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Inhibition of Sprout Growth and Increase Storability of Processing Potato by Antisprouting Agent

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ABSTRACT

The investigation provides a novel anti-sprouting agent for inhibiting growth of potato tubers (*Solanum tuberosum* L. cv. Fridor). The antisprouting of CIPC, geranyl acetate, geraniol, camphor, citral, linalool, l-carvone, d-carvone, d-citronellol and l-citronellol of essential oils were used. Subsequent experiment has also been established to study the effect of geraniol and citral at different concentrations (4, 6 and 8 mM) on eyes sprouted (%) into the tuber. Therefore, four storage experiments were carried out at El-Mansoura Horticultural Research Station, Egypt, during the two successive summer seasons of 2012 and 2013. Potato tubers treated with geraniol or citral emulsions and stored at ambient temperature showed the lowest significant values of sprouting and weight loss percentage in both seasons of the study. CIPC inhibited sprouting over 98.5%. Application of geraniol or citral resulted in the highest value of dry matter and had a significant effect on reducing sugars and total free amino acids, in both seasons. Tubers of control treatment were of the lowest significant peroxidase activity POD. All treatments, except for the control, gave the best quality processing of chips and French fries. In another experiment sprouting was completely inhibited at 6 or 8 mM concentrations in the end of storage period (120 DAS). The study suggests that using geraniol or citral emulsions (8 mM) and stored potato tuber at ambient temperature are safe, ecofriendly and economically viable.

Key words: *Solanum tuberosum*, anti-sprouting agent, ambient temperature, sprout growth

INTRODUCTION

Respiration of tubers during storage and breakdown of dormancy during storage result in sprouting and loss of nutritive value of tubers (Suhag *et al*., 2006). Sprouting reduces the weight, the nutritional and processing quality of tubers and the number of marketable potatoes, being responsible for important economic losses during potatoes storage (Delaplace *et al*., 2008). These physiological changes affect the internal composition of the tuber and destruction of edible material and changes in nutritional quality (De Carvalho and Da Fonseca, 2006). Various methods are available to control sprouting during storage. The primary method to control sprouting in storage is with postharvest application of isopropyl N-(3-chlorophenyl) carbamate (chloropropham; CIPC). CIPC inhibits sprout development by interfering with cell division (Pringle *et al*., 2009). Therefore, a pressing need exists to find other, more environmentally acceptable sprout inhibitors for tubers. Nowadays it's very important to use natural products compounds such as essential oils as well as the pure compound derived from essential oils. Naturally occurring compounds could be used as

anti-sprouting agents in potatoes, based on the common idea that natural products are less harmful to the environment than chemical products (Frazier *et al*., 2004). Effective sprout control is a major component of managing stored potato quality. Several research groups in the United States and Europe are investigating alternative chemical inhibitors (Rama and Narasimham, 1987). Feldheim (1985) "Practicability and mode of action of quality storage of potatoes after harvest" reported that oil from the Muna plants was more effective than CIPC in inhibiting sprouting, fresh weight loss and the incidence of rotted tuber parts over a period of 120 days. The authors also reported that the main components of the oil, including the monoterpenes alpha and beta-pinene and limonene and the oxygenated monoterpenes pulegone and menthone/isomenthone are effective in this regard. Vaughn (1992) reported a method for inhibiting sprouting of tubers including the step of exposing tubers to the oxygenated monoterpenes.

Some plants release certain chemicals in their immediate environment which inhibit or stimulate nearby growing plants. The phenomenon is referred to as allelopathy and such plants are known as allelopathic plants (Bagchi *et al*., 1997). A variety of allelochemicals have been identified including phenolic acids, coumerins, terpenoids, flavonoids, alkaloids, glycosides etc. (Putnam and Tang, 1986). The chemicals are considered as resources for developing herbicides, plant growth stimulators and pharmaceuticals. The allelopathic potential of volatiles from *Echinacea angustifolia* have been examined on lettuce seeds (Viles and Reese, 1996). Certain aldehydes such as citral, cinnamaldehyde, salicyladehyde and benzaldehyde may be inhibitors of growth and germination (Steward and Krikorian, 1971). Salvia is known to produce volatile inhibitors. The air around Salvia has been reported to contain two terpenes, i.e., cineole and camphor. Cineole inhibited germination and growth of *Brassica compestris* (Koitabashi *et al*., 1997). The inhibitory action of volatile oil and its constituents of *Lavandula angustifolia* (lavender), *Mentha pulegium* (mint), *Mentha spicata* (spearmint), *Origanum* onites (Turkish oregano), *Origanum vulgare* ssp. *hirtum* (Greek oregano), *Rosmarinus officinalis* (rosemary) and *Salvia fruticosa* (sage) were tested on potato sprout suppressant. Potato sprout growth was inhibited when use these volatile oil and its constituents (Vokou *et al*., 1993).

An antisprouting agent for potatoes based on the essential oil of caraway (rich in carvone) has been suggested (Capelle *et al*., 1996). De Vries (1999) has reported that a combination of carvone and one or more fungicides lead to synergistic effect for inhibiting sprouting. Benzaldehyde, salicylaldehyde and substituted benzoic acids have been found in uncooked and baked potato tubers (Coleman *et al*., 2001). These compounds have been shown to be inhibitory to the growth of plants, fungi and bacteria (Kurita *et al*., 1981). Vaughn and Spencer (1993) who used several naturally occurring volatiles, thymol cuminaldehyde and salicylaldehyde. They were applied as volatiles or directly tubers stored at 22°C. They also found that thymol and volatiles have effectively inhibited sprouting relative to control of 98% sprouting. Daniels and George (1996) continuously bathed potato tuber to 1, 8-cineol, monoterpene of essential oil and ozone as alternatives to CIPC to control sprouting at ambient temperature. They found that 1, 8-cineol was as effective as CIPC in suppressing of sprouting.

The above described chemicals used for checking sprouting of potatoes suffer from number of disadvantages:

- Some chemicals do not show 100% inhibition of potato tubers
- The chemicals are not easily available in the market as they are not industrially produced

- Chemicals are costly
- CIPC is synthetic chemical and its residue is left in the tubers which is harmful for human body

To overcome the drawbacks in the prior art, the applicants have developed a novel formulation useful as an anti-sprouting agent for inhibiting tuber sprouting without necrosis or softening of the tuber, especially in potatoes.

The main object of the present invention is to provide a novel anti-sprouting agent for inhibiting tuber sprouting at ambient temperature 35/15°C (day/night) without necrosis or softening of the tuber in potatoes. Also compared with those treated with anti-sprouting agent and CIPC which were stored at 10°C on storability and optimizing processing related characters as well as final product quality.

Another object of the present invention is to provide an anti-sprouting agent comprising terpenoids obtained from herbs, so that the agent is safe, ecofriendly easily available and doesn't exhibit adverse effect on potatoes and can effectively be used as antisprouting agents.

Yet another object of this invention is to provide an anti-sprouting agent for inhibiting tuber sprouting using a compound that has low mammalian toxicity, is rapidly biodegradable, inexpensive and which doesn't impart an unpleasant taste or odour to the treated tuber.

MATERIALS AND METHODS

Experiment condition: Four storage experiments were carried out at El-Mansoura Horticultural Research Station, Egypt, during the two successive summer seasons of 2012 and 2013. The experiments were designed to investigate the effects of anti-sprouting agents for inhibiting tuber sprouting, increase storability and quality using compounds comprising terpenoids obtained from herbs.

Tuber material: Potato tubers were harvested from the field on 29th May of two seasons from Nubaria district, Behera Governorate, cured for 12 days at 25±5°C under rice straw. Uniformly sized potato tubers (*Solanum tuberosum* L. cv. Fridor) of 60-80 mm in diameter (~180-250 g) were selected without any anti-sprouting treatment. Each treatment treated with natural antisprouting agent and stored for four months at ambient temperature (average: 35/15°C day/night and 70% RH) in laboratory.

Experimental procedure and design: The monoterpenes used in this invention were obtained from aromatic plants. The aromatic plants yield essential oils which are composed of different types of monoterpenes. The essential oils were obtained from 250 g leaves, plant herb and seeds of aromatic plants by water steam distillation for 2 h. The plants used in this study are:

- *Cymbopogen martini* which has high content of geraniol (66.7 μg mL^{-1}; leaves), geranyl acetate (48.2 μg mL^{-1}; leaves)
- *C. flexuosus* with high contents of citral (75.3%; leaves)
- *C. winterianus* rich and citronellol (80.5%; leaves)
- *Ocimum sanctum* rich in ketone, camphor (65.4%; plant herb)
- *Carum carvi* rich in carvone (73.7%; seeds)
- *Artemisa annua* rich in ketone camphor (77.2%; leaves) and
- *Lavendula officinalis* rich in linalool (49.5%; leaves)

The isolated terpenoids were used as such for checking the sprouting or were further purified by HPLC and the purified fractions were tested for the response. Essential oils were purified by column chromatography and substantially pure compounds were used. Exposure of the tubers to the composition may be initiated at any time after harvest or during the storage of the tuber. However, exposure after 1 month of harvest or at such time that the tubers begin to sprout should be preferred. Emulsions of the compounds were prepared of 8 mM concentration of each compound in distilled water containing Tween 20 (6%) as emulsifier (control tubers were treated with Tween 20 only). Tubers were treated by dipping each tuber in emulsion for 30 min; where upon excess liquid was allowed to drain off. Sixty tubers per treatment were used, with three replicates, the tubers "equal size" were kept in net plastic bags (5 kg, 23-26 tuber). CIPC was applied at 100 ppm for treatment.

The terpenes were applied at 4, 6 and 8 mM for 30 min by dipping the tubers and then the tubers were kept in net plastic bags in room temperature for 4 months.

The first experiment was designed in a complete randomized blocks design with three replicates. The experiment included 11 treatments which were as follows: (1) Storing potato tubers at ambient temperature (35/15°C-day/night) as control, (2) Chloropropham (CIPC) at cold storage (8°C), (3) Geranyl acetate, (4) Geraniol, (5) Camphor (6) Citral, (7) Linalool, (8) l-carvone, (9) d-carvone, (10) d-citronellol and (11) l-citronellol. The treatments from 3-11 were stored at ambient temperature for four months.

The acyclic monoterpene promising compounds geraniol and citral (according to their storage behavior during experiment 1) were applied at 4, 6 and 8 mM for 30 min plus control (distillated water) and used as the second experiment and was designed in a complete randomized blocks design with three replicates.

Studied characteristics: Sprouting, weight losses, eyes sprouted percentage and dry matter at the end of storage, i.e., four months were determined. Reducing sugars and total amino acids were determined according to the methods described by AOAC (1990). Enzyme analysis peroxidase POD was determined using standard methods described by Yamazaki and Piette (1963). At the end of storing period, four tubers from storage treatments were taken and used for assessing suitability for processing quality, thin potato slices for crisps or 9×9 mm for French fries were prepared.

Statistical analysis: All statistical analyses were performed, using the CoStat for Windows software version 6.311. Data were analyzed by analysis of variances (ANOVA) one-way fixed factor. Duncan's multiple range test was calculated for multiple mean comparisons at a significance level of $*p<0.05$.

RESULTS AND DISCUSSION

Experiment 1

Sprouting, weight losses and dry matter: Results are shown in Table 1 all control tubers displayed heavy sprouting and weight loss at the end of storage period. Only geraniol and citral completely inhibited sprouting and decreased weight loss and no rotting was observed as well as attaining higher tuber dry matter content in both seasons. Geranyl acetate inhibited sprouting by 95%. Linalool and l-carvone had no significant effect on tuber sprouting. It is interest to note that l-carvone and d-carvone displayed little or no inhibition of sprouting even though this compound has been reported to inhibit sprouting in potatoes (Oosterhaven *et al*., 1995). Geraniol, citral,

Table 1: Sprouting behavior characters and dry matter of potato tubers as affected by anti-sprouting agent during 2012 and 2013 (after 4 months of storage period)

	Sprouting (%)		Weight loss (%)		Dry matter (%)	
Treatments	2012	2013	2012	2013	2012	2013
Control	100.00^{a}	96.00^{a}	25.12^{a}	26.18^{a}	21.65^{f}	22.80^{e}
CIPC	2.49^{e}	1.20^{e}	4.33^{e}	2.80^{ef}	23.60^{a-d}	23.66^{d}
Geranyl acetate	4.68^{d}	4.33^{c}	3.41^{f}	4.65^{d}	22.50^{ef}	24.55^{ab}
Geraniol	0.00^{f}	0.00^{e}	2.19^{h}	1.45^{g}	24.56^{a}	25.30^{a}
Camphor	6.92^{c}	5.98^{c}	2.88^{g}	2.95^{ef}	23.33^{b-e}	24.38^{bc}
Citral	0.00^{f}	0.00^{e}	1.51^{i}	1.26^{g}	24.00^{ab}	24.95^{ab}
Linalool	100.00^{a}	72.00^{b}	9.50^{b}	8.00^{b}	22.66^{de}	23.60^{d}
l-Carvone	70.58^{b}	62.00^{b}	9.50^{b}	6.25^{c}	22.80^{cde}	23.70^{cd}
d-Carvone	72.00^{b}	76.98^{b}	8.03^{c}	3.45^{e}	22.90^{cde}	24.89^{ab}
d-Citronellol	2.89^{e}	2.00^{e}	6.75^{d}	5.73^{c}	23.60^{a-d}	24.68^{ab}
l-Citronellol	0.00^{f}	0.00^{e}	2.25^{gh}	2.10^{fg}	23.80^{abc}	24.55^{ab}

Means followed by the same letter(s) within each column do not significantly differ using Duncan's multiple range test at the level of 5%

citranellol and citranellal were as effective as reported monoterpenes such as benzaldehyde, cinnamaldehyde, eugenol, menthyl acetate and thymol (Hartmans *et al.*, 1995). CIPC inhibited sprouting over 98.5%.

The antisprouting agent acts as an uncoupling agent in mitochondria at low concentration (Pauly *et al.*, 1981), thereby, inhibit mitochondrial respiration (Lorber and Muller, 1980), membrane disturbances (Lorber and Muller, 1980) which may be suppressing to the sprouting. Similar finding was obtained by Kurita *et al.* (1981) who reported that these compounds have been shown to be inhibitory to the growth of plants, fungi and bacteria. Klinge and Palomino (2009) reported that oil from the Muna plants from South America was more effective than CIPC in inhibiting sprouting, fresh weight loss and the incidence of rotted tuber parts over a period of 120 days. The authors also reported that the main components of the oil, including the monoterpenes alpha and beta-pinene and limonene and the oxygenated monoterpenes pulegone and menthone/isomenthone are effective in this regard. Vaughn (1992) reported a method for inhibiting sprouting of tubers including the step of exposing tubers to the oxygenated monoterpenes.

Under this work condition, the beneficial effect of the applied anti-sprouting agent especially geraniol and citral on tubers dry matter could be associated with their similar advantages effect in preservation of their tubers starch, carbohydrates, sugars and amino acid content (Table 2). Besides their suppressive action in controlling and reducing incidence of sprouting, weight loss and damage. Suppression of sprouting and weight loss logically associated with maintenance of dry matter. Furthermore, the antioxidant protective role and responses of such monoterpenes could be added other advantages in their regard too.

Reducing sugars, amino acids and activity of peroxidase POD: All storage treatments (anti-sprouting agent/monoterpenes) gave significant lower values of reducing sugars and amino acids during both seasons as compared to the control (Table 2). The lowest significant values of reducing sugars and amino acids content were found in tubers treated with geraniol and citral at ambient temperature, without significant difference between the two treatments.

Table 2: Reducing sugars, amino acids and peroxidase enzyme of potato tubers as affected by anti-sprouting agent during 2012 and 2013 (after 4 months of storage period)

	Reducing sugars (%)		Total free amino acids (%)		Peroxidase activity POD (%)	
Treatments	2012	2013	2012	2013	2012	2013
Control	4.29^{a}	4.52^{a}	0.352^{a}	0.348^{a}	56.77^{g}	55.51^{g}
CIPC	2.05^{e}	3.18^{d}	0.307^{ab}	0.301^{ab}	95.81^{b}	94.63^{b}
Geranyl acetate	1.39^{ed}	3.93^{b}	0.084^{bc}	0.047^{c}	79.75^{e}	79.33^{e}
Geraniol	1.24^{d}	1.51^{f}	0.030^{c}	0.028^{c}	97.33^{a}	96.29^{a}
Camphor	3.41^{b}	3.48^{c}	0.152^{abc}	0.153^{abc}	80.68^{e}	80.26^{e}
Citral	1.25^{d}	1.52^{f}	0.045^{c}	0.045^{c}	97.68^{a}	96.46^{a}
Linalool	4.07^{ab}	4.13^{b}	0.106^{bc}	0.108^{bc}	80.67^{e}	79.06^{c}
l-Carvone	3.81^{ab}	1.83^{e}	0.084^{bc}	0.151^{abc}	81.67^{e}	80.50^{e}
d-Carvone	1.45^{ed}	1.68^{ef}	0.146^{abc}	0.157^{abc}	77.55^{f}	76.77^{f}
d-Citronellol	1.76^{ed}	1.54^{f}	0.186^{abc}	0.187^{abc}	84.50^{d}	83.62^{d}
l-Citronellol	1.29^{d}	1.58^{f}	0.147^{abc}	0.059^{c}	87.67^{c}	86.65^{c}

Means followed by the same letter(s) within each column do not significantly differ using Duncan's multiple range test at the level of 5%

This greatly confirmed the potency of such treatments in preservation and maintenance of the stored tubers reserves, keeping the internal biochemical enzymatic activities in minimum level and in more stable case thereby prolonged their dormancy case. Also, proved that these treatments were highly effective in protection of their tubers against the were known degradable effects of higher temperature/oxidative stressful storage conditions and accordance to the findings of Davies (1990) who indicated that those essential oils and/or their basic constituents (monoterpenes and antioxidants) tended to slow down the activity of carbohydrates and protein breakdown associated enzymatic systems as well as respiration and energy metabolism enzyme. The role of POD in sprouting of vegetables was widely investigated, particularly its degrading activity of IAA which is considered an effective promoter of sprouting (with cytokinins) (Thomas, 1969).

All treatments induce higher activity for peroxidase enzyme of their tubers than the control at the two seasons (Table 2). Also, cleared that among storage treatments, geraniol and citral were significantly increased the activity of peroxidase. Understanding of ambient higher temperature storage condition as a stressful factor, induce more serious internal oxidative stress, generation of elevated level of degradable and toxic Reactive Oxygen Species (ROS) (O^{-}_{2}, OH^{-} and H_2O_2) (Rojas *et al*., 2000). In such case, the enzymatic defense against high temperature inducible oxidative stress is of great importance and depending on the activation degree of peroxidase as affected by storage treatments. Thereby, the level of ROS degradation and the internal protective capacity (Rojas *et al*., 2000).

Processing quality of potato chips and french fries: All anti-sprouting agent treatments at ambient temperature and CIPC treatment gave the highest chips and French fries quality characters, i.e., color, crispiness and taste (with no considerable differences between them), in comparison with the control treatment (Table 3).

The present results could be expected based on the similar beneficial effect of these treatments on dry matter, storability, sprouting behavior (Table 1), tubers reserves especially reducing sugars and amino acids (Table 2).

Table 3: Quality processing of potato tubers as affected by anti-sprouting agent during 2012 and 2013 (after 4 months of storage period)

	Chips						French fries					
	Color		Taste		Crispness		Color		Taste		Crispness	
Treatments	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Control	3.00^{e}	3.33^{c}	3.00^{d}	3.33^{bc}	4.33^{abc}	4.33^{abc}	3.33^{de}	3.00^{d}	3.33^{cd}	4.00^{bcd}	4.67^{ab}	4.67^{ab}
CIPC	3.33^{de}	3.33^{c}	4.33^{abc}	4.33^{ab}	4.33^{abc}	4.67^{ab}	3.67^{cde}	3.33^{cd}	4.00^{abc}	4.33^{abc}	4.67^{ab}	4.67^{ab}
Geranyl acetate	4.67^{ab}	4.67^{ab}	5.00^{a}	4.67^{a}	5.00^{a}	5.00^{a}	4.67^{ab}	4.67^{ab}	5.00^{a}	4.67^{ab}	5.00^{a}	4.33^{abc}
Geraniol	5.00^{a}	5.00^{a}	5.00^{a}	4.67^{a}	5.00^{a}	5.00^{a}	4.67^{ab}	4.67^{ab}	5.00^{a}	4.67^{ab}	5.00^{a}	4.33^{abc}
Camphor	4.67^{ab}	4.67^{ab}	5.00^{a}	4.67^{a}	5.00^{a}	5.00^{a}	4.67^{ab}	4.67^{ab}	4.67^{ab}	4.67^{ab}	5.00^{a}	5.00^{a}
Citral	5.00^{a}	5.00^{a}	5.00^{a}	4.67^{a}	5.00^{a}	5.00^{a}	5.00^{a}	5.00^{a}	4.67^{ab}	5.00^{a}	5.00^{a}	5.00^{a}
Linalool	4.67^{ab}	4.67^{ab}	4.64^{ab}	4.67^{a}	5.00^{a}	5.00^{a}	4.67^{ab}	4.67^{ab}	4.67^{ab}	4.67^{ab}	5.00^{a}	5.00^{a}
l-Carvone	4.67^{ab}	4.67^{ab}	4.67^{ab}	4.67^{a}	5.00^{a}	5.00^{a}	4.67^{ab}	4.67^{ab}	5.00^{a}	5.00^{a}	5.00^{a}	5.00^{a}
d-Carvone	5.00^{a}	5.00^{a}	5.00^{a}	4.67^{a}	5.00^{a}	5.00^{a}	5.00^{a}	5.00^{a}	4.67^{ab}	5.00^{a}	5.00^{a}	5.00^{a}
d-Citronellol	4.00^{bcd}	4.67^{ab}	4.67^{ab}	4.67^{a}	4.67^{ab}	4.67^{a}	4.00^{bcd}	4.00^{abc}	4.33^{abc}	4.33^{abc}	4.67^{ab}	5.00^{a}
l-Citronellol	4.33^{abc}	4.67^{ab}	4.67^{ab}	4.67^{a}	4.67^{ab}	4.67^{a}	4.00^{bcd}	4.33^{abc}	3.67^{bcd}	4.33^{abc}	4.67^{ab}	4.67^{ab}

Means followed by the same letter (s) within each column do not significantly differ using Duncan's multiple range test at the level of 5%

The same treatments greatly controlled and prevented the accumulation of sugars, optimized the stored tubers content of reducing sugars and amino acids after storage at ambient temperature. Thus, it could explain the worst processing quality (darkened chips of bad taste and crispiness) of storage treatments based on the occurrence of Millard reaction during frying process due to the extremely accumulated reducing sugars and amino acids (Brierley *et al*., 1996; Herrman *et al*., 1996). The same processing quality parameters were correlated with dry matter content (Hesen, 1981) and with amino acids content (Table 2) in both seasons. These results are in harmony with those previously obtained by El-Awady (2006). With the same basis, this could explain the best processing quality of essential oils produced chips, the considerable control (optimization) of reducing sugars and amino acids of their tubers thereby, the prevention of Millard reaction occurrence during frying processes and in turn best color, crispiness and taste.

The results in hand have evidently confirmed the association between the storability characters and the internal biochemical status of potato tubers at the end of storage and their subsequent chips quality character after frying.

Experiment 2

Percentage of eyes sprouted at different storage period: Tubers were treated with geraniol and citral the two promising chemicals at different concentrations. Sprouting was completely inhibited at 6 and 8 mM concentrations. The experiment was continued till 120 days after treatment and sprouting was not observed. The results are given in Table 4.

Completely suppressed sprouting and damage incidence of their tubers also highly reduced the length of the emerged sprout during both seasons.

Similar results were obtained by Vaughn and Spencer (1993), Coleman *et al*. (2001) and Frazier *et al*. (2004).

Table 4: Percentage of eyes sprouted of potato tubers as affected by geraniol and citral agents at different concentrations during 2012 and 2013 (after 4 months of storage period)

			Percentage eyes sprouted							
			2012 (DAS)				2013 (DAS)			
Treatments	Concentration (mM)	Size of potato (cm)	30	60	90	120	30	60	90	120
Geraniol	4	7.3	0.00^{b}	8.70^{b}	13.40^{b}	18.20^{b}	2.60^{b}	8.70^{b}	15.30^{b}	20.20^{b}
	6	7.7	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}
	8	7.2	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}
Citral	4	6.8	0.00^{b}	2.80^{c}	11.30^{b}	14.10^{b}	0.00^{b}	5.20^{b}	10.10^{b}	16.30^{b}
	6	7.0	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}
	8	6.3	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}
Control	---	6.7	15.70^{a}	80.00^{a}	92.50^{a}	100.00^{a}	12.40^{a}	73.20^{a}	88.10^{a}	100.00^{a}

Means followed by the same letter(s) within each column do not significantly differ using Duncan's multiple range test at the level of 5%, DAS: Days after storage

In this connection, high temperature known to induce serious internal oxidative stress, accumulation of toxic and degradable levels of the Reactive Oxygen Species (ROS). These known to be induce the incidence of internal disturbances and dramatic events, induced membrane breakdown, extreme permeability and solutes leakage, high respiration and depletion of carbohydrate pools within the stressed tissues (Bowler *et al*., 1992). Antioxidants containing substances (monoterpenes) known to be effectively protect and preserve the stressed tissue against the degradable effects of high temperature inducible oxidative stress via their antioxidantal phenols (Cakmak and Marschner, 1992). On the other hand, the pronounced worst storability of control tubers includes progressive sprouting, weight loss and damage incidence. This could be interpreted based on the same previously mentioned considerations. Since, it can be suggested that, the control tubers had less or no capabilities to protect and preserve against such stressfull effects.

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