Journal of Applied Botany and Food Quality 89, 258 - 263 (2016), DOI:10.5073/JABFQ.2016.089.033

Süleyman Demirel University, Faculty of Agriculture, Field Crops Department, Turkey

Caraway (*Carum carvi* L.) seed treatments and storage temperature influences potato tuber quality during storage

Arif Şanli

(Received June 13, 2016)

Summary

The present research was conducted to determine the effects of chemical and natural sprout inhibitors on potato (*Solanum tuberosum* 'Agria') tuber quality at two storage temperatures (8 °C or 15 °C). Four doses (0, 50, 100, 150 g/10 L) of ground and whole caraway (*Carum carvi* L.), containing high levels of *S*-(+)-carvone, and chlorpropham (CIPC) were applied. Tubers were stored for a total of 135 days in plastic containers (10 L) and placed in cold storage rooms at 8 °C or 15 °C with 85% relative humidity. Sprout inhibitors were applied only once at the start of experiment. At the end of 135 days the tubers stored at 8 °C had high starch and vitamin C content with a higher degree of firmness as compared to the tubers stored at 15 °C. Total soluble sugar content (TSS) of tubers increased during the storage period and the increase was high at 15 °C than 8 °C of storage condition. Low temperature storage and ground caraway treatments at high temperature caused accumulation of reducing sugars (RS). In general, ground caraway and CIPC treatments were more effective in maintaining tuber quality than the control and whole caraway treatments during the storage period.

Key words: Caraway seed, chlorpropham, potato, storage temperature, tuber quality

Introduction

In most countries, potatoes are harvested once a year. Adequate and steady supply of tubers depends on long term storage for domestic consumption, food-processing industries, starch production and planting material purposes. High moisture content and metabolic activity of potatoes lead to both losses of weight and quality. The primary causes of these losses are respiration, transpiration and sprouting (Burton et al., 1992). Respiration of tubers during storage and breakdown of dormancy result in sprouting, thereby causing the alterations in weight, texture, nutritional value, shrinkage and the formation of toxic alkaloids (Suhag et al., 2006; Delaplace et al., 2008). To increase the amount of marketable potatoes after storage and to avoid quality deterioration, good storage conditions and effective treatments are necessary.

Methods of storage have been designed to prolong the dormant period and to retard or inhibit undesirable quality changes. Storage at low temperatures delays sprouting but also leads to sweetening of potatoes due to accumulation of RS. It is complicated to store potatoes intended for processing because relatively high storage temperatures are required (8-10 °C) to prevent RS accumulation. Prolonged storage of potatoes at temperatures higher than 7-8 °C requires the use of sprout inhibitors. Chlorporpham is the most effective sprout inhibitor registered for use in potato storage (Saraiva and Rodrigues, 2011). However, many countries have restricted the use of CIPC due to problems associated with chemical residues (Hartmans et al., 1995).

An increasing public demand for the safety issues of chemicals raises to use the natural inhibition agents. The essential oils of aromatic plants are found to have this potentially. Many studies have been conducted to investigate the sprout suppressing capacity of natural products with different active substances involving caraway (Silva et al., 2007; Şanli et al., 2010), clove (Song et al., 2004; Elsadr and Waterer, 2005), dill (Song et al., 2004; Gomez et al., 2010), peppermint (Frazier et al., 2004) and spearmint (Frazier et al., 2004; Song et al., 2004; Elsadr and Waterer, 2005). Studies indicate that carvone, the major compound in caraway and dill seed oil, is an effective inhibitor of sprout growth in potatoes (Song et al., 2004; Şanli, 2012). Suppressing effect by carvone is reversible (Ooesterhaven et al., 1993), and thus carvone could be used as a sprout growth regulator of seed potatoes during storage (Sorce et al., 1997). In addition to sprout suppression, several studies have shown that carvone can effectively inhibit the growth of certain fungi and bacteria (Hartmans et al., 1995; Ooesterhaven et al., 1995; Frazİer et al., 2004). To date, (S)-(+)-carvone is commercially marketed (Talent^{TM}) in some European countries (Gomez-Castillo et al., 2013). However, its production is too costy and its application at storage rooms requires special arrangements. Therefore, the use of pure chemical form of carvone is limited as compared to conventional sprout suppressants such as CIPC (Coleman et al., 2001). Use of natural forms of these EOs (i.e. seeds, leaves) may provide an alternative in order to manage sprouting during storage. Even the active substances of essential oils are less effective than the pure active agents they will likely to be more readily available and cheaper. It is also expected that release of active substances from natural forms will be slower but will have more active substances present in the used parts of plants (Elsadr and Waterer, 2005). While the sprout suppression effects of many EOs and their major compounds have been studied, the effects of these compounds on the quality of potato tubers have not been clearly defined. Hence the objective of this study was to determine the effects of CIPC and caraway seeds on the quality of potato tubers stored for a long time at low and high temperature conditions.

Materials and methods

It was previously published a study on the effects of caraway seed applications on sprouting and weight loss of potato tubers (Şanli et al., 2010). In the current study, it was aimed to investigate the effects of CIPC and caraway seeds on the quality of potato tubers. This study is a continuation of the earlier study (Şanli et al., 2010) with different test and analysis such as tuber quality after the applications. The two studies are linked and published in two parts.

Plant material and storage condition

Potatoes were grown at the research farms of Suleyman Demirel Universty and tubers were harvested in October 2008. Selected tubers (100 kg) were kept at 15 °C for one month for the curing period. At the end of the curing period, tubers were immediately analysed to determine initial contents for total starch, protein, ascorbic acid, TSS, RS, and their firmness. Potato tubers were stored under two different temperature regimes, 8 °C and 15 °C, respectively. The relative humidity of storage rooms were adjusted to 85%.

Caraway seed and CIPC treatments

Caraway seeds were purchased from a local farmer in Turkey and CIPC (Grostop 300 EC (300 g/L CIPC) was commercially obtained from Poland. EO content of caraway seeds (4.2%) was determined by the Clevenger hydrodistillation method (British Pharmacopoeia, 1980). Constituents of caraway EO were determined by Gas Chromatograph-Mass Spectrometry (GC-MS) and it was found that caraway oil contained approximately 56% *S*-(+)-carvone. GC-MS analysis was performed on Shimadzu 2010 Plus GC-MS equipped with a Quadrupole (QP-5050) detector. The analysis was performed under the following conditions: capillary column, CP-Wax 52 CB (50 m × 0.32 mm, film thickness 0.25 µm); injector and detector temperature, 240 °C; stove heat program, from 60 °C (10 min. hold) to 90 °C rising at 4 °C/min., and increasing to 240 °C (11.5 min. hold) rising at 15 °C/min.; flow speed, 1 psi; detector: 70 eV; ionization type, EI; carrier gas, helium (20 mL/min.); sample injected 1 µL. Identification of constituents was carried out with the help of retention times of standard substances by composition of mass spectra with the data given in the Wiley, NIST Tutor library. The quantitative analysis was conducted using Gas Chromatography/ Flame Ionization Detector (GC-FID), Shimadzu Model Thermo Ultra Trace, operating at the same conditions of GC-MS. 50 µL of the volatile oil was solubilized in 5 mL of n-hexane and injected in to the split mode 1/100.

Treatment doses of caraway seeds were determined by taking into consideration ratio of commercial *S*-(+)-carvone application rate (600 ml per 1000 kg tuber) (Hartmans et al., 1995) and were calculated according to EO and *S*-(+)-carvone content of caraway seeds. Application rate of CIPC was 20 g/ton tubers (application rate of Gro-Stop 300 EC was 60 ml/ton tubers), similar to that applied commercially (Hartmans et al., 1995). Twenty potato tubers (~ 4 kg) were placed in a plastic container (10 L) and one of four doses of whole or ground caraway seeds (0, 50, 100 and 150g/ 4 kg tuber) were applied to potato tubers. Whole (W) and ground (G) caraway seeds were wrapped in cheese cloths and placed on the top of tubers within each container. Chlorporpham was applied as a dry powder by dusting. Caraway seed and CIPC treatments were applied to each container once at the beginning of the experiment and the lids of containers closed tightly. In order to allow oxygen exchange for respiration of tubers, lids were opened every two days for 10 minutes. Tubers were stored for a total of 135 days starting from November 2008 to March 2009. At the end of the storage period, firmness and quality changes of tubers were evaluated.

Tuber Quality Evaluation

Total starch content of potato was determined based on AOAC (1984). Firmness of the tubers was measured with a brand penetrometer (PCE-PTR 200, PCE Instruments UK Ltd, United Kingdom, SE=±0.1kg) equipped with a 0.8 cm wide conical probe (Rezaee et al., 2011). For the determination of ascorbic acid content, 20 g of sliced potato sample was homogenized in the presence of 6% HPO_3 in a mixer for 5 min at 4000 rpm. The extract was filtered under vacuum with a Whatman filter paper and volume was adjusted to 100 ml with 6% HPO_3. Ascorbic acid content of the samples (mg/ 100 g FW) were determined by titration method and 2,6-dichlorophenolindolphenol solution used as colouring agent (AOAC, 1984). For the determination of protein content, samples were ground and 2 g was used. The amount of N in each sample was determined using the Kjeldahl method and the protein content (%) was calculated by multiplying the N amount of each sample by 6.25 (Bradford, 1976). Total soluble sugars and reducing sugar contents of the samples were determined with phenol sulphuric acid assay (Dubois et al., 1956) and Nelson-Somogyi method (Somogyi, 1952). Results were expressed as mg/100 g FW.

All analyses were performed in triplicate. Data were subjected to analysis of variance (ANOVA) procedure with SAS (2009) statistical program (INC SAS/STAT user's guide release 7.0, Cary, NC, USA). Means were compared using Duncan's multiple range test.

Results and discussion

Total starch content

Total starch content of tubers decreased significantly (P<0.01) during the storage and the decrease in starch content of tubers was higher at 15 °C storage. Average total starch content of tubers was 13.7% and 12.9% for 8 °C and 15 °C storage conditions, respectively (Tab. 2). Ground caraway and CIPC treatments yielded higher starch contents at both storage temperatures than the control treatment, and no significant difference was detected between the control and whole caraway treatments for starch content (Tab. 1). Ground caraway treatments yielded higher starch content at both storage temperatures than the whole caraway treatments, but the starch contents did not differ significantly between the doses for both ground and whole caraway treatments. The tuber starch content treated with ground caraway and stored at 8 °C was similar to the starch content of CIPC treated tubers whereas the starch content of tubers stored at 15 °C was higher than that of CIPC treated tubers. Ground caraway treatments were effective in preserving starch content at both storage temperatures while starch content loss was more pronounced at 15 °C storage than that at 8 °C storage conditions (Tab. 2). Storage temperature is an important factor to minimize postharvest losses during the storage of potato tubers. Sugars used as substrates for respiration are produced from the starch hydrolysis. The respiration rates of potato tubers have been reported to be minimum at 4 °C, and increase at higher temperatures (Wustman and Struic, 2007). Lower storage temperatures (4 °C and 8 °C) tended to be more effective in reduction of starch hydrolysis of the potato tubers as compared to higher temperatures (12 °C and 25 °C). Higher temperatures increase metabolism, respiration and physiological aging of potato tubers, resulting in the observed earlier sprouting and higher carbohydrate consumption (Wiltshire and Cobb, 1996). Loss

Tab. 1: Analysis of variance (ANOVA) results for the examined parameters in the experiment (F values).

Sources of Variation	TS (%)	F (N)	Vit. C (mg/100 g)	PC (%)	TSS (%)	RS (mg/100 g FW)
Storage Temperature (S)	91.3**	48.2**	384.9**	133.6**	91.6**	724.3**
Treatments (T)	24.8**	32.0**	179.7**	31.9**	41.3**	92.7**
S × T interaction	4.2**	1.3	7.0**	3.1*	7.3**	28.3**
Coefficient of variation (%)	2.1	2.8	6.0	2.3	4.6	5.2

*: P≤ 0.05 ** P≤ 0.01

TS (%): Total starch content, F (N): Firmness, Vit. C (mg/100 g FW): Vitamin C content, PC (%): Protein content, TSS (%): Total soluble sugar content, RS (mg/100 g FW): Reducing sugar content.

of dormancy results in sprouting which in turn causes tuber dehydration and weight losses by increased respiration and transpiration. SEDLOKOVA et al. (2003) reported that carvone concentration was higher in ground caraway than whole caraway seeds. Caraway and CIPC treated tubers stayed dormant for a period longer than the control tubers which explains the higher starch content observed in those treatments than the control. Ground caraway treatments gave higher starch content than whole caraway seed treatments at both storage conditions which could be explained by the higher carvone concentrations released by grounded seeds. It was also observed that humidity caused by respiration of tubers during storage was absorbed by whole caraway seeds and caused seeds to deteriorate during storage, an effect detrimental to stored tubers. While, caraway seeds deteriorate was not observed in ground caraway applications.

Firmness

Firmness of tubers decreased significantly during the storage. Overall the firmness of tubers stored at 8 °C and 15 °C was 81.3 N and 77.2 N; respectively (Tab. 2). Caraway and CIPC applications reduced firmness loss as compared to the control at both storage conditions in the experiment. At 8 °C storage, no significant differences were detected for firmness between all doses of ground caraway, a dose of 150 g whole caraway and CIPC treatments. At 15 °C storage, the ground caraway and CIPC treatments gave better results for preserving firmness of tubers than the whole caraway treatments. At both storage conditions, the lowest firmness was observed in the control tubers (Tab. 2). Firmness of potatoes is related to turgidity, and the best way to preserve firmness is to restrict water loss of tubers during storage. Firmness of tubers usually decrease steadily during storage and the loss of firmness is more pronounced over 12 °C storage conditions (KAUR et al., 2008). High storage temperatures caused softening and irregularities of tuber surface due to water and solid matter loss, and these changes in turn reduced appearance, quality and marketability of tubers. NOURIAN et al. (2003) reported that the tubers stored at low storage temperatures generally have better quality and marketability due to firmness and overall appeal of tubers. On the other hand AFEK et al. (2000) showed that tubers stored at 10 °C and high (94-98 %) and low (82-84 %) relative humidity had 74 N and 63 N firmness. In addition to water loss and infections during the storage cause softening of tubers during storage. In a pervious study (ŞANLI et al., 2010), sprouting rate was found to be lower at both storage conditions for ground caraway treatments. Consequently, firmness was higher for ground caraway treatments at both storage conditions. Treatments that reduce water loss and preserve solid matter content will have higher firmness as evidenced in the present study.

Vitamin C content

During the storage, vitamin C content of tubers decreased significantly ($P<0.01$). The reduction in vitamin C content of tubers was 16.3 % and 11.8 % at 8 °C and 15 °C storage conditions, respecitvely (Tab. 1). At 8 °C significant differences were not observed between ground and whole caraway and CIPC treatments. At 15 °C ground caraway and CIPC treatments had higher vitamin C content as compared to whole caraway treatments (Tab. 2). At both storage conditions, there was no difference between different doses of ground and whole caraway treatments (Tab. 2). Vitamin C is lost during the storage and processing due to oxidation EMESE and NAGYMATE (2008). Vitamin C loss depends on storage time and storage temperature, and it was reported to change between 35 and 60 % (MONDY and MUNSHI, 1993; NOURIAN et al., 2003). Vitamin C metabolism is closely related to carbohydrate metabolism in plants. Storage temperatures and treatments that reduce sprouting and maintaining dry matter content could help reduce vitamin C losses during storage. Different sprout inhibitors such as caraway and dill extracts and CIPC reduce vitamin C loses during storage (ŞANLI, 2012).

Protein content

Protein content of potatoes decreased significantly during the storage ($P<0.01$). Storage temperature was also found to be an important factor for protein content of tubers during the storage ($P<0.01$). Tubers stored at 8 °C had lower protein content (1.71 %) than those tubers (1.84 %) stored at 15 °C (Tab. 2). Control tubers had the lowest protein content at both 8 °C (1.59 %) and 15 °C (1.76 %) storage temperatures (Tab. 2). At 8 °C storage, ground caraway and CIPC treated tubers had higher protein content than control, however at the same storage temperature, there was no significant difference between whole caraway treated tubers and the control. Significant differences were not detected between CIPC and 50 g and 100 g ground caraway treatments for protein content, but the protein content of 150 g ground caraway treatment was found to be higher than

Tab. 2: Comparison of means of total starch content (TS), firmness (F) and vitamin C of potato tubers with caraway seed and CIPC applications at 8 °C and 15 °C temperature.

Treatments/ Doses (g)		TS (%)		F (N)		Vit. C (mg/100 g FW)	
	Temperature	8 °C	15 °C	8 °C	15 °C	8 °C	15 °C
	Initial	14.3±0.20^{a}		86.3±1.5^{a}		26.1±1.5^{a}	
Ground Caraway	50	13.9±0.33^{abc}	13.5±0.20^{abcd}	83.0±2.6^{abc}	79.7±2.5^{def}	16.1±0.7^{b}	11.70.9±^{e}
	100	13.8±0.20^{abc}	13.4±0.26^{bcd}	83.7±2.5^{ab}	81.3±1.5^{bcde}	15.5±0.8^{bc}	11.51.5±^{e}
	150	13.9±0.20^{ab}	13.7±0.41^{abc}	86.0±3.0^{a}	82.0±1.7^{bcd}	15.8±0.6^{bc}	11.50.8±^{e}
Whole Caraway	50	13.4±0.47^{bcd}	12.3±0.13^{ef}	78.0±1.7^{def}	72.0±1.0^{g}	14.6±1.0^{bcd}	8.9±0.5^{f}
	100	13.4±0.40^{bcd}	12.4±0.23^{ef}	79.0±3.6^{cde}	74.3±2.3^{g}	14.6±0.9^{bcd}	8.8±0.2^{f}
	150	13.4±0.37^{bcd}	12.2±0.10^{ef}	80.7±1.5^{abcd}	75.3±1.5^{def}	14.8±0.4^{bcd}	8.9±0.2^{f}
CIPC		13.8±0.28^{abc}	12.9±0.29^{de}	82.3±2.3^{abc}	77.3±2.1^{f}	15.8±0.7^{bc}	10.4±0.4^{e}
Control		13.1±0.38^{cd}	11.8±0.16^{f}	73.0±2.0^{h}	66.0±3.0^{ı}	13.4±0.7^{d}	8.5±0.3^{f}
Mean[1]		13.7^{a}	12.9^{b}	81.3^{a}	77.2^{b}	16.3^{a}	11.8^{b}

Mean values with different superscript letters in the same column differ significantly according to Duncan's test ($P\leq 0.05$). Values are means ± SD (n = 3).
[1]: indicates the sum of storage temperature.

that of CIPC treatment at 8 ºC storage. The protein contents of CIPC (1.88 %) and 150 g ground caraway (1.89 %) treated tubers were higher than those of whole caraway treated tubers at 15 ºC storage (Tab. 2). At the same storage conditions, ground caraway (50, 100 g) treatments and whole caraway treatments gave similar results for protein content. At both storage conditions, the protein contents of control and whole caraway applied tubers did not differ from each other significantly (Tab. 2). Similarly, Pinto et al. (1993) reported a decrease in the protein content of potato tubers at high storage temperatures due to the increases in the activities of protease and amylase enzymes. During dormancy both proteinase activity and free amino acids levels are at the minimum level. However, after breaking of dormancy proteinase activity increases and the mobilizations of nitrogen reserves increase within tubers (Nowak, 1977). Dormancy was broken down at the earlier stages of storage in the control and whole caraway applied tubers which in turn leaded to an increase in proteinase acitivity but a decrease in protein content observed in those treatments. Since the increase in sprout weight at higher temperature (Şanli et al., 2010), indicated a higher available protein content at this temperature that was ultimately used during sprout growth. An increase in free amino acid content commonly occurred during the latter part of storage, caused by an upturn of proteinase activity on the break of dormancy.

Total soluble sugars

Total soluble sugar content of tubers increased depending on the storage temperature (P<0.01). The tubers stored at 8 ºC had 1.53 % TSS while the tubers stored at 15 ºC had 1.72 TSS (Tab. 3). At both storage temperatures the highest TSS value was observed in control tubers. The TSS contents of ground caraway applied tubers at both temperatures did not differ significantly from each other however their TSS contents were lower than those of the tubers treated with whole caraway at both storage conditions (Tab. 3). While CIPC treated tubers stored at 8 ºC had similar TSS content to ground caraway treated tubers, CIPC treated tubers had higher TSS content at 15 ºC storage. The TSS contents of the control and whole caraway apllied tubers had higher TSS contents at 15 ºC (Tab. 3). Respiration during the storage period causes breakdown of starch leading to increased TSS content of the tubers (Matsura-Endo et al., 2004). Storage temperature and duration affect TSS content of potato tubers (Karim et al., 2008). Sprouting appeared earlier in the control and whole caraway treated tubers and consequently the control and whole caraway applied tubers had higher TSS contents as compared to CIPC and ground caraway applied tubers in the present study. Energy requirement of sprouting is mainly supplied by the hydrolysis of glucose and sucrose which in turn increase TSS content. Razee et al. (2011) reported that radiation of tubers stored for 5 months delayed sprouting as compared to non radiated tubers and leaded to reduced TSS content as compared to the control treatment.

Reducing sugars

The effect of storage temperature on reducing sugars content was significant (P<0.01). Initial reducing sugars content of tubers was 188 mg/100 g FW at the beginning of the experiment and at the end of the experiment final concentration of reducing sugars were 300 and 205 mg/100 g FW for 8 ºC and 15 ºC storage; respectively (Tab. 3). While reducing sugars content increased in tubers stored at 8 ºC during storage for all treatments, the changes in reducing sugars content of tubers were depended on treatments at 15 ºC storage. At both storage temperatures the lowest amount of reducing sugars was observed from the control tubers. Ground (50, 100, 150 g) and whole (150 g) caraway treatments did not differ from each other for reducing sugars content and they had the highest level of sugars observed in the experiment at 8 ºC (Tab. 3). Ground caraway treatment had higher amount of reducing sugars than whole caraway treatment at 15 ºC storage. Chlorporpham treated tubers had lower reducing sugars than caraway treated tubers at 8 ºC whereas CIPC treatment did not affect reducing sugars content 15 ºC storage (Tab. 2). Reducing sugars contents of tubers generally increase during the storage (Matsuura-Endo et al., 2004; Rezaee et al., 2011). During storage, reserve starch accumulated in tubers are converted to sucrose, glucose and fructose to produce energy which in turn increases the level of reducing sugars content of tubers. Under low storage temperatures, starch is converted to sucrose by UDP-Glucose Pyrophosphorylase and sucrose phosphate synthase enzymes and sucrose is converted to reducing sugars by acid invertases (Zrenner et al., 1996) and it is called low temperature

Tab. 3: Comparison of means of protein content (PC), total soluble sugar (TSS) and reducing sugar (RS) of potato tubers with caraway seed and CIPC applications at 8 ºC and 15 ºC temprature.

Treatments/ Doses (g)		PC (%)		TSS (%)		RS (mg/100 g FW)	
	Temperature	8 ºC	15 ºC	8 ºC	15 ºC	8 ºC	15 ºC
	Initial	1.99±0.05^{a}		1.38±0.08^{h}		188±9.5^{f}	
Ground Caraway	50	1.75±0.05^{efg}	1.85±0.03^{bcd}	1.46±0.08^{gh}	1.51±0.04^{efgh}	347±20.6^{a}	281±14.4^{d}
	100	1.73±0.02^{fgh}	1.84±0.04^{bcd}	1.46±0.07^{gh}	1.53±0.07^{efgh}	335±14.0^{abc}	275±20.0^{d}
	150	1.78±0.03^{def}	1.89±0.05^{b}	1.45±0.09^{gh}	1.52±0.06^{efgh}	343±9.1^{ab}	294±11.4^{d}
Whole Caraway	50	1.62±0.02^{ij}	1.79±0.04^{def}	1.61±0.08^{ef}	1.91±0.06^{b}	316±11.0^{c}	166±7.6^{fg}
	100	1.63±0.06^{ij}	1.78±0.04^{def}	1.63±0.06^{def}	1.88±0.05^{b}	323±12.9^{bc}	162±5.3^{g}
	150	1.66±0.06^{hij}	1.81±0.05^{cde}	1.54±0.13^{efg}	1.84±0.03^{bc}	329±13.0^{abc}	169±11.4^{fg}
CIPC		1.68±0.01^{ghi}	1.88±0.08^{bc}	1.49±0.08^{fgh}	1.65±0.07^{de}	274±19.4^{d}	185±15.0^{fg}
Control		1.59±0.02^{j}	1.76±0.02^{ef}	1.75±0.09^{cd}	2.27±0.09^{a}	243±8.1^{e}	121±9.1^{h}
Mean1		1.71^{b}	1.84^{a}	1.53^{a}	1.72^{b}	300^{a}	205^{b}
CV		2.3		4.6		5.1	

Mean values with different superscript letters in the same column differ significantly according to Duncan's test (P≤ 0.05). Values are means ± SD (n = 3).
[1]: indicates the sum of storage temperature.

sweetening of tubers. At high storage temperatures, the increased level of respiration leads to the breakdown of fructose and glucose, which are used to produce necessary energy for sprout development, and reducing sugars levels are decreased (REZAEE et al., 2011). At the present study, reducing sugar levels of tubers were lower at 15 ºC than that of the tubers stored at 8 ºC. Dormancy breakdown and sprout development of tubers start earlier at 15 ºC which explains lower levels of reducing sugars of tubers stored at higher temperature.

Conclusion

In the present study, the effects of sprouting inhibitor CIPC and caraway applications, a natural source of carvone, on the quality of tubers were studied using the tubers stored at different temperatures. At low storage temperature, the examined quality parameters were better with the exception of RS which negatively affects chips qaulity. Ground caraway applications were more effective than the whole caraway applications overall, but the effects of caraway doses on the quality parameters were all similar. At low temperature condition, the effects of CIPC and ground caraway applications on quality parameters were similar, but at the higher storage temperature ground caraway applications yielded better results as compared to CIPC application. Reducing sugar levels of ground caraway applications were high yet their levels were within acceptable levels for chips production (300-400 mg/100 g FW) (DUPLESSIS et al., 1996). At the end of the study, it was concluded that the ground caraway applications prevented quality losses of the tubers at high temperature storage conditions. There is no literature for the effects of caraway seed treatments on tuber taste and scent. In a study that we have done before, the tubers treated with caraway essential oil showed low carvone residue levels (1 ppm in peeled tubers and 4 ppm in peelings), as compared to those of S-(+)-carvone and CIPC applied tubers (ŞANLI, 2012). In addition, no carvone residues at 15-20 days after storage were found at the same study. Therefore, it is believed the tubers treated with caraway seed could not be showed a significant change in terms of flavor and taste. Due to the fact that the carvone has a low human toxicity level (KERSTHOLT et al., 1997) and has Generally Recognized As Safe (GRAS) status (HALL and OSER, 1965), the use of ground caraway show promise as a replacement to CIPC in prevent quality losses of tubers at high storage temperatures.

Acknowledgements
We thank to Suleyman Demirel University Faculty of Agriculture and Dr. Muhammet Tonguç for chemical analysis, and to Dr. Sulhattin Yaşar and Yaşar Karakurt for editing the manuscript.

References

AFEK, U., ORENSTEIN, J., NURIEL, E., 2000: Using the tabor atomizer system to maintain weight and firmness in stored potato tubers. Amer. J. Potato Res. 77, 203-205.

AOAC, 1984: Official Methods of analysis. 14th Edition Association of Official Analytical Chemist. Washington, D.C.

BRADFORD, M.M., 1976: A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Analy. Biochem. 72, 248-254.

BRITISH PHARMACOPOEIA, 1980: Vol. II. HM Stationary Office, London.

BURTON, W.G., VAN ES, A., HARMANTS, K.J., 1992: The physics and physiology of storage. In: Harris, P.M. (ed.), The potato crop, 608-727. London, Champman and Hall.

COLEMAN, W.K., LONERGAN, G., SILK, P., 2001: Potato sprout growth suppression by menthone and neomenthol, volatile oil components of Minthostachys, Satureja, Bystropogon and Mentha species. Amer. J. Potato Res. 78, 345-354.

DELAPLACE, P., BROSTAUX, Y., FAUCONNIER, M.L., DU JARDIN, P., 2008: Potato (*Solanum tuberosum* L.) tuber physiological age index is a valid reference frame in postharvest ageing studies. Postharvest Biol. Technol. 50, 103-106.

DUBOIS, M., GILLES, K.A., HAMILTON, J.K., 1956: Colorimetric method for determination of sugars and related substances. Anal. Chem. 28, 350-356.

DUPLESSIS, P.M., MARANGONI, A.G., YADA, R.Y., 1996: A mechanism for low temperature induced sugar accumulation in stored potato tubers: The potential role of the alternative pathway and invertase. Amer. Potato J. 73, 483-494.

ELFNESH, F., TEKALIGN, T., SOLOMON, W., 2011: Processing quality of improved potato (*Solanum tuberosum* L.) variety as influenced by growing environment and blanching. Afr. J. Food Sci. 5, 324-332.

ELSADR, H., WATERER, D., 2005: Efficacy of natural compounds to suppress sprouting and fusarium dry rot in potatoes. www.usask.ca/agriculture/plantsci/vegetable. Accessing date:15.07.2016.

EMESE, J., NAGYMATE, P.F., 2008: The stability of vitamin C in different beverages. British Food J. 110, 296-309.

FRAIZER, M.J., OLSEN, N.L., KLEINKOPF, G.E., 2004: Organic and alternative methods of potato sprout control in storage. University of Idaho Extension. http://www.cals.uidaho.edu/edComm/pdf/cis/cis1120.pdf. Accessing date:10.06.2016.

GOMEZ, D., BOBO, G., ARROQUİ, C., VİRSEDA, P., 2010: Essential oils as sprouting inhibitor on potatoes tuber. Int. Conf. Food Innov., Spain, 1-4.

GOMEZ-CASTILLO, D., CRUZA, E., IGUAZ, A., ARROQUIA, C., VIRSEDA, P., 2013: Effects of essential oils on sprout suppression and quality of potato cultivars. Postharv. Biol. Tech. 82, 15-21.

HALL, R.L., OSER, B.L., 1965: Recent progress in consideration of flavoring ingredients under food additivies amendment. III. GRAS substances. Food Tech. 19, 151-197.

HARTMANS, K.J., DIEPENHORST, P., BAKKER, W., GORRIS, L.G.M., 1995: The use of karvon in agriculture, sprout suppression of potatoes and antifungal activity against potato tuber and other plant diseases. In: Meijer, W.J.M. (ed.), Applications, properties and production of S-(+)-carvone from caraway, 3-13. Ind. Crops Prod. 4.

KARIM, M.D.R., KHAN, M.M.H., UDDIN, M.D.S., SANA, N.K., NIKKON, F. and RAHMAN, M.D.H., 2008: Studies on the sugar accumulation and carbonhydrate splitting enzyme levels in post harvested and cold stored potatoes. J. Biosciences 16, 95-99.

KAUR, A., SINGH, N., EZEKIEL, R., 2008: Quality parameters of potato chips from different potato cultivars, effect of prior storage and frying temperatures. Int. J. Food Prop. 11, 791-803.

KERSHOLT, R.P.V., REE, C.M., MOLL, H.C., 1997: Environmental life cycle analysis of potato sprout inhibitors. Indust. Crops Prod. 6, 187-194.

MATSUURO-ENDO, C., KOBAYASHI, A., NODA, T., TAKIGAWA, S., YAMAUCHI, H., MORİ, M., 2004: Changes in sugar content and activity of vacuolar acid invertase during low-temperature storage of potato tubers from six Japanese cultivars. J. Plant Res. 117, 131-137.

MONDY, N.I., UNSHI, C.B., 1993: Effect of madurity and storage on ascorbic acid and tyrosine concentrations and enzymatic discoloration of potatoes. J. Agr. Food Chem. 41, 1868-1871.

NOURIAN, F., RAMASWAMY, H.S., KUSHALAPPA, A.C., 2003: Kinetics changes in cooking quality of potatoes stored at different temperatures. J. Food Engg. 60, 257-266.

NOWAK, J., 1977: Biochemical changes in stored potato tubers with different rest periods. II. Influence of storage temperature and isopropyl phenylcarbamates on enzyme activities. Zeits. Pflanzenphysiol. 81, 125-140.

OOSTERHAVEN, K., HARTMANS, K.J., HUIZING, H.J., 1993: Inhibition of potato (*Solanum tuberosum*) sprout growth by the monoterpene S-carvone: Reduction of 3- hydroxy-3-methylglutaryl coenzyme A reductase activity without effect on its mRNA level. J. Plant Physiol. 141, 463- 469.

Oosterhaven, K., Poolman, B., Smid, E.J., 1995: S-Carvone as a natural potato sprout inhibiting, fungistatic and bacteristatic compound. Ind. Crop. Prod. 4, 23-31.

Pinto, J.E.B.P., Pinto, C.A.B.P., Barbosa, M.H.P., 1993: Effects of different storage temperatures on protein cuantities of potato tubers. R. Bras. Fisiol. Veg. 5, 167-170.

Rezaee, M., Almassi, M., Majdabahi, F.A., Minaei, S., Khodadah, M., 2011: Potato sprout inhibition and tuber quality after post harvest treatment with gamma irradiation on different dates. J. Agr. Sci. Tech. 13, 829-842.

Saraiva, J.A., Rodrigues, I.M., 2011: Inhibition of potato tuber sprouting by pressure treatments. Int. J. Food Sci. Technol. 46, 61-66.

Sedlokova, J., Kocourkova, B., Lojkova, L., Kuban, V., 2003: Determination of essential oil content in caraway (*Carum carvi* L.) species by means of supercritical fluid extraction. Plant Soil Environ. 49, 277-282.

Silva, M.C.E., Galhano, C.I.C., Moreira Da Silva, A.M.G., 2007: A new sprout inhibitor of potato tuber based on carvone/b-cyclodextrin inclusion compound. J. Incl. Phenom. Macroycl Chem. 57, 121-124.

Somogyi, M., 1952: Notes on sugar determination. J. Biol. Chem. 195, 19-23.

Song, X., Neeser, C., Bandara, M., Tanino, K.K., 2004: Using essential oils as sprout inhibitors and their effects on potato seed tubers performance. http://www.oacc.info/Docs/Plant%20Canada%202007%20Poster-Xin%20Song.pdf. Accessing date:10.07.2016.

Sorce, C., Lorenzi, R., Ranalli, P., 1997: The effects of (S)-(+)-carvone treatments on seed potato tuber dormancy and sprouting. Pot. Res. 40, 155-61.

Suhag, M., Nehra, B.K., Singh, N., Khurana, S.C., 2006: Storage behavior of potato under ambient condition affected by curing and crop duration. Haryana J. Hortic. Sci. 35, 357-360.

Şanli, A., Karadoğan, T., Tonguç, M., Baydar, H., 2010: Effects of caraway (*Carum carvi* L.) seed on sprouting of potato (*Solanum tuberosum* L.) tubers under different temperature conditions. Tur. J. Field Crops. 15, 54-58.

Şanli, A., 2012: Effects of volatile oils containing carvone on sprouting of Potato (*Solanum tuberosum* L.) tubers at storage conditions. PhD Thesis, Grduate School of Natural and Applied Sciences, Field Crops Department, Suleyman Demirel University, Turkey.

Wiltshire, J.J.J., Cobb, A.H., 1996: A review of the physiology of potato tuber dormancy. Ann. Appl. Biol. 129, 553-569.

Wustman, R., Struic, P.C., 2007: The canon of potato science: Seed and ware potato storage. Potato. Res. 50, 351-355.

Zrenner, R., Schuler, K., Sonnewald, U., 1996: Soluble acid invertase determines the hexose-to-sucrose ratio in cold-stored potato tubers. Planta. 198, 246-252.

Address of the author:
Süleyman Demirel University, Faculty of Agriculture, Field Crops Department, Turkey
E-mail: arifsanli@sdu.edu.tr