at non-irradiated tubers. Table (4b) represents the means comparisons of DMC as affected by irradiation and storage conditions for big tubers.

Tables (4b): effects of irradiation doses and storage conditions on dry matter content% of big tubers.

Irradiation	Storage temperature°C

doses (min)	Ambient air	13	8
0	22c	28.5a	27.5a
10	22.55b	28.53a	28a
15	25.08a	26.76b	26.95b
20	25.3a	26.57b	26.75b

Means in the same columns not sharing a common letter (s) are significantly different ($LSD_{0.05}$=0.402)



Figure(4a): Dry matter content of small potato tubers (Spunta variety) after different UV-C treatments and different storage conditions for four months.

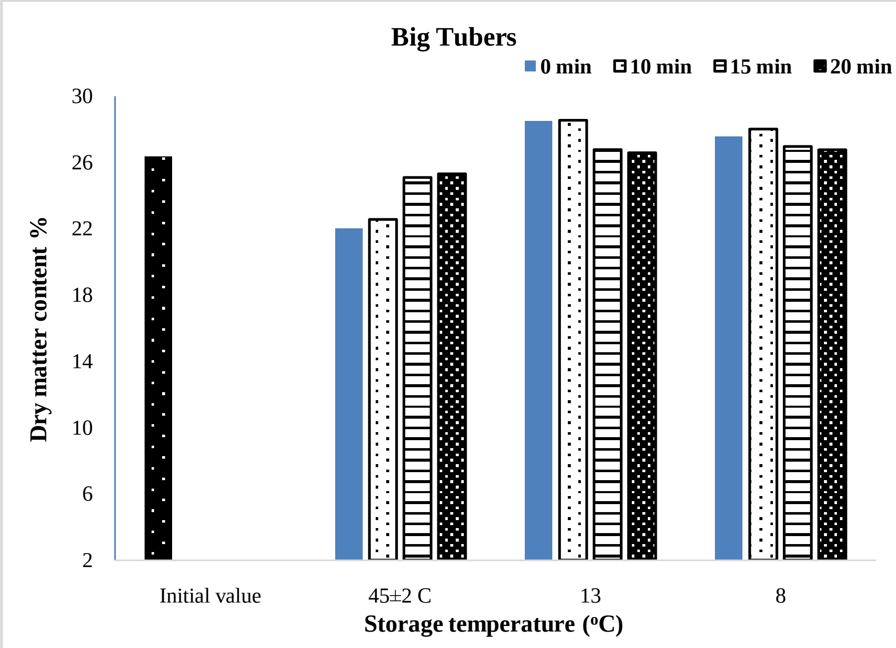


Figure (4b): Dry matter content of big potato tubers (Spunta variety) after different UV-C treatments and different storage conditions for four months.

Soluble solids content (SSC) of potato tubers: -

Figure (5) shows the effects of different irradiation UV-C doses and different storage conditions on the percentage increase of soluble solids content of two different potato tubers weights. It was noticed that soluble solids content significantly increased at all storage conditions but storage of potatoes at 13°C significantly reduced the increment of SSC than the others storage conditions. Since the sugar content is the mainingredient of the soluble solids content and sprouted tubers at 13°C consumed sugar for growth and development of sprouts, on contrary, the consumption of accumulated sugars in tubers stored at 8°C was low because the respiration rate and sprouting was inhibitedat this storage temperature,Rezaee et al. (2011). Also the storage at ambient air with high temperature and high respiration rate stimulates the converted starch into sugar which caused excessive breakdown of DMC and significant increase of SSC. However, 20 min exposure of UV-C significantly decreased the change of SSC to be 16.25% at small tubers and 11.07% at big tubers which mean that storage at high temperature needs higher levels of UV-C to decrease the conversion of starch. As shown in table (5) it was noticed that 20 min of UV-C reduced the SSC value of big tubers which were stored at 13°C and 8°C without significant difference since the SSC at 13°C and 8°C were (1.61 and 2.32%) respectively. This means that higher irradiation doses can be used as an effective irradiation treatment to reduce the SSC when the potatoes of big weight stored at higher temperature (13°C). for small tubers,15 min of UV-C was good enough for storing the small tubers at 13°C or 8°C without any difference of SSC between both storage conditions (3.75 and 4.11%).

Table (5): Means comparisons of soluble solids percentage of small and big potato tubers which were exposure to different UV-C doses and were stored at different storage conditions.

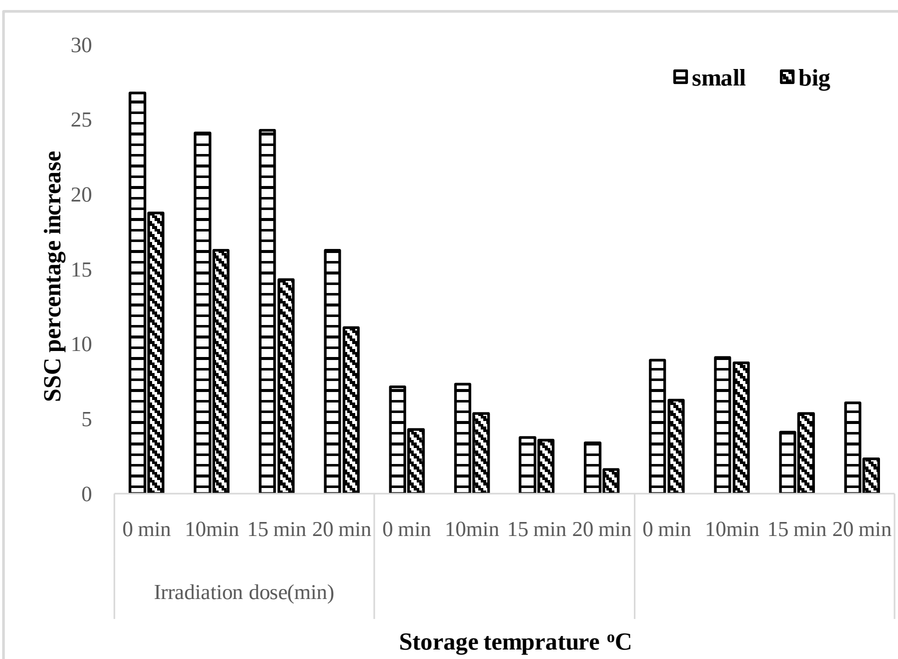
Storage Temperature (C°)	Tubers weight	Irradiation dose (min)			
		0	10	15	20
Ambient air	**Small**	26.79a	24.11b	24.29b	16.25d
	Big	18.75c	16.25d	14.29e	11.07f
13	**Small**	7.14hi	7.32h	3.75m	3.39mn
	Big	4.29km	5.36jk	3.57m	1.61o
8	**Small**	8.93g	9.11g	4.11m	6.07ij
	Big	6.25hj	8.75g	5.36jk	2.32no

Means in columns and rows not sharing the common letter(s) are significantly different ($P<0.05$, $LSD_{0.05}=1.11$).

Figure (5): Effect of different UV-C doses and different storage conditions on soluble solids percentage of small and big tubers after four months of storage.

The percentage of damaged tubers: -

Only 15.6 and 7.8% of small and big tubers were rotten and completely damaged when potatoes stored at ambient air without irradiation treatment.



Conclusions:-

The best treatment for inhibiting sprouts of Spunta potato tubers after four months of storage is exposing each of small and big tubers for 15 or 20 min of UV-C light before storage at 8^{o}C. Although sprouting was not completely inhibited after the same irradiation doses when tubers were stored at 13^{o}C, but sprouting still was in minimum range (3-4.95g/3kg).Storage at ambient air needs high levels of irradiation to suppress the sprouting.

Increasing irradiation doses and decreasing storage temperature is good combination for reducing weight loss percentage and soluble solids content increment, increasing firmness and remaining on the dry matter content almost constant.

The higher irradiation doses at cold storage (8^{o}C) may leads to adverse results in case of storing small seeds, so 15 min of UV-C is recommended dose for storing small tubers at this temperature.

Storage temperature of 13^{o}Cis allowed when small and big tubers are exposed to 20 min of UV-C light. Since, the sprouting still in minimum range and weight loss percentage is very low.

20 min of UV-C kept the DMC of big tubers without change when tubers stored at 13^{o}C or 8^{o}C and reduce the breakdown of dry matter content for both small and big tubers when tubers stored at ambient air.

As general, the firmness significantly increased for all treatments as compared to the average firmness of fresh tubers (2.84kg/cm^{2}). Tubers stored at ambient air had the lowest value of firmness due to breakdown of dry matter content.

Soluble solids content significantly increased at all storage conditions but 20 min of UV-C reduced this increment except for small tubers which stored at 8^{o}C since 15 min is the suitable treatment for reducing SSC to its minimum limit.

10 min irradiation treatment was very low to be effective for sprouting suppression or maintain other quality attributes at all storage temperatures.

References:-

1. Bachmann, R. 1975. Sterilization by intense UV radiation. Brown Boveri Rev., 62: 206 – 209.
2. Bal, E. 2012. Effect of postharvest UV-C treatments on quality attributes of fresh fig. Bulg. J. Agric. Sci., 18: 191-196.
3. Brandt, T. L.; G. E. Kleinkopf; N. L. Olsen and S. Love. 2003. Storage management for Umatilla Russet potatoes. University of Idaho, College of Agricultural and Life Sciences, bulletin 0839.
4. Burton, W. G.1992. The physics and physiology of storage. In: P.M. Harris (Ed), The Potato Crop, second edition. Chapman Hall, London, pp. 608-727.
5. Chourasia, M. K. and T. K. Goswami. 2001. Losses of potato in cold storage vis-à-vis types, mechanism and influential factors. J. Food Sci. Tech., 38(4):301–313.
6. Corry, J. E.; C. James; S. J. James and M. Hinton. 1995. *Salmonella*, *campylobacter* and *Escherichia coli* O157:H7 decontamination techniques for the future. Intl. J. Food Micro., 28: 187-196.
7. Daniels-Lake, B. J.; R. K. Prange; W. Kalt; C. L. Liew; J. Walsh; P. Dean and R. Coffin. 1996. The effects of ozone and 1, 8-cineole on sprouting, fry color and sugars of stored Russet Burbank potatoes. A. Potato J., 73(10): 469-481.
8. Elbashir, H. A.; A. R. Ahmed and K. S. Yousif. 2011. Effect of Spearmint Oil on Sprouting and Processing Quality of Diamant and Sinora Potato Varieties. Current Research Journal of Biological Sciences, 3(5): 530-534.
9. FAO, 2015. Food and agriculture organization of the United Nations.www.fao.org.
10. Frazier, M. J.; G. E. Kleinkopf; R. R. Brey and N. L. Olsen. 2006. Potato sprout inhibition and tuber quality after treatment with high-energy ionizing radiation. American J. of Potato Res., 83: 31-39.
11. Frazier, M. J.; N. Olsen and G.E. Kleinkopf. 2004. Organic and alternative methods for potato sprout control in storage. University of Idaho Extension, Idaho Agricultural Experiment Station, Moscow. Available at http: // www.kimberly.uidaho.edu/potatoes/CIS 1120.pdf.
12. Gichohi, E. G. and M. K. Pritchard. 1995. Storage temperature and maleic hydrazide effects on sprouting, sugars, and fry color of Shepody potatoes. A. Potato J., 72(12): 737-747.

13. Hidaka, Y. and K. Kubota. 2006.Study on the sterilization of grain surface using UV radiation. (Development and Evaluation of UV Irradiation Equipment). Crop Production Machinery and System Department, Bio-oriented Technology Research Advancement Institute (BRAIN), 40(2): 157-161.
14. Joshi, M. R.; A. N. Srirangarajan, and P. Thomas. 1990. Effects of gamma irradiation and temperature on sugar and vitamin C changes in five Indian potato cultivars during storage. Food Chem. J., 35(3): 209-216.
15. Karanja, B. K.; D. K. Isutsa and J. N. Aguyoh. 2013. Curing reduces postharvest deterioration of biozyme produced potatoes (*Solanum tuberosum* l.). G.J.B.B., 2(3): 353-360.
16. Kleinkopf, G. E. 1995. Early season storage. A. Potato J., 72(8): 449 - 462.
17. Kleinkopf, G. E.; D. T. Westermann; M. J. Wille and G. D. Kleinschmidt. 1987. Specific gravity of Russet Burbank potatoes. American Potato J., 64:581-587.
18. Kolasa, K.M. 1993. The potato and human nutrition. American Journal of Potato Research. 70:375-384.
19. Koutchma, T. N.; L. J. Forney and C. I. Moraru. 2009.Ultraviolet light in food technology. Principles and applications. CRC Press, Boca Raton, FL. 103-123.
20. Kumar, D.; B. P. Singh and P. Kumar. 2004. An overview of the factors affecting sugar content of potatoes. Ann. appl. Biol., 145:247-256.
21. Lu, J. Y.; C. Stevens; V. A. Khan; M. Kabwe and C. L. Wilson. 1991. The effect of ultraviolet irradiation on shelf-life and ripening of peaches and apples. J. Food Qual., 14 (4): 299-305.
22. Maharaj, R.; J. Arul and P. Nadeau. 1999. Effect of photochemical treatment in the preservation of fresh tomato (Lycopersicon esculentum cv. Capello) by delaying senescence. Postharvest Biol. Tech., 15:13-23.
23. Matsuura-Endo, C.; A. Kobayashi; T. Noda; S. Takigawa; H. Yamauchi and M. Mori. 2004. Changes in sugar content and activity of vacuolar acid invertase during low-temperature storage of potato tubers from six Japanese cultivars. Journal of plant research, 117:131-137.
24. Mehta, A. and H. N. Kaul. 1991. Effect of sprout inhibitors on potato tubers (*Solanum tuberosum* L.) stored at ambient or reduced temperatures. Potato Research, 34(4): 443-450.
25. Ministry of Agriculture and Land Reclamation.Arab Republic of Egypt. http://www.agr-egypt.gov.eg.
26. Neiderhauser, J. S. 1992. The role of potato in the conquest of hunger and new strategies for international cooperation. Journal of Food Technology. P. 91-95.
27. Mohsenin, N.N. 1986. Physical properties of plant and animal materials: structure, physical characteristics and mechanical properties. New York: Taylor and Francis.
28. Prange, R.; W. Kalt; B. Daniels-Lake; C. Liew; J. Walsh; P. Dean; R. Coffin and R. Page. 1997. Alternatives to currently used potato sprout suppressants. Conference Proceedings, Postharvest News and Information, 8:37-41.
29. Ranganna, B. 1996. Thermal treatments for short-term storage of potato *(solanum tuberosum l.)*. PhD. Thesis, Department of Agricultural and Biosystems Engineering, Macdonald Campus of McGill University Canada.
30. Rastovski, A. and V. A. Es. 1981. Storage of Potatoes Post-Harvest Behaviour, Store Design, Storage Practice and Handling ISBN 90-220-0897-5. Pudoc Wageningen, p. 5.
31. Rezaee, M.; M. Almassi; A. Majdabadi Farahani; S. Minaei; and M. Khodadadi. 2011. Potato sprout inhibition and tuber quality after post-harvest treatment with gamma irradiation on different dates. J. Agr. Sci. Tech., 13: 829-842.
32. Rezaee, M.; M. Almassi; A. Majdabadi Farahani; S. Minaei; and M. Khodadadi. 2011. Potato sprout inhibition and tuber quality after post-harvest treatment with gamma irradiation on different dates. J. Agr. Sci. Tech., 13: 829-842.
33. Shetty, K.; M. Casada; H. Zhu; M. Thornton and P. Notle. 1998. Fresh-pack potatoes handling, packaging, and transportation in refrigerated railcars. Idaho Agricultural Experiment Station, BUL., 804.
34. Tazawa, S. 1998. UV to seibutsusangyo. (UV and industry). Eds. The Illuminating Engineering Institute of Japan, Yokendo Ltd., Tokyo, In Japanese, 127–138.
35. Todoriki, S. and T. Hayashi. 2004. Sprout inhibition of potatoes with soft-electron (low-energy electron beams). Journal of the Science of Food and Agriculture, 84(15): 2010–2014.
36. Vecchia, P.; M. Hietanen; B. E. Stuck; E. van Deventer and S. Niulnter. 2007. Protecting workers from ultraviolet radiation. International Commission on Non-Ionizing Radiation Protection ICNIRP Cataloguing in Publication Data 14/2007.
37. Vicente, A. R.; C. Pineda; L. Lemoine; P. M. Civello; G. A. Martinez and A. R. Chaves. 2005. UV-C treatments reduce decay, retain quality and alleviate chilling injury in pepper.Postharvest Biology and Technology, 35: 69–78.
38. Walsh, J.R.1995. Utilizing the stored crop. American Potato Journal, 72(8):481-492.

39. Yaun, B. R. 2002. Efficacy of ultraviolet treatments for the inhibition of pathogens on the surface of fresh fruits and vegetables. Master thesis of Science in Food Science and Technology. Virginia Polytechnic Institute and State University, Blacksburg.