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AN EVALUATION OF GUELDER ROSE (*Viburnum opulus* L.) AND HAWTHORN (*Crataegus monogyna)* CONCENTRATES AS ALTERNATIVE ANTIOXIDANT SOURCES TO BHT AND NITRITE IN POULTRY MEAT MODEL SYSTEM

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Abstract

This study aimed to determine the effectiveness of hawthorn (HT) and guelderrose (GR) concentrates (65%) at different levels (1, 5, 10%) as an alternative antioxidant sources for nitrite (N) (25, 50, 100, 156 ppm) and butylatedhydroxytoluene (BHT) (0.01%) in cooked turkey ground meat stored under aerobic and anaerobic conditions at 4°C. Cooking loss (CL), pH, CIE L, a*, b*, texture profile analysis (TPA) and thiobarbituric acid reactive substances (TBARS) levels were determined. The use of 5% and 10% of the HT and GR concentrates increased CL compared to control and nitrite-containing groups (P<0.05). A significant differences were not found in terms of pH among groups stored under aerobic conditions. However, the highest pH values were determined in groups containing 10% HT or 100 ppm nitrite, whereas the lowest pH values were obtained in both BHT and control groups stored under anaerobic condition (P<0.05).TBARS increased during storage in both storage types (P<0.05). The lowest TBARS were determined in groups containing 156 ppm or 100 ppm nitrite, ora 10% HT in both storage conditions (P<0.05). The addition of GR and HT reduced the TBARS and this effect was further enhanced with increasing GR and HT levels (P<0.05). Furthermore, the groups containing 10% HT or GR were found to be have lower TBARS than the both control and BHT (P<0.05). It was determined that the all treatments did not have a significant effect on the L* values, the addition of nitrite and GR increased the a* values, and the addition of HT also increased the b* values (P<0.05). Addition of nitrite, BHT, HT or GR did not cause a significant changes chewiness, springiness, cohesiveness and adhesiveness. The lowest hardness and gumminess were determined in 10% HT or GR added samples compared with BHT or nitrite (156 ppm) containing groups (P<0.05). Study results suggested that the use of GR or HT (especially 10%) may be effective strategy in delaying the oxidative changes in poultry meat.*

Key words*: hawthorn, guelder rose, concentrate, poultry meat, antioxidant.*

INTRODUCTION

Poultry meat is more preferred than red meat due to low connective tissue and fat content, and high protein content (Ismail and Joo, 2017). However, it is highly susceptible to oxidation reaction due to its high content of polyunsaturated fatty acids (Arguelo et al., 2016).Oxidative deterioration is one of the most important chemical reactions limiting shelf-life and causing quality loss of meat products (Min and Ahn, 2005).During the oxidation, toxic compounds such as hydroperoxide, carbonyl compounds, aldehydes, acids, ketones, epoxides and carboxy acids are formed (Reitznerová et al., 2017). These compounds cause undesirable changes in the texture, color, taste and odor of meat products. Oxidation-related changes have a complex process and are influenced by many factors such as light, oxygen, storage temperature, metal ions and meat compositions (Sen and Mandal, 2017). The most commonly used method to prevent oxidation is the use of synthetic or natural antioxidants. Synthetic antioxidants are mainly used in meat industry to delay oxidation and prolong the storage period of meat products because of their strong antioxidant activity, and these additives are also cheaper than natural antioxidants (Karre et al.,

2013). However, many studies have shown that synthetic antioxidants such as sodium nitrite, butylatedhydroxytoluene (BHT), butylatedhydroxyanisole (BHA) and propyl gallate (PG) exhibit carcinogenic and teratogenic effects in living organisms. Therefore, many studies are focused on natural antioxidants that can be an alternative to synthetic antioxidants (Naveena et al., 2008).

The guelder rose *(Viburnum opulus* L.) is an edible and dark-red colorfruit which is known as "Gilaburu" in Anatolian region (Kalyoncu et al., 2013). It is known with several other names such as European cranberrybush (Akbulut et al., 2008), crampbark (Özrenk et al., 2011), whitten tree androse elder (Akbulut et al., 2008). GRis consumed as fruit juice, dried fruits, jam and pickles. GRfruits are especially used to treat of kidney problems. In addition, it is also reported to have antidiabetic and antispasmodic effects. Furthermore, GR fruits have antioxidant effects due to its high content of polyphenols such as chlorogenic acid, (+)-catechin, (–)-epicatechin, quercetin glycosides and proanthocyanidins (Levent et al., 2008; Özrenk et al., 2011; Moldovan et al., 2012; Kalyoncu et al., 2013; Ozola and Kampuse, 2018).Although there are studies showing the antioxidant activity of GRfruits (Levent et al., 2008; Şeker et al., 2016), there is no study on the use of this fruit on meat products.

Hawthorn used in the treatment of cardiovascular disease is a fruit having a high antioxidant activity. HT fruits contain high amount of flavonoids, phenolic acids (chlorogenic and caffeic acids) and oligomericprocyanidins. These compounds have lipid-lowering, antioxidant and anti-inflammatory properties (Liu et al., 2010; Shortle et al., 2014; Papuc et al., 2018). There are limited studies on the use of HT fruits on meat products. Ganhão et al. (2010a), Ganhão et al. (2010b), Shortle et al. (2014), Akcan et al. (2017) and Pabuc et al. (2018) investigated the efficiency of HT fruit extracts as inhibitors of oxidative reactions in cooked and raw pork patties, bovine muscle homogenates, ready-to-eat pork patties and minced pork, respectively. The goal of this study was to investigate the effectiveness of using HT and GR concentrates at different levels as a natural antioxidant sources in cooked turkey meat model system.

MATERIALS AND METHODS

Turkey breast meat (*Musculus superficiolis*) were purchased from a local slaughterhouse for each of two replications on separate production days. GR fruit concentrate (65%) was supplied by Kayseri Pazarı BioBitkisel Ürünler San.veTiç. A.Ş (Kayseri, Turkey). HT fruits were taken from a local market and concentrates were prepared according to the following procedure. HT fruit were dried in an air circulatory drier (FN 500, Nüve, Turkey) at 40°C for 48 h, and ground in an analytical mill to a grain diameter of less than 0.5 mm. The HT fruit powders were mixed with distilled water to be a concentration of 65%.

Sample Preparation: All experimental groups contained 2% sodium chloride and 10% distilled water over meat weight. Twelve experimental groups were formulated ascontrol (without additive) group and BHT (0,01%) ornitrite (25, 50, 100, 156 ppm) or HT (1%, 5%, 10%) or GR (1%, 5%, 10%; table 1) incorporated groups. The experimental samples formulated according to treatment groups (approximately 45 greach) were filled into 50 mL centrifuge tubes and cooked in a water bath until final internal temperature of 74^{o}C. Cooked samples were cooled to room temperature. Samples were stored under aerobic and anaerobic conditions at 4^{o}C for 30 days.

Physico-chemical analyses: The pH measurements were performed by using a portable pH meter (HI 9024, Hanna Instruments, Germany) with spear electrode (FC 200, Hanna Instruments, Germany). Color values of cooked treatments were measured with respect to CIE Lab Color System using a Minolta Colorimeter (Model CR-200, Minolta corp., Ramsey, Nj, USA). Thiobarbituric acid reactive substances (TBARS) analysis were applied according to the method stated by Kilic and Richards (2003). TPA tests were performed using a Brookfield CT3 Texture Analyzer (Brookfield Engineering Laboratories, Inc., USA) to determine hardness (N), adhesiveness (mJ), springiness, cohesiveness, gumminess (N), chewiness (N), and resilience. Conditions were: aluminium rectangular probe (9 mm x 35 mm x 0.05 mm), compression 70%, and 25 kg load cell.

Table 1. Coding for hawthorn (HT) and guelder rose (GR) concentrates, sodium nitrite (N) and butylatedhydroxytoluene (BHT) evaluated

Groups	HT, GR, and N treatments
Control	Without additive
BHT	% 0,01 BHT
N156	156 ppm sodium nitrite
N100	100 ppm sodium nitrite
N50	50 ppm sodium nitrite
N25	25 ppm sodium nitrite
HT1	1% Hawthorn concentrates
HT5	5% Hawthorn concentrates
HT10	10% Hawthorn concentrates
GR1	1% Guelder rose concentrates
GR5	5% Guelder rose concentrates
GR10	10% Guelder rose concentrates

Statistical Analysis: Statistical analysis was performed using the Minitab 17.3.1 program (Minitab Inc., UK).

The cooking loss data were implemented to one-way analysis of variance (one-way ANOVA).

The pH, color, texture profile analysis and TBARS data were implemented to two-way analysis of variance (two-way ANOVA).

The differences between means in all experimental groups were determined by using Tukey multiple range test P values < 0.05 were considered as significant.

RESULTS AND DISCUSSIONS

The CL results are shown in Table 2. The use of GR and HT concentrate at 5% or 10% increased the CL compared to the control and nitrite containing groups (P<0.05).

Ganhão et al. (2010a) reported that the addition of HT fruit extract (3%) in burger patties did not affect the moisture loss after cooking and chill storage.

In present study, an increasing added HT or GR concentrates in turkey meat formulation has been caused to an increase in cooking loss (P<0.05).

The highest CL value was determined in the sample containing 10% GR concentrate, whereas the lowest CL values were determined in the control samples and nitrite containing samples (P<0.05).

In addition, the cooking loss was increased with increasing GR concentrate levels (P<0.05). A similar effect were also present between HT5 and HT10 groups (P<0.05).

Table 2. The results of cooking loss in cooked turkey ground samples

Groups	Storage time (Day)
Control	9.17^{ef}±0.36
BHT	8.87^{ef}±0.29
N156	9.17^{ef}±0.08
N100	9.39^{de}±0.17
N50	8.51^{f}±0.35
N25	8.36^{f}±0.23
HT1	10.04^{cd}±0.25
HT5	10.44^{c}±0.20
HT10	11.96^{b}±0.45
GR1	10.21^{cd}±0.52
GR5	11.28^{b}±0.25
GR10	13.79^{a}±0.51

Means ± standard deviation (SD)

$^{a-f}$Within a column, values superscripted with different letters are significantly different (P<0.05)

The changes in pH values of the samples stored under aerobic and anaerobic conditions are presented in table 3 and table 4, respectively. There was no significant difference in the pH values of all treatment groups stored under aerobic conditions on processing day. No significant changes in pH were also observed during aerobic storage. At the end of 30 d storage period, the higher pH value was obtained in the GR1 group which was similar to HT5 (P<0.05). In the samples stored under anaerobic conditions, the lowest pH was determined in the group containing 25 ppm nitrite (N25), whereas the highest pH were determined in the groups of GR5 and GR10at the beginning of storage (P<0.05). There are no generally significant changes in pH values during storage in anaerobic conditions. At the end of the storage, the highest pH value was determined in group of HT10, whereas the lowest pH value was determined in group with

BHT (P<0.05). In the groups stored under anaerobic condition, the pH values of the samples containing HT concentrates were higher than the pH values of the samples containing GR concentrates (P<0.05). pH values were increased at increasing HT concentrate ratios in anaerobic storage conditions (P<0.05). Tengilimoglu-Metin et al. (2017) noted that the addition of the HT extract in beef and chicken breast meat had caused significant increase on pH values.

Table 3. Results of pH values of treatments stored under aerobic condition

	Storage time (Day)				
Groups	0	5	10	15	30
Control	5.75^{bcd}±0.01	5.76^{bcd}±0.02	5.78^{bcd}±0.01	5.70^{bcd}±0.03	5.61^{cd}±0.04
BHT	5.72^{bcd}±0.02	5.87^{abc}±0.01	5.82^{a-d}±0.02	5.81^{a-d}±0.01	5.59^{cd}±0.01
N156	5.70^{bcd}±0.01	5.76^{bcd}±0.01	5.74^{bcd}±0.03	5.83^{a-d}±0.01	5.71^{bcd}±0.01
N100	5.73^{bcd}±0.01	5.79^{a-d}±0.01	5.79^{a-d}±0.01	5.80^{a-d}±0.01	5.75^{bcd}±0.01
N50	5.71^{bcd}±0.01	5.81^{a-d}±0.02	5.78^{bcd}±0.01	5.83^{a-d}±0.01	5.76^{bcd}±0.01
N25	5.75^{bcd}±0.01	5.82^{a-d}±0.01	5.77^{bcd}±0.02	5.80^{a-d}±0.01	5.72^{bcd}±0.01
HT1	5.77^{bcd}±0.03	5.84^{a-d}±0.02	5.76^{bcd}±0.01	5.72^{bcd}±0.01	5.60^{cd}±0.01
HT5	5.67^{bcd}±0.01	5.75^{bcd}±0.01	5.75^{bcd}±0.01	5.83^{a-d}±0.01	5.81^{a-d}±0.01
HT10	5.87^{abc}±0.02	5.94^{ab}±0.02	5.73^{bcd}±0.02	5.72^{bcd}±0.03	5.71^{bcd}±0.02
GR1	5.82^{a-d}±0.05	5.79^{a-d}±0.01	5.73^{bcd}±0.02	5.74^{bcd}±0.02	5.98^{a}±0.05
GR5	5.88^{abc}±0.03	5.77^{bcd}±0.01	5.72^{bcd}±0.01	5.68^{bcd}±0.01	5.61^{cd}±0.02
GR10	5.72^{bcd}±0.04	5.89^{abc}±0.02	5.81^{a-d}±0.01	5.70^{bcd}±0.02	5.54^{d}±0.01

Means ± standard deviation (SD)
$^{a-d}$Within a table, values superscripted with different letters are significantly different (P<0.05)

Table 4. Results of pH values of treatments stored under anaerobic condition

	Storage time (Day)				
Groups	0	5	10	15	30
Control	5.70^{stu}±0.01	5.77^{l-s}±0.01	5.72^{q-u}±0.01	5.83^{e-l}±0.01	5.72^{q-u}±0.01
BHT	5.72^{q-u}±0.02	5.77^{k-r}±0.01	5.75^{n-t}±0.01	5.78^{j-r}±0.01	5.68^{tu}±0.01
N156	5.77^{k-r}±0.01	5.76^{l-s}±0.02	5.76^{m-s}±0.01	5.81^{g-n}±0.01	5.84^{e-k}±0.01
N100	5.74^{n-t}±0.01	5.81^{g-n}±0.01	5.98^{ab}±0.01	5.99^{a}±0.04	5.75^{m-s}±0.01
N50	5.73^{p-u}±0.01	5.86^{d-h}±0.01	5.89^{cde}±0.01	5.86^{d-h}±0.01	5.74^{n-t}±0.01
N25	5.67^{u}±0.02	5.80^{h-o}±0.02	5.86^{d-i}±0.01	5.81^{g-n}±0.01	5.75^{m-s}±0.02
HT1	5.76^{l-s}±0.01	5.83^{e-l}±0.01	5.81^{g-n}±0.01	5.76^{l-s}±0.02	5.71^{r-u}±0.02
HT5	5.81^{g-n}±0.01	5.87^{c-g}±0.01	5.83^{e-l}±0.02	5.87^{c-h}±0.01	5.80^{h-o}±0.01
HT10	5.72^{q-u}±0.03	5.92^{bcd}±0.01	5.84^{e-k}±0.01	5.89^{cde}±0.01	5.93^{abc}±0.01
GR1	5.78^{j-q}±0.03	5.79^{i-p}±0.02	5.75^{n-t}±0.06	5.74^{o-t}±0.01	5.75^{n-t}±0.01
GR5	5.88^{c-f}±0.01	5.83^{e-l}±0.01	5.82^{f-m}±0.01	5.70^{stu}±0.02	5.80^{h-o}±0.01
GR10	5.87^{c-g}±0.01	5.84^{e-t}±0.01	5.74^{n-t}±0.06	5.78^{j-q}±0.01	5.77^{k-r}±0.01

Means ± standard deviation (SD)
$^{a-u}$Within a table, values superscripted with different letters are significantly different (P<0.05)

The changes in TBARS values of treatments stored under aerobic and anaerobic conditions are shown in Table 5 and Table 6, respectively. There was no significant difference between the TBARS values of all treatment groups in both storage conditions at the beginning of storage. There was a gradual increase in TBARS values in all treatment groups stored under aerobic and anaerobic conditions during storage (P<0.05). In the samples stored under aerobic conditions, the higher (P<0.05) TBARS levels were determined in control, HT1 and GR1 groups compared to other treatment groups during first 15 days of storage. Similar results were reported by Akcan et al. (2017). Researchers pointed out that the highest TBARS values were obtained in the control group during storage period. On the 10thand 15thdays of storage, the lowest TBARS values were determined in N156, N100, HT10 and GR10 groups (P<0.05). The highest TBARS values were obtained in the control and GR1 groups on the last day of storage under aerobic conditions (P<0.05). The lowest TBARS values were also determined in HT10 and N156 groups (P<0.05). TBARS values obtained from

both HT10 and GR10 groups were lower than TBARS values of BHT group in the samples stored under aerobic conditions at the end of the storage (P<0.05).

Table 5. Results of TBARS values of treatment groups stored under aerobic condition

	Storage time (Day)				
Groups	0	5	10	15	30
Control	1.12^{vw}±0.07	6.13^{m-s}±0.52	13.55^{efg}±1.07	21.36^{b}±1.98	28.66^{a}±0.74
BHT	1.05^{vw}±0.03	2.59^{t-w}±0.48	7.18^{k-p}±0.68	9.98^{h-l}±0.70	16.26^{cde}±0.88
N156	1.15^{vw}±0.16	2.23^{t-w}±0.16	3.20^{s-w}±0.10	5.64^{n-t}±0.38	6.40^{m-s}±0.14
N100	0.98^{w}±0.21	3.01^{s-w}±0.50	3.94^{o-w}±0.09	5.65^{n-t}±0.11	7.24^{k-p}±0.54
N50	0.78^{w}±0.21	4.29^{o-w}±0.69	4.53^{o-v}±0.71	7.22^{k-p}±0.14	8.70^{j-n}±0.03
N25	1.44^{vw}±0.32	4.11^{o-w}±0.33	5.56^{n-t}±0.59	9.24^{j-m}±0.72	9.34^{i-m}±0.34
HT1	1.12^{vw}±0.21	6.97^{k-q}±0.56	9.63^{i-m}±0.16	17.99^{bcd}±1.55	15.03^{def}±1.86
HT5	1.28^{vw}±0.17	4.21^{o-w}±0.09	6.46^{l-s}±0.53	11.84^{f-j}±0.05	12.83^{e-i}±0.33
HT10	1.37^{vw}±0.45	1.40^{vw}±0.26	2.25^{t-w}±0.24	3.71^{p-w}±0.54	5.12^{o-u}±0.85
GR1	1.64^{uvw}±0.39	6.74^{k-r}±0.73	13.23^{e-h}±1.02	19.72^{bc}±1.18	27.00^{a}±0.45
GR5	1.18^{vw}±0.02	3.42^{r-w}±0.26	8.80^{j-n}±0.88	11.49^{g-j}±1.25	19.35^{bc}±0.52
GR10	0.88^{w}±0.14	1.56^{vw}±0.19	3.55^{q-w}±0.72	7.33^{k-o}±0.61	9.99^{h-k}±0.25

Means ± standard deviation (SD)
[a-w]Within a table. values superscripted with different letters are significantly different (P<0.05)

Table 6. Results of TBARS values of treatment groups stored under anaerobic condition

	Storage time (Day)				
Groups	0	5	10	15	30
Control	1.54^{p-x}±0.31	3.06^{j-u}±0.64	6.42^{c-f}±0.90	8.92^{b}±1.02	12.38^{a}±0.73
BHT	1.01^{t-x}±0.22	2.01^{m-x}±0.02	3.49^{j-r}±0.10	3.99^{g-n}±0.49	5.73^{d-i}±0.30
N156	1.12^{s-x}±0.35	0.73^{wx}±0.07	0.90^{u-x}±0.10	1.55^{p-x}±0.02	2.32^{l-x}±0.44
N100	0.83^{v-x}±0.21	0.85^{v-x}±0.11	1.04^{t-x}±0.36	2.15^{l-x}±0.35	2.86^{k-w}±0.27
N50	0.99^{t-x}±0.16	1.89^{n-x}±0.43	1.88^{n-x}±0.45	2.63^{k-w}±0.13	3.58^{i-q}±0.28
N25	1.15^{s-x}±0.03	1.73^{o-x}±0.14	2.94^{j-v}±0.42	3.67^{h-p}±0.06	3.83^{h-o}±0.33
HT1	0.88^{u-x}±0.00	2.09^{l-x}±0.26	5.08^{e-j}±0.63	7.48^{bcd}±0.44	8.61^{bc}±0.58
HT5	1.44^{q-x}±0.00	1.53^{p-x}±0.23	4.14^{g-m}±0.26	3.69^{h-p}±0.21	5.86^{d-h}±0.69
HT10	0.71^{wx}±0.17	1.60^{p-x}±0.02	3.05^{j-u}±0.47	3.10^{j-t}±0.43	3.15^{j-t}±0.04
GR1	1.42^{q-x}±0.00	2.83^{k-w}±0.14	4.60^{f-k}±0.29	6.95^{b-e}±0.86	8.41^{bc}±0.34
GR5	1.23^{s-x}±0.19	2.00^{m-x}±0.32	3.31^{j-s}±0.33	4.27^{e-l}±0.36	6.04^{d-g}±1.00
GR10	0.42^{x}±0.11	1.37^{r-x}±0.28	2.96^{j-v}±0.24	4.24^{f-l}±0.35	4.17^{g-m}±0.01

Means ± standard deviation (SD)
[a-x]Within a table values superscripted with different letters are significantly different (P<0.05)

Similarly, Pabuc et al. (2018) indicated the addition of HT berry ethanolic extract into minced pork meat was more effective than BHA in reducing lipid oxidation. Additionally, Keser et al. (2012) pointed out that the water and ethanolic extracts of HT showed powerful total antioxidant activities when compared to BHA and α-tocopherol. Levent et al. (2008) reported that GR extracts showed better antioxidant effect than BHT. In another study, it was reported that procyanidins obtained from HT fruit showed antioxidant activity at the similar level as trolox and BHT (Soko´ł-Łe¸towska et al., 2007). In present study, the addition of GR and HT concentrate (except for HT1 group) reduced the TBARS levels and this effect was further enhanced with increasing GR and HT concentrate levels (P<0.05). Akcan et al. (2017) indicated that the adding HT extract into the pork burger patties decreased the TBARS values. Additionally, researchers pointed out that increasing the amount of HT extract added was further reduced the TBARS values. Şeker et al. (2016) stated that the radical-scavenging activity levels of cake samples increased proportionally with the ratio of GR pomace incorporation. Additionally, HT10 group showed similar TBARS values

with N156 and N100 groups, and lower TBARS values than N50 and N25 groups (P<0.05). In the samples stored under anaerobic condition during the storage period the highest (P<0.05) TBARS values were determined in the control. In the first 15 days period of storage the lowest (P<0.05) TBARS values were determined in the group containing 156 ppm nitrite. According to the TBARS measurements performed at the end of the storage. the lowest (P<0.05) TBARS values were determined in N156, N100 and HT10 groups. Whereas there was no significant difference between TBARS values of HT and GR groups in the first 10 days of storage, it was determined that TBARS values decreased at increasing levels of HT and GR concentrates on the 15^{th} and 30^{th} days of storage stored under anaerobic condition (P<0.05). At the end of the storage, HT10 group had lower TBARS values than BHT containing group (P<0.05). Similar results were reported by Ganhão et al. (2010b) for the raw pork burger patties. Researchers noted that HT fruits exhibited strong antioxidant activity against lipid oxidation. In addition, Shortle et al. (2014) indicated the HT extracts significantly decreased the level of lipid oxidation in bovine muscle homogenates. The TBARS values of samples stored in aerobic conditions were higher than those of stored in anaerobic conditions (P<0.05). It is reported that the moleculer oxygen is a pro-oxidative factor which accelerates the oxidation of lipids in many studies (Min and Ahn. 2005; Kang et al., 2014; Ahmed et al., 2016).

The CIE color results (data is not presented) demonstrated the highest L* values were determined in GR1 (76.74±0.64) and GR5 (76.88±0.64) groups in aerobic storage conditions (P<0.05). The lowest L* values (P<0.05) in the samples stored under the same conditions were obtained in N100 (72.52±0.64) groups. No significant differences were found between the L* values of HT and GR groups in both storage conditions. Ganhão et al. (2010a) reported that the addition of HT extracts in cooked pork burger patties had no effect on L* values. In present study, a significant decrease and increase (P<0.05)in L* values was determined on the 5^{th}(72.42±0.41) and 10^{th}(75.60±0.41)day of aerobic storage, respectively. No significant changes were determined after the 10^{th} day of storage. In the groups stored under anaerobic conditions, the highest (P<0.05) L* values were determined in HT1 (74.77±0.79) and HT5 (74.83±0.79) groups. The lowest L* values (P<0.05) were determined in BHT (70.77±0.79) containing groups. Whereas a significant decrease in L* values were observed on the 5^{th} day of anaerobic storage, no significant changes were observed during anaerobic storage after the 5^{th} day of storage. In the samples stored under aerobic condition, whereas the highest a* value was determined in GR10 (7.96±0.17) group, and the lowest a* values were determined in control (1.74±0.17) and HT1 (2.01±0.17) groups (P<0.05). The a* values of the N156 (7.08±0.17) and N100 (6.45±0.17) groups were lower than those obtained from the GR10 (7.96±0.17) group but they had higher a* values than all the other experimental groups (P<0.05).The addition of GR increased a* values more than the addition of HT in both storage conditions (P<0.05). The addition of GR increased a* values and this effect was further increased at increasing GR ratios in both storage conditions (P<0.05). Similar effect was not determined in groups with HT. GR fruit flesh and skin have a dark-red color, therefore it caused to increase the redness values of cooked turkey meat (Levent et al., 2008; Özrenk et al., 2011). No significant differences were found between the a* values of N50 (4.91±0.17), N25 (4.50±0.17) and GR5 (4.93±0.17) groups in aerobic storage condition. In addition, a* values of HT10 (3.08±0.17) and HT5 (2.50±0.17) groups were determined to be higher (P<0.05) than the control (1.71±0.17). Similarly, Ganhão et al. (2010b) reported that significantly higher a* values in raw pork patties containing HT berry extracts compared to control group, on day 12 of aerobic storage. Additionally, researchers claimed that the protecting the colour characteristics of HT berry extracts in raw pork meat were as a result of the inhibition of lipid oxidation (Ganhão et al.. 2010b). In general, it was determined that there was a decrease (P<0.05) in a* values with storage in both storage conditions. Similarly, it has been reported to decrease in a* values during storage (Ganhão et al. 2010b). In the groups stored under anaerobic condition, whereas the highest

a* value was determined in GR10 (9.50±0.17) group, the lowest a* values were determined in control (2.27±0.17) and BHT (1.69±0.17) groups (P<0.05). The highest a* value among the groups containing nitrite was determined in the N156 (7.69±0.17) group, whereas the lowest a* value was determined in the N25 (5.48±0.17) group in anaerobic storage condition (P<0.05). The GR10 group was higher a* values than all nitrite containing groups(P<0.05).It was found that GR5 (5.96±0.17) group had a* values similar to all nitrite containing groups except N156 (7.69±0.17) group. In both storage conditions the highest (P<0.05) b* values were determined in the HT10 group, whereas the lowest(P<0.05) b* values were also determined in all nitrite containing groups. The b* values obtained from HT10 and HT5 groups were higher (P<0.05) than the groups containing GR or nitrite. The use of HT in cooked turkey meat increased b* values and this increase was also increased with increasing HT concentrate levels in both storage conditions (P<0.05). In the samples with GR. a similar relationship was found between the samples containing only 1% and 10% GR concentrates (P<0.05). No significant differences were found between b* values of nitrite containing groups in both storage conditions. b* values of treatments stored under aerobic conditions increased (P<0.05) at 5th days of storage, whereas no significant changes were observed in the b* values of the treatments stored under anaerobic conditions during storage. In addition, L* and b* values of treatments stored in aerobic conditions were higher, whereas a* values were lower than compared to the treatments stored under anaerobic conditions (P<0.05).

The results of texture profile analysis of treatment groups stored under aerobic and anaerobic conditions are presented in Table 7 and Table 8, respectively. The results of TPA demonstrated the use of nitrite, BHT, HT and GR in cooked turkey meat did not cause a significant changes in the values of chewiness, springiness and adhesiveness in the samples stored under aerobic storage conditions. In addition, no significant differences were found between resilience, cohesiveness, springiness, gumminess, chewiness and adhesiveness values of all treatment groups stored under anaerobic storage conditions. There was no significant difference between the groups stored under anaerobic conditions in terms of hardness values at the beginning of storage. There were no changes in hardness values of all treatment groups stored under anaerobic conditions during storage. At the end of the anaerobic storage, hardness value of N156 group was found to be higher than the value of HT5 group (P<0.05). In the samples stored under aerobic condition, whereas the highest resilience value was determined in GR5 group, the lowest resilience value was determined in N100 group at the beginning of storage (P<0.05). There were no significant changes in resilience and cohesiveness (except for control and GR5 groups) and hardness (except forGR5 group) values in all treatment groups during storage in aerobic storage conditions. Ganhão et al. (2010a) stated that the hardness and chewiness values increased in burger patties containing HT extracts during the 12 days of storage. In present study, on the 15th day of storage, there was a significant decrease in resilience and cohesiveness values of control and GR5 groups, and significant increase in hardness value of GR5 group (P<0.05). Ganhão et al. (2010a) reported the addition of HT extracts significantly increased the hardness of cooked burger patties. The highest hardness value was determined in BHT group, whereas the lowest hardness value was determined in GR5 group at the beginning of aerobic storage (P<0.05). At the end of the aerobic storage, the N156 group was higher hardness value than those of HT10 group (P<0.05). Furthermore, at the beginning of aerobic storage, the highest gumminess value was determined in HT5 group, whereas the lowest gumminess values were determined in GR5 and GR10 groups (P<0.05). There were no significant differences between the groups in terms of both gumminess and cohesiveness values at the end of the aerobic storage.

Table 7. Results of Texture Profile Analysis of treatment groups stored under aerobic condition at 30 days storage

	Hardness (N)			Adhesiveness (mJ)			Resilience			Cohesiveness		
Groups	0	15	30	0	15	30	0	15	30	0	15	30
Control	2.38^{de} ±0.19	4.02^{a-d} ±0.00	3.65^{a-e} ±0.69	1.31^{a} ±0.07	0.75^{a} ±0.21	1.10^{a} ±0.21	0.23^{ab} ±0.02	0.06^{d} ±0.01	0.08^{cd} ±0.02	0.81^{a} ±0.12	0.47^{cde} ±0.01	0.45^{cde} ±0.08
BHT	4.54^{abc} ±0.01	3.88^{a-e} ±0.81	4.22^{a-d} ±0.86	0.45^{a} ±0.07	1.00^{a} ±0.14	1.10^{a} ±0.17	0.11^{cd} ±0.01	0.06^{d} ±0.01	0.08^{cd} ±0.03	0.54^{b-e} ±0.08	0.43^{de} ±0.03	0.49^{b-e} ±0.07
N156	3.87^{a-e} ±0.16	3.49^{a-e} ±0.32	4.92^{a} ±0.32	0.65^{a} ±0.11	1.15^{a} ±0.21	1.25^{a} ±0.21	0.09^{cd} ±0.02	0.07^{d} ±0.01	0.07^{cd} ±0.00	0.49^{b-e} ±0.01	0.47^{cde} ±0.02	0.47^{cde} ±0.01
N100	4.05^{a-d} ±0.21	3.80^{a-e} ±0.37	4.62^{abc} ±0.35	0.95^{a} ±0.07	0.80^{a} ±0.00	1.35^{a} ±0.24	0.05^{d} ±0.00	0.07^{d} ±0.01	0.10^{cd} ±0.01	0.41^{e} ±0.03	0.42^{de} ±0.00	0.49^{b-e} ±0.01
N50	3.00^{a-e} ±0.25	4.33^{a-d} ±0.49	4.19^{a-d} ±0.10	0.40^{a} ±0.12	1.15^{a} ±0.07	1.10^{a} ±0.00	0.16^{bc} ±0.03	0.08^{cd} ±0.02	0.09^{cd} ±0.01	0.64^{a-d} ±0.04	0.46^{c-e} ±0.08	0.46^{c-e} ±0.05
N25	3.03^{a-e} ±0.01	3.61^{a-e} ±0.00	4.17^{a-d} ±0.62	0.15^{a} ±0.07	0.40^{a} ±0.00	1.05^{a} ±0.07	0.13^{cd} ±0.04	0.09^{cd} ±0.00	0.09^{cd} ±0.01	0.55^{b-e} ±0.10	0.56^{b-e} ±0.00	0.51^{b-e} ±0.05
HT1	3.72^{a-e} ±0.62	4.32^{a-d} ±0.22	4.56^{abc} ±0.01	1.30^{a} ±0.11	1.00^{a} ±0.00	0.95^{a} ±0.07	0.11^{cd} ±0.03	0.07^{d} ±0.02	0.10^{cd} ±0.01	0.53^{b-e} ±0.02	0.48^{b-e} ±0.01	0.47^{cde} ±0.03
HT5	4.45^{abc} ±0.56	3.77^{a-e} ±0.64	4.13^{a-d} ±0.04	0.35^{a} ±0.01	1.90^{a} ±0.14	1.40^{a} ±0.14	0.12^{cd} ±0.01	0.06^{d} ±0.01	0.07^{cd} ±0.03	0.60^{a-e} ±0.01	0.43^{de} ±0.08	0.45^{cde} ±0.06
HT10	3.45^{a-e} ±0.37	4.21^{a-d} ±0.18	2.87^{b-e} ±0.19	0.45^{a} ±0.09	1.20^{a} ±0.14	0.90^{a} ±0.18	0.12^{cd} ±0.02	0.08^{cd} ±0.03	0.06^{d} ±0.01	0.49^{b-e} ±0.08	0.43^{de} ±0.02	0.44^{cde} ±0.01
GR1	3.94^{a-d} ±0.78	4.77^{ab} ±0.33	4.51^{abc} ±0.37	0.75^{a} ±0.21	1.30^{a} ±0.14	1.10^{a} ±0.28	0.08^{cd} ±0.01	0.08^{cd} ±0.00	0.06^{d} ±0.01	0.66^{abc} ±0.08	0.48^{b-e} ±0.02	0.46^{c-e} ±0.01
GR5	1.93^{e} ±0.25	4.16^{a-d} ±0.20	4.14^{a-d} ±0.03	0.20^{a} ±0.04	1.45^{a} ±0.21	1.30^{a} ±0.14	0.27^{a} ±0.00	0.08^{cd} ±0.03	0.07^{d} ±0.02	0.70^{ab} ±0.01	0.55^{b-e} ±0.06	0.42^{de} ±0.05
GR10	2.79^{cde} ±0.16	3.08^{a-e} ±0.58	3.13^{a-e} ±0.04	0.25^{a} ±0.01	0.85^{a} ±0.14	0.85^{a} ±0.04	0.09^{cd} ±0.01	0.09^{cd} ±0.03	0.09^{cd} ±0.01	0.46^{cde} ±0.00	0.50^{b-e} ±0.11	0.47^{cde} ±0.04

	Springiness			Gumminess (N)			Chewiness (N)		
	0	15	30	0	15	30	0	15	30
Control	0.90^{a} ±0.11	0.91^{a} ±0.07	1.49^{a} ±0.21	1.92^{abc} ±0.44	1.90^{abc} ±0.05	1.61^{abc} ±0.03	1.74^{a} ±0.39	1.73^{a} ±0.18	2.41^{a} ±0.34
BHT	1.00^{a} ±0.20	0.91^{a} ±0.00	0.92^{a} ±0.02	2.45^{ab} ±0.41	1.66^{abc} ±0.25	2.02^{abc} ±0.11	2.49^{a} ±0.51	1.52^{a} ±0.23	1.85^{a} ±0.06
N156	0.87^{a} ±0.04	0.88^{a} ±0.04	0.93^{a} ±0.01	1.88^{abc} ±0.11	1.61^{abc} ±0.07	2.32^{abc} ±0.08	1.63^{a} ±0.17	1.42^{a} ±0.13	2.16^{a} ±0.05
N100	0.87^{a} ±0.01	1.65^{a} ±0.05	0.91^{a} ±0.02	1.66^{abc} ±0.04	1.59^{abc} ±0.14	2.27^{abc} ±0.09	1.44^{a} 0.01	2.70^{a} ±0.91	2.06^{a} ±0.13
N50	0.84^{a} ±0.01	1.68^{a} ±0.11	0.87^{a} ±0.01	1.91^{abc} ±0.26	1.96^{abc} ±0.09	1.91^{abc} ±0.25	1.60^{a} ±0.18	3.22^{a} ±0.71	1.66^{a} ±0.18
N25	0.78^{a} ±0.04	0.94^{a} ±0.00	0.88^{a} ±0.04	1.67^{abc} ±0.30	2.02^{abc} ±0.00	2.13^{abc} ±0.50	1.29^{a} ±0.18	1.90^{a} ±0.00	1.88^{a} ±0.22
HT1	0.85^{a} ±0.01	0.93^{a} ±0.01	0.89^{a} ±0.04	1.96^{abc} ±0.25	2.05^{abc} ±0.16	2.15^{abc} ±0.14	1.66^{a} ±0.23	1.91^{a} ±0.12	1.91^{a} ±0.03
HT5	0.90^{a} ±0.06	0.87^{a} ±0.06	0.92^{a} ±0.01	2.69^{a} ±0.48	1.60^{abc} ±0.03	1.87^{abc} ±0.25	2.44^{a} ±0.15	1.39^{a} ±0.13	1.72^{a} ±0.21
HT10	0.86^{a} ±0.01	0.91^{a} ±0.02	0.90^{a} ±0.01	1.70^{abc} ±0.47	1.79^{abc} ±0.14	1.25^{c} ±0.11	1.46^{a} ±0.39	1.62^{a} ±0.09	1.12^{a} ±0.11
GR1	0.96^{a} ±0.10	0.92^{a} ±0.04	0.91^{a} ±0.01	2.55^{ab} ±0.18	2.27^{abc} ±0.06	2.05^{abc} ±0.14	2.44^{a} ±0.08	2.08^{a} ±0.02	1.87^{a} ±0.11
GR5	0.79^{a} ±0.01	0.96^{a} ±0.04	0.90^{a} ±0.01	1.34^{c} ±0.20	2.28^{abc} ±0.12	1.72^{abc} ±0.17	1.06^{a} ±0.13	2.18^{a} ±0.19	1.54^{a} ±0.14
GR10	0.80^{a} ±0.01	0.88^{a} ±0.08	0.87^{a} ±0.01	1.28^{c} ±0.06	1.51^{bc} ±0.06	1.47^{bc} ±0.12	1.02^{a} ±0.06	1.32^{a} ±0.07	1.27^{a} ±0.11

Means ± standard deviation (SD)

[a-h]Values superscripted with different letters for each textural property are significantly different ($P<0.05$)

Table 8. Results of Texture Profile Analysis of treatment groups stored under anaerobic condition at 30 days storage

	Hardness (N)			Adhesiveness (mJ)			Resilience			Cohesiveness		
Groups	0	15	30	0	15	30	0	15	30	0	15	30
Control	2.54^{h} ±0.37	4.61^{a-h} ±0.39	5.20^{a-g} ±0.08	0.15^{b} ±0.01	1.55^{ab} ±0.21	1.30^{ab} ±0.25	0.15^{a} ±0.01	0.06^{a} ±0.00	0.09^{a} ±0.02	0.76^{a} ±0.04	0.49^{a} ±0.01	0.52^{a} ±0.04
BHT	4.19^{a-h} ±0.34	5.45^{a-f} ±0.17	5.25^{a-f} ±0.04	0.65^{ab} ±0.07	0.95^{ab} ±0.29	1.45^{ab} ±0.28	0.13^{a} ±0.01	0.12^{a} ±0.05	0.08^{a} ±0.04	0.59^{a} ±0.05	0.56^{a} ±0.12	0.47^{a} ±0.08
N156	4.40^{a-h} ±0.28	5.76^{a-d} ±0.49	6.22^{a} ±0.22	0.55^{ab} ±0.21	1.90^{ab} ±0.14	2.65^{a} ±0.35	0.11^{a} ±0.01	0.07^{a} ±0.02	0.06^{a} ±0.00	0.50^{a} ±0.02	0.54^{a} ±0.05	0.43^{a} ±0.01
N100	4.19^{a-h} ±0.29	5.68^{a-d} ±0.12	6.01^{ab} ±0.01	0.95^{ab} ±0.07	1.05^{ab} ±0.28	0.95^{ab} ±0.35	0.08^{a} ±0.01	0.11^{a} ±0.06	0.10^{a} ±0.04	0.50^{a} ±0.07	0.51^{a} ±0.08	0.51^{a} ±0.08
N50	4.48^{a-h} ±0.54	3.99^{a-h} ±0.01	4.42^{a-h} ±0.25	0.60^{ab} ±0.14	1.25^{ab} ±0.35	1.10^{ab} ±0.14	0.13^{a} ±0.01	0.07^{a} ±0.01	0.07^{a} ±0.03	0.56^{a} ±0.07	0.49^{a} ±0.07	0.45^{a} ±0.08
N25	4.14^{a-h} ±0.03	5.80^{abc} ±0.30	5.55^{a-e} ±0.03	0.55^{ab} ±0.11	2.65^{a} ±0.07	1.10^{ab} ±0.25	0.13^{a} ±0.03	0.09^{a} ±0.01	0.09^{a} ±0.05	0.62^{a} ±0.08	0.55^{a} ±0.01	0.49^{a} ±0.05
HT1	4.01^{a-h} ±0.29	3.98^{a-h} ±0.08	4.51^{a-h} ±0.47	1.05^{ab} ±0.24	1.70^{ab} ±0.28	1.60^{ab} ±0.37	0.13^{a} ±0.02	0.06^{a} ±0.01	0.06^{a} ±0.02	0.46^{a} ±0.03	0.79^{a} ±0.12	0.41^{a} ±0.04
HT5	3.51^{c-h} ±0.41	3.26^{e-h} ±0.13	3.79^{b-h} ±0.30	0.45^{ab} ±0.07	0.85^{ab} ±0.07	1.25^{ab} ±0.07	0.11^{a} ±0.02	0.08^{a} ±0.01	0.06^{a} ±0.02	0.53^{a} ±0.04	0.50^{a} ±0.05	0.46^{a} ±0.01
HT10	3.44^{d-h} ±0.01	3.14^{fgh} ±0.22	3.83^{b-h} ±0.16	0.45^{ab} ±0.11	0.90^{ab} ±0.17	1.75^{ab} ±0.49	0.09^{a} ±0.01	0.11^{a} ±0.01	0.07^{a} ±0.02	0.54^{a} ±0.01	0.59^{a} ±0.08	0.56^{a} ±0.16
GR1	5.32^{a-f} ±0.54	5.17^{a-g} ±0.74	5.83^{abc} ±0.47	1.50^{ab} ±0.28	1.60^{ab} ±0.42	1.40^{ab} ±0.14	0.06^{a} ±0.01	0.08^{a} ±0.01	0.08^{a} ±0.01	0.52^{a} ±0.08	0.48^{a} ±0.01	0.49^{a} ±0.06
GR5	3.16^{fgh} ±0.50	5.13^{a-g} ±0.45	4.81^{a-h} ±0.70	0.10^{b} ±0.14	1.25^{ab} ±0.07	1.30^{ab} ±0.42	0.14^{a} ±0.04	0.10^{a} ±0.00	0.09^{a} ±0.02	0.55^{a} ±0.04	0.51^{a} ±0.01	0.50^{a} ±0.04
GR10	2.89^{gh} ±0.50	5.05^{a-g} ±0.68	4.08^{a-h} ±0.11	0.50^{ab} ±0.14	1.95^{ab} ±0.33	1.35^{ab} ±0.07	0.10^{a} ±0.01	0.11^{a} ±0.02	0.06^{a} ±0.01	0.50^{a} ±0.00	0.59^{a} ±0.13	0.47^{a} ±0.14

	Springiness			Gumminess (N)			Chewiness (N)		
	0	15	30	0	15	30	0	15	30
Control	0.85^{a} ±0.01	0.90^{a} ±0.06	0.92^{a} ±0.00	1.92^{a} ±0.19	2.24^{a} ±0.25	2.67^{a} ±0.21	1.62^{a} ±0.14	2.01^{a} ±0.10	2.46^{a} ±0.19
BHT	0.90^{a} ±0.06	0.91^{a} ±0.06	0.90^{a} ±0.01	2.45^{a} ±0.11	3.03^{a} ±0.32	2.46^{a} ±0.43	2.19^{a} ±0.06	2.72^{a} ±0.46	2.21^{a} ±0.36
N156	0.89^{a} ±0.01	0.94^{a} ±0.03	0.94^{a} ±0.02	2.18^{a} ±0.23	3.08^{a} ±0.04	2.69^{a} ±0.21	1.92^{a} ±0.18	2.90^{a} ±0.12	2.52^{a} ±0.25
N100	1.50^{a} ±0.22	0.90^{a} ±0.01	1.29^{a} ±0.40	2.12^{a} ±0.43	2.92^{a} ±0.05	3.04^{a} ±0.50	3.35^{a} ±0.38	2.62^{a} ±0.91	4.03^{a} ±0.17
N50	0.84^{a} ±0.04	0.94^{a} ±0.04	0.87^{a} ±0.01	2.49^{a} ±0.02	1.95^{a} ±0.28	2.00^{a} ±0.47	2.09^{a} ±0.09	1.83^{a} ±0.33	1.75^{a} ±0.43
N25	0.87^{a} ±0.02	0.97^{a} ±0.01	0.91^{a} ±0.02	2.57^{a} ±0.36	3.06^{a} ±0.06	2.70^{a} ±0.28	2.22^{a} ±0.37	3.01^{a} ±0.04	2.44^{a} ±0.20
HT1	0.86^{a} ±0.01	1.00^{a} ±0.10	0.85^{a} ±0.06	1.85^{a} ±0.57	3.10^{a} ±0.58	1.81^{a} ±0.02	1.59^{a} ±0.46	3.18^{a} ±0.89	1.54^{a} ±0.12
HT5	0.89^{a} ±0.03	0.90^{a} ±0.01	1.18^{a} ±0.33	1.87^{a} ±0.48	1.60^{a} ±0.23	1.75^{a} ±0.08	1.67^{a} ±0.37	1.44^{a} ±0.18	2.07^{a} ±0.26
HT10	0.83^{a} ±0.05	0.90^{a} ±0.02	0.92^{a} ±0.04	1.84^{a} ±0.03	1.79^{a} ±0.44	2.13^{a} ±0.51	1.52^{a} ±0.11	1.60^{a} ±0.35	1.96^{a} ±0.32
GR1	0.96^{a} ±0.00	0.96^{a} ±0.04	0.94^{a} ±0.04	2.71^{a} ±0.02	2.45a ±0.29	2.86^{a} ±0.08	2.60^{a} ±0.03	2.34^{a} ±0.19	2.68^{a} ±0.18
GR5	0.79^{a} ±0.04	0.90^{a} ±0.05	0.91^{a} ±0.01	1.72^{a} ±0.13	2.60^{a} ±0.28	2.39^{a} ±0.52	1.36^{a} ±0.18	2.33^{a} ±0.38	2.17^{a} ±0.45
GR10	0.87^{a} ±0.01	0.92^{a} ±0.06	0.90^{a} ±0.02	1.45^{a} ±0.25	2.86^{a} ±0.33	1.92^{a} ±0.51	1.25^{a} ±0.23	2.61^{a} ±0.12	1.72^{a} ±0.42

Means ± standard deviation (SD)

[a-h]Values superscripted with different letters for each textural property are significantly different ($P<0.05$)

CONCLUSIONS

Results of the present study indicated that the addition of the GR or HT concentrates to ground turkey meat effectively delayed the reactions of lipid oxidation. The pH, color and textural properties of cooked ground turkey meat were not negatively affected by the use of GR or HT concentrates.

Overall results suggested that the use of GR or HT concentrates (especially 10%) to reduce lipid oxidation and the amount of added nitrite in poultry meat products can be an effective strategy for improving the color properties and shelf-life of poultry meat.

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