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COMPARING INHIBITORY EFFECT OF CHLORPROPHAM AND CORIANDER ESSENTIAL OILS ON POTATO SPROUTING DURING THE STORAGE

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ABSTRACT

There are some chemicals like chlorpropham which efficiently control sprouting; however, the application of which has been challenged due to the incidence of quality problems and the growing interest in organic food consumption. In response to this need, application of 0, 0.5, 1, 2 and 4 µl/l Coriander essential oils (CEO) at regular intervals of 2, 4, and 6 weeks on Agria potato sprouting control was tested. All experiments were replicated 3 times. Data was analyzed by a completely randomized design (CRD) with a factorial experiment at a statistical level of 5%. According to the results, by increasing CEO application up to 2µl/l, the sprouting of tubers was significantly controlled for 3 months. Using 4µl/l CEO did not significantly increase the inhibitory effect. Furthermore, the use of 0.5µl/l CEO stimulated the sprouting of tubers compared to the control samples. Using 2µl/l CEO for every 4 weeks showed the best result. Yet, its inhibitory effect was not that much as CIPC's was, especially from the fourth month on. Organoleptic evaluation of the boiled and fried potato samples treated with CEO and chlorpropham did not show significant differences, but both of them received higher scores compared to the control treatment.

KEY WORDS
storage, sprouting, potato, Coriander (Coriandrum sativum L.)

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INTRODUCTION

At the end of the dormancy period, the potato (Solanum tuberosum L.) tubers begin to sprouting, resulting in weight and nutritional value loss, wilting and toxic alkaloid production. The sprouted tubers are neither desirable for processing nor suitable for the next year's planting as tuber seed. Although the cold storage (2 - 4 °C) inhibits potato tuber sprouting for a long time, it is not always possible due to the technical or practical reasons. Using sprout inhibitors, a reliable alternative to cold storage, has made the availability of high-quality potatoes possible during almost the whole year [1][2]. Chlorpropham (CIPC) is one of the most effective sprout inhibitors having an irreversible constant effect and extensively used in potato tuber storage but not seed tuber ones [3][4]. The interest in producing and using organic or at least healthy food has doubled the attempt to limit the use of artificial preservatives and find the safe alternatives [3][5]. Using chemical compounds such as ethylene, ozone, aromatic aldehydes, naphthalene acetic acid, hydrogen peroxide, and alcohol as well as methods like storage at high levels of carbon dioxide in order to control sprouting either encounters technical and practical problems or is not very effective [6][7][1][(8][9]. Using the leaves of Muna plants containing monoterpenic volatile essentials, the Inca (the most important civilization in South America) was the first tribe managing to store potatoes in an acceptable manner [10]. Vaughn and Spencer [1993], conducted a study on using environmentally friendly natural compounds including net monoterpenes 'Terpineol', 'Citronellol', 'Citral', 'Geraniol', and 'Cineole' so as to control potato tuber sprouting during storage; it was concluded that none of them can be as effective as chlorpropham [9]. De Vries [1999] invented a compound base on caraway extracts with the brand 'TM-Talent' in Netherlands and claimed that the aerosol form of this compound delays potato sprouting for 3 months [11]. Using 8 mmol/l of a compound made of clove extracts for 6 consecutive weeks, Slininger et al [2000] managed to control potato sprouting by 56% for 4 months [12]. Biox-A is another clove-based compound controlling potato sprouting by 73% for 3 months. There was not a significant difference between the inhibitory effect of this compound and 60ppm chlorpropham [13]. Coriander is extensively cultivated in Iran, the seed of which contains 0.6 to 2.2 percent volatile oil (CEO). The most important terpenic and terpenoidic compounds of coriander include 'alpha-Linalool' (60-85%), 'Geraniol' (4-7%), and 'Geranyl acetate' (2-6%) [14]. In this study, a comparison was made between chlorpropham and coriander essential oils (Moriandrum sativum L.) as available resources of monoterpenic compounds to examine their inhibitory effect on potato sprouting.

MATERIALS AND METHODS

Healthy fresh Agria tubers with 3.5-5.5 cm in diameter were selected in late October 2015. After a 15-day curing, selected potato pile was devided to 4-kg groups and each one was put in a 10-liter container. Then, all of them were placed in a dark storage with a temperature of 12 ± 1°C and relative humidity of 92±3%. Storage in this temperature helps to the dormancy breaking of the tubers and better evaluation of solutions in controlling tuber sprouting. Using a Clevenger apparatus (Wertheim, Germany), the essential oils used in the experiment was extracted from fresh coriander seeds in 2 hours, at 97-98°C distilled water, and with the normal air pressure [15]. The CEO was transferred to a dark glass bottle by means of petroleum ether (as solvent) after being dried by anhydrous sodium sulfate and was kept at 2°C until being used [16]. In middle December 2015, the tubers of each container were exposed to the emitted vapors of 5, 10, 20, or 40µl CEO. For this purpose, a Whatman filter paper (Whatman #1; 23mm diam; Whatman, Maidstone, Kent, UK) was placed in each container, on which the above mentioned amounts of CEO solutions were dripped, and the aperture containers were immediately closed. Direct contact between tubers and the CEO was not let . To provide the needed oxygen for the tubers respiration, the containers aperture were opened for 15 minutes every four weeks and sealed again. This was repeated at regular intervals of every 2, 4, or 6 weeks during the experiment. A group of tubers was only treated by 37g chlorpropham (5% purity), produced by Aldrich Corporation. To do this, the powder was poured into the container, completely sealed and slowly shaken for 10 minutes. The sealed container was kept at room temperature for 48 hours [4] [2]. During the storage, the parameters of percentage weight loss as well as the percentage of sprouted tubers were measured monthly, using direct observation method [17]. At the end of the storage term, the total weight of the tuber sprouts in each treatment was measured. All experiments were repeated 3 times. At the end of the experiment, the results were statistically analyzed by a completely randomized design (CRD) with a factorial experiment at a statistical level of 5%, by means of SPSS 16 software. Finally, the treatment showing the best inhibitory effect on potato tuber sprouting while using the minimum essential oil in the storage period was compared with the chlorpropham-used treatment. Furthermore, using Hedonic Scaling Test, a 12-person group of evaluators did an organoleptic evaluation of the selected coriander essential oils, the chlorpropham and control treatment cooked in two ways: boiled potatoes (cooking at 95±2°C water for 30 minutes) and fried potato strips (deep frying in sunflower oil for 1.2 minutes at 180°C). Then, the scores of treatments were analysised using ANOVA test and then was compared with each other by Least Significant Difference Test [18].

RESULTS

Storage Period

By increasing the storage period, there was a significant increase in the tubers' being dehydration. Such that the moisture content of tuber in the four-time monthly sampling compared to the harvesting time, was decreased by 4, 11.5, 16.3, and 18.7 percent, respectively. along with these changes, the percentage of sprouted tubers and the total weight of sprouts were significantly increased [Table 1]. There were more changes in the last month of storage. Just in the fourth month of storage, the percentage of sprouted tubers and the total weight of sprouts were increased by 166 and 335 percent, respectively.

CEO Concentration

By increasing the amount of CEO application from 5 to 20µl, the tuber moisture content was significantly increased and the percentage of sprouting as well as the total weight of sprouts were significantly decreased. There was no significant change in any of the studied variables when the amount of CEO applied was increased from 20 to 40µl. As such, the amounts of 20 and 40µl CEO were more significantly effective than control and other treatments in inhibitory of potato sprouting as well as preserving the moisture content of the tubers. On average, the moisture content of the tubers treated with 20µl CEO in the storage period was more than the control treatment by 12.2 percent. In the same period, the percentage of sprouting and the total weight of the tuber sprouts under control treatment were as 5.5 and 3.2 times larger than the ones in tubers treated by 20µl-CEO. The increase in the percentage of sprouted tubers treated by 5µl CEO, compared to the control treatment, was an important point in the present study [Table 2].

Number of CEO Application

By increasing the application of CEO from every 6 weeks to every 4 weeks, the sprouting percentage and the total weight of the sprouts were decreased by 24 and 27 percent, respectively. More increase in the application of CEO from every 4 weeks to every 2 weeks (5-time more application in the storage period) had a slight effect but insignificant difference on the study components [Table 3].

Table1: Comparison of studied variables changes of the Potato Tubers Treated with CEO during the storage

Studied parameters			Storage duration after Treatment (month)
Total sprout weight of tubers (g/kg)	Sprouting (%)	Moisture content (%)	
0.00±0.00^{d}	0.00±0.00^{d}	82.50±1.12^{a}	0
0.00±0.00^{d}	0.00±0.00^{d}	79.00±1.31^{b}	1
1.78±0.84^{c}	3.40±2.40^{c}	73.01±0.85^{c}	2
8.95±2.45^{b}	21.00±1.50^{b}	69.05±1.22^{d}	3

39.00±2.71[a]	56.00±1.83[a]	67.00±0.74[d]	4

Means ± SD of three replicates
Means within each column followed by different letter are significantly different ($p \geq 0.05$).

Study of the sprouted tuber at the end of the storage period indicated that the 4-week interval of 20µl CEO application was the best treatment to control sprouting in potato samples. This treatment was able to control tuber sprouting for more than 3 months. It was significantly more effective than the treatments with the same or even more amounts of CEO application (treatment with10 times of 10µl CEO application and 3 times of 40µl CEO application); moreover, there was not a significant difference between this treatment and the treatment with 5 times of 40g/l CEO application. Therefore, the monthly 20µl-CEO application was selected as the best treatment to be compared with chlorpropham treatment.

Table 2: Comparison of different amounts application effects of CEO on studied variables in treated potato tubers

Studied parameters			CEO application)µl(
Sprout weight 0f tubers (g/kg)	Sprouting (%)	Moisture content)%(	
15.25±2.21[b]	28.09±1.65[b]	69.03±1.52[d]	0 (control)
16.70±0.98[a]	30.50±1.80[a]	70.20±0.88[c]	5
8.90±1.11[c]	11.33±0.95[c]	76.51±1.63[b]	10
4.67±1.15[d]	5.06±0.5[d]	77.40±1.33[a]	20
4.15±0.77[d]	4.53±0.70[d]	77.43±1.42[a]	40

Means ± SD of three replicates
Means within each column followed by different letter are significantly different ($p \geq 0.05$).

Table 3: The effects of The interval between two consecutive applications of CEO on studied variables changes in treated potato tubers

Studied parameters			The interval between two consecutive applications of CEO (week)
Sprout weight 0f tubers (g/kg)	Sprouting (%)	Moisture content)%(	
9.24±0.62[b]	14.84±0.88[b]	77.41±2.13[b]	2
9.38±0.83[b]	15.08±1.11[b]	77.28±2.74[b]	4
11.21±1.89[b]	18.44±1.49[b]	67.65±1.48[a]	6

Means ± SD of three replicates
Means within each column followed by different letter are significantly different ($p \geq 0.05$).

Comparison of the inhibitory effect of Selected CEO and CIPC Treatments

The efficiency comparative results of the chlorpropham powder treatment and the 20µl-CEO treatment on the sprouting of tubers indicated that the first is able to Decisively control tuber sprouting. Such that at the end of the storage period, only 1 percent of the CIPC treated tubers started initial sprouting. The other tubers under this treatment did not sprout. The tubers of the selected CEO treatment started sprouting from the second week of February. So, this treatment was almost completely effective in controlling tuber sprouting until late February (the fourth month of storage after the first treatment). At the end of the fourth month, its inhibitory ability decreased and was significantly less effective than the chlorpropham; however, it was still stronger compared to the the inhibitory effect of control treatment [Table 4].

Table 4: Effect of selected CEO and CIPC powder treatments on the sprouting (%) and total sprout mass (g/kg) of the potatoes tubers at the end of 3rd and 4th months of storage

Studied Parameters		Comparison Time	Sprout Control Method
Total sprout mass (g/kg)	**Sprouting (%)**		
00.75±0.11 d	3.00±0.62 d	End of month 3	**Monthly Application of 20 µl CEO**
2.75±0.44 c	15.00±1.67 c	End of month 4	
00.00±0.00 d	00.00±0.00 e	End of month 3	**CIPC**
00.08±0.02 d	1.00±0.66 e	End of month 4	
15.33±1.71 b	43.00±2.50 b	End of month 3	**No Control**
57.08±2.03 a	99.00±2.13 a	End of month 4	

Means ± SD of three replicates
Means within each column followed by different letter are significantly different ($p \geq 0.05$).

Organoleptic Evaluation

The organoleptic evaluation indicated that there is not a significantly distinguishable difference between the potatoes treated with CEO and chlorpropham regarding the organoleptic features of the products. The control samples, compared to CEO and CIPC treatments, received a significantly lower score in both cooking and frying tests from the panelists [Table 5].
Shrinkage, increasing of the reducing sugar followed by texture softnesss, sweetening, and darkening the fried potato due to tuber sprouting are among the major reasons the panelist group was dissatisfied with control sample.

Table 5: Organoleptic score comparing of the cooked Potato Samples Treated with CEO, CIPC and Control Sample

Sprout Control Method			Cooking method
CIPC	Monthly application of 20 µl CEO	control	
18.63±1.69 a	18.50±2.72 a	11.55±2.38 b	Boiled
18.72±2.06 a	18.66±3.40 a	8.32±1.41 b	Fried

Means ± SD of three replicates
Means within each row followed by different letters are significantly different ($p \geq 0.05$).

DISCUSSION

By the end of the physiological dormancy period of potato tubers and initiation of sprouting in which, the weight loss changes in tubers is also initiated and intensified in line with the sprouting development level. As a matter of fact, the initiation and development of tuber sprouting accelerate the breakdown and consumption of the starch stored in potato tubers in order to supply the needed energy for the quick growth and propagation of the sprout meristematic cells. The starch breakdown into simple sugars is a kind of process needing to use water; tuber sprouting development increases evaporation and moisture transpiration, all of which increase tuber weight loss. Longer storage of the sprouted tubers results in increasing shrinkage and moisture content losses [19].

According to the findings of this study, the coriander essential oil, taking appropriate concentration and application sequences, had a competitive inhibitory effect on potato tuber sprouting compared to the control treatment and chlorpropham; however, a longer storage of tubers (more than 3 months) showed a more inhibitory effect of chlorpropham compared to others [table 4]. It is worth noting that the control tuber sprouting was initiated in the first week of the 2nd month of storage (January). Nevertheless, the sprouting of tubers treated with the selected CEO and chlorpropham was delayed until the 3rd week of the 3rd month of storage. Boylston et al., [20] reported that the sprouting of tubers treated with CIPC, salicylaldehyde, and clove extracts was delayed until 5.5, 3, and 3 months, respectively.
The equilibrium between the application interval and amount of CEO was a determining factor in achieving an optimal treatment and preserving the needed concentration of monoterpenic compounds in the storage environment. In other words, the monoterpenic compounds are volatile and their concentration is immediately increased after application in the study environment and rapidly declined after a while. Therefore, the number of applications of which is of importance in keeping the inhibitory and effectiveness threshold and cannot be replaced by other components - such as increasing the solution concentration. Kleinkopf et al., [21] had also paid attention to the equilibrium between concentration and the number of applications of mint volatile oils. It seems that a monthly 20µl-application of coriander essential oils is able to preserve the monoterpenic compounds' concentration inhibiting sprouting in the atmosphere around tubers within the effectiveness threshold range; as such, increasing the amount of which did not have a significant impact on controlling sprouting.

The results of the present study are similar to what De Vries [11],Kleinkopf and Frazier [13], and Vaughn and Spencer [22] have reported with respect to the inhibitory effect of caraway, mint, and clove. However, a clear comparison of the inhibitory effect of these compounds cannot be made. Observing the stimulatory effect of a 5µl dose of CEO in tuber sprouting was an important point. In this treatment, there were more sprouted tubers although the total mass weight of sprouts was lower than that in the control treatment. The shape of sprouts (including the grown sprouts and the necrotic ones) in the tubers treated with different concentrations of CEO was consistent with the reported mechanism regarding the effect of monoterpenic compounds on controlling tuber sprouting. It seems that the following hypothesis, compared to other theories, gives a better explanation of the controlling effect of the extracts containing monoterpenic compounds such as CEO. "The alpha- and beta-unsaturated carbonylic compounds or the alcoholic-unsaturated compounds contained in these extracts play an inhibitory role in this process by damaging apical meristem cells of the sprouts. The respiration rate of the apical meristematic cells increasingly rises in the presence of these compounds. This condition progresses in a way that the cell membrane wall fats are severely oxidized and the meristematic tissues are exposed to oxidative stress. Therefore, the cell membrane increasingly loses moisture and impairs the functions such as transferring nutrients into the cells. All these conditions result in cellular death and necrosis. These sprouts take a burnt corky form. However, if the monoterpenic concentration is less than the effectiveness threshold, the lateral sprouts are stimulated and start growing. These sprouts are thinner and of less sprouting volume and thickness compared to those produced by apical meristems [23] [24] [25].

CONCLUSION

To sum up, this study indicated that CEO is a great alternative for mid-term storage of potatoes that can replace chlorpropham for 3 months; the application of which does not have a negative impact on the organoleptic favorability of the processed potatoes from the consumer's perspective. However, to facilitate the complete exclusion of chlorpropham from the potato storage chain, it may seem necessary to study other aromatic extracts and volatile oils with similar structures so as to discover more effective compounds and also the probable impact of their application on the characteristics of the processed potatoes.

CONFLICT OF INTEREST

There is no conflict of interest.

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FINANCIAL DISCLOSURE

None

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