Assessment of Bulb pungency level in Indian onion cultivars under influence of low doses of Ionizing radiation and short term storage

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Abstract: Investigation on the assessment of the chemical quality changes in different Indian onion (Allium cepa L) cultivars under the influence of low doses of gamma-irradiation and short-term storage was carried out. Cured bulbs of both onion (var.Bellary red) and shallots(var.Ascalonicum) were irradiated to low doses of gamma rays (0, 22, 72, 128 and 150 Gy) in gamma chamber (Model GC-5000) at dose rate of 6.28 kGy/hr and were stored at room temperature storage (26± 3ºC; 60-75% RH)conditions for short-term storage upto 75 days. Response of irradiated and non irradiated bulbs of these cultivars to short term storage in terms of major chemical quality parameter the total pyruvic acid ate content was distinct and notable. Combined effect of gamma irradiation (128.04 Gy) and short storage time (up to 64 days) had significant impact on increase in pools of the total pyruvic acid content of both onion(22 µ mol/ml.juice) and shallot(28.50 µ mol/ ml.juice) bulbs as compared to their non irradiated ones(17 and 27 µ mol/ml.juice) with better retention of other quality attributes(texture, color) and with no significant losses of nutrients, and pungency characteristics in these onion cultivars during 64 days of storage period.

Index terms : Gamma irradiation, Onions, Pyruvic acid, Short term storage,

1. Introduction

The quality of onion depends on its pungency. While highly pungent onions are popular in India, less pungent ones are preferred in other countries. A special class of biologically active organosulfur compounds dominates onion flavor. The pungent flavor of onions is produced by hydrolysis of the flavor precursor compounds, like,S-alk (en)yl-L-cysteine sulfoxides, when the cells are mechanically ruptured, such as by cutting or macerating. The hydrolysis reaction is catalyzed by allinase and is completed within 6 min [1]. This reaction produces thiopropanol S-oxide (lacrymator), pyruvic acid, ammonia and many sulfur volatiles [2]. The determination of pyruvate as an indicator of pungency is perhaps the most established method for pungency assessment in onion and garlic. The consumption of onion is increasing in both developed and developing countries every year. The compounds like sugars and organic acids are contributing to the organoleptic test and contribute to the distinctive flavor and aroma. Pungency level and total soluble solids are important quality attributes of onion bulbs. The contents of soluble carbohydrates contribute to onion sweetness.

All of the above parameters are important in processing and export quality of bulbs [3].

The data on the changes in physiological and biochemical characteristics of the bulbs of quality of promising varieties of onion treated by these techniques are well documented [4]. It is also reported[5]that similar studies in valenciana sintetica 14 onion, the most marketable variety in Argentina. Shallots (*Allium cepa* L.var.Ascalonicum) is onion like plant that originated in western Asia, with high flavored and pungent strength as compared to big onions and is grown largely in South East Asia and southern India. Tropical shallots are highly seasonable and matures in 60-75 days with storage potential (>5months) superior to big onions [6]. The compounds like sugars and organic acids are contributing to the organoleptic test and contribute to the distinctive flavour and aroma. Pungency level and total soluble solids are important quality attributes of onion bulbs. The contents of soluble carbohydrates contribute to onion sweetness. All of the above parameters are important in processing and export quality of bulbs [3]. Many of such compounds can be chemically quantified. Estimation of pungency in bulbs has become necessary as the popularity of high pungent Indian onion cultivars in India has increased. Assessment of bulb pungency level in different Indian cultivars of onion (*Allium cepa* L.) was also reported [6]. They classified the onion cultivars based on pyruvic acid levels ranged from 1 to18 µlmol into various pungency groups. The onions are classified on the basis of pungency as low pungency/sweet (0–3 µlmol pyruvicacid/g FW); medium pungency (3–7 µlmol pyruvic acid/g FW); high pungency (above 7 µlmol pyruvic acid/g FW). Indian onion cultivars are falls under high pungency (above 7 µlmol pyruvic acid/g FW) category of onion cultivars. Literature survey on the assessment in changes in the pungency profile and other chemical quality of high pungent Indian onion cultivars under influence of gamma irradiation and the short term storage is scanty and very limited. At present, no data on the above aspect is available. Keeping this in view, the objective of this study was focused on assessment of the chemical quality changes in different Indian onion (*Allium cepa* L)cultivars under the influence of low doses of gamma-irradiation and short-term storage upto 75 days.

2. Materials and methods

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2.1. Onions and shallots

Freshly harvested, cured onion cultivars (var.Bellary red and Ascalonicum) were procured through Horticultural Produce Cooperative and Marketing Society Market (HOPCOMS), Mysore. Cured big onion (var.Bellary red), uniform in size (60-75mm in diameter),with 70.6g mean weight and shallots (var. Ascalonicum) small size(25-30mm in diameter) with 18.4 g mean weight were sorted and graded for uniform shape and size and closed neck. Diseased, bruised, infected ones were discarded from the selected bulb lots. The selected bulbs of onion and shallots were then segregated into five batches in each case of both before subjecting them to further treatment.

2.2 Ionizing treatment

Bulbs of shallots and onions 150 kg each were irradiated at different doses of gamma rays (0, 22, 72, 128 and 150 Gy) in gamma chamber(BARC,Model GC-5000,India) loaded with ^{60}Co as radio isotope source with 12 kCi source strength, at dose rate of 6.28 kGy/hr, under ambient conditions (25.6 ºC to 28.4 ºC). The Ceric-Cerous dosimetry system was used as proven dosimetry system[7] using spectrophotometry method in our dosimetry experiment to perform radiation dose measurements, prior to actual radiation treatments given to the experimental materials (Onions, Shallots) with a range of 0-150Gy. The dose measurement uncertainty was ±3.0 % / ±0.15kGy. The ratio of maximum dose to the minimum dose, expressed in to terms of uniformity ratio in the dose distribution in the irradiated samples was 1.05.

2.3 Storage conditions

Immediately after ionizing treatment, both shallots and onion bulbs were loaded into cross ventilated plastic crates and stored at ambient conditions (26±3ºC; 60-75% RH) up to 75 days of post irradiation period. The dose of gamma irradiation and days of sampling were determined based on the experiment design.

2.4. Experimental design

A central composite rotatable design (CCRD) experimental design[8]with two independent variables irradiation dose and storage period(days) was used to study the response pattern and to determine the optimum combination of these variables.

2.5. Sampling method

For each treatment six replicates of samples with 5 kg of bulbs per replicate were maintained. From each treatment three replicates of samples were labeled for record of Physiological Loss in Weight (PLW) on each sampling day. The remaining samples were placed in ventilated plastic crates and stored at ambient conditions on a clean platform for a period of 75 days. Samples from each treatment were periodically drawn on 0,11,37, 64 and 75 days and were used for analysis for physical characteristics such as Texture and Colour; Chemical characteristics such as pH, Total Soluble Solids (TSS), Titratable acidity, Total sugars, Total Pungency (in terms of total Pyruvic acid content). In case of each treatment the homogenate of composite bulb sample was used for analysis of these chemical parameters. The collected data was subjected to statistical analysis using Duncans Multiple Range Test (DMRT) at 5% significance level ($p<0.05$) for physical characteristics and Response Surface Methodology (RSM) analysis for chemical parameters.

2.6. Analyses

2.6.1. Physiological Loss in Weight (PLW %):

The labeled samples from each treatment were periodically weighed before and during ambient storage by using electronic balance (Teraoka, Capacity 2000 g; Model DI 170). It was calculated as cumulative % loss in weight based on the initial fruit weight (before storage) and loss in weights recorded at the time of periodical sampling during ambient storage and is expressed in percentage.

2.6.2 Texture:

Penetration Test: Bulb texture was measured using a texture analyzer (Instron Universal Testing Machine (Instron Model-4301, UK) fitted with the needle probe 5mm diameter with load cell 100Newtons (N) and cross speed of 50 mm/minute. Randomly selected bulb samples from each treatment were placed at the base of the analyzer. The maximum force to achieve a penetration to a depth of 10mm and 5mm on the surface of the onion bulb and shallot bulb samples respectively were recorded and the force is expressed in terms of Newton (N).

2.6.3 Chemical characteristics:

pH:

The pH of extracted juice, using a kitchen blender followed by filtering through a muslin cloth, from randomly sampled onions and shallots from each treatment was measured by using Control Dynamic pH meter. (Model: APX 175).

Total Soluble Solids (°Brix): The soluble solids content (SSC) was measured with a Hand refractometer (Erma, Japan) and expressed as %.

Titratable Acidity (%):

Acidity of onion and shallot juice sample was estimated by following method as suggested [9]and is expressed in percentage.

Total Sugars (%):

Total Sugars in onion and shallot bulb sample was estimated by the Lane and Eynon method [10].

Total Pungency (Pyruvic acid content, µmol/ml of juice):

Pungency in both onion and shallot juice samples was estimated as flavor strength and is expressed in terms of total pyruvic acid content present in the extracted juice using an improved version of the procedure suggested by [1],[11] and the pungency is expressed in µmol pyruvic acid content /ml of juice.

2.6.4 Statistical analysis: A second order polynomial equation was used to fit the experiment data. The model proposed for the response Y.

$$Y=B_{\circ} + \sum Bi\ Xi + \sum Bii\ Xi^2 + \sum Bij\ Xi\ Xj$$

Where Y represents the experimental response $B_{\circ}$, Bi, Bii and Bij are constant and regression coefficient of the model and Xi Xj are independent variables in coded values [13], [14]. Statistical analysis of the collected data was performed by using Duncan's Multiple Range Test (DMRT) procedure of Statistical Analysis System [15], for all physical characteristics and Response Surface Methodology (RSM) analysis for all chemical characteristics [15]. Data presented are the averages of three samples analysed in triplicate.

3.0 Results and Discussion:

3.1 Physical characteristics:

Physiological Loss in Weight (PLW %):

Figure 1 showed that irrespective treatments, similar trend in physiological loss in weight (PLW) in both irradiated and non-irradiated bulbs of onion and shallots with storage time. However, the PLW in shallots bulbs was more than two folds of weight loss in onion bulbs on each day of sampling. The higher weight loss in shallots bulbs could be attributed to the less bulb size and exposure of more surface area than the bulbs of onions. Also [16]observed similar results on loss in weight due dehydration of shallots irradiated between 50 to 80 Gy doses at the end of 60 days of storage at 20ºC to 37ºC. Among the treatments, only T_1 (22 Gy) and T_3 (128 Gy) recorded the low PLW during storage irrespective of bulbs of onion and shallots. This could be due to prevention of bulb weight loss and sprout inhibition after exposure to these doses. Similar observation of reduction in weight loss in irradiated onion and garlic bulbs were also reported [12], [17].

Bulb Texture:

Initially after irradiation, only T_1 (22 Gy) and T_4 (150 Gy) among the treatments were recorded (P>0.05) higher bulb texture of onions on par with the non irradiated control bulbs. However, with storage time, only the bulbs of onion irradiated at higher doses (128 and 150 Gy) showed better bulb texture than control at the end of storage (upto 75 days). This result reveals that irradiated samples tend to be more firm than non-irradiated control bulbs of onion during 75 days of storage. Similarly,[18]reported that at the end of 90 days, irradiated onion and garlic bulbs showed more firmness as compared to untreated control samples. The textural changes in the bulbs of onion and shallots (Tables 1&2) indicated that the force required to penetrate the bulbs of both irradiated and non irradiated control ones decreased upto 37 days of post irradiation storage period. This change in textural character could not be attributed to gamma irradiation treatment alone but could be probably due to gradual loss in bulb weight in all these bulbs. In case of shallots, only T_3 (128Gy) among the treatments recorded (P>0.05) higher bulb texture on par with the non irradiated control bulbs. This could be due to prevention of weight loss and sprout inhibition after exposure to this dose. However, the bulb texture in shallots declined with storage time irrespective of treatments. These observations are contradictory to those of [16]who opined that irradiated shallots retained better bulb hardness(2.7Kg/cm^2)than their control samples(2.5Kg/cm^2) during 2 months of storage at room temperature.

3.2 Chemical quality attributes of bulbs

The results on changes on the chemical quality attributes of bulbs of onion and shallots are presented in figures 2, 3, 4 and 5 respectively. The compounds like sugars and organic acids are contributing to the organoleptic test and contribute to the distinctive flavor and aroma. Pungency level and total soluble solids are important quality attributes of onion bulbs and shallots. The contents of soluble carbohydrates contribute to onion sweetness of onion bulbs and shallots.

Titratable acidity of bulbs

The acidity of aqueous extracts from bulbs of irradiated and nonirradiated onions(figure 2 and 4) shown to be identical during ambient storage (up to 37.50 days), thereafter, the acidity in all the irradiated onion bulbs increased with the storage time and dose levels. This increase in acidity could be attributed to increase in PLW with storage days. The bulbs of irradiated onions at 128 Gy showed the highest acidity (0.381%) after 64.02 days of storage. However, the acidity of onions irradiated at 75 Gy declined to 0.37% at the end of storage (up to 75 days). However, there was decrease in acidity in shallots and increase in onions with increased dose levels during 75 days of storage time.

pH of bulbs:

The *pH* of aqueous extracts from bulbs of irradiated onions (figure 2 and 4) was same as that of nonirradiated onions upto 37.5 days. Similar observation in both irradiated and non-irradiated bulbs of valenciana sintetica 14 onion variety during the storage period was reported [12]. However, decline in *pH* (5.4%) of bulbs irradiated at 75 Gy was observed at the end of storage period.

Total sugars in bulbs:

There was increase in the total sugar content of onions with dose levels(figure 3 and 5). There was reduction in total sugar content in all the irradiated onion bulbs at all dose levels and with storage time upto 75 days. [12]also found that a decrease in carbohydrate content in valenciana sintetica 14 variety of onion in both control and samples irradiated at 50 Gy, with storage time upto 180 days.

Total Pungency: Results (figure 3 and 5) indicated that the response of irradiated and non irradiated bulbs of onion and shallots with short term storage (of 75 days) in terms of chemical quality particularly the total pyruvate content was distinct and varied. Similarly, many studies on the effect of sprout inhibiting doses of gamma irradiation on flavor and pungency of onion and garlic reported to be divergent[19],[20],[21]. Initially, non-irradiated bulbs of onion and shallots showed low value of 17.25 and 26.91 μ mol/ml.juice respectively. With increased dose levels, the pyruvate content decreased to a low value of 14.16 and 24.91 μ mol/ml.juice in irradiated bulbs of onion and shallots respectively at 150 Gy after 37.50 days of storage. Shallots irradiated at 21.95 and 128.04 Gy showed the highest level of pyruvate content of 28.93 and 28.50 μ mol/ml.juice respectively after 64.02 days of storage. While the onion irradiated only at 128.04 Gy showed the highest level of pyruvate content of 21.68 μ mol/ml.juice after 64.02 days of storage. Increase in pungency with storage days(upto 64.02 days) in bulbs of onion and shallots irradiated at 128.04 Gy only showed could be attributed to retention of higher acidity and also due to higher PLW than others and control with storage time(upto 64.02 days). Similarly, Increase in pungency in shallots of irradiated at 21.95 Gy with storage days (upto 64.02 days) could be attributed to retention of highest acidity alone. It was reported [22] that this increase in the intensity of pungent flavor with storage period up to 3 months at room temperature, in Japanese variety of onion irradiated at 70 and 150 Gy could be attributed to increase in the pools of enzymatically formed pyruvate content. [19]also reported similar results of increased levels of pungent flavor with storage days for irradiated onions in the range of 0 to 150 Gy at room temperature. At the end of storage, onion bulbs irradiated at 75 Gy showed that the pyruvate content was reduced to 16.91 μ mol/ml.juice.

Conclusion

Response surface methodology was effectively used to determine the combined effect of gamma irradiation (128.04 Gy) and short storage time (64 days) which indicated that significant impact on improving bulb quality in terms of increase in pools of the total pyruvic acid content of both onion (22 μ mol/ml.juice) and shallot(28.50 μ mol/ml.juice) bulbs as compared to their non irradiated ones(17 and 27 μ mol/ml.juice) with better retention of other quality attributes (texture,color). when stored up to 64 days. With no significant losses of nutrients, and pungency characteristics in both the onion cultivars, latter being the main reason for quality improvement during 64 days of storage period.

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Table 1: Effect of irradiation treatment on texture of onion sample as a measure of penetration force (N)over a storage period of 75 days.

Days ➔ ➔Treatment	Texture(N)				
	Days after storage				
	0	11	37	64	75
Control	52.75 b	43.68 a	47.23 b	56.65 a	55.62 a
T1	51.55 b	41.46 a	40.61 a	57.58 a	56.87 a
T2	41.02 a	42.85 a	45.30 b	59.13 a	54.03 a
T3	41.43 a	42.20 a	38.49 a	61.55 a	63.73 b
T4	50.01 b	39.80 a	41.04 a	57.11 a	63.13 b

Mean score with different letters differ significantly (P<0.05) by DMRT (n=3)

Table 2: Effect of irradiation treatment on texture of shallot sample as a measure of penetration force (N) over a storage period of 75 days.

Days ➔ ➔Treatment	Texture(N)				
	Days after storage				
	0	11	37	64	75
Control	41.26^{b}	30.38^{a}	25.19^{a}	39.14^{b}	31.20^{a}
T1	34.92^{a}	29.08^{a}	23.38^{a}	37.65^{a}	33.11^{a}
T2	48.97^{c}	29.76^{a}	24.62^{a}	34.79^{a}	31.01^{a}
T3	42.12^{b}	28.32^{a}	25.87^{a}	35.46^{a}	30.96^{a}
T4	31.82^{a}	30.02^{a}	31.74^{b}	39.76^{b}	33.38^{a}

Mean score with different letters differ significantly (P<0.05) by DMRT (n=3)

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

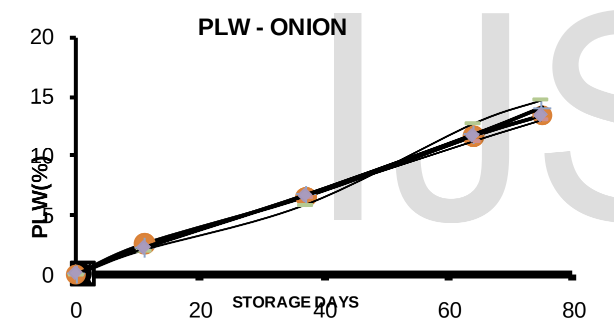

Fig.1a.Effect of gamma irradiation on the changes in physiological loss in weight(%)of onion(*var.Bellary red*) during post irradiation storage period up to 75 days at ambient conditions (26±3ºC; 60-75% RH) (n=3).

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

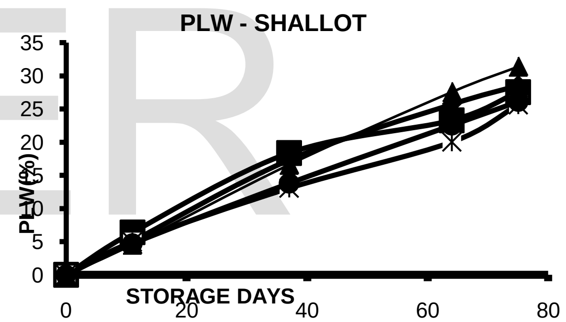

Fig.1b.Effect of gamma irradiation on the changes in physiological loss in weight(%)of shallots *var. Ascalonicum*) during post irradiation storage period up to 75 days at ambient conditions (26±3ºC; 60-75% RH) (n=3).

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

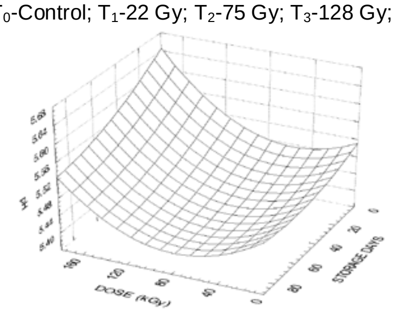

Fig.2a.Effect of gamma irradiation on the changes in the chemical quality attributes(pH)of onion (*var.Bellary red*) during post irradiation storage period up to 75 days at ambient conditions (26±3ºC; 60-75% RH) (n=3).

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

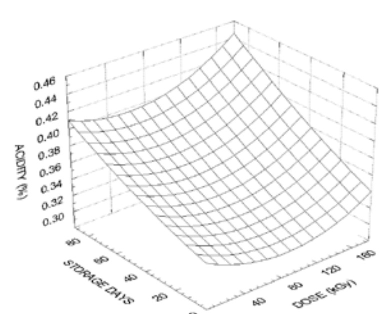

Fig.2b.Effect of gamma irradiation on the changes in the chemical quality attributes(Acidity,%)of onion(*var.Bellary red*) during post irradiation storage period up to 75 days at ambient

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

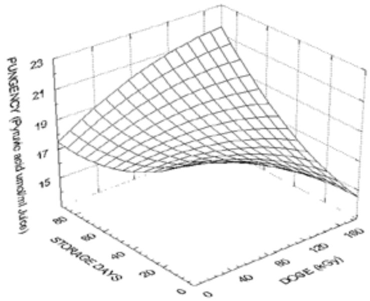

Fig.3a.Effect of gamma irradiation on the changes in the chemical quality attributes(Pungency, mol/ml.juice)of onion(*var.Bellary red*) during post irradiation storage period up to 75 days at ambient conditions (26±3ºC; 60-75% RH) (n=3).

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

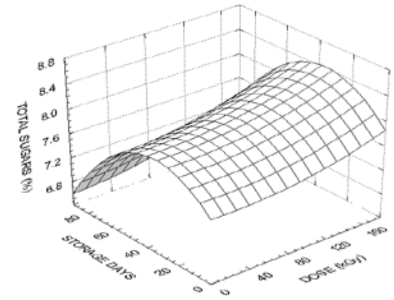

Fig.3b.Effect of gamma irradiation on the changes in the chemical quality attributes(Total sugars,%)of onion(*var.Bellary red*) during post irradiation storage period up to 75 days at ambient conditions (26±3ºC; 60-75% RH) (n=3).

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

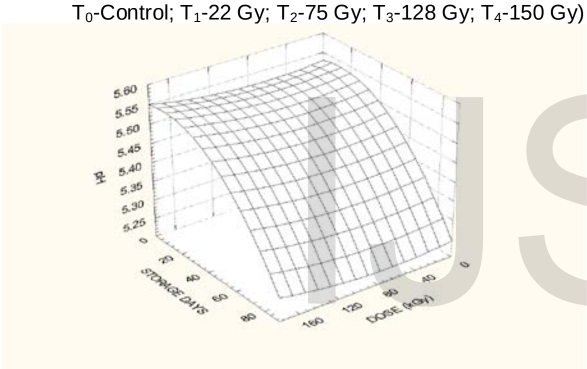

Fig.4a.Effect of gamma irradiation on the changes in the chemical quality attributes(pH)of shallots(*var.Ascalonicum*) during post irradiation storage period up to 75 days at ambient conditions (26±3ºC; 60-75% RH) (n=3).

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

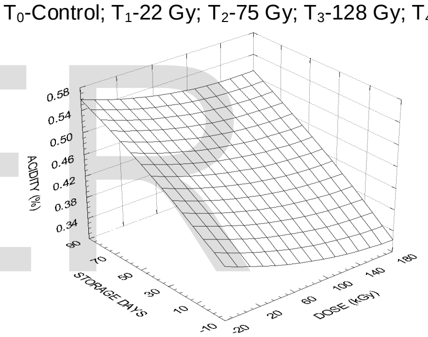

Fig.4b.Effect of gamma irradiation on the changes in the chemical quality attributes(Acidity,%)of shallots(*var.Ascalonicum*) during post irradiation storage period up to 75 days at ambient conditions (26±3ºC; 60-75% RH) (n=3).

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

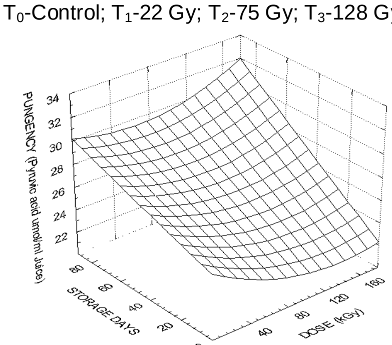

Fig.5a.Effect of gamma irradiation on the changes in the chemical quality attributes (Pungency, mol/ml.juice)of shallots (*var.Ascalonicum*) during post irradiation storage period up to 75 days at ambient conditions (26±3ºC; 60-75% RH) (n=3).

LEGENDS:
T_0-Control; T_1-22 Gy; T_2-75 Gy; T_3-128 Gy; T_4-150 Gy)

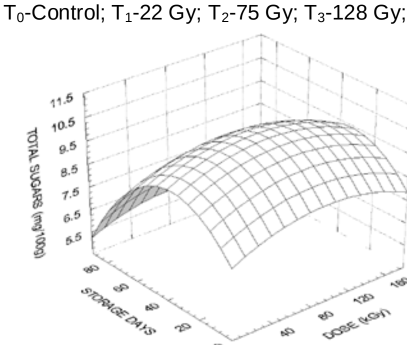

Fig.5a.Effect of gamma irradiation on the changes in the chemical quality attributes (Total sugars, %) of shallots (*var. Ascalonicum*) during post irradiation storage period up to 75 days at ambient conditions (26±3ºC; 60-75% RH) (n=3).
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