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Effect of Essential Oils, Chlorpropham and Fresh Back on Storing Potato Tubers and Quality

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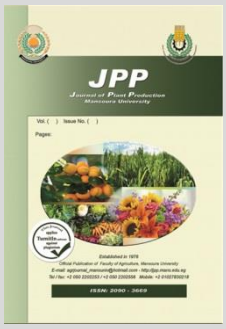

ABSTRACT

Potato tubers (Lady Rosetta and Hermes cvs) were exposed to natural essential oils, CIPC and Fresh Back and then stored for five months at cold temperature to study the effect of these compounds on tuber sprouting, storability and quality. The tubers were exposure to the pure essential oils after 15 Days of harvesting. Essential oils were prepared of 5 ml concentration of each compound. Tubers of control weren't applied with any compounds. Tubers were treated for 5 hours in a room temperature jointed with a refrigerator. Pure essential oils were applied to tubers by thermal fogger machine (Super-2000 Gold sprayer). Both cultivars treated with CIPC or clove oil were of lowest sprouting, weight loss and decay percentage in comparison with all storage treatments during the two seasons. Treated potato tubers of Lady Rosetta cultivar with clove oil essential oil at 10ºC gave the highest levels of DM, vit C and phenols compared with other treatments at the end of storage periods in two seasons. The study suggests using clove oil with Lady Rosetta or Hermes cultivars once time before storage at a rate of 100 ml/ton by fogging and stored potato tuber at 10 ºC day/night and 95% RH for 5 months as an efficient natural to reduce sprouting, weight loss and decay percentages with an increase in its quality contents. Moreover, the essential oils are safe for use not produce any adverse effects on the potatoes. The anti-sprouting agent is eco-friendly and economically viable.

Keywords: Potato; oils; fogging; Refrigerator

INTRODUCTION

Major variations on the quality of potato happen while being stored, which influences the quality of potato. Rotting and sprouting are the most major problems that occur at the time potato storage.

Controlling stored potato quality requires effective sprout control. In addition, tuber quality will reduce if effective sprout control is not maintained. significantly, as will the capacity to keep for long periods. Weight loss is promoted by sprouting. A decrease in air frequently causes higher temperatures in pile as well as a rise in disease issues. Potato sprouting is also linked to starch conversion, it is undesirable in potato industry because it causes fried potatoes to darken. Consumers dislike visible sprouts on potatoes. The dormancy length varies depending on storage temperature and cultivar. Knowing the differences in varieties is important in order to choose the best storage temperature and know when to use a growth control agent.

There are many ways to control growth while storage. The main technique for controlling growth in storage is post-harvest treatment with isopropyl N-(3-chlorophenyl) carbamate (chlorbenzamide; CIPC). By preventing with cell division, CIPC suppresses sprout growth. (Amjad *et al*., 2020), Because of the rising concern for consumer health and safety, it is necessary to replace synthetic pesticides such as chlorpropham (CIPC) with effective potato sprout suppressants that have a low harmful effect on the environment. Even though knowing that the time of dormancy varies depending on cultivar and storage temperature. It is crucial to understand cultivar variations throughout the dormancy period the cultivar's ideal storage temperature and when to administer the chemical for sprout control.

Essential oils produced by spices and herbs have already been demonstrated to reducing potato sprouting and it can be applied on organically certified crops. These compounds are volatile plant derivatives such as caraway, thyme essential oils in addition more compounds like hydrogen peroxide, it should be mentioned that essential oils plus hydrogen peroxide don't stop potato sprouts. On the other hand, they limit their growth by creating an environment inappropriate for more growth. New sprouts will appear on the potatoes on a regular basis however, with frequent applications of essential oils and hydrogen oxide, the growth of these sprouts can be controlled. Vaughn and Spencer (1993) applied thymol cumin aldehyde and salicylaldehyde, two naturally occurring volatiles. These were used as volatiles on stored tubers at 72°F. They discovered that volatiles and thymol successfully suppressed potato sprouting compared to the control. Abd El-Kader *et al* (2016) used nature essential oils Such as garlic oil, eucalyptus oil, basil oil, clove oil, lemonion oil, peppermint oil mixture of these oils and selecron. They showed that peppermint and clove oils gave the lowest significant values of sprout weight, weight loss, sprout length and sprouting rates. To inhibit sprouting at room temperature, potato tubers were continually soaked in 1, 8- cineol, monoterpene of essential oil, and ozone as alternatives to CIPC. They discovered that 1, 8-cineol was just as effective as CIPC at suppressing sprouting. Frazier

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et al. (2004) applied fogging method to inhibit the growth of potato tubers and stored tubers for nine months at 7°C using multiple naturally occurring volatiles clove oil, spearmint and peppermint. They discovered that clove and mint oils inhibiting potato sprouting

Current study aims for studying the influence of several essential oil application compare with CIPC and Fresh back on potato tuber kept at 10°C on storability and improving processing associated features in addition to final product quality.

MATERIALS AND METHODS

Experiment was conducted at a private refrigerator (Baraka refrigerator), Kafr Saad, Damietta Governorate, Egypt, during May 2021 and May 2022 seasons. The studies carried out to investigate the effect of natural essential oils compared to chemical anti-sprouting agents to improve the quality and storability of potato tubers under refrigerator storage for five months. All storage treatments and measurement applied as follow.

Experimental materials, treatment and design:

Plant materials:

Cultivars of potato under study was Lady Rosetta and Hermes, Uniformly sized potato tubers diameters ranging from 40 to 60 mm, (weighed 120-150 g) were collected from Nubaria district, Beheira Governorate and Mohamed Naguib site for protective cultivation, Marsa Matrouh Governorate. Fresh tubers not treated with anti-sprouting and cured for 12 days at 25±5ºC and 75 % RH under rice straw.

Anti-sprouting compounds

It was used a lot of anti-sprouting compound such as; (1) chloropropham (CIPC), (2) Fresh-Pack®-50EC, (3) mint oil, (4) caraway oil, (5) clove oil, (6) sage brush oil and (7) lavender oil.

CIPC

Chemical sprout inhibitor CIPC named SPUD-NIC 4A (49.7% w/v chloropham) imported from Aceto Agricultural Chemicals Cooperation, USA and was used at 33 ml/ton of stored potatoes. At high temperatures, to produce thermal fog or an aerosol, CIPC is frequently using a thermal applicator and applied with fogging machine (pulsFOG Co., USA).

Fresh Pack

Fresh-Pack®-50EC is an organic certified clove oil (eugenol) based solution used as a sprout suppressant for the potato fresh-market industry. Fresh-Pack® produced by Aceto Agric. Chem. Co. and proper treatment solutions of 84 ml/ton which used by fogging machine as natural essential oils.

Essential oils

Natural essential oils extracted from leaves, flowers, flower bud and aromatic plant seeds by steam distillation method. The following plants applied in the current study: *Mentha spicata* (spearmint; leaves), *Carum carvi* (caraway; seeds), *Syzygium aromaticum* (clove; flower buds) *Artemisia* sp. (common sagebrush; leaves) and *Lavandula spica* (lavender leaves and flowers).

Essential oils extracted separately from dried aromatic plants (200 g). The plant components extracted by hydro-distillation via the Clevenger equipment for 150 min, according to Charles and Simon (1990). Oils purified by column chromatography and stored them in dark glass bottles at 4°C.

Analysis of essential oils:

The analysis of main components of spearmint leaves (*Mentha spicata*) was mentha-6, 8-dien 2 one (49.39%), carvone (38.32%), anisole (2.53%), and limonene (1.96%).

The *Carum carvi* oil was carvon (61.88 %), limonene (29.22%), and ß-myrcene (3.97%).

The major components of clove *Syzygium aromaticum* were eugenol (37.22%) and eugenol acetate (14.71 %) as the major compounds.

The main ingredients of sage brush (*Artemisia* sp.) were camphor (40%), α-pinene (20%), and terpinene (12%).

The most ingredients of *Lavandula spica* were linalool (34.76%), linalyl acetate (27.59%), cis-β-ocimene (5.05), trans β-ocimene (4.09), terpinene-4-ol (4.86), lavandulyl acetate (5.90) i β-caryophyllene (3.93).

The compositions of main components of all essential oils estimated by GC/MS (Hewlett Packard 5890 series II GC equipped with a Flame Ionization Detector (FID).

Studied traits:

Studied traits divided into two division as physical and chemical. All physical quality traits were determined every 15 days from beginning of storage and collected at 60, 90 and 150 days from storage. While, chemical quality traits measured at the end of storage period. Potato tubers tested as the following measurements:

Physical quality traits

Sprouting (%):

Number of sprouted tubers recorded for the whole tubers of each net plastic bag. Then sprouting percentage calculated as follows:

Sprouting (%) = (No. of sprouted tubers / No. of total tubers) x 100

Weight loss (%):

All tubers weighted at the beginning of storage and during storage to estimate loss weight at different storage periods as follows:

$$\text{Weight loss (\%)} = ((A - B) / A) \times 100$$

While,

A; Average weight of tuber at the beginning of storage

B; Average weight of tuber at the different times

Decay (%):

The decayed - rotted and damaged- tubers of each potato net plastic bag were counted and excluded out which calculated as follow:

Decay (%) = (No. of total tubers – No. of healthy tubers that still at different times / No. of total tubers) x 100

Chemical quality traits:

Samples of 5 tubers were randomly chosen from each plot for chemical analysis, all sprouts on tuber surface were removed, and the tubers washed with distilled water, then 100 g of fresh pieces from those were oven dried, grounded and used for determination of dry matter and chemical analysis as follows:

The total phenol:

content in the tubers will determine using the Folin-Ciocalteu method Vaher *et al*., (2014).

Vitamin C:

Determination of vitamin C content is determined using UV spectroscopy Desai and Desai (2019).

Dry matter (%):

An electronic balance was used to weigh fresh tuber samples. Samples dried on air for 3 days then dried in an oven for 16 hours at 90°C. Samples of dried tubers weighed once again. Dry matter percent calculated by formula:

Dry Matter (%) = (Oven dry weight / initial fresh weight) x 100

Experimental design

Experiment conducted as factorial in completely randomized design with three replicate. Experiment included 16 treatments which the interaction among two cultivars and eight anti-sprouting compound. Experimental plot was one net plastic bag weighed 25 kg of uniformity tubers of potato. Each treatment used 75 Kg of healthy tubers and maintained in three net plastic bags in refrigerator for 5 months at $10C^{O}$ and 95% relative humidity.

All anti sprouting compounds applied for five hours by fogging in room temperature jointed with a refrigerator before storage at 15 days from harvest. Fogging treatments were; control tuber not treated with anti- sprouting agent, CIPC used at 33 ml/ ton, Fresh back used at 84 ml/ ton as well as five pure essential oils were prepared of 5 ml per 50 kg tubers of each oil (El-Awady *et al*., 2014) equal 100 ml/ton. Pure essential oils applied by thermal fogger machine (Super-2000 Gold sprayer, South Korea).

Statistical analysis

Data were analysing by analysis of variance method and the differences between individual pairs of treatment means compared by Duncan Multiple Range Test at 5% depending on Snedecor and Cochran (1982).

RESULTS AND DISCUSSION

1. Storage behavior.

Effect of cultivars.

Data in Table 1 show the effect of potato Lady Rosetta and Hermes cultivars on sprouting, weight loss and decay during five months storage period of 2021 and 2022.

After 150 days storage, Tubers of Hermes cultivar were significantly lower sprouting, weight loss and decay percentages than those of Lady Rosetta cultivar in both seasons except for the sprouting and decay in 2022 and 2021, respectively.

Under current work conditions, the pronounced best storability performance of Hermes cultivar compared to Lady Rosetta cultivar could be logically true, may be due to their genetic variation since the former is sensitive to internal bruising and mechanical damage. Meanwhile Hermes. may possess an active mechanism that slows or prevents the activity of degradable and respiratory.

Sprout inhibitors are required for potatoes that is possible consumed processed or fresh. Therefore, sprouting decreases weight, processing quality and nutritional of tubers in addition to the number of marketable potatoes. These results are in a similar direction of view to those mentioned before about (Sheibani *et al*., 2014; Pankomera *et al*., 2016; Aroiee *et al*. (2022).

Effect of essential oils.

The results in Table 2 show the effect of essential oils at 10°C storage treatments on sprouting behaviour, weight loss and decay percentages of their tubers stored during long period of 2021 and 2022 seasons.

All the essential oils, Fresh Back and CIPC treatments at 10°C storage one greatly suppressed the incidence of sprouting, weight loss and decay compared with those of the control in the two seasons of study. Treatments of clove oil caused fully (100%) inhibition bud development and incidence of sprouting, greatly reduced weight loss and prevented completely tubers decay compared with other treatments in both seasons followed by CIPC and Fresh Back. The results mentioned above may be related to the major bio-constituents (eugenol, 37.22% and eugenol acetate 14.71 %) in clove oil that reflects on bio-constituents in tubers.

Essential oil can reduce or inhibit potato tubers from sprouting. They attributed this effect to the monoterpene components in the oil, which causes internal necrosis of the bud meristem and prevents bud sprouting.

On the other hand, the pronounced worst storability of control tubers including progressive sprouting, weight loss and decay incidence, could be interpreted based on the same reasons mentioned previously considerations. Since, it can be suggested that, Control tubers had less or no capabilities to protect and preserve against such stress. Consequently, they severely suffering from carbohydrate degradation and sugars depletion contained poor amino acids and phenols had low peroxidase activity as well as low ABA and high GA's content . As regards, the inducible oxidative stress caused by excessive O_2^- diffusion, respiration rise, carbohydrate degradation and sugars depletion. In turn, it was providing more energy and structural components for the rapidly developing sprout tissues, since the sprouts serves as a powerful sink for the mobilized materials).

The used clove essential oil because it was rich in phenolic antioxidants, *i.e*., eugenol and eugenol acetate and caraway oil (carvon, limonene and ß-myrcene) Such antioxidants, known to be catalysed the enzymatic breakdown of the toxic ROS. These results are in a similar direction of view to those mentioned before about (Amjad *et al*., 2017 ; Şanlı and Karadoğan, 2019; Amjad *et al*., 2020 ; Belay *et al.,* 2022).

Effect of interaction:

Table 3 show the effect of interaction among potato cultivars (Lady Rosetta and Hermes) and storage treatments on storability of their tubers during 2021 and 2022. Data clear that treated potato tubers of two cvs with essential oils that stored at 10°C were significantly kept well storability than untreated potato during two seasons.

Tubers of Lady Rosetta and Hermes cultivars treated with clove oil or CIPC gave lowest sprouting, weight loss and decay % in comparison with all storage treatments during the two seasons. These results can be attributed to the aforenoted reasons regarding the genetic differences between the two varieties and the effect of the components of clove oil and CIPC and the interaction of these effects with each other can cause these clear differences. These results are in a similar direction of view to those mentioned before about (Frazier *et al*., 2004; Du Plooy *et al* ., 2009; Teper-Bamnolker *et al* ., 2010).

Table 1. Sprouting, weight loss and decay percentages of potato tubers at 60, 90 and 150 DAS as affected by cultivars in 2021 and 2022 seasons.

Storage treatments	Sprouting(%)						Weight loss(%)						Decay(%)					
	60 Days		90 Days		150 Days		60 Days		90 Days		150 Days		60 Days		90 Days		150 Days	
(cultivars)	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Lady Rosetta	0.29 a	0.11 a	2.18 a	1.68 a	5.91 a	5.30 a	1.54 a	1.54 a	6.75 a	6.04 a	12.16 a	9.91 a	1.58 a	1.33 a	4.62 a	4.33 a	8.95 a	7.33 a
Hermes	0.00 a	0.45 a	1.03 a	0.91 a	2.78 b	2.05 a	1.75 a	1.95 a	3.50 b	3.95 b	6.41 b	6.41 b	0.20 b	0.12 b	2.66 a	2.20 b	5.87 a	3.66 b

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Table 2. Sprouting, weight loss and decay percentages of potato tubers at 60, 90 and 150 DAS as affected by essential oils in 2021 and 2022 seasons.

Storage treatments	Sprouting(%)						Weight loss(%)						Decay(%)					
	60 Days		90 Days		150 Days		60 Days		90 Days		150 Days		60 Days		90 Days		150 Days	
(Essential oils)	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Control	0.00a	0.00a	6.66a	5.66a	14.9a	14.83a	7.00a	7.83a	15.66a	17.5a	33.33a	33.00a	12.33a	12.33a	14.6a	16.5a	35.5a	25.33a
CIPC	0.00a	0.00a	0.00b	0.00b	0.45c	0.00d	0.00c	0.00c	0.66d	0.00d	3.33cd	0.83ef	0.00c	0.00d	0.83bc	0.5bc	2.00cd	1.33cd
Fresh Back	1.19a	0.47a	1.19b	0.57b	3.45bc	0.99cd	1.00bc	0.00c	6.66b	3.00cd	7.66b	4.16cd	1.33bc	0.66bcd	2.00bc	1.5bc	3.66c	3.5b
Mint oil	0.00a	0.00a	2.17b	1.50b	5.55b	3.50c	2.00b	1.16bc	6.33b	3.83bcd	8.16b	4.83cd	1.00b	0.83bc	2.33bc	1.83b	4.00c	3.16b
Caraway oil	0.00a	0.00a	1.50b	1.83b	6.17b	6.58b	0.00c	0.00c	5.00b	2.33cd	6.00bc	3.5de	1.00b	0.33cd	2.33bc	1.66bc	3.83c	3.00bc
Clove oil	0.00a	0.00a	0.00b	0.00b	0.00c	0.00d	0.00c	0.00c	0.00d	0.00d	0.00d	0.00f	0.00c	0.00d	0.00c	0.00c	0.00d	0.00d
Sagebrush oil	0.00a	0.00a	0.00b	0.00b	1.22c	0.66cd	2.00b	2.66b	5.00bc	6.00bc	8.00b	7.00c	1.83bc	1.16b	2.66bc	2.16b	3.83c	3.66b
Lavender oil	0.00a	0.00a	1.33b	0.00b	3.00bc	2.33cd	1.16bc	2.33b	1.66cd	7.33b	7.83b	12.00b	1.66bc	0.5bcd	4.33b	2.00b	6.5b	4.00b

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5 %

Table 3. Sprouting, weight loss and decay percentages of potato tubers at 60, 90 and 150 DAS as affected by cultivars and essential oils in 2021 and 2022 seasons.

Storage treatments		Sprouting (%)						Weight loss (%)						Decay (%)					
		60 Days		90 Days		150 Days		60 Days		90 Days		150 Days		60 Days		90 Days		150 Days	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Lady Rosetta	Control	0.00a	0.00a	15.00a	15.66a	24.88a	17.66a	12.66a	13.66a	18.66a	21.33a	40.00a	42.00a	3.33a	7.66a	17.66a	19.66a	43.66a	32.66a
	CIPC	0.00a	0.00a	0.00b	0.00b	0.90c	0.00c	0.00c	0.00b	1.33cd	0.00c	6.00cde	1.66e	0.00c	0.00b	1.66c	1.00c	4.00cd	2.66cd
	Fresh Back	2.38a	0.00a	2.38b	1.15b	3.56c	1.32c	2.00bc	0.00b	10.66bc	6.00bc	12.00c	6.33cde	2.66ab	1.33b	4.00c	3.00c	5.33cd	4.66c
	Mint oil	0.00a	0.95a	3.75b	3.00b	7.84bc	4.92c	4.00b	2.33b	9.33bcd	3.33c	12.33c	4.00de	2.00abc	1.66b	3.00c	2.66c	4.00cd	4.33cd
	Caraway oil	0.00a	0.00a	3.00b	3.66b	11.65b	12.5b	0.00c	0.00b	4.66bcd	2.66c	5.33cde	4.00de	2.00abc	0.66b	2.66c	2.33c	4.00cd	4.00cd
	Clove oil	0.00a	0.00a	0.00b	0.00b	0.00c	0.00c	0.00c	0.00b	0.00d	0.00c	0.00e	0.00e	0.00abc	0.00b	0.00c	0.00c	0.00d	0.00d
	Sagebrush oil	0.00a	0.00a	0.00b	0.00b	2.44c	1.32c	1.33bc	1.66b	6.00bcd	7.33bc	10.00cd	9.66cd	2.00abc	1.33b	2.66c	3.00c	3.33cd	4.66c
	Lavender oil	0.00a	0.00a	2.66b	0.00b	6.00bc	4.66bc	2.33bc	4.66b	3.33cd	7.66bc	11.66c	11.66c	0.66bc	1.00b	5.33c	3.00c	7.33c	5.66c
Hermes	Control	0.00a	0.00a	11.66a	14.66a	15.00a	18.00a	11.00a	12.00a	12.66b	13.66b	27.66b	24.00b	3.23a	7.00a	11.66b	13.33b	27.33b	18.00b
	CIPC	0.00a	0.00a	0.00b	2.66b	0.00c	5.00bc	0.00c	0.00b	0.00d	0.00c	0.66de	0.00e	0.00c	0.00b	0.00c	0.00c	0.00d	0.00d
	Fresh Back	0.00a	0.00a	0.00b	0.00b	3.33c	0.00c	0.00c	0.00b	2.66cd	0.00c	3.33cde	2.00e	0.00c	0.00b	0.00c	0.00c	2.00cd	2.33cd
	Mint oil	0.00a	0.00a	0.60b	0.00b	3.26c	0.00c	0.00c	0.00b	3.33cd	4.33bc	4.00cde	5.66cde	0.00c	0.00b	1.66c	1.00c	4.00cd	2.00cd
	Caraway oil	0.00a	0.00a	0.00b	0.00b	0.7c	2.41c	0.00c	0.00b	5.33bcd	2.00c	6.66cde	3.00de	0.00c	0.00b	2.00c	1.00c	3.66cd	2.00cd
	Clove oil	0.00a	0.00a	0.00b	0.00b	0.00c	0.33c	0.00c	0.00b	0.00d	0.00c	0.00e	0.00e	0.00c	0.00b	0.00c	0.00c	0.00d	0.00d
	Sagebrush oil	0.00a	0.00a	0.00b	0.00b	0.00c	0.66c	2.66bc	3.66b	4.00bcd	4.66bc	6.00cde	4.33de	1.66abc	1.00b	2.66c	1.33c	4.33cd	2.66cd
	Lavender oil	0.00a	0.00a	0.00b	0.00b	0.00c	0.00c	0.00c	0.00b	0.00d	7.00bc	4.00cde	12.33c	0.00c	0.00b	3.33c	1.00c	5.66cd	2.33cd

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%

2. Dry matter and antioxidants content.

Effect of cultivars.

Lady Rosetta tubers gave significant superiority in dry matter and total phenols content characteristics than Hermes cultivar and insignificant differences between them in vitamin C in seasons 2021 and 2022. Table 4.

Lady Rosetta was superior in quality characters at the end of storage period could be logically true, since, the same cultivar compared with the other one possessed similar superior responses regarding its tubers bio-constituents, activity of the protective antioxidant enzymatic systems, favourite hormonal balance.

Effect of essential oils.

Data in Table 5 illustrate that tuber dry matter; vitamin C and total phenol content were significantly affected by the use of applied essential oils. The highest significant values of most parameters were shown by tubers treated with CIPC, Fresh Back and Clove oil compared to other treatments in two seasons. Suppression of potato sprouting and the loss of weight are logically linked to the preservation of vit C and dry matter. Also, preservation of carbohydrates, sugars and starch is closely associated too with the levels and content of vitamin C. Also, the antioxidant protective role and reactions of such oils may confer additional benefits in their favour. protective role and responses of such oils could be added other advantages in their regard too.

On the other hand, the decreases in the inter components of the control treatment tubers at 10 °C may be attributed to an increase in the respiration moreover the increase of the activity of degradation enzymes comparing to the treatments and consequently, a decrease in the internal biological components, which reduces the quality characteristics.

Effect of interaction.

Data in Table 6 indicate the effect of interactions among cultivars and essential oils application on dry matter percentage and antioxidants content. Data indicate that, treated potato tubers of Lady Rosetta cultivars with CIPC, Fresh back and clove oil at 10ºC during the two seasons gave the most significant values of Dry matter, vit C and phenols compared with other treatments at end of period of storage. Essential oil inhibits the activity of enzymatic processes, particularly those involving tuber carbohydrate stores that are reduced to sugars via respiration and energy metabolism. The decrease in dry matter content in the untreated control could be attributed to sprouting, weight loss, and tuber

decomposition. These results are in a similar direction of view to those mentioned before about. (El-Awady *et al*., 2014; Agrawal *et al*., 2015; Sanli and Karadoğan, 2019).

Economic evaluation:

Net profit of final products was estimated as a relationship between gross return and total treatment cost Table 7. Results indicated that the most net return (L.E. 3400/ton) was achieved by the use of clove oil treatment when used as a fumigation method on Lady Rosetta cultivar at temperature (10°C) followed by CIPC or Fresh Back x Lady Rosetta (L.E. 3375/ton and L.E. 3269/ton, respectively) and Hermes x clove oil (L.E. 2900/ton) as compared to other treatments. Thus, this application proved to be highly economical for potato storage.

Table 4. Tuber quality and antioxidant content of potato as affected by cultivars in 2021 and 2022 seasons.

Storage treatments (cultivars)	Dry matter (%)		Vitamin C (mg 100g^{-1})		Total phenols (mg g^{-1})	
	2021	2022	2021	2022	2021	2022
Lady Rosetta	25.68 a	25.49 a	17.86 a	18.89 a	34.00 a	33.99 a
Hermes	22.62 b	23.61 b	17.85 a	18.78 a	27.08 b	27.42 b

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5 %

Table 5. Tuber quality and antioxidant content of potato as affected by application of essential oils in 2021 and 2022 seasons.

Storage treatments (Esential oils)	Dry matter(%)		Vitamin C (mg 100g^{-1})		Total phenols(mg g^{-1})	
	2021	2022	2021	2022	2021	2022
Control	21.38 f	22.63 d	16.72 d	17.54 d	26.47 e	26.56 c
CIPC	24.72 ab	24.63 ab	18.38 a	19.18 ab	32.12 a	32.18 ab
Fresh Back	25.00 ab	24.59 ab	18.47 a	19.42 a	32.16 a	32.17 ab
Mint oil	24.30 de	23.55 c	17.52 c	18.54 bc	29.96 c	31.04 ab
Caraway oil	23.51 e	23.55 c	17.28 c	18.29 c	29.19 d	27.80 c
Clove oil	25.39 a	24.75 a	18.57 a	19.67 a	32.56 a	33.26 a
Sagebrush oil	24.54 bc	24.48 ab	18.02 b	19.11 ab	30.93 b	30.83 b
Lavender oil	24.36 cd	24.23 b	17.87 b	18.94 abc	30.94 b	31.79 ab

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Table 6. Tuber quality and antioxidant content of potato as affected by cultivars and essential oils in 2021 and 2022 seasons.

Storage treatments		Dry matter (%)		Vitamin C (mg 100g^{-1})		Total phenols (mg g^{-1})	
		2021	2022	2021	2022	2021	2022
Lady Rosetta	Control	22.36 h	21.48 f	16.30 h	16.74 c	28.87 e	28.95 b
	CIPC	26.32 ab	25.62 a	18.56 ab	19.04 ab	35.63 a	35.69 a
	Fresh Back	26.93 ab	25.33 a	18.76 a	19.34 ab	35.89 a	35.81 a
	Mint oil	25.86 de	23.5 cd	17.35 efg	18.86 ab	33.64 c	35.25 a
	Caraway oil	24.38 e	23.44 cd	17.03 g	18.23 b	32.72 d	29.48 b
	Clove oil	27.62 a	25.51 a	18.90 a	20.35 a	36.2 a	37.20 a
	Sagebrush oil	26.18 bc	25.44 a	18.17 bc	19.88 ab	34.85 b	34.43 a
	Lavender oil	25.78 cd	24.61 b	17.71 c-f	18.74 ab	34.22 bc	35.13 a
Hermes	Control	20.39 h	20.78 f	16.20 h	18.34 b	28.87 e	24.18 b
	CIPC	23.12 de	23.65 cd	18.21 bc	19.33 ab	24.07 i	28.68 b
	Fresh Back	23.07 de	23.85 bc	18.18 bc	19.51 ab	28.61 e	28.53 b
	Mint oil	22.73 e	23.60 cd	17.7 cdef	18.22 b	28.43 e	26.84 b
	Caraway oil	22.64 e	23.65 cd	17.53 d-g	18.36 b	26.27 h	26.12 b
	Clove oil	23.17 de	23.98 bc	18.24 bc	18.99 ab	25.66 h	29.33 b
	Sagebrush oil	22.89 de	23.52 cd	17.87 cde	18.35 b	28.92 e	27.24 b
	Lavender oil	22.94 de	23.86 bc	18.04 bcd	19.15 ab	27.02 g	28.45 b

Means followed by the same letter within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5 %

Table 7. Estimate of additional net return of storage treatments.

Treatments	Gross return* (L.E. Ton^{-1})	Storage treatment cost** (L.E. Ton^{-1})	Total cost*** (L.E. Ton^{-1})	Net return (L.E. Ton^{-1})	Benefit/cost**** ratio	order
1. L.R. x Control	3000.00	1000.00	5000.00	- 2000.00	0.00	13
2. L.R. x CIPC	8500.00	1125.00	5125.00	3375.00	0.66	2
3. L.R. x Fresh Back	8500.00	1231.00	5231.00	3269.00	0.62	3
4. L.R. x Mint oil	6500.00	1090.00	5090.00	1410.00	0.28	8
5. L.R. x Caraway oil	6500.00	1090.00	5090.00	1410.00	0.28	8
6. L.R. x Clove oil	8500.00	1100.00	5100.00	3400.00	0.67	1
7. L.R. x Sagebrush oil	6500.00	1080.00	5080.00	1420.00	0.28	7
8. L.R. x Lavender oil	6500.00	1100.00	5100.00	1400.00	0.27	9
9. H. x Control	2000.00	1000.00	5000.00	- 3000.00	0.00	14
10. H. x CIPC	8000.00	1125.00	5125.00	2875.00	0.56	5
11. H. x Fresh Back	8000.00	1231.00	5231.00	2769.00	0.53	6
12. H. x Mint oil	6000.00	1090.00	5090.00	910.00	0.18	11
13. H. x Caraway oil	6000.00	1090.00	5090.00	910.00	0.18	11
14. H. x Clove oil	8000.00	1100.00	5100.00	2900.00	0.57	4
15. H. x Sagebrush oil	6000.00	1080.00	5080.00	920.00	0.18	10
16. H. x Lavender oil	6000.00	1100.00	5100.00	900.00	0.17	12

L.R.: Lady Rosetta, H.: Hermes

***Gross return of final products was estimated according to the quality of potato tuber at the end of storage (healthy tuber, free in virtual and physiological defects and good quality for processing products) and ranging from £.€ 2000: 8000/ton.**

****Treatment cost was calculated according to the following prices: Refrigerator storage cost £.€ 800.00/ton; bags and transport 200.00/ton; CIPC £.€ 125.00 (£.€ 3787.00/l.); Fresh Back £.€ 231.00 (£.€ 2750.00/l.), mint and caraway oils £.€ 90.00 ((£.€ 900.00/l.), sagebrush oil £.€ 90.00 (£.€ 800.00/l.), and clove and lavender oils £.€ 100.00 (£.€ 1000.00/l.).**

*****Total costs were price of potato tubers per ton before storing which equal nearly £.€ 4000, plus treatment cost.**

******Benefit/cost ratio was divided by net return in total costs**

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تأثير الزيوت العطرية والكلوروبروفام والفريش باك على تخزين وجودة البطاطس

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الملخص

تم تعريض درنات البطاطس (صنفي ليدى روزيتا وهيرمس) لكل معاملة بالزيت العطري الطبيعي، بالإضافة إلى مركب الكلوروبروفام CIPC والفريش باك، وتم تخزينها لمدة خمسة أشهر في درجة حرارة منخفضة لدراسة تأثير هذه المركبات علي تزريع الدرنات والقدرة التخزينة والجودة.تعرضت الدرنات للزيوت العطرية النقية بعد ١٥ يوم من الحصاد. تم تحضير زيوت عطرية نقية بتركيز ٥ مل لكل مركب ولم يتم معاملة الكنترول بأي من المركبات. عوملت الدرنات لمدة ٥ ساعات علي درجة حرارة الغرفة الملحقة بالثلاجة. تم تطبيق الزيوت العطرية النقية على الدرنات بواسطة آلة الرش الحراري(Super-2000 Gold sprayer). استخدم CIPC بمعدل ٣٣ مل / طن من البطاطس المخزنة، وكان معدل استخدام الفريش باك ٨٤ مل لكل طن بواسطة آلة الضباب مثل تطبيق استخدام الزيوت العطرية.اعطت معاملة درنات ليدى روزيتا والهيرمس بزيت القرنفل أو CIPC اقل القيم معنويا في تزريع الدرنات والفقد فى الوزن ونسبة التالف بالمقارنة بباقى المعاملات فى كلا الموسمين. أعطت معاملة الدرنات لصنف ليدى روزيتا المعاملة بزيت القرنفل تفوقا معنويا فى زيادة محتواها من المادة الجافة وفيتامين ج والفينولات الكلية بالمقارنة بالكنترول وباقى المعاملات فى كلا الموسمين. تقترح هذه الدراسة استخدام زيت القرنفل مع صنفى ليدي روزيتا أو هيرميس مرة واحدة قبل التخزين بمعدل ١٠٠ مل/طن عن طريق التبخير والتخزين على (١٠ درجة مئوية نهارًا / ليلًا , ٩٥٪ رطوبة نسبية) لمدة ٥ أشهركطريقة طبيعية وفعالة لتقليل نسبة التزريع والفاقد في الوزن ونسبة التالف مع زيادة جودة درناتها علاوة على ذلك، فإن الزيوت العطرية آمنة للاستخدام ولا تسبب أي آثار ضارة على البطاطس، كما تعتبر مضادات الإنبات الطبيعية صديقة للبيئة ومجدية اقتصاديًا.