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ORIGINAL PAPER

Effect of Grape Seed Extracts on the Physicochemical and Sensory Properties of Corn Chips during Storage

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Abstract This study evaluated the effectiveness of grape seed extracts (GSE) on lipid oxidation of corn chips stored for 90 days in comparison to *tert*-butylhydroxytoluene (BHT). Proximate chemical analysis results showed that corn chips contained low moisture contents (less than 2%) and also that no significant differences were found in the dry matter values in ash, fat, protein, and fiber. Antioxidant activity of the GSE measured by an oxidative stability instrument ranged from 1.6 to 9.3 h of induction time, while BHT prevented oxidation by 18.8 h. GSE (800 ppm) increased the redness and decreased the brightness and yellowness of the corn chip samples, whereas no significant differences were observed for other concentrations of the GSE compared to the control. The peroxide values (PV) for the control and the lower concentration (200 ppm) of GSE increased from 4.5 to 32.7 mequiv/kg, and from 4.4 to18.7 mequiv/kg, respectively, while no increase in PV was found for the higher level (400 and 800 ppm) of GSE or BHT. These changes were observed after 90 days of storage. Descriptive and consumer results showed that the control and the low concentration of GSE were associated with an increase in rancidity and the appearance of off-flavor, while no noticeable increase in either rancidity or off-flavor was observed when using a higher concentration of GSE or BHT. GSE has great potential for use as a natural antioxidant to preserve the extruded corn chips.

Keywords Lipid oxidation · Sensory · Antioxidants

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Introduction

Many foods, e.g., snacks and ready-to-eat (RTE) breakfast cereals, are processed by extrusion technology [1]. Extruded foods, particularly expanded products such as corn chips, are highly susceptible to lipid oxidation. Factors that enhance such oxidation include low moisture, increased surface, and temperature. Lipid oxidation is considered to be one of the major problems facing corn chips during storage. Lipid oxidation is one of the important parameters of food quality [2]. It may lead to the development of rancid off-flavors, color changes, shelf life reduction, and a deterioration in nutritional quality [3, 4].

Due to toxicological concerns regarding synthetic antioxidants, there has been increasing interest in identifying plant extracts to minimize or retard lipid oxidation in fat-containing food products [5]. Most of these natural antioxidants come from plants, fruits, vegetables, spices,

grains, and herbs [5, 6]. Several studies have shown that lipid oxidation can be minimized by adding synthetic or natural antioxidants [5–7]. Grape seed extracts (GSE) contain a large amount of phenolic compounds and antioxidants [5, 6]. Rababah et al. [5] found that GSE had the highest antioxidant activities among several other plant extracts.

GSE is rich in proanthocyanidins and its mechanism of antioxidative activity lies in its capability of radical scavenging, metal chelation, and synergism with other antioxidants [8]. Most of the studies that address the effect of GSE on lipid oxidation were conducted on meats. Mielnik et al. [9] demonstrated that grape seed extract was effective in inhibiting lipid oxidation of cooked turkey meat during chill-storage. Rababah et al. [10] reported that GSE is an effective antioxidant to minimize irradiation-induced lipid oxidation developments of breast meats. GSE can be used to stabilize sunflower oils [11]. Also, GSE reduced the formation of detrimental N^{ε}-(carboxymethyl) lysine in bread [12].

Currently, no literature information is available on the effect of plant extracts including GSE on lipid oxidation of corn chips during storage. Therefore, the objective of this study was to evaluate and compare the effectiveness between synthetic and natural antioxidants on lipid oxidation of corn chips during storage.

Materials and Methods

Materials

Corn flour, salt, and shortening were obtained from a corn chip factory in Jordan. Butylated hydroxyltoluene (BHT) was purchased from the Tubrug Company (Amman-Jordan). Grape seeds (*Vitis vinifera*) were collected from northern Jordan.

Preparation of GSE

GSE were prepared as described by Rababah et al. [5]. Grape seeds were ground in a mill (Braun Aromatic KSM2, Braun Canada Div., Gillette Canada Company, Mexico) and passed through a 60 mesh. The ground seeds were defatted in hexane (1:3) with agitation for 30 min, and filtered under a vacuum. The residue was defatted again using the same procedure. The defatted residue was air dried overnight under a fume hood to remove residual hexane. The defatted residues were extracted in methanol (1:3) with stirring for 30 min and filtered under a vacuum. The filtrate was concentrated in a rotovapor and dried under a fume hood overnight. The dried GSE were stored at 4 °C until use.

Determination of Antioxidant Activities of GSE Using Shortening Substrate by Oxidative Stability Instrument (OSI)

Oxidative stability of the GSE at four levels (100, 200, 400, and 800 ppm), BHT (200 ppm), and the control (shortening) was evaluated using an OSI (Metrohom model 743, Herisau, Switzerland). Triplicate samples were homogenized for 3 min with fat (melted in a water bath at 60 °C) using a Hamilton Beach Scovel homogenizer (NSF, USA), and transferred into the OSI tubes. Sample tubes were held in a thermostatic block in the OSI machine at 110 °C, and a stream of air at 210 g/cm^2 was bubbled through the sample. The air pressure was allowed to equilibrate at 176 g/cm^2. The volatiles released from the sample passed through rubber tubing into a tube containing deionized water and a conductivity probe. A water trap was placed between the sample tube and the conductivity tube to facilitate condensation of water from the sample and aid the free flow of volatiles into the conductivity tube. The probe measured the changes in conductivity of deionized water due to collected volatiles. The induction period was expressed in hours before detectable levels of volatile organic acids were trapped in the deionized water. The software analyzed the data and generated the induction period as the OSI number. A longer induction period indicated a better oxidative stability of the sample.

Preparation of Corn Chips

The main steps involved in the preparation of corn chips are ballet preparation and the extrusion process. Corn chips samples were prepared according to a commercial procedure in a corn chip factory in Jordan. In the ballet preparation, 100 g of corn flour was blended with other ingredients (shortening 0.5 g, salt 0.93 g) and 8 g of water for 30 min at a mixing speed of 45 rpm using a mixer (type DITO-SAMA Aubusson, France). The produced ballets were then subjected to the extrusion process. Extrusion was carried out according to a procedure descried by Sacchetti et al. [13] and Faller et al. [14] with some modifications. The single screw extruder (Brabender 19/20 DN, DGE 330, PL 2200) used for the extrusion process had a compression ratio of 1.6:1, a screw diameter of 19.1 mm, a screw length of 20 times its diameter, a rotational speed of 80 rpm, and a die diameter of 3 mm. The heating system was in four stages: a pre-heating zone, followed by two heating zones and a cooling zone. The temperatures in the barrel from the inlet to the die were set at 160 °C in the pre-heating zone and 220 °C in the expansion zone. The feed mass flow rate was kept constant at 62 g/min. The ballet samples were subjected to extrusion to yield an extrudate (i.e., the extruded corn chip) of approximately 1.54 cm high and

1.12 cm thick. The extrudates were immediately packed in corn chips packages and used as the control.

Preparation of Corn Chips with Antioxidants

A similar procedure of the ballet and extrusion process as described above was used for the preparation of corn chips with antioxidants. Antioxidants were added at three concentration levels for the GSE (i.e., 200, 400, and 800 ppm) or one level of BHT (200 ppm), in conjunction with 0.5% shortening addition. The GSE or BHT was mixed thoroughly by homogenization for 3 min with fat (melted in a water bath at 60 °C) and mixed with other ballet ingredients.

Triplicate corn chip samples with and without antioxidants were stored at 0, 30, 60, and 90 days at room temperature and evaluated for physicochemical and sensory properties.

Proximate Chemical Analysis

Proximate analysis (protein, ash, lipid, fiber, and moisture) of corn chip samples was carried out according to procedures outlined by the AOAC [15]. The moisture content (Method # 14.004) of samples was determined by drying the samples at 100 °C until a constant weight was obtained. Dried samples were analyzed to determine the total nitrogen content using the micro-Kjeldahl method (Method # 14.067). A conversion factor of 6.25 was used to calculate the protein content. The ash content (Method # 7.009) was determined by burning 1 g of an oven-dried sample in a crucible in a muffle furnace at 550 °C for 24 h. The total lipids were isolated from samples using the Soxhlet method (Method # 7.062). Crude fiber (Method # 7.070) was measured by digestion with 1.25% sulfuric acid followed by 1.25% of potassium hydroxide.

Color Measurement

The color of corn chip samples was measured by a Color Tec-PCM^{TM} (Pittsford, NY, USA) and recorded using the L*a*b* color system. The L*a*b* color system consists of a luminance or lightness component (L*) and two chromatic components: the a* component for green (−a) to red (+a) and the b* component from blue (−b) to yellow (+b) colors. The colorimeter was calibrated using a standard white plate. Values of the white standard were $L = 97.10$, $a = +0.13$, $b = +1.88$, $c = 1.88$ and $h^{o} = 86.1$. Color measurements were averaged.

Peroxide Value (PV) Determination

A ground sample (5 g) was mixed with 75 mL petroleum ether for 6 min at room temperature. The mixture was passed through a Whatman #1 paper filter into a 250-mL round-bottomed flask. The procedure was repeated. Ether was removed by roto-evaporation at 40–50 °C. Flasks were flushed with nitrogen to remove air. The recovered oil was kept for PV analysis. The PV was analyzed for a 5-g sample of extracted lipid as described by Paquot and Hautfenne based on IUPAC 2.501 [16]. The PV was evaluated by measuring the iodine released from potassium iodide titrated with sodium thiosulfate solution. The PV was expressed as milliequivalents per kilogram of oil.

Trained Sensory Evaluation (Descriptive Analysis)

A seven-member trained descriptive panel, who consumed corn chips at least once per month, was trained according to the spectrum methodology. The spectrum method involves scoring perceived intensities with reference to pre-learned scales using attribute names with their standards that define a scale of intensity [17]. Four 3-h orientation sessions were organized for the panel to become familiarized with the test methodology necessary to describe the characteristics of sensory attributes of corn chip samples. Panelists underwent an orientation session using corn chip without antioxidant addition (control) and corn chip with antioxidant addition (GSE and BHT) at different concentrations. During the orientation, the panelists were able to narrow down the reference (oxidized corn seed oil) for the descriptor (flavor associated with rancid/oxidized oil). The panelists used the orientation session to improve their reproducibility and accuracy.

The treatments were evaluated for the rancidity attribute. A 15-point intensity scale anchored by references as defined by the spectrum methodology was used in assigning values to this descriptor. The treatments with and without addition of antioxidants were evaluated for the rancidity attribute. In addition to descriptive analysis a Yes/No test was used to evaluate the presence of off-flavor in the samples. Trained panelists evaluated the corn chips samples at 0, 30, 60, and 90 days.

Consumer Testing

Consumers of corn chips were selected from students in the Jordan University of Science and Technology who were 18–60 years of age and of various socioeconomic backgrounds. Only those who consumed corn chips at least once per month were selected to participate in this study. A total of 60 consumers were selected to participate and complete the consumer tests.

Consumer testing was conducted at the Jordan University of Science and Technology Laboratories. Corn chip samples were coded with randomly selected three digit numbers and analyzed using a blind basis method [17].

Each consumer was provided with a tray containing 20 pieces of corn chip treatments (for each of sample) in 50 mL plastic sample containers. To eliminate carry over factors, consumers were also provided with unsalted crackers and room temperature water for mouth cleansing between samples. The consumers were asked to record their acceptance of intensity scores for rancid flavor (9-point intensity scale of rancid flavor with 9 = "extremely rancid" and 1 = "not extremely rancid") and off-flavor (yes or no). The same consumers were asked to evaluate the treatments at 0, 30, 60, and 90 days.

Statistical Analysis

Data were presented as means from three corn chips (i.e., three replicates) taken randomly and analyzed using the general linear model (GLM) procedure using the SAS software (SAS Institute, 2002) version 8.2. The model included the main effects of replicates, antioxidant treatments (200, 400, and 800 ppm of GSE, BHT, and control), four storage times (0, 30, 60, and 90 days). The model was built for the measured variables (chemical analysis, color, and PV) and sensory evaluation. Means were separated by LSD analysis at a least significant difference using alpha = 0.05.

Results and Discussion

Oxidative Stability Index of Shortening Fat Mixed with GSE or BHT

Antioxidant activities of the GSE at four levels (100, 200, 400, and 800 ppm), BHT (200 ppm), and the control using OSI are shown in Fig. 1. Induction times of the oil treated with GSE were much lower than BHT (18.8 h) and ranged from 1.6 to 9.3 h (Fig. 1), but longer than that of the control (1.4 h). Only the GSE at 100 ppm was not significantly different ($P > 0.05$) compared with the control. These results demonstrated that OSI can be used effectively to determine antioxidant activities in lipid-based products such as shortening fat, confirming previous research findings [5, 6, 18, 19].

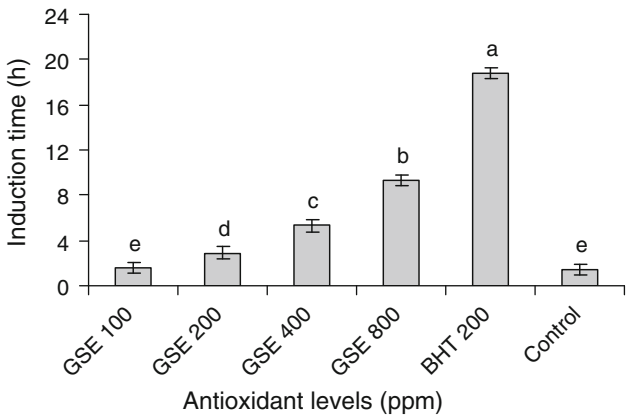

Fig. 1 Induction time (h) of shortening fats blended with *BHT* and grape seed extracts (*GSE*) measured by oxidative stability instrument, Column with the same letters were not significantly different ($P < 0.05$)

The three levels (800, 400, and 200 ppm) of GSE showed significant antioxidant activities compared with the control. Therefore, these levels were used in the preparation of corn chips for oxidative and sensory evaluations during storage.

Chemical Analysis

The changes in the chemical composition of corn chips during a 90-day period are shown in Table 1. Corn chip samples have a low moisture content (less than 2%) and the range of dry matter was between 98.4 and 98.8%. The results (Table 1) also showed that the amounts of ash, fat, protein, and fiber were in the ranges of 2.3–2.5, 5.3–5.6, 6.1–6.3, and 6.4–6.6, respectively. From the results, the corn chips contain low amounts of ash and moderate amounts of fat, proteins, and fiber. No significant difference ($P > 0.05$) was observed for dry matter, ash, fat, protein, and fiber during 90 days of storage.

Color Measurement

The lightness (L*), redness (a*), and yellowness (b*) measurement values of corn chips during 90 days of storage are shown in Tables 2, 3, 4. The lightness, redness, and yellowness values of control corn chips were not significantly different ($P > 0.05$) from chips made with 200 and 400 ppm GSE and BHT. Whereas, GSE at 800 ppm level increased the redness and decreased the lightness and yellowness of the corn chips. These observations could be due to the color of anthocyanins in grape seeds [3, 12]. Also, the 90 days of storage results (Tables 2, 3, 4) did not show any significant effect on color measurements.

Peroxide Value

The PV values of corn chips during 90 days of storage are shown in Table 5. The PV of the chips containing GSE or BHT were lower than the control. GSE, which contain a large amount of polyphenolic and phenolic compounds [5, 6], and BHT minimized lipid oxidation in corn chips. The lower PV could be due to the inhibition of free radical formations during the initiation step, interruption of the propagation of the free radical chain reaction by acting as an electron donor [2], or scavengers of free radicals in corn

Table 1 Chemical composition of corn chips during 90 days of storage

Corn chips sample	Storage period (days)	Dry matter (%)	Ash (%)[a]	Fat (%)[a]	Protein (%)[a]	Fiber (%)[a]
GSE (200 ppm)	0	98.7 ± 8.6	2.4 ± 0.1	5.4 ± 0.4	6.2 ± 0.5	6.6 ± 0.5
	30	98.6 ± 8.3	2.5 ± 0.2	5.6 ± 0.3	6.3 ± 0.4	6.5 ± 0.4
	60	98.4 ± 8.2	2.5 ± 0.1	5.5 ± 0.5	6.1 ± 0.5	6.6 ± 0.5
	90	98.8 ± 8.5	2.3 ± 0.2	5.3 ± 0.3	6.3 ± 0.6	6.4 ± 0.3
GSE (400 ppm)	0	98.7 ± 8.5	2.3 ± 0.2	5.4 ± 0.4	6.1 ± 0.3	6.6 ± 0.2
	30	98.8 ± 8.5	2.3 ± 0.2	5.3 ± 0.3	6.3 ± 0.6	6.4 ± 0.3
	60	98.6 ± 8.3	2.5 ± 0.2	5.6 ± 0.3	6.3 ± 0.4	6.5 ± 0.4
	90	98.4 ± 8.2	2.5 ± 0.1	5.5 ± 0.5	6.1 ± 0.5	6.6 ± 0.5
GSE (800 ppm)	0	98.6 ± 7.8	2.4 ± 0.2	5.7 ± 0.3	6.2 ± 0.4	6.6 ± 0.4
	30	98.7 ± 8.5	2.4 ± 0.2	5.5 ± 0.4	6.1 ± 0.3	6.6 ± 0.2
	60	98.4 ± 8.2	2.5 ± 0.1	5.5 ± 0.5	6.1 ± 0.5	6.6 ± 0.5
	90	98.8 ± 8.5	2.3 ± 0.2	5.3 ± 0.3	6.3 ± 0.6	6.4 ± 0.3
BHT (200 ppm)	0	98.6 ± 7.6	2.3 ± 0.1	5.7 ± 0.2	6.3 ± 0.3	6.6 ± 0.5
	30	98.8 ± 8.5	2.3 ± 0.2	5.3 ± 0.3	6.3 ± 0.6	6.4 ± 0.3
	60	98.7 ± 8.5	2.4 ± 0.2	5.5 ± 0.4	6.1 ± 0.3	6.6 ± 0.2
	90	98.4 ± 8.2	2.5 ± 0.1	5.5 ± 0.5	6.1 ± 0.5	6.6 ± 0.5
Control	0	98.7 ± 8.1	2.4 ± 0.2	5.4 ± 0.4	6.1 ± 0.3	6.5 ± 0.2
	30	98.8 ± 8.3	2.3 ± 0.2	5.3 ± 0.3	6.3 ± 0.6	6.4 ± 0.3
	60	98.6 ± 8.0	2.5 ± 0.2	5.6 ± 0.3	6.2 ± 0.4	6.6 ± 0.4
	90	98.4 ± 8.2	2.4 ± 0.1	5.5 ± 0.5	6.3 ± 0.5	6.5 ± 0.5

GSE grape seed extracts

[a] The values are computed on a dry weight basis

Table 2 Lightness (L*) color values of corn chips during 90 days of storage

Treatment	Level ppm	L*			
		Storage time (days)			
		0	30	60	90
GSE	200	67.7[a1]	67.8[a]	67.2[a]	67.2[a]
GSE	400	66.8[a]	66.7[a]	66.7[a]	66.8[a]
GSE	800	63.4[b]	63.2[b]	63.2[b]	63.1[b]
BHT	200	67.4[a]	68.1[a]	67.8[a]	67.6[a]
Control	–	68.6[a]	67.5[a]	67.9[a]	68.1[a]

GSE grape seed extracts

[1] Column values with the same letters were not significantly different ($P < 0.05$)

Table 3 Redness (a*) color values of corn chips during 90 days of storage

Treatment	Level ppm	a*			
		Storage time (days)			
		0	30	60	90
GSE	200	0.97[b]	0.96[b]	0.95[b]	0.96[b]
GSE	400	1.01[b]	1.02[b]	1.02[b]	1.03[b]
GSE	800	1.32[a1]	1.27[a]	1.29[a]	1.28[a]
BHT	200	0.95[b]	0.93[b]	0.96[b]	0.97[b]
Control	–	0.94[b]	0.92[b]	0.91[b]	0.93[b]

GSE grape seed extracts

[1] Column values with the same letters were not significantly different ($P < 0.05$)

chips samples [20]. The PV increased significantly during storage (4.5–32.7 mequiv/kg) in the control and treated samples with GSE at the 200 ppm level (4.4–18.7 mequiv/kg). Whereas, no significant changes in PV were observed due to the addition of GSE at the 400 and 800 ppm levels and BHT. This observation agreed with OSI measurements (Fig. 1) that demonstrated higher levels (400 and 800 ppm) of GSE had higher induction time (h) values than lower levels (200 ppm) confirming previous results [5, 21–23]. These results agreed with Artz et al. [21] and Camire and Dougherty [22] who found BHT and natural antioxidants reduced the PV of extruded products during storage. Also, Burri et al. [23] reported that natural antioxidant such as vanillin reduced the oxidation in cereals.

Descriptive Sensory Attributes

Rancidity and off-flavor of descriptive sensory attributes are shown in Table 6. Compared with the control, the rancidity decreased when the GSE and BHT were added. Also, rancidity increased significantly during storage of the control (1.2–8.4) chips and chips containing 200 ppm GSE (1.2–5.8). In contrast, no significant changes were observed in samples containing 400 and 800 ppm GSE and BHT.

Table 4 Yellowness (b*) color values of corn chips during 90 days of storage

Treatment	Level ppm	b*			
		Storage time (days)			
		0	30	60	90
GSE	200	4.46^{a1}	4.44^{a}	4.43^{a}	4.45^{a}
GSE	400	4.39^{a}	4.38^{a}	4.38^{a}	4.37^{a}
GSE	800	3.81^{b}	3.78^{b}	3.87^{b}	3.82^{b}
BHT	200	4.44^{a}	4.43^{a}	4.45^{a}	4.42^{a}
Control	–	4.46^{a}	4.44^{a}	4.43^{a}	4.45^{a}

GSE grape seed extracts

[1] Column values with the same letters were not significantly different ($P < 0.05$)

Table 5 Peroxide values (mequiv/kg) of corn chips during 90 days of storage

Treatment	Level ppm	Peroxide value (mequiv/kg)			
		Storage time (days)			
		0	30	60	90
GSE	200	4.4^{a1}*	6.8^{b2}	14.8^{b3}	18.7^{b4}
GSE	400	4.6^{a1}	4.7^{c1}	4.8^{c1}	5.2^{c1}
GSE	800	4.4^{a1}	4.5^{c1}	4.7^{c1}	4.9^{c1}
BHT	200	4.4^{a1}	4.5^{c1}	4.6^{c1}	4.8^{c1}
Control	–	4.5^{a1}	13.2^{a2}	21.3^{a3}	32.7^{a4}

GSE grape seed extracts

* Column (a–c) and row (1–4) values with the same letters were not significantly different ($P < 0.05$)

The rancidity development of the control and low level (200 ppm) GSE could be due to lipid oxidation [3, 4]. BHT (200 ppm) and GSE at higher levels (400 and 800 ppm) were the most effective antioxidant at preventing rancidity, which agrees with the descriptive results as reported by Rababah et al. [3] who found that natural antioxidants reduced some flavor attributes, and Camire and Dougherty [22] who found that natural phenolic compounds can be considered as antioxidants of extruded foods. Similar results were also observed for off-flavor (Table 6). This observed off-flavor could be due to lipid oxidation development during storage [3, 24].

Consumer Testing

Compared with the control, the intensity of rancidity was lower when the GSE and BHT was added (Table 7). The intensity of rancidity significantly increased during storage of the control (2.4–7.4) and treated samples at level 200 ppm (2.4–6.2), whereas no significant difference in the rancidity score were observed in chips containing 400 and 800 ppm GSE and BHT. This increase in rancidity could be due to lipid oxidation [3, 4, 22, 24]. Off-flavor was noticed for the control after 30 and 60 days in the low level (200 ppm) GSE samples after storage (Table 7), while higher levels (400 and 800 ppm) and BHT did not cause any off-flavor.

Table 6 Descriptive sensory attribute scores of corn chips during 90 days of storage

Treatment	Level ppm	Rancidity				Off-flavor			
		Storage time (days)				Storage time (days)			
		0	30	60	90	0	30	60	90
GSE	200	1.2^{a1}*	1.9^{2b}	3.4^{b3}	5.8^{b4}	No	Yes	Yes	Yes
GSE	400	1.1^{a1}	1.2^{c1}	1.4^{c1}	1.5^{c1}	No	No	No	No
GSE	800	1.1^{a1}	1.2^{c1}	1.3^{c1}	1.4^{c1}	No	No	No	No
BHT	200	1.1^{a1}	1.2^{c1}	1.2^{c1}	1.4^{c1}	No	No	No	No
Control	–	1.2^{a1}	2.6^{a2}	5.3^{a3}	8.4^{a4}	No	Yes	Yes	Yes

GSE grape seed extracts

* Column (a–c) and row (1–4) values with the same letters were not significantly different ($P < 0.05$)

Table 7 Consumer scores of corn chips during 90 days of storage

Treatment	Level ppm	**Rancid flavor				[&]Off-flavor			
		Storage time (days)				Storage time (days)			
		0	30	60	90	0	30	60	90
GSE	200	2.4^{a1}*	3.7^{b2}	4.9^{b3}	6.2^{b4}	No	No	Yes	Yes
GSE	400	2.3^{a1}	2.6^{c1}	2.6^{c1}	2.9^{c1}	No	No	No	No
GSE	800	2.4^{a1}	2.6^{c1}	2.7^{c1}	2.8^{c1}	No	No	No	No
BHT	200	2.2^{a1}	2.4^{c1}	2.5^{c1}	2.6^{c1}	No	No	No	No
Control	–	2.4^{a1}	4.8^{a2}	6.1^{a3}	7.4^{a4}	No	Yes	Yes	Yes

GSE grape seed extracts

* Column (a–c) and row (1–4) values with the same letters were not significantly different ($P < 0.05$)

** Rancid flavor (9 point scale with 9 = "extremely rancid" and 1 = "not extremely rancid")

[&] Off-flavor (yes or no)

Conclusions

The findings of this study demonstrate that storage of corn chips increases lipid oxidation. Addition of BHT and GSE (400 and 800 ppm) into corn chips prevents lipid oxidation. Consumer and descriptive results demonstrated that the GSE at higher levels and BHT additions decrease the rancidity and prevent off-flavors. Instrumental color results demonstrated that only GSE additions at level 800 ppm affect color measurements.

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