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Enhancing color stability of raw chicken patties using instant tea: A comparative study of instant tea produced from low- and high-quality black tea

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Abstract

This study evaluated the efficacy of instant tea powder made from low- and high-quality black tea on the color stability of raw chicken patties stored under refrigerated conditions. The phenolic content and antioxidant properties of the tea were assessed using in vitro assays. Results indicated that instant tea made from high-quality tea had a higher total phenolic content than that made from low-quality tea. Both teas from low- and high-quality raw materials demonstrated significant DPPH radical scavenging and ferric-reducing capacities, indicating their potential as effective natural antioxidants for preserving meat quality. Both teas significantly mitigated CIE a* color loss in chicken patties, performing comparably to commercial antioxidants such as sodium ascorbate and (+/-)-α-tocopherol. The study found no significant difference between the two types of tea, suggesting that low-quality tea is a cost-effective and sustainable alternative. Moreover, a concentration of 250 mg of instant tea powder/kg meat was adequate to maintain the color of raw chicken patties. These findings highlight the potential of instant tea as a natural color preservative, meeting consumer demand for natural additives while promoting resource use efficiency by utilizing tea byproducts.

Keywords: Instant tea; Phenolics; Color stability; Chicken patties; Myoglobin

1. Introduction

The color of meat is an important consideration when meat and meat products are purchased. Discoloration in fresh meat is often interpreted as an indicator of the loss of freshness and wholesomeness. Therefore, meat color is among the most critical factors influencing meat purchases (Mancini & Hunt, 2005). Myoglobin, the primary heme pigment, is responsible for the color of fresh meat, which appears to be purplish red when deoxygenated and bright red when oxygenated. However, fresh meat tends to change from red to brown because of myoglobin oxidation during processing and storage (Mancini & Hunt, 2005). Therefore, the oxidation of myoglobin is a critical factor in determining the quality of meat. Several studies have investigated various methods to slow the oxidation of myoglobin. The application of antioxidants is highly intriguing, and a significant amount of research has been conducted on the preservation of meat color via antioxidants derived from natural sources. Consumers are increasingly demanding more natural foods, requiring the industry to include natural antioxidants in foods and these natural antioxidants are deemed safer than synthetic antioxidants (Brewer 2011). Natural antioxidants are derived from various plant sources, such as leaves, fruits, and seeds, each with unique properties that combat oxidation (Farag et al. 2006; Mansour and Ali 2000, Devatkal et al. 2011; Pathiraja et al., 2023). Flavonoids, a vast group of polyphenolic compounds, contribute to the antioxidant properties of fruits, vegetables, and herbs and are notable examples of compounds that prevent oxidative damage in meat. A range of other plant-derived compounds, including extracts from herbs, spices, and fruits such as rosemary, green tea, and tomatoes, are continually being researched for their preservative effects on meat, revealing the potential of natural substances in food preservation (Nieto et al., 2023).

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Tea is one of the most consumed beverages around the world and is manufactured from the leaves of the plant *Camelia sinensis* L. Tea is rich in polyphenols that give it a distinct flavor and aroma. Owing to its health-promoting properties, tea has gained popularity because of the presence of functional polyphenols that possess highly effective antioxidant properties. The potent antioxidant activities of these compounds have been attributed to their ability to scavenge free radicals, chelate pro-oxidant metals, act as reducing agents, and quench singlet oxygen (Nikmaram et al., 2018). Tea polyphenols have also been found to be potent antioxidants in meat systems. Studies have shown that tea polyphenols can retard lipid oxidation in pig meat (Fan et al., 2024), chicken meat (Tang et al., 2002), and beef (Kırmızıkaya et al., 2021). Moreover, these studies have shown that the antioxidant properties of tea phenolics are as effective as those of the well-known antioxidant compounds a-tocopheryl acetate and butylated hydroxy anisole (BHA). Although some research has been conducted on the impact of tea phenolics on the lipid oxidation of meat, there is a lack of research on their impact on color stability.

In the manufacturing of different teas, the tea plucking process varies widely. The highest-quality teas often require fine plucking of just the top two leaves and a bud. For many green and oolong teas, a medium consisting of three leaves and a bud is standard and a coarse mixture of up to five leaves and a bud is employed for the majority of black teas varieties. During the manufacturing of black tea, certain fractions, consisting of pieces of leaves and stalks, are rejected. This byproduct, known industrially as broken mixed fannings (low quality), is a valuable source of polyphenols (Dalpathadu et al., 2020). Despite being low-quality, this tea provides an economical source of phenolics, enabling cost-effective extraction and enhancing resource utilization efficiency.

The objective of this study was to evaluate the efficacy of instant tea made from low-quality tea (broken mixed fannings) on the color stability of fresh chicken patties stored under refrigerated conditions. Additionally, the effects of these teas were compared with those of instant teas produced from high-quality tea and the commercially available antioxidant compounds; sodium ascorbate and (+/-)-α-tocopherol.

2. Materials and Methods

2.1. Materials

- *Chemicals*: 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,4,6-tripyridy-s-triazine, Folin-Ciocalteu reagent, ferric chloride, gallic acid, sodium ascorbate, and (+/-)-α-tocopherol were purchased from Sigma Chemical Co. (New Delhi, India). All other chemicals used were of analytical grade.
- *Teas*: Instant tea produced from low-quality tea (broken mixed fannings/refuse tea) and high-quality tea was obtained from an instant tea manufacturing company in Sri Lanka.
- *Chicken meat*: Skinless chicken thighs purchased from a commercial supplier were first manually deboned. The meat was minced through a 3 mm plate using a benchtop-type meat mincer. To minimize variability between replicates, a single master batch of ground chickens was utilized in this investigation to eliminate the possibility that differences between batches of ground chickens could influence experimental error. Portions weighing one kilogram each were vacuum-sealed and stored at -19 °C for subsequent utilization in this study.

2.2. Methods

2.2.1. Preparation of tea extracts

The phenolics were extracted from instant tea using the method outlined in ISO 14502-1(ISO, 2005). Briefly, 200 mg of each sample was weighed and transferred to an extraction tube containing 5 mL of 70% methanol at 70 °C. The sample mix was heated at the same temperature in a water bath for 10 minutes. After cooling to room temperature, the extract was vortexed for 5 minutes and decanted into a 10 mL volumetric flask. The extraction process was repeated once, and the resulting extracts were combined. Finally, the volume was adjusted to 10 mL using cold 70% methanol.

2.2.2. Preparation of chicken patties

The ground meat was thawed overnight at 4 °C. All batches of chicken patties were prepared using the same formulation, except for the antioxidant ingredients. Each formulation consisted of 85% meat, 5% wheat binder, 2.5% condiments (salt and spices), water, and the antioxidant ingredient. The meat samples were separately mixed with tea at two different concentrations: 250 mg tea powder/kg meat and 500 mg/kg meat. For comparison, sodium ascorbate and (+/-)-α-tocopherol were used at concentrations of 500 mg/kg meat. A control sample with no added antioxidant additives was also prepared by adding deionized water instead of the antioxidant ingredient. These samples were then mixed in a mixer for 2 minutes. The average temperature of the meat after mixing was 8 °C. Meat batter samples from each treatment were divided into smaller portions and shaped into patties using a mold, each with a thickness of 1.5 cm and

a diameter of 8 cm. These patties were wrapped in low-density polyethylene film, each separately, and stored under refrigerated (4 °C) conditions for 8 days. All analyses were performed in triplicate at 0, 2, 4, 6, and 8 days of storage.

2.2.3. Estimation of total phenolic content (TPC)

The Folin–Ciocalteu assay described by Djordjevic et al. (2011) with modifications was used to determine the TPC of tea extracts, with gallic acid serving as a standard. Briefly, 0.5 mL of extract and 0.1 mL of Folin-Ciocalteu reagent (0.5 N) were mixed and incubated at room temperature for 15 minutes in the dark. Afterward, 2.5 mL of 7.5% sodium carbonate was added to the mixture. The mixture was then incubated for 2 hours in the dark at room temperature. The absorbance of the mixture was measured at 760 nm using a UV/VIS spectrometer (Evolution™ 201/202, Thermo Fisher Scientific) against a blank. The TPC was estimated as mg of gallic acid equivalents (GAE) using a gallic acid standard curve.

2.2.4. Determination of total flavonoid content

The quantification of flavonoids in the extracts was conducted as described by Zhishen et al. (1999). Initially, 1 mL of the extract was transferred into a volumetric flask containing 4 mL of deionized water. Subsequently, 300 µL of both 5% sodium nitrite and 10% aluminum chloride were introduced into the mixture. After a 6-minute interval, 2 mL of sodium hydroxide (1 M) was added, and the volume was brought to 10 mL with 2.4 mL of water. The mixture was then thoroughly vortexed, and its absorbance was recorded at 510 nm using a UV–VIS spectrophotometer (Evolution™ 201/202, Thermo Fisher Scientific), with a reagent blank where deionized water was used instead of extract as the reference. The flavonoid content was reported as milligrams of rutin equivalents per gram of tea (mg RE/g).

2.2.5. Determination of caffeine content

The caffeine content was determined following the method outlined by Dalpathadu et al. (2020). Briefly, a 200 mg sample was dissolved in 250 mL of deionized water in a volumetric flask. A 10 mL portion of this mixture, along with 20 mL of chloroform, was placed into a separating funnel. After thorough mixing and allowing the solution to separate into two layers, the chloroform layer was extracted. The absorbance of this mixture was measured at 276 nm using a UV/VIS spectrophotometer (Evolution™ 201/202, Thermo Fisher Scientific), and the caffeine content was quantified using a standard of caffeine.

2.2.6. Determination of DPPH free radical scavenging activity

The free-radical scavenging activity of tea extracts against 2,2-diphenyl-1-picrylhydrazyl (DPPH•) radicals was assessed using the method described by Brand-Williams et al. (1995). The analysis was performed on diluted samples, and the absorbance was measured at 517 nm using a UV/VIS spectrophotometer (Evolution™ 201/202, Thermo Fisher Scientific).

2.2.7. Determination of ferric ion-reducing antioxidant power (FRAP)

The FRAP assay was performed as described by Benzie and Strain (1996). In brief, 900 µL of freshly prepared FRAP reagent (2.5 mL of a 10 mmol/L 2,4,6-tripyridy-s-triazine (TPTZ) solution in 40 mmol/L HCl, 2.5 mL of 20 mmol/L ferric chloride, and 25 mL of 0.3 mol/L acetate buffer) was mixed with deionized water (90 µL) and the test sample (30 µL). The absorbance at 593 nm was recorded 4 minutes after mixing using a spectrophotometer (Evolution™ 201/202, Thermo Fisher Scientific). A standard curve using ferrous sulfate was used to calculate the ferric ion-reducing capacity, which was expressed as the equivalent of ferrous sulfate.

2.2.8. Determination of the CIE color and percentage of metmyoglobin (MetMb%)

The CIE color values L*, a*, and b* were measured using a colorimeter (Konica Minolta CR-400, Tokyo, Japan). The instrument was calibrated with a standard white plate, and measurements were taken at two locations on each patty. The color difference (ΔE) was calculated on the basis of the changes in the L*, a*, and b* values from days 0 to 8 (Li, 2017), and the percentage of metmyoglobin (MetMb%) was determined following the method described by Liu et al. (2015).

2.2.9. Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) followed by Tukey's mean separation to determine the significance of the effects of antioxidant ingredients on the test parameters. All the statistical tests were performed at a significance level of $p < 0.05$. Three replicates were performed for each measurement. All the statistical analyses were performed using MINITAB 19 statistics software.

3. Results and Discussion

3.1. Total phenolic content (TPC)

Tea is well known for its high phenolic content. The phenolic levels in both teas produced from low- and high-quality tea were significantly different (Table 1). The TPC was 232.12 mg GAE/g in instant tea made from high-quality tea and 207.65 mg GAE/g in instant tea made from low-quality tea. These findings indicated that high-quality tea has a greater TPC than low-quality tea, likely due to variations in the source material.

Table 1 Phenolic contents and antioxidant activities of instant black teas

	Instant tea made from high quality black tea	**Instant tea made from low quality black tea**
Phenolic content		
Total phenolic content (mg GAE/g DW)	232.12±8.25[a]	207.65±10.60[b]
Total flavonoid content (mg RE/g DW)	47.49±3.30[a]	58.19±4.18[a]
Caffeine content (mg/g DW)	29.68±1.81[a]	25.43±1.42[b]
Antioxidant activity		
DPPH (mmol TE/g DW)	353.12 ± 6.08[a]	338.97 ± 7.14 [b]
FRAP (mmol FeSO4/g DW)	43.85 ± 1.131[a]	38.19 ± 2.361[b]

Data are expressed as the mean ± SD (n = 3) on a dry weight basis. Means within the same raw with different letters are significantly different ($p < 0.05$)

Several factors, including plant material, climate conditions, and processing methods, can influence the phenolic content of tea. For instance, Odumosu et al. (2015) reported a wide range of TPC values in instant teas from various countries, highlighting the variability in phenolic content due to differences in processing and source materials. The low-quality tea used in the present study consisted of fragments of leaves and stalks that resulted from the tea processing and sorting stages. However, the TPC estimated in the present study was within the ranges reported previously. Odumosu et al. (2015) reported that the TPC in instant teas across 10 brands from different countries ranged from 360.62 ± 25.70 mg GAE/g to 195.21 ± 18.65 mg GAE/g. Alasalvar and colleagues (2013) compared instant teas made from low- and high-quality teas and reported no significant difference in their TPC. However, the reported TPC values were lower than those reported in the present study.

3.2. Total flavonoid content (TFC)

Flavonoids in tea are polyphenolic compounds known for their potent antioxidant properties. The flavonoid contents were 47.49±3.30 and 58.19±4.18 mg RE/g in high- and low-quality tea, respectively. Interestingly, these two teas were not significantly different, suggesting that the raw material used did not significantly affect the flavonoid content of the instant tea. Compared with the values reported in the literature, these values align closely with the flavonoid content reported by Rahman et al. (2021) for tea extracts. Conversely, Odumosu et al. (2015) reported lower levels of total flavonoid content in various instant teas from different origins, ranging from 6.48 to 33.24 mg RE/g tea.

3.3. Caffeine content

Caffeine is widely recognized as one of the most frequently consumed dietary components globally, with tea and coffee being the primary sources (Heckman et al., 2010). An examination of the caffeine contents in instant tea revealed (Table 1) that high-quality tea had a higher ($p<0.05$) caffeine content (29.68 mg/g) than did low-quality raw tea (25.43 mg/g). Typically, the caffeine content in regular brewed tea varies between 22 and 27 mg/100 mL (Suteerapataranon et al., 2009). A previous study (Alasalvar et al., 2013) reported that the caffeine contents of instant tea produced from low- and high-quality teas were 43.98 mg/g and 39.64 mg/g, respectively, which were higher than the values found in the present study. Additionally, they reported that the caffeine content was greater in teas made from low-quality raw materials than in those made from high-quality materials, which contrasts with the findings of the present study. These differences could be attributed to the differences in the growing conditions of tea as well as the instant tea processing conditions.

Overall, the results of this study revealed that the TPC and TFC were greater in instant tea produced from high-quality raw materials. This can be attributed to variations in the phenolic composition between low- and high-quality raw materials. Compared with other plant-based materials previously studied as natural antioxidants in meat products (Nissen et al., 2004; Rojas and Brewer, 2007; Pathiraja, 2020; Pathiraja et al., 2023), both tea extracts presented comparatively higher levels of phenolics. Therefore, the presence of relatively high levels of phenolic compounds is promising for determining potential antioxidant properties in meat.

3.4. DPPH free radical scavenging activity

Assessing antioxidant activity through multiple assays allows for a more accurate evaluation of potential antioxidant efficacy in biological systems. In vitro antioxidant assays are based on distinct mechanisms, such as hydrogen atom transfer, electron transfer, or radical scavenging, which can yield varying results depending on the sample and the antioxidant compound. In this study, the DPPH• radical scavenging capacity and FRAP were evaluated, highlighting that radical formation and the presence of ferric ions acting as prooxidants are significant contributors to oxidation in meat systems. The results are presented in Table 1.

A significant difference was observed in the DPPH• scavenging ability between the two samples. The instant tea produced from high-quality tea exhibited a higher radical scavenging ability, with a value of 353.12 ± 6.08 mg GAE/g, than the value of 338.97 ± 7.14 mg GAE/g for tea made from low-quality tea. This variation could be due to differences in the phenolic composition of the teas, which also showed a similar pattern to that of the ferric-reducing capacity.

The DPPH method is widely recognized for its ability to evaluate the free radical scavenging abilities of various substances, providing quantitative insight into their antioxidant potential. A study conducted by Nhu-Trang et al. (2023) evaluating both wild/ancient and cultivated teas from Vietnam noted DPPH• scavenging activity values ranging from 1745 to 2769 mmol Trolox equivalents per gram of dry matter. These values are, however, lower than those of the DPPH• scavenging activity values found for the instant tea in the present study. This may be partly because instant tea is a concentrated source of phenolics. The concentrated nature of instant tea implies that smaller quantities may be required to achieve the necessary level of antioxidant capacity. Furthermore, the findings of the present study also highlighted that the instant tea exhibited superior DPPH• radical scavenging activity than the 13 plant extracts analyzed by Fernandes et al. 2016. The latter included a variety of plants known for their antioxidant potential in meat products, such as tea, mint, and rosemary. These observations suggest that instant tea could be a superior natural source of antioxidants.

3.5. Ferric ion-reducing antioxidant power (FRAP)

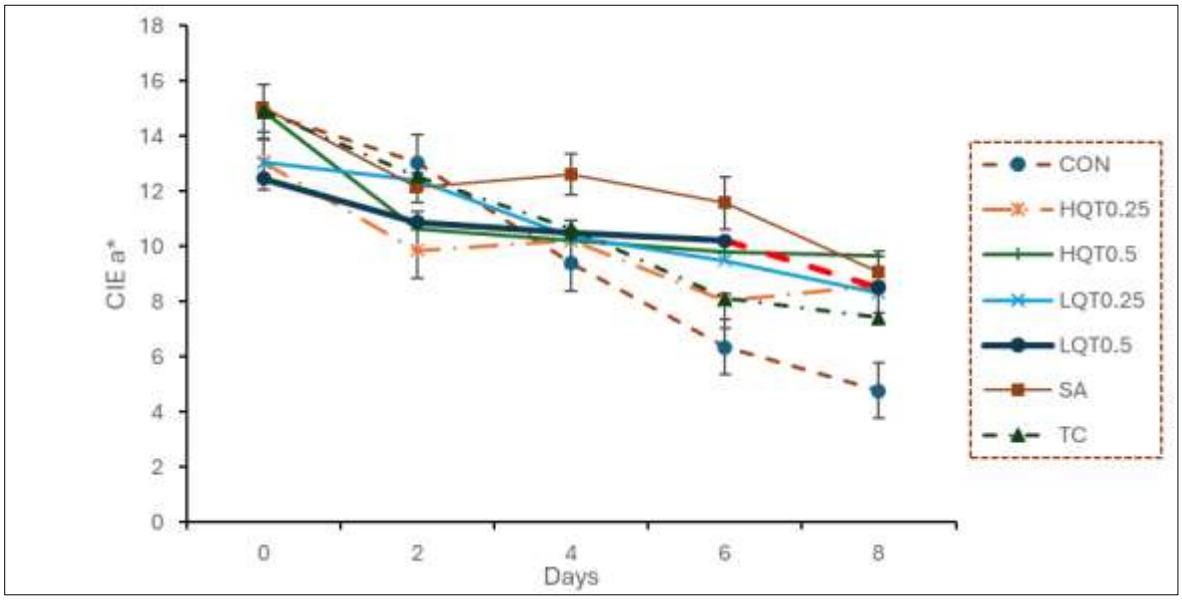
The FRAP values indicate the ability of plant extracts to reduce ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}), reflecting their potential to neutralize oxidative species. Both Fe^{3+} and Fe^{2+} are necessary to initiate lipid peroxidation (Braughler et al., 1986), and they have also been found to accelerate the oxidation of oxymyoglobin and cause discoloration in raw meat products (Gorelik & Kanner, 2001; Allen & Cornforth, 2006). The FRAP values of the tea samples analyzed in this study were significantly different ($p<0.05$). Teas produced from high-quality raw materials had a value of 43.85 ± 1.13 µmol FeSO4/g, whereas those made from low-quality raw materials had a value of 38.19 ± 2.36 mmol FeSO4/g. These variations in FRAP values among different types of tea may be attributed to differences in phenolic content and other antioxidant compounds present. For example, a study evaluating 30 tea infusions from green, black, oolong, white, yellow, and dark teas reported FRAP values ranging from 504.80 ± 17.44 to 4647.47 ± 57.87 µmol Fe^{2+}/g dry weight (DW) (Zhao et al., 2019). Among these, green tea generally presented the highest FRAP values, followed by yellow, oolong, dark, black, and white tea. (Zhao et al., 2019). Compared with these reported values, the instant tea in the present study presented a ferric reducing capacity approximately 10 times greater. This significant increase may be attributed to the concentrated form of phenolic compounds present in instant tea. The high concentration of these phenolic compounds likely enhances the ability of tea to reduce ferric ions, thereby increasing its overall antioxidant capacity.

The findings of this study, which analyzed the phenolic compounds and in vitro antioxidant activities of instant tea, suggest that instant tea may be employed to improve the oxidative stability of chicken meat. The higher antioxidant activity observed in the analyzed instant teas supports this hypothesis, indicating their potential as natural preservatives. This hypothesis is further examined and assessed in the following section, which provides an in-depth analysis of their potential use as natural preservatives in the meat industry.\

3.6. Color

The global demand for natural antioxidants is increasing as consumers become more aware of their health benefits. This study focused on assessing the impact of low- and high-quality tea on the color stability of raw chicken during storage at 4 °C. For comparison, two commercial antioxidants, sodium ascorbate and (+/-)-α-tocopherol, were used along with a negative control with no added antioxidant ingredients.

Figure 1 illustrates the changes in CIE a* color during the refrigerated storage. All the treatments resulted in similar trends in the CIE a* color over time. The a* values, which indicate the redness of the meat, were highest on day one and gradually declined throughout the storage period across all the treatments. Both the type of antioxidant and the duration of storage had a significant effect on the a* values ($p<0.05$).



CON: control, HQT0.25: instant tea produced from high quality tea added at 250 mg/kg, HQT0.5: instant tea produced from high quality tea added at 500 mg/kg, LQT0.25: instant tea produced from low quality tea added at 250 mg/kg, LQT0.5: instant tea produced from low quality tea added at 500 mg/kg, SA: sodium ascorbate, TC: (+/-) - α- tocopherol

Figure 1 Change in CIE a* value of raw chicken patties treated with antioxidants refrigerated (4°C) storage (n = 3)

On day 0, the addition of tea powder appeared to reduce the a* value, likely due to the dark color of the extracts. Similar findings have been reported when dark-colored plant extracts were mixed with meat (Li, 2017; Pathiraje et al, 2023). By day 6, the a* values of all the samples were significantly lower ($p < 0.05$) than those on day one, indicating a deterioration in the redness of the raw patties. However, the rate of reduction in redness was lower in samples treated with antioxidant ingredients than in the negative control. Notably, by day 8, the samples treated with tea powder retained higher a* values than did the negative control samples prepared without the addition of antioxidants. These findings suggest that instant tea powder significantly mitigates color loss in raw chicken meat during storage, irrespective of whether it is produced from high- or low-quality raw materials.

Furthermore, the antioxidant efficacy of instant tea was comparable to that of commercial antioxidants; sodium ascorbate and (+/-)-α-tocopherol. There was no significant difference between the two types of tea powders in their ability to maintain meat redness. This finding is significant because it indicates that low-quality raw material (refuse tea) is as effective as high-quality tea with respect to their antioxidant efficacy. This offers a cost-effective solution and enhances the efficiency of resource utilization. The study also demonstrated that tea powder added at 250 mg/kg was just as effective in producing an antioxidant effect as 500 mg/kg tea powder. Furthermore, instant tea did not exhibit any prooxidant effects on the meat. Therefore, an application level of 250 mg/kg would be sufficient to provide a color-stabilizing impact comparable to that of (+/-)-α-tocopherol and sodium ascorbate, which are currently used in commercial meat product processing.

3.7. Change in color (ΔE)

Figure 2 depicts the color difference (ΔE) of all the treatments from day 0 to day 8. The ΔE value integrates the three color parameters (L*, a*, and b*) into a single metric. From day 0 to day 4, all the samples exhibited similar color changes

($p > 0.05$). However, after day 4, the control formulation presented a greater ΔE ($p > 0.05$) than all the other formulations treated with antioxidant compounds, including tea extracts. These results further confirmed that the color-preserving effect of instant tea is comparable to that of (+/-)-α-tocopherol and sodium ascorbate, indicating that the addition of tea powder positively impacts color stability.

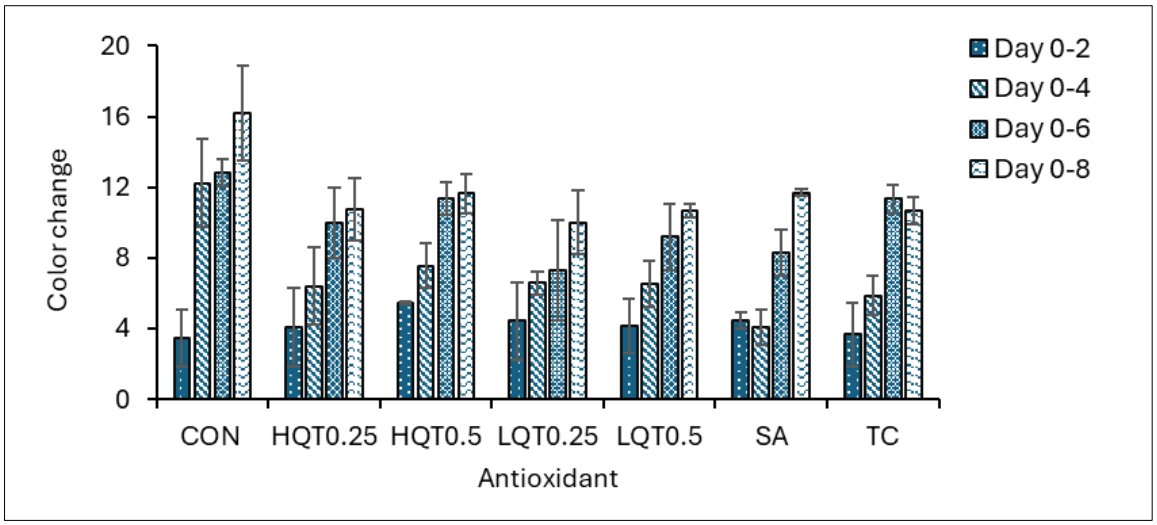


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Figure 2 Effect of antioxidants on color change in raw chicken patties during refrigerated storage (4 °C) (n = 3)

Therefore, incorporating instant tea powder into chicken patties would be beneficial for maintaining color during storage. The color changes in the control samples were anticipated, as previous studies have shown that refrigerated samples without antioxidants experience more significant deterioration in a* values. The potentially lower rate of color deterioration in patties made with tea powder aligns with previous studies that reported similar trends with other plant extracts in beef and pork patties stored under refrigerated conditions (Li. 2017; Zhang et al, 2019, Pathiraja, 2020).

Despite this, all patties (both control and antioxidant-treated) exhibited ΔE values between 3.49–5.46 (day 0 vs. day 2) and 10.03–16.20 (day 0 vs. day 8), which exceeded the threshold value of 2, indicating noticeable visual color changes (Lorenzo et al., 2014). Consequently, these results suggest that consumers will perceive color changes in patties during storage for each treatment. However, it is noteworthy that the color change over time was significantly lower in samples treated with antioxidant ingredients, including both teas, compared to the negative control.

3.8. Metmyoglobin percentage (MetMb%)

The initial appearance of meat, particularly its color, significantly influences consumer choices. The pigment myoglobin, which is responsible for the color of fresh meat, undergoes various chemical reactions influenced by factors such as oxygen, light, and heat. Consequently, the chemical state of myoglobin is crucial for consumer acceptance. Oxymyoglobin, the oxygenated form of myoglobin, imparts a bright red color to the meat. However, after several days of exposure to air, the iron atom in myoglobin oxidizes to MetMB, losing its oxygen-binding ability and causing the meat to turn brown (Suman and Joseph, 2013). Although this color change reduces consumer appeal, the meat remains safe for consumption. The changes in MetMb% in the present study are shown in Figure 3.

Storage time significantly affected MetMb%, with values increasing progressively ($p < 0.05$) over the 8-day refrigerated storage period. Initially, the MetMb% ranged between 2% and 4%, but by day 8, it had risen to between 25% and 30%. However, neither the type of antioxidant compound nor the amount of tea powder had a significant effect on MetMb%. In contrast, Liu (2015) reported that beef patties treated with antioxidants presented lower MetMb% than control beef during storage. Their study demonstrated that the effectiveness of antioxidants in inhibiting myoglobin and/or oxymyoglobin oxidation followed the order of carnosine > grape seed extract > vitamin E > tea catechins > BHA. Similarly, Li (2017) found that lentil seed extracts retarded MetMb accumulation in beef burgers. Conversely, Bekhit et al. (2003) reported that, compared with the control, the antioxidant carnosine accelerated the accumulation of MetMb. However, the results of the present study did not indicate any effect of prooxidant activity on the oxidation of myoglobin at the concentrations used. Importantly, the quality of the raw tea material did not compromise the efficacy of the

resulting instant tea as an antioxidant. The comparable potency of instant tea manufactured from low- and high-quality raw materials to well-known antioxidants like sodium ascorbate and (+/-)-α-tocopherol is promising for the meat processing industry, suggesting a potentially cost-effective alternative without compromising antioxidant benefits.

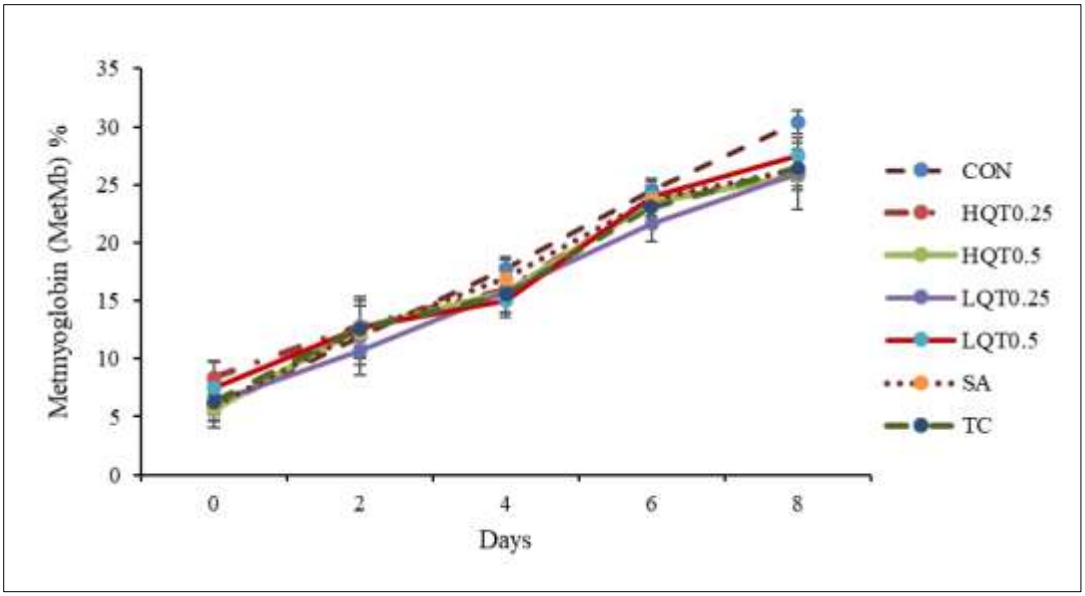

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Figure 3 Effect of antioxidants on metmyoglobin content in raw chicken patties during refrigerated storage (4 °C) (n = 3)

4. Conclusions

In conclusion, this study demonstrated that instant tea from both high-quality and low-quality tea effectively enhances the color stability of fresh chicken patties during refrigerated storage. The tea extracts, which are rich in phenolic compounds, exhibited significant antioxidant properties comparable to those of commercial antioxidants such as sodium ascorbate and (+/-)-α-tocopherol. Notably, the use of low-quality tea, a byproduct of tea manufacturing, offers a cost-effective and sustainable alternative without compromising efficacy. The findings suggest that incorporating tea extracts at a concentration of 250 mg/kg is sufficient to maintain meat color and prevent oxidative deterioration, providing a promising natural preservative solution for the meat industry. This approach not only meets consumer demand for natural additives but also promotes resource use efficiency by utilizing tea byproducts.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest in this manuscript.

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