

Quality Characteristics of Raw and Cooked Spent Hen *Pectoralis major* Muscle During Chilled Storage: Effect of Tea Catechins

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Abstract: The effects of different concentrations (0, 100, 150 and 200 mg/kg samples) of antioxidant from Tea Catechins (TC) on oxidative stability of raw and cooked spent hen *Pectoralis major* muscles during chilled storage were studied. Adding TC could delay the accumulation of oxidation in both meat without any effect on shear force value and yield throughout chilled storage. However, discoloration of meat caused by adding TC was more pronounced in cooked samples than that found in raw meat.

Key words: Spent hens, tea catechins, chilled storage, oxidative stability

INTRODUCTION

Excessive expansion of egg industry resulted in abundant availability of spent hens so additional usage need to be developed to enhance value of it meat. Although, toughness prevents spent hen use in whole meat food and reduces the market value in many countries such as Korea, Taiwan, Japan and United States (Sams, 1990; Nowsad *et al.*, 2000a,b; Lee *et al.*, 2003; Li, 2006), meat from spent hen is a good protein source (Rhee *et al.*, 1999; Lee *et al.*, 2003), highly enriched with omega-3 fatty acids and lower in cholesterol content in particular breast muscle (Ajuyah *et al.*, 1992) which have been shown to have health promoting benefits. However, meat from spent hen may promote faster oxidation than broiler during processing and storage due to higher fat content consisting with high content of unsaturated fatty acids. Antioxidant from TC has been reported to be more powerful than the synthetic antioxidants in vegetable oil (Chen and Chan, 1996; Zandi and Gondon, 1999; Yanishlieva and Marinova, 2001), marine oil (Wanasundara and Shahidi, 1998), animal diets (Tang *et al.*, 2000; Tang *et al.*, 2001a,b; Tang *et al.*, 2002; O'Grady *et al.*, 2006), fish muscle model systems (He and Shahidi, 1997), cooked beef and chicken meat (Tang *et al.*, 2000; Tang *et al.*, 2001a), raw red meat, poultry and fish muscle (Tang *et al.*, 2001b), patties formed from fresh and previously frozen pork (McCarthy *et al.*, 2001), minced raw beef (Tang *et al.*, 2006) and frozen chicken (Tang *et al.*, 2001c). Thus, application of TC may be another way to prevent lipid oxidation in spent hen meat during chilled storage. Therefore, the objective of this study is to obtain the information on the effect of TC on quality of spent hen meat either raw or cooked during chilled storage.

MATERIALS AND METHODS

Tea catechins: Tea Catechins (TC) (80.15%) was obtained from Kinglong National Plant Industry Ltd., Changsha, Hunan, China.

Muscle samples and storage condition: Sixty-four spent hens aged 72 weeks of 1.5 ± 0.2 kg live weights, obtained from Department of Animal Science, Faculty of Natural Resource, Prince of Songkla University were slaughtered by methods of Wattanachant *et al.* (2004). *Pectoralis major* muscles (breast muscles) were dissected from the carcasses and trimmed of obvious fat and connective tissue after chilling at 4°C for 24 h and then cut into 2 pieces with the same size (3.0 x 5.0 x 1.0 cm³). Samples were randomly assigned to one of the following 4 groups; untreated, TC100 (meat plus 100 mg TC/kg muscle), TC150 (meat plus 150 mg TC/kg muscle) and TC200 (meat plus 200 mg TC/kg muscle). To ensure even distribution of the additive throughout the pieces of meat, TC was freshly dissolved in boiled water (100, 150 or 200 mg antioxidant/10 ml water for 1 kg muscle) and sprayed as a fine aerosol on the both side of the pieces. Each group of sample was subdivided into 2 groups of raw and cooked samples. Cooked samples were heated with steam without pressure by putting the muscles on aluminum racks and placed in the stovetop steamer until an internal temperature of 80°C was obtained and then allowed to cool and gently blotted with a paper towel to remove surface moisture. Temperature was monitored by thermocouple inserted into the thickest part of the samples. All samples of each group were weighed, placed individually on the supporting mesh and inserted in the labeled polyethylene plastic bags before sealing. Samples were kept in chilled room at 4°C for 9 days. At 0, 3, 6 and 9 days of storage, four packs of each group were randomized for analysis.

Chemical properties analysis

Determination of TBARS: Lipid oxidation of samples was quantified using Thiobarbituric Acid Reactive Substances (TBARS) determined spectrophotometrically by method of Buege and Aust (1978). Butylated hydroxytoluene (0.08% in hexane) was added to 5 g samples (0.03% by wt) to protect oxidation prior to

homogenize with 25 ml of TBARS solutions (0.375% TBA, 15% TCA and 0.25 N HCl) at speed of 11,000 rpm for 60 s. The mixture was heated for 10 min in boiling water (95-100°C) to develop a pink color, cooled in an ice water bath and then centrifuged at 5,500 rpm for 25 min. The absorbance of the supernatant was measured at 532 nm using a spectrophotometer. TBARS value was calculated from the standard curve of Malondialdehyde (MDA) and expressed as µg MDA/g sample.

Physical properties analysis

Determination of cooking loss and weight loss:

Cooking loss of raw muscle samples was determined according to the method of Wattanachant *et al.* (2004). To prepare cooked muscles, small pieces (1.5 x 3.0 x 0.5 cm³) of raw samples were cut, weighed, put in a tightly sealed plastic bag and cooked in water bath at 80°C for 10 min. After being cooked, the samples were cooled by immersing in an ice water bath for 2 min and then removed from the container, blotted with a paper towel and reweigh to determine the cooking loss as a percentage of initial weight (w/w, wet basis).

Weight loss of cooked samples were determined in four replicates by calculating the weight loss during chilling as a percentage of the initial weight as described by Woelfel *et al.* (2002) and Honikel (1998) with a slight modification. Each sample was weighed at the time before chilling (initial weight). After a storage period, samples were taken immediately from the containers, gently blotted dry and reweighed.

Shear force analysis: Samples were cut (1.0 x 3.0 x 0.5 cm³) paralleled with the muscle fiber at the middle portion of the fillets fiber for shear analysis using the Texture Analyzer equipped with a Warner-Bratzler shear apparatus (Stable Micro System, TA-XT 2i, UK). The operating parameters consisted of a cross head speed of 2 mm/s and a 25 kg load cell (Wattanachant *et al.*, 2005). The shear force perpendicular to the axis of muscle fibers was measured in eight replicates for each treatment. The peak of the shear force profile was regarded as the shear force value (kg).

Determination of surface color: Raw muscle slices were measured in eight replicates at the inner surface of breast muscle using a Hunterlab colorimeter (ColorFlex, Hunter Lab Reston, USA) and reported as the complete International Commission on Illumination (CIE) system color profiles of lightness (L*), redness (a*) and yellowness (b*).

Sensory evaluation: Oxidized odor was evaluated by 30 experienced panelists using a six-point category scale (1 = very strong, 2 = strong, 3 = moderately strong, 4 = moderate, 5 = just detectable, 6 = not detectable) according to the intensity scale for evaluation off flavors in meat by Tarladgis *et al.* (1959 cited in Melton *et al.*,

1987). The panelists were explained for standard scores of oxidized odor. To prepare standard odor scores, subcutaneous fat kept at 4°C for 7 days was blended with distilled water at the ratio of 1:1 (w/v), kept in screw caps which corresponding to very strong oxidized odor sample, while distilled water was used as not detectable sample. The strong, moderately strong, moderate and just detectable oxidized odor samples were prepared by dilution the suspension of very strong oxidized odor sample with distilled water at a ratio of 1:1, 1:2, 1:3 and 1:4 (v/v), respectively.

Statistical analysis: All data were subjected to Analysis of Variance (ANOVA) and differences between means were evaluated by Duncan's Multiple Range Test (Steele and Torrie, 1980) using analysis software computer.

RESULTS AND DISCUSSION

Changes in chemical properties

Changes in TBARS: Effect of TC on lipid oxidation of spent hen *Pectoralis major* muscle samples during chilled storage was evaluated changes in TBARS values as presented in Fig. 1. Storage time had effect on lipid oxidation of both raw and cooked spent hen meat either treated or untreated muscle samples. As storage time increased from day 0 to day 6, a dramatic increase in TBARS values of raw untreated samples were found ($p < 0.05$) and then approached a plateau thereafter ($p \geq 0.05$). Whereas a slight increase in all TC treated samples were observed throughout storage ($p < 0.05$). Treated raw muscle samples with TC could reduce lipid oxidation of both raw and cooked muscle samples during chilled storage as evidenced by lower TBARS values of all treated samples compared to untreated samples throughout storage ($p < 0.05$). In addition, TC treated at higher level exhibited greater efficient to retard lipid oxidation in both raw and cooked spent hen meat. In raw muscle samples, adding TC at the level of 150 and 200 mg/kg muscle showed significantly lower TBARS values than at the level of 100 mg/kg muscle throughout storage ($p < 0.05$), whereas in cooked samples the lowest values were found when treated with TC at the level of 200 mg/kg muscle ($p < 0.05$). The results indicated that TC could delay the accumulation of oxidation products in spent hen meat during chilled storage. The results obtained were in agreement with previous researchers reported effective of TC to reduce lipid oxidation in cooked beef, beef patties and chicken meat (Tang *et al.*, 2001a; Mitsumoto *et al.*, 2005), in raw red meat, poultry and fish muscle (Tang *et al.*, 2001b). The tea catechins and other flavonoids in green tea have been recognized as efficient antioxidants for scavenging oxygen radicals and chelating metal ions (Wanasundara and Shahidi, 1998; Bozkurt, 2006). Tea catechins have been studied to have a wide concentrations range of 200-10,000 mg/kg meat to reduce lipid oxidation in raw and cooked meat (Mitsumoto *et al.*, 2005). This study

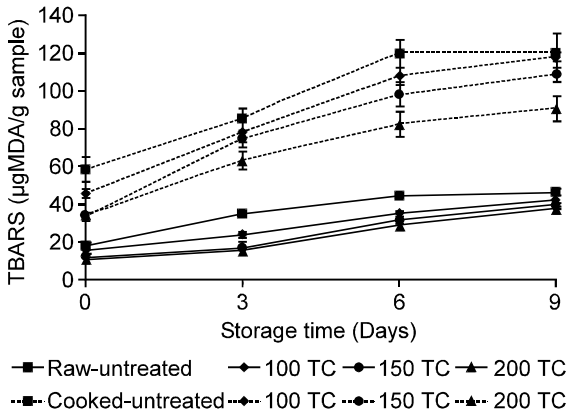


Fig. 1: Changes in TBARS values ($\mu\text{g MDA/g sample}$) during chilled storage at 4°C of raw and cooked spent hen *Pectoralis major* muscles treated with TC 0, 100, 150 and 200 mg/kg muscle. Bars represent the standard deviations for triplicates determinations

indicated that lower TC concentration of 150-200 mg/kg meat had ability to retard lipid oxidation in spent hen meat probably due to more purify of catechins (84.84%) consisting of high contents of (3)-Epigallocatechin Gallate (EGCG) (70%) used in current study. The relationships between the free radical scavenging activities and the chemical structures of tea catechins and their corresponding epimers have been reported by Tang *et al.* (2002). Their results showed that the presence of the gallate group at the 3 position plays the most important role in free radical-scavenging ability of catechins resulted in the effects of galloyated catechins on free radicals were stronger than those non galloyated catechins. In addition, EGCG could permeate with the lipid bilayer membrane structure due to their high affinity for lipid bilayers (Hashimoto *et al.*, 1979) that could be more efficiency to use with spent hen meat which containing high fat content. Moreover, cooked muscle samples had faster oxidation than raw muscle samples as elucidated by all treated samples and control of cooked sample showed dramatic increase in TBARS values compared with gradual increased in these values of raw samples during chilled storage ($p < 0.05$). Cooking not only disrupts the membrane structure but also facilitates release of iron from the iron carrier proteins or iron storage conditions (Ahn *et al.*, 1993). Under such conditions oxygen can directly react with the ferrous iron in the meat and activate the ground state oxygen to a highly reactive form (Halliwell and Gutteridge, 1990) resulted in rapid oxidation leading to high TBARS value. However, the chelating effect of TC could reduce this phenomenon by binding with the iron components, stabilizing them in an inactive or insoluble form (Allen and Cornforth, 2009) resulted in more efficiency of TC to reduce lipid oxidation in cooked meat.

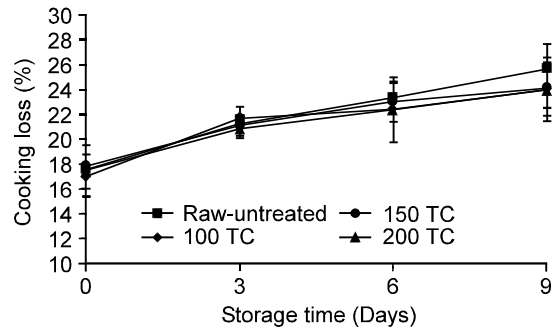


Fig. 2: Changes in cooking loss (%) during chilled storage at 4°C of raw spent hen *Pectoralis major* muscles treated with TC 0, 100, 150 and 200 mg/kg muscle. Bars represent the standard deviations for eight determinations

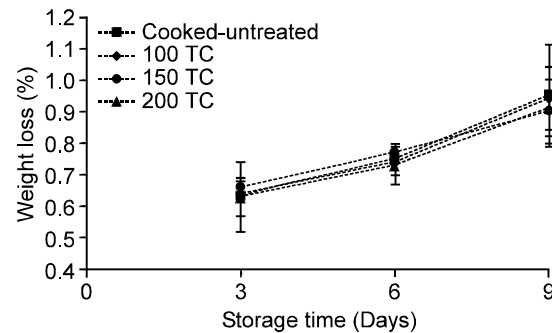


Fig. 3: Changes in weight loss (%) during chilled storage at 4°C of cooked spent hen *Pectoralis major* muscles treated with TC 0, 100, 150 and 200 mg/kg muscle. Bars represent the standard deviations for four determinations

Changes in physical properties

Cooking loss and weight loss: The effect of TC on WHC of spent hen *Pectoralis major* muscle samples during chilled storage was evaluated by determining cooking loss of raw and weight loss of cooked samples as presented in Fig. 2 and 3. Cooking loss of raw and weight loss of cooked samples was not affected by adding TC as elucidated by significant differences between untreated and treated samples were not found throughout storage ($p \geq 0.05$). This was indicated that TC treated had no effect on WHC of both raw and cooked muscle samples. However, both parameters were affected by storage time. An increase in cooking loss of raw samples were found in all TC treated and control untreated samples ($p < 0.05$). The same trends were found in weight loss of cooked samples. These results were expected. As mentioned earlier, during chilled storage caused protein degradation resulted in low property of proteins to hold water in muscles and exhibited increase in both values.

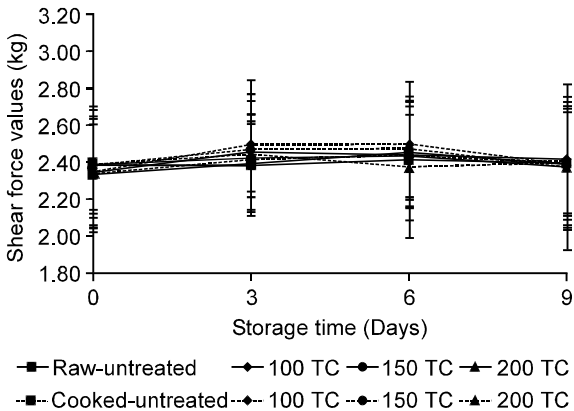


Fig. 4: Changes in shear force values (kg) during chilled storage at 4°C of raw and cooked spent hen *Pectoralis major* muscles treated with TC 0, 100, 150 and 200 (mg/kg muscle). Bars represent the standard deviations for eight determinations

Warner-Bratzler shear force values: The effect of TC on texture of spent hen *Pectoralis major* muscle samples during chilled storage was evaluated Warner-Bratzler shear force values as shown in Fig. 4. Adding TC had no effect on texture of spent hen *Pectoralis major* muscles during chilled storage as elucidated by no significant differences in Warner-Bratzler shear force values between all TC treated and untreated samples for both raw and cooked muscle samples throughout chilled storage ($p \geq 0.05$). In addition, no changes on texture were observed in both raw and cooked samples during storage ($p \geq 0.05$).

Surface color: Changes in surface color of raw and cooked spent hen *Pectoralis major* muscles treated with TC 0, 100, 150 and 200 mg/kg muscle during chilled storage are presented in Fig. 5. Treatment of TC had influence on L*, a* and b* values of raw and cooked samples, especially in cooked meat. It showed darker color compared to untreated samples. TC used in the present study was a fine and water soluble powder and was red-brown in color. Therefore, it was expected that spent hen muscle samples treated with TC had different color from untreated samples. Discoloration of meat caused by adding TC have been reported in raw beef muscles by Zembayashi *et al.* (1999) and in meat patties (darker in color) by Mitsumoto *et al.* (2005). Tea catechins caused discoloration possibly by binding with the iron component of myoglobin (Mitsumoto *et al.*, 2005). Conversely, a greatly improved color by adding TC have also reported in minced raw beef (Maher *et al.*, 2002) and raw pork patties (Jo *et al.*, 2003). This was probably caused by different kinds of raw material used. Mitsumoto *et al.* (2005) found that TC had greater influence on meat discoloration in meat patties prepared from white meat (chicken) than red meat (beef).

As shown in Fig. 5a, treated raw spent hen meat with TC had no effect on L* values as indicated by no significant differences in L* values in all treated samples, compared to untreated samples throughout storage ($p \geq 0.05$). In contrast, adding TC had more influence on L* values of cooked samples. All TC treated samples showed significantly lower L* values, compared to untreated samples throughout chilled storage ($p < 0.05$). In addition, samples with increasing level of TC exhibited more decrease in L* values. Storage time had little effect on L* values of raw samples as indicated by slight decrease in these values either treated or untreated samples, especially at day 9 of storage ($p < 0.05$). For cooked samples, storage time had more pronounced influence on TC treated samples. As storage time increased from day 0 to day 6, adding TC at the level of 100 mg/kg muscle resulted in slight decrease in L* values, whereas dramatic decreases in these values were found in samples treated with TC at the level of 150 and 200 mg/kg muscle.

As shown in Fig. 5b, adding TC had marked influence on a* values of both raw and cooked spent hen meat. Raw and cooked treated samples showed significantly higher a* values, compared to untreated samples throughout storage ($p < 0.05$), especially in cooked samples. The higher a* value in cooked samples in comparison with raw counterpart, might be affected by denatured myoglobin during heat treatment. Tea catechins might work as reducing agent, which could reduce metmyoglobin to oxymyoglobin to some degree. Lawrie (1991) noted that denaturation of red myoglobin and conversion to brown myohaemochromogen starts at 40°C and is almost completely denatured between 80-85°C. However, spent hen muscle had low content of myoglobin that resulted in negative a* value in raw muscle and changed to be positive a* value after cooking, indicating browner color. Tang *et al.* (2006) reported redder color in beef patties after TC treatment. The authors also suggested that TC polyphenol react readily with iron in meat to promote discoloration. However, this hypothesis requires for further study (Mitsumoto *et al.*, 2005; Tang *et al.*, 2006). During storage, treatment of TC at higher levels had no change on a* value of raw samples ($p \geq 0.05$). However, cooked meat treated with TC 100 mg/kg showed significant decrease in a* value ($p < 0.05$), while treatment of TC at 150 and 200 mg/kg muscle resulted in stability of a* value in cooked samples during 3 to 9 days of storage ($p \geq 0.05$). However, Zembayashi *et al.* (1999) found that dietary green tea (0.5 kg/day for 174 days before slaughter) decreased the iron content and a* value of raw beef muscles compared to controls and they suggested that dietary tea reduced iron absorption in meat.

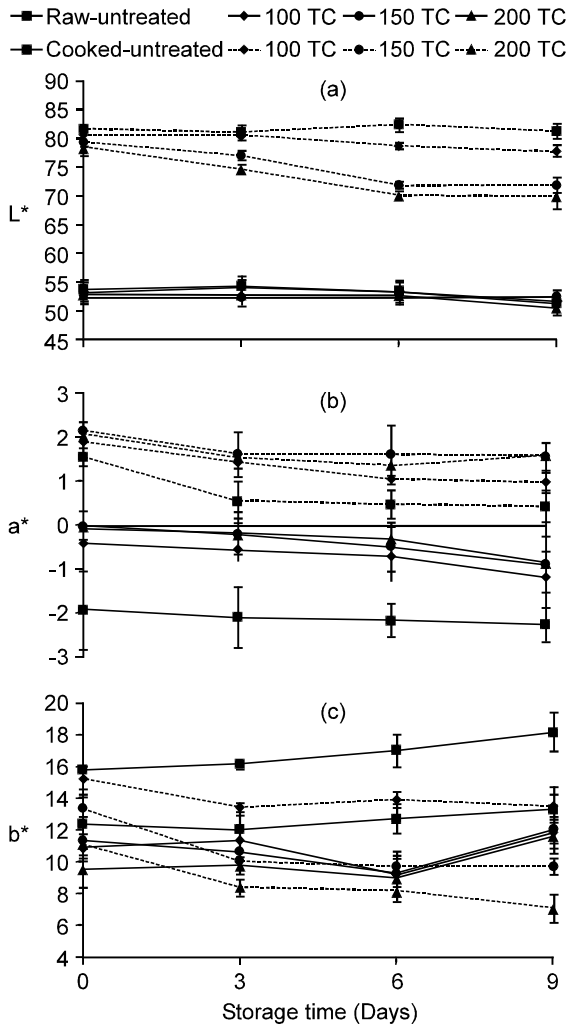


Fig. 5: Changes in L* values (a), a* values (b) and b* values (C) during chilled storage at 4°C of raw and cooked spent hen *Pectoralis major* muscles treated with TC 0, 100, 150 and 200 mg/kg muscle. Bars represent the standard deviations for eight determinations

From Fig. 5c, adding TC had more effect on cooked spent hen samples than raw samples. All cooked TC treated samples exhibited significantly lower b* values compared to untreated samples throughout storage ($p < 0.05$), while this phenomenon was less pronounced in raw samples during storage. In addition, adding TC at higher level in cooked meat resulted in lower b* values. Storage time had slight increase in b* of cooked untreated, while all TC cooked treated samples showed dramatic decrease in these values on day 0 to day 3 of storage. As the storage time increased, no changes in b* values for all TC treated were found. Discoloration caused by TC might reduce the visual appearance and overall acceptability of spent hen meat,

especially cooked spent hen meat products without adding other seasoning which consumers expect more white color. TC 200 was superior to TC150 for inhibiting lipid oxidation in both raw and cooked spent hen meat; however, it caused more discoloration which clearly reduced the visual appearance. Therefore, in current study, TC 150 was more suitable to process either raw or cooked spent hen meat.

Table 1: Oxidized odor scores during chilled storage at 4°C of cooked spent hen *Pectoralis major* muscles treated with TC 0, 100, 150 and 200 mg/kg muscle

Storage time (days)	Oxidized odor scores (mg/kg muscle)			
	0	100	150	200
0	5.07±0.83 ^{a,x}	5.13±0.86 ^{a,x}	5.17±0.75 ^{a,x}	5.20±0.96 ^{a,x}
3	4.70±0.84 ^{a,x}	4.80±0.76 ^{a,x}	5.03±0.76 ^{a,x}	5.10±0.88 ^{a,x}
6	3.27±0.98 ^{b,y}	3.77±0.94 ^{b,y}	4.27±0.78 ^{b,x}	4.37±0.72 ^{b,x}
9	2.40±0.89 ^{c,x}	2.47±0.82 ^{c,x}	2.87±0.86 ^{c,x}	2.83±0.91 ^{c,x}

Data are presented as mean ± standard deviation; n = 30. (6 = not detectable, 1 = very strong).

*cMeans with differing superscripts in the same column are significantly different ($p < 0.05$).

**Means with differing superscripts in the same row are significantly different ($p < 0.05$).

Sensory changes: Sensory changes during chilled storage of cooked spent hen samples treated with TC were evaluated oxidized odor scores as shown in Table 1. As expected, oxidized odor scores increased as storage time increased for all TC treated and untreated samples ($p < 0.05$). In addition, Panelists could just detected oxidized odor of both TC treated and untreated samples at the beginning time of storage. Thereafter, moderated oxidized odor scores of untreated and TC treated at the level of 100 mg/kg muscle were found, whereas moderate oxidized odor were observed on TC treated samples at the higher level. For longer time of storage all samples either treated or untreated samples showed strong oxidized odor scores, however, TC treated samples at the higher level slightly had better scores than that found in untreated and TC treated at 100 mg/kg muscle. This result was concomitant well with TBARS values. Therefore, it could be indicated the effectiveness of TC to retard lipid oxidation of spent hen meat.

Conclusion: Adding TC had no effect on texture and yield of spent hen meat either raw or cooked samples during chilled storage. It could delay the accumulation of oxidation products in spent hen meat during chilled storage. However, discoloration caused by TC might reduce the visual appearance and overall acceptability of spent hen meat, especially cooked spent hen meat products without adding other seasoning which consumers expect more white in color.

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