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Araştırma/ *Research*

THE EFFECTS of VACUUM TUMBLING COMBINED with SODIUM TRIPOLYPHOSPHATE on LIPOLYTIC and OXIDATIVE CHANGES in BEEF DÖNER

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Abstract

This study was designed to investigate the effects of vacuum tumbling (intermittent tumbling-IT or continuous tumbling-CT) combined with sodium tripolyphosphate (STPP-0% or 0.25% w/w) on lipolytic and oxidative changes in döner meat during marination and cooking process. The usage of 0.25% STPP decreased formation of free fatty acids and slowed lipid and myoglobin oxidation in raw döner meat within 48 h of marination at 4°C ($P<0.05$). Moreover, STPP was found effective to retard lipid oxidation reactions during cooking process ($P<0.05$). IT caused higher free fatty acids, TBA value and metmyoglobin content when compared to CT and non-tumbled treatments ($P<0.05$). In addition, a positive correlation was determined between lipid and myoglobin oxidation rates (r=0.519; P=0.000). Neither tumbling nor STPP did not differ L^* value ($P>0.05$). However, a significant increase was measured for a^* value after 48 h of marination ($P<0.05$). Besides, both IT and STPP were significantly effective on b^* value ($P<0.05$).

Keywords: Döner, vacuum tumbling, sodium tripolyphosphate, lipid oxidation, myoglobin oxidation

DÖNER ETİNDE TUMBLİNG ve SODYUM TRİPOLİFOSFATIN LİPOLİTİK ve OKSİDATİF DEĞİŞİMLER ÜZERİNE ETKİSİ

Özet

Bu araştırma kapsamında, döner etinin marinasyonu ve pişirilmesi aşamalarında renk ve lipid fraksiyonlarındaki lipolitik ve oksidatif değişimler üzerine kesikli ya da sürekli vakumlu tumbling uygulamasının ve sodyum tripolifosfat (STPF) kullanımının (0.25% w/w) etkisi incelenmiştir. STPF kullanımı 4°C'de marinasyon işlemi süresinde döner etinde serbest yağ asidi oluşumunu azaltmış ve lipid ile myoglobin oksidasyonunu geciktirmiştir ($P<0.05$). Ayrıca STPF pişirme esnasında da lipid oksidasyon reaksiyonlarını engellemiştir ($P<0.05$). Kesikli tamburlanan gruplarda sürekli tamburlama uygulanan ve tamburlama uygulanmayan gruplara kıyasla daha yüksek serbest yağ asidi miktarı, TBA değeri ve myoglobin oksidasyonu belirlenmiştir ($P<0.05$). Ayrıca lipid oksidasyonu ile myoglobin oksidasyonu arasında pozitif bir korelasyon da bulunmuştur (r=0.519; P=0.000). Tamburlama işlemi ve STPF uygulamasının L^* değeri üzerine herhangi bir etkisi belirlenmemiştir ($P>0.05$). a^* değeri 48 saatlik marinasyon sonrasında önemli düzeyde artış göstermiş ($P<0.05$), b^* değeri ise kesikli tamburlama uygulaması ve STPF ilavesinden etkilenmiştir. ($P<0.05$).

Anahtar kelimeler: Döner, vakumlu tumbling, sodium tripolifosfat, lipit oksidasyonu, myoglobin oksidasyonu

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INTRODUCTION

Döner, a traditional Middle East meat product, has been known in many areas of the world with different names such as "gyro", "donair", "dona kebab", "chawarma" and "shawirma". The production process of döner involves 5 steps: [1] Preparation of meats; [2] Marination of meats and holding at 4 °C to increase effectiveness of the process; [3] Preparation of döner meat block; [4] Storage in the freezer or transportation of döner meat block to consumption site; [5] Cooking and serving (1-3). Döner is especially produced from marinated red meat and tallow. Marination is made with a special sauce by using tumbling process (3). Tumbling, a mechanical process, is generally used in restructured meat products to facilitate homogenous diffusion of marination sauce to meat tissue by disrupting muscle cells and loosing actomyosin complex. Although formation of uniform cured color and improvement of sensory properties are some of the benefits of tumbling, the alteration in the muscle structure makes meat more sensitive against to lipid and myoglobin oxidation (3-5).

Lipid oxidation, a crucial reaction to determine the quality and acceptability of meat and meat products, is responsible for the production of carcinogenic compounds and formation of rancid odours and flavours (4). On the other hand, myoglobin oxidation occurs by oxidazing of ferrous heme iron, present in the structure of myoglobin (Mb), to its ferric form, present in the structure of metmyoglobin (MetMb). This reaction causes discoloration that means meat color changes from red to brownish (6). Previous studies have reported that there is a relationship between lipid oxidation and myoglobin oxidation (6-10). Basically, these studies have determined that primary and secondary oxidation products derived from unsaturated fatty acids oxidation could enhance myoglobin oxidation. On the other hand, non-heme and heme iron which are an important mineral for human diet and present in especially red meat at high levels are also the major catalysts for lipid oxidation (6, 11, 12).

In light of these explanations, utilization of some ingredients in the marination sauce to prevent oxidative changes is desired in meat products subjected to tumbling process (4, 5, 13). However, formulation of marination sauce differs according to the producers, phosphates are one of the basic and important ingredients for restructured meat products to enhance cooking yield by increasing water holding capacity of meats. In addition, it retards oxidation reactions by creating chelates with free iron ions and binding some prooxidants (14, 15). In recent twenty years, previous researchers have reported that phosphates are more effective to reduce lipid oxidation when they used with a combination of tumbling (4, 16, 17). From this viewpoint, the aim of the current study was to investigate the effects of vacuum tumbling combined with sodium tripolyphosphate on lipolytic and oxidative changes in lipids of döner meat during marination and cooking process. In addition, the changes in color of raw döner meat during 48 h of marination at 4 °C were also examined.

MATERIALS AND METHODS

Döner Manufacturing

Two year old Holstein beef cattle were slaughtered at Ekinciler Stockfarming in Kazan, Ankara. Carcasses were transfered to the facility, Haz Stockfarming Meat and Food Plant (Ankara), under hygenic conditions and full use of the cold chain. The experiment was carried out in this plant. Deboned meats (1-1.5 kg each) from hindquarter part of the carcass were trimmed of visible fat and connective tissues. Then, they were formed by using regular knife and flattening machine in a processing room (4 °C). Prepared meats were divided into six batches and one batch (approximately 80 kg) was used for each experimental group. The first three batches were marinated with a marination sauce (8 kg (10% w/w) for each batch) without sodium tripolyphosphate (STPP). The remainder three batches were also marinated with a sauce containing STPP. 8 kg of marination sauce was also prepared for each batch by dissolving 200 g (0.25% w/w) of STPP ($Na_5P_3O_{10}$, Merck). The basic ingredients of the marination sauce were milk, yoghurt, onion, olive oil, salt and black pepper. For the following step, two batches (one included STPP and the other one batch without STPP) were subjected to intermittent tumbling (IT) during 30 min (3 min work, 2 min rest) by using temperature controlled tumbler (Vakona W-35, Germany) under vacuum (80%) at 25 rpm and 4°C. The other two treatments were subjected to continuous tumbling (CT) for 20 min under the same tumbling conditions. The remainder two treatments were completely marinated with a sauce by hand and left in the processing room at 4 °C (non-tumbled (NT) groups). Overall, based

on the aim of the study, six different experimental groups were set up as follow: 1) IT+0.25% STPP, 2) CT+0.25% STPP, 3) NT+0.25% STPP, 4) IT+0% STPP, 5) CT+0% STPP, 6) NT+0% STPP. Upon the completion of tumbling, raw döner meats were selected randomly from six treatments and two packages (at least 2.5 kg each) were prepared. They were transported immediately to the Ankara University Meat Science Laboratory within a cooler to conduct initial analysis (0 h). The rest of the meat was kept in the facility for 48 h at 4°C to increase the effectiveness of the marination. At the end of the time, two raw döner meat packages were prepared as described above and transported to the laboratory for analysis at 48 h. After the sampling was completed, the remainder meat was spitted on a döner kebab stick based on the TS 11658 regulations, shaped into a cone (15 kg each) and placed in front of an open gas oven. The distance between döner meat block and oven was 15 cm. At first, the meat block was pre-cooked about 30 min rotating continuously. Then, each side of döner meat block was cooked during 5 min. After 5 min, döner meat block was rotated for cooking the other side while cooked surface was shaved off into approximately 5 mm thickness. The approximate temperature of the slices was 110 °C. Cooked slices were collected into two packages (at least 2.5 kg each) for each treatment. They were also transported to the laboratory to perform analysis. Two replications were carried out for this study in different times. Regarding the aim of the study, thiobarbituric acid (TBA) and free fatty acid (FFA) analysis were conducted in both raw and cooked döner meats to assess lipid oxidation rate. In addition, total heme pigment (THP), heme iron (HI) and methmyoglobin (MetMb) analysis, L^*,a^*,b^* color measurement were performed in raw döner meats to determine changes in color and myoglobin oxidation rate. Proximate composition was also determined in raw meat, raw döner meat, and cooked döner meat. Before chemical analysis, L^*,a^*,b^* color values were measured on the surface of the whole meat and six measurements were obtained by using Minolta colorimeter (CR 300, Japan). Then, the döner meats were homogenized by meat grinder (HV8 Moulinex, France) and the homogenous samples were used for the analysis.

Proximate Composition and pH Value

Moisture (950.46), crude fat based on soxhlet procedure (991.36), crude protein according to Kjeldahl method to determine percentage of nitrogen (955.04) and ash contents (920.153) of samples were determined according to the AOAC (18) methods. The conversion factor of 6.25 was used to convert nitrogen to percentage protein. The pH value was measured by dipping a pH electrode into döner meat samples (10 g) in 100 mL of distilled water. The measurement was performed at room temperature using a pH meter (Hanna HI 221, Ann Arbor, Michigan, USA).

Free Fatty Acids (FFA) Analysis

Crude fat was extracted from döner meat according to the cold extraction method of Bligh and Dyer (19) and FFA (%) amount was determined based on the method of Mauriello et al. (20).

Thiobarbituric Acid (TBA) Analysis

TBA analysis was performed according to the distillation method of Tarladgis et al. (21). The TBA value (mg malonaldehyde (MA)/kg döner meat) was calculated by multiplying the absorbance by 7.8.

Total Heme Pigment (THP) Measurement

THP analysis was performed according to the modified method of Ockerman (22). A total of 5 g sample was mixed with 20 mL of acetone, 1 mL of H_2O and 0.5 mL of concentrated HCl, covered with parafilm and kept in the dark for 1 h. Then, samples were filtered through Whatman No:1 filter paper. The absorbance of the filtrate was measured at 640 nm with a UV–VIS double beam spectrophotometer against to blank. The THP (µg hematin/g meat) was calculated by multiplying the absorbance by 680.

The Heme Iron (HI) Content

The HI content (µg iron/g meat) was calculated with the factor of 0.0882 µg iron/µg hematin according to the following Formula (15)

HI (µg iron/g meat) = THP (µg hematin/g meat) x 0.0882

Metmyoglobin (MetMb) Measurement

According to the method of Kannan et al. (7) approximately 5 g of sample was homogenized with 25 mL of phosphate buffer solution (pH 6.8, 40 mM, 4 °C) using an ultraturrax for 10 s at 13500 rpm. The homogenized samples were kept at 4 °C for 1 h and then centrifuged at 5000 rpm for 30 min at 4ºC (Hermle Z 326K, Germany). The supernatant was filtered through Whatman No:1 filter paper, and the absorbance of filtrate was read at 700, 572, and 525 nm using a UV–VIS double beam spectrophotometer. The %MetMb was determined using the following Formula;

MetMb%={1.395–[(A572-A700)/(A525-A700)]}x100

Statistical Analysis

Three-way general linear model for raw döner meats and two-way general linear model for cooked döner meats was used to determine the differences between treatments by using MINITAB 15 statistic program. Significant differences were also analysed according to the Duncan's Mean Seperation Test by using MSTAT statistic program.

RESULTS and DISCUSSION

Proximate composition results and pH values of raw meat, raw döner meat and cooked döner meat are seen in Table 1.

Lipolytic and Oxidative Changes in Lipids of Raw Döner Meat during Marination Process

Lipolysis is main reaction for the hydrolysis of triglycerides and phospholipids in fresh meat during processing. This reaction results in formation of FFAs which are major substrat for lipid oxidation (23). FFAs that formed as a result of lipolysis or are present inherently in meat react with molecular oxygen via free radical chain mechanism under the suitable condition during processing, cooking and storage of meat. This reaction is called lipid oxidation which causes formation of carcinogenic compounds. TBA analysis is used to measure lipid oxidation rate in meat and meat products from past to date (15, 16). Main effect of both "tumbling" and "STPP" were determined statistically significant ($P<0.05$) regarding FFA results of raw döner meat (Table 2). Intermittent tumbled groups had significantly higher FFA value than those of continuous tumbled and non-tumbled ($P<0.05$). But, the difference between CT and NT was insignificant. Döner meats with STPP had lower FFA value than those of without STPP that means the usage of STPP decreased the formation of FFA during 48 h of marination at 4 °C ($P<0.05$).

In reference to TBA values, two-way interactions of both "tumbling x STPP" and "marination day x STPP" were found to be statistically significant (Table 2). Regarding "tumbling x STPP" interaction, treatments subjected to IT had significantly higher TBA value than those of treated with CT and NT whether they including STPP or not ($P<0.05$). However, the difference between CT and NT was not significant. In addition, the usage of STPP significantly decreased TBA value when comparing those of without STPP in all treatments subjected to IT, CT, or NT ($P<0.05$). For "marination day x STPP" interaction, TBA value in döner meat marinated with STPP was found significantly lower than those of marinated without STPP on both 0 h and 48 h ($P<0.05$). In addition, a significant increase was determined for TBA value in döner meats without STPP from 0 h to 48 h while no significant changes were seen those of including STPP ($P<0.05$). Overall, the addition of STPP into marination sauce prevented lipolytic reactions and lipid oxidation in döner

Table 1. Proximate composition and pH value of raw meat, raw döner meat and cooked döner meat*

		pH	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Raw meat		5.70±0.03	73.00±1.42	19.60±1.15	5.78±1.75	1.04±0.11
IT+0.25%STPP	0h	5.96±0.04	71.55±1.74	19.53±1.46	7.81±1.09	1.73±0.18
	48h	5.97±0.02	75.41±0.63	18.79±0.59	4.50±1.15	1.75±0.12
	Cooked	6.29±0.03	51.83±0.61	26.31±2.51	15.60±0.72	2.97±0.25
CT+0.25%STPP	0h	6.12±0.08	71.61±2.70	18.50±0.30	8.62±2.43	1.84±0.09
	48h	6.03±0.05	72.60±0.73	18.49±0.38	7.93±0.29	1.57±0.14
	Cooked	6.27±0.04	54.15±0.56	27.85±3.30	14.16±0.72	2.94±0.01
NT+0.25%STPP	0h	6.07±0.09	73.28±1.42	17.24±1.25	7.61±0.37	1.82±0.13
	48h	6.03±0.03	74.46±0.54	18.34±0.48	6.39±1.88	1.67±0.09
	Cooked	6.18±0.03	52.17±0.10	28.32±5.19	14.76±0.59	2.77±0.14
IT+0%STPP	0h	5.56±0.15	70.20±1.34	18.89±0.27	7.15±2.12	1.65±0.04
	48h	5.75±0.03	72.31±2.05	19.41±0.81	4.22±0.92	1.55±0.09
	Cooked	6.04±0.02	53.34±0.58	28.06±2.85	16.86±1.48	2.58±0.11
CT+0%STPP	0h	5.87±0.22	69.60±1.77	18.51±0.57	7.83±2.55	1.57±0.16
	48h	6.11±0.04	69.59±1.14	19.52±0.17	6.25±1.38	1.26±0.15
	Cooked	6.21±0.01	55.77±0.98	27.64±2.23	13.34±1.94	2.43±0.16
NT+0%STPP	0h	5.87±0.02	71.16±0.46	19.53±0.69	6.55±1.42	1.55±0.05
	48h	5.85±0.02	72.66±1.59	19.77±0.62	4.30±0.45	1.40±0.10
	Cooked	6.07±0.05	52.00±0.39	26.81±1.95	17.42±0.77	2.70±0.10

STPP: Sodium tripolyphosphate, IT: Intermittent tumbling, CT: Continuous tumbling, NT: Non-tumbled. *n=2

meat during 48 h of marination at 4 °C. On the contrary, IT did not retard these reactions as a result of more cell distruption due to long processing time of IT. However, CT did not effect negatively these reactions when compared to non-tumbling. In parallel with our results, Cheng and Ockerman (4) reported that phosphates slowed effectively lipid oxidation in precooked roast beef during refrigerated storage but intermittent non-vacuum tumbling did not differ TBARS value comparing non-tumbled treatments. Cheng et al. (16) notified that antioxidant usage in roast beef provided lipid stability during refrigerated storage for 14 days but tumbling method (vacuum or non-vacuum tumbling) did not found effective on TBARS value. Cheng and Ockerman (24) also reported that the usage of three antioxidants was more effective for retarding lipid oxidation than tumbling process. Vara-ubol and Bowers (17) noted that STPP at 0.2% and 0.3% levels provided some protection against lipid oxidation in ground turkey and ground pork meat during refrigerated storage.

Lipolytic and Oxidative Changes in Lipids of Cooked Döner Meat

Two-way interaction of "tumbling x STPP" was found significant for FFA contents and TBA values of cooked döner meats (Table 3). The highest FFA content was determined in group subjected to IT among treatments with STPP and that of subjected to CT among treatments without STPP (*P<0.05*). Concerning TBA results, tumbling did not create an alteration in cooked döner samples containing STPP, but significantly highest TBA value was observed in NT group, followed by CT and then IT among treatments without STPP ($p<0.05$). As expected, the presence of STPP lowered TBA value in all groups subjected to IT, CT or NT since it is well documented that STPP chelates free iron, a major catalyst for lipid oxidation, released from heme group as a result of cooking process.

Oxidative Changes in Color of Raw Döner Meat During Marination Process

Two-way interaction of "tumbling x marination day" was evaluated (*P<0.05*) for both THP and HI content (Table 4). Although there was no significant difference between tumbled and non-tumbled treatments at 0 h, groups subjected to IT and CT had lower THP and HI content than those of NT at 48 h (*P<0.05*). In addition, THP and HI content in NT groups increased from 0 h to 48 h at 4 °C (*P<0.05*). STPP did not differ THP and HI content of raw döner meat (*P>0.05*). In

Table 2. FFA content and TBA value of raw döner meat within 48 h of marination at 4 °C*

FFA (%)	0.25% STPP			0% STPP			
	0h	48h	M±SEM*	0h	48h	M±SE*	M±SEM§
IT	1.49±0.44	1.42±0.44	1.46±0.29	1.49±0.39	1.41±0.33	1.45±0.24	1.46±0.18^{A}
CT	1.12±0.27	1.05±0.26	1.09±0.17	1.20±0.30	1.34±0.39	1.27±0.23	1.18±0.14^{B}
NT	1.07±0.26	1.04±0.24	1.06±0.16	1.24±0.27	1.28±0.26	1.26±0.17	1.16±0.12^{B}
M±SEM**	1.23±0.18	1.17±0.18		1.31±0.17	1.34±0.17		
M±SEM§§	1.20±0.13^{D}			1.33±0.12^{C}			
TBA (mg MA/kg)							
IT	0.43±0.08	0.41±0.06	0.42±0.05^{bc}	0.73±0.15	0.77±0.05	0.75±0.08^{ac}	0.59±0.05^{A}
CT	0.22±0.01	0.22±0.01	0.22±0.008^{bd}	0.24±0.03	0.45±0.03	0.35±0.03^{ad}	0.29±0.02^{B}
NT	0.23±0.01	0.21±0.02	0.22±0.009^{bd}	0.30±0.01	0.47±0.05	0.39±0.03^{ad}	0.31±0.02^{B}
M±SEM**	0.29±0.03^{h}	0.28±0.03^{h}		0.42±0.07^{fg}	0.56±0.04^{eg}		
M±SEM§§	0.29±0.02^{D}			0.49±0.04^{C}			

^{A,B}: Means with different letters are significant among tumbling applications (*P<0.05*).
^{C,D}: Means with different letters in groups with STPP or not are significant (*P<0.05*).
^{a,b}: Means with different letters in a row indicate significant differences resulted from the usage of STPP (*P<0.05*).
^{c,d}: Means with different letters in a column indicate significant differences among tumbling applications (*P<0.05*).
^{e,f}: Means with different letters are significant between 0 h and 48 h in treatments without STPP (*P<0.05*).
^{g,h}: Means with different letters in a row indicate significant differences resulted from the usage of STPP at 0 h or 48 h (*P<0.05*).
M±SEM§: Means±standard error of the mean for treatments subjected to IT, CT, or NT.
M±SEM§§: Means±standard errror of the mean for treatments with STPP or not.
M±SEM*: Means±standard errror of the mean regarding "tumbling x STPP" interaction
M±SEM**: Means±standard error of the mean regarding "marination day x STPP" interaction.
STPP: Sodium tripolyphosphate, IT: Intermittent tumbling, CT: Continuous tumbling, NT: Non-tumbled.
* n=2

common with our results, Cheng et al. (15) determined that THP and HI content of pork patties containing STPP did not change up to 7 days of refrigerated storage.

Regarding MetMb content of raw döner meat (Table 4), two-way interaction of "STPP x marination day" as well as main effect of "tumbling" was found significant ($P<0.05$). Intermittent tumbled treatments demonstrated higher MetMb content than those of subjected to CT and NT owing to possible more cell distruption as a result of long processing time. In reference to interaction results, MetMb content for treatments containing STPP or not was 27.69±3.68 and 32.67±2.82 at 0 h and 25.46±4.81 and 35.60±3.92 at 48 h, respectively (data not shown). That means STPP significantly lowered MetMb content at both 0 h and 48 h. In addition, MetMb content decreased from 27.69% to 25.46% within 48 h of marination in treatments with STPP ($P<0.05$) due to possible conversion of MetMb to other forms in the presence of antioxidative agents (data not shown). Based on these results, it could be asserted that utilization of STPP prevented myoglobin oxidation reactions in raw döner meat during 48 h of marination at 4 °C. In general, when the results concerning lipid and myoglobin oxidations were examined, it is possible to report that tumbling and STPP presented the same effects. These results were approved by a relationship existed between lipid and myoglobin oxidations (r=0.519; P=0.000). This positive correlation means that lower level of lipid oxidation can be determined while lower level of myoglobin oxidation is measured or vice versa. Similarly with our results, Kannan et al. (7) and Hur et al. (25) also reported the positive correlation between lipid and pigment oxidation in their study.

Color measurements of raw döner meats are presented in Figure 1. L^* indicates lightness, $+a^*$ indicates redness and $+b^*$ indicates yellowness color coordinates. Neither STPP nor tumbling was not significanly effective on L^* values of raw döner meat ($P>0.05$). For a^* value of raw döner meat, only main effect of "marination day" was found significant (P<0.05). The avarage redness value was 16.14±0.37 at 0 h and 20.46±0.30 at 48 h (data not shown). The inhibition effect of STPP for MetMb formation and the conversion of MetMb to other forms in the presence of STPP could be a possible explanations for this increase in a^* value. For long storage time, Cheng et al. (15) reported that a^* value of fresh pork patties was lower at day 7 than those of at day 0 and day 4 even tough STPP was added to patties. They demonstrated that myoglobin oxidation still happened during long refrigerated storage. As is known, myoglobin oxidation causes formation of MetMb pigment which has brownish color. As a result of MetMb accumulation, the color changes from red to brownish in meat and a^* value decreases for long storage time (6, 15). In parallel with this expression, in the current study, STPP delayed myoglobin oxidation by chelating iron during 48 h of marination and thus the redness value did not decrease. Besides, shorter holding time at 4 °C could be another explanation. In addition, the insignificant correlation calculated between MetMb content and a^* value of raw döner meat (r = -0.089; P=0.548) could be a evidence for this result. Regarding b^* values, main effect of "STPP" and two-way interaction of "tumbling x marination day" were found to be significant ($P<0.05$). Treatments containing STPP (7.38±0.29) had lower b^* value than those of without STPP (8.20±0.33). Cheng et al. (15)

Table 3. FFA content and TBA value in cooked döner meat*

FFA (%)	IT	CT	NT	M±SEM*
0.25% STPP	1.13±0.01^{ac}	0.49±0.02^{be}	0.70±0.01^{d}	0.77±0.12
0% STPP	0.91±0.08^{bcd}	1.06±0.01^{ac}	0.74±0.09^{d}	0.90±0.07
M±SEM**	1.02±0.07	0.78±0.16	0.72±0.04	
TBA (mg MA/kg)				
0.25% STPP	0.69±0.08^{b}	0.77±0.02^{b}	0.69±0.02^{b}	0.72±0.03
0% STPP	1.24±0.10^{ad}	1.57±0.02^{ac}	1.64±0.05^{ac}	1.48±0.06
M±SEM**	0.97±0.12	1.17±0.15	1.17±0.18	

^{a,b}: Means with different letters in a column indicate significant differences resulted from the usage of STPP ($P<0.05$).
^{c,d,e}: Means with different letters in a row indicate significant differences among tumbling applications ($P<0.05$).
M±SEM*: Means±standard error of the mean for treatments with STPP or not.
M±SEM**: Means±standard error of the mean for treatments subjected to IT, CT, or NT.
STPP: Sodium tripolyphosphate, IT: Intermittent tumbling, CT: Continuous tumbling, NT: Non-tumbled.
*n=2

Table 4. Total heme pigment, heme iron and metmyoglobin contents of raw döner meat*

	Intermittent Tumbling		Continuous tumbling		Non-tumbling		
	0h	48h	0h	48h	0h	48h	M±SEM§
Total heme pigment (µg hematin/g meat)							
0.25% STPP	259.1±4.95	233.8±7.17	221.0±8.78	227.3±7.83	255.4±14.2	262.3±12.40	243.2±4.89
0% STPP	268.3±21.30	251.1±22.40	259.6±10.10	237.2±3.30	232.6±6.69	286.0±28.30	255.8±7.49
M±SEM*	263.7±10.30	242.5±11.4[b]	240.3±9.57	232.3±4.35[b]	244.0±8.44[d]	274.2±15.0[ca]	
M±SEM**	253.1±7.89		236.3±5.19		259.1±9.18		
Heme iron (µg iron/g meat)							
0.25% STPP	22.84±0.44	20.62±0.63	19.49±0.77	20.05±0.69	22.52±1.25	23.13±1.09	21.44±0.43
0% STPP	23.66±1.88	22.14±1.97	22.89±0.89	20.91±0.29	20.51±0.59	25.22±2.50	22.56±0.66
M±SEM*	23.25±0.91	21.38±1.00[b]	21.19±0.84	20.48±0.38[b]	21.52±0.75[d]	24.18±1.32[ca]	
M±SEM**	22.32±0.70		20.84±0.46		22.85±0.81		
Metmyoglobin (%)							
0.25% STPP	29.70±7.33	30.67±11.60	28.32±5.64	22.96±8.01	25.06±7.74	22.76±6.51	26.58±2.97
0% STPP	37.13±6.22	39.80±7.71	31.83±3.55	35.80±8.53	29.05±5.02	31.22±4.98	34.14±2.38
M±SEM*	33.42±4.67	35.24±6.68	30.08±3.16	29.38±5.94	27.06±4.34	26.99±4.12	
M±SEM**	34.33±3.94[e]		29.73±3.25[f]		27.03±2.89[f]		

[a,b]: The means with different letters among tumbling procedures are significant at 48 h (*P<0.05*).
[c,d]: The difference between 0 h and 48 h is significant in non-tumbled groups (*P<0.05*).
[e,f]: Means with different letters are significant among tumbling applications (*P<0.05*).
M±SEM§: Means±standard errror of the mean for treatments with STPP or not.
M±SEM*: Means±standard error of the mean regarding "tumbling x marination day" interaction.
M±SEM**: Means±standard error of the mean for treatments subjected to IT, CT, or NT.
STPP: Sodium tripolyphosphate, IT: Intermittent tumbling, CT: Continuous tumbling, NT: Non-tumbled. *n=2

reported that *b** values of fresh pork patties containing STPP fluctuated during 7 days of refrigerated storage but the differences was not significant. In reference to interaction effect (regardless STPP), at 0 h, *b** values for the treatments subjected to IT, CT and NT were 8.73±0.58, 5.95±0.42, and 5.65±0.46 respectively. Intermittent tumbled groups had significantly higher *b** value than others. At 48 h, *b** values were measured for treatments subjected to IT, CT and NT as 9.16±0.31, 9.01±0.35, and 8.26±0.61 respectively. As can be seen from these results, a significant increase for *b** values in continuous tumbled and non-tumbled groups was measured during 48 h of marination at 4 °C, however the highest *b** value was determined in intermittent tumbled treatments (*P<0.05*).

CONCLUSION

The addition of STPP alone retarded lipid and myoglobin oxidation in raw döner meat during 48 h of marination at 4 °C. When STPP combined with vacuum tumbling, it is possible to report that IT was found uneffective to retard lipolytic and oxidative changes due to more cell distruption. However, CT did not create a statistically significant alterations regarding oxidative reactions in comparison with non-tumbling. Consequently, it is possible to note that the usage of CT combined with 0.25% STPP could be suggested as a more effective method than IT and an alternative technique against to NT since our published data (3) presented that 0.25% STPP combined with continuously vacuum tumbling brings some advantages to döner meat concerning water holding capacity, cooking yield and sensory properties.

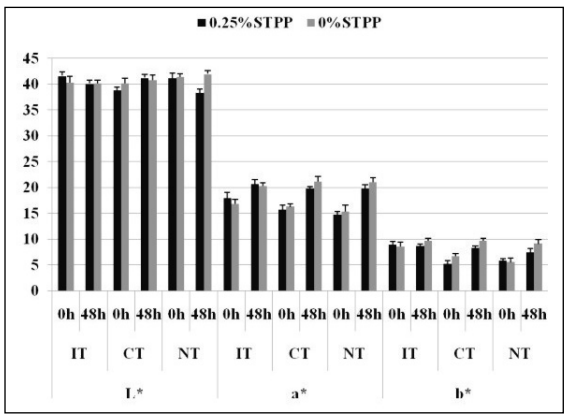

Figure 1. *L**, *a**, *b** color values of raw döner meat*
STPP: Sodium tripolyphosphate, IT: Intermittent tumbling, CT: Continuous tumbling, NT: Non-tumbled. *n=2

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