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FULL PAPER

Green tea extract improved minced mutton quality during chilled storage

[1]Alnori, H.M., [1,*]Saeed, O.A., [2]Alnoori, M.A., [3]Leo, T.K. and [4]Sani, U.M.

[1] *Department of Animal Production, College of Agriculture, University of Anbar, Anbar, Ramadi, Iraq*
[2] *Department of Public Health, College of Veterinary Medicine, University of Fallujah, Fallujah, Iraq*
[3] *Research and Development, Nexus Wise Sdn Bhd, Selangor, Malaysia*
[4] *Department of Animal Science, Faculty of Agriculture, Taraba State University, P.M.P. 1167, Jalingo, Nigeria*

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Abstract

Natural antioxidant has been used to prevent lipid oxidation and microbiological development in meat and meat products. This study was carried out to evaluate the effects of different concentrations of green tea extract on minced mutton quality during chilled storage. The minced mutton was divided into 5 treatment groups, with TGE1 as negative control while TGE2, TGE3, TGE4 and TGE5 were added with green tea extracts at 0.5%, 1%, 1.5% and 2%, respectively. The pH, myoglobin, water holding capacity (WHC), drip and cooking loss of minced mutton were studied during chilled storage at days 0, 3, 6, 9 and 12. Present findings showed that minced mutton added with green tea extract had significantly higher ($P<0.05$) pH, myoglobin content and WHC than the untreated control group at days 3, 6, 9 and 12. In addition, minced mutton with added green tea extract also had significantly lower ($P<0.05$) drip and cooking loss than the control group. This study also showed that a higher concentration of green tea extract added had a better effect on the meat quality traits measured. Taken together, these results indicate that the addition of green tea extract improved the minced mutton quality.

1. Introduction

Meat plays a vital role in human nutrition as a source of high-quality proteins, fatty acids, minerals and vitamins (Pal and Devrani, 2018). Nowadays, the acceptability of meat and meat products is determined by several qualities including organoleptic (appearance, texture, juiciness and flavour) and nutrition. Many factors can affect the quality of meat, including diet, age, sex, post-mortem ageing and post-slaughter processing conditions (e.g. chilling conditions and application of additives) (Needham *et al*., 2019). The application of natural additives has been advocated as an effective method in preventing the deterioration of quality and extending the shelf-life of meat and meat products. The shelf life of meat and meat products is limited to a few days at refrigerated temperatures as meat provides an ideal environment for microbial development. During chilled storage, lipid and protein oxidation could cause flavour deterioration due to the generation of secondary lipid oxidation products and sulfur compounds on the surface of the meat (Martinaud *et al*., 1997). In addition, lipid and protein oxidation could have negative impacts on the water-holding capacity and tenderness of meat (Rowe *et al*., 2004; Kim *et al*., 2010).

Green tea extract has been used to prevent oxidation and microbial development in meat and meat products. Green tea is a powerful source of antioxidants containing high content of active compounds such as flavonoids, phenols, and tannins (Manessis *et al*., 2020). Numerous health benefits of green tea have been highlighted in recent studies including anti-carcinogenic, antibacterial and anti-arteriosclerotic effects (Needham *et al*., 2019; Quilez-Molina *et al*., 2020). Furthermore, catechins, the main bioactive compounds in green tea leaves, have been shown to exert a substantial impact on food nutrition and shelf life when used as an additive (Lee *et al*., 2014; Quilez-Molina *et al*., 2020). The effects of green tea extracts on the quality of meat and meat products have been reported in beef, chicken, and pork, but limited in mutton. Hence, the present study was conducted to examine the effects of different concentrations of green tea extract on the water holding capacity, drip loss, cooking loss, myoglobin content and pH of minced mutton during chilled storage.

*Corresponding author.
Email: *osama_anwr85@uoanbar.edu.iq*

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2. Materials and methods

2.1 Extraction of green tea leaves

The procedure of green tea leaves extraction followed the method described by Bellés *et al.* (2017). Four concentrations of green tea extract (0.5%, 1%, 1.5% and 2%) were prepared by soaking green tea leaves (0.5, 1, 1.5 and 2 g) in 100 mL distilled water. The mixtures were incubated at room temperature for 12 hrs with constant stirring. After that, the extracts were filtered with Whatman No.1 filter paper before being concentrated using a rotary vacuum evaporator (Buchi R -114, Switzerland) at 40°C.

2.2 Sample preparation

Awassi Sheep aged 1.5 years old was slaughtered, eviscerated and subjected to 24 hrs post-mortem. After 24 hrs, meat was trimmed from both of the legs (*Semitendinosus* muscle), chopped into medium-sized pieces and minced with an electric machine (HMG-51S, China). The minced meat samples were divided into 5 equal proportions. To one proportion, green tea extract was not added (control), while the other 4 proportions were mixed with 0.5%, 1% 1.5% and 2% of green tea extracts, respectively. Samples from each group were further divided into 5 groups and subjected to 0, 3, 6, 9 and 12 days of storage in the refrigerator at 4°C. Water holding capacity (drip loss and cooking loss), pH and myoglobin content of the meat were determined.

2.3 Determination of water holding capacity

The technique was used to determine the water holding capacity (Grau *et al*., 1953). Approximately 5 g of meat were placed between two filter papers and two quartz plates, then squeezed for 5 mins with a weight of 2500 g. The meat was then removed and weighed, and WHC was determined as a percentage of the initial weight.

$$\text{Water Holding Capacity (\%)} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100$$

2.4 Determination of cooking loss

The cooking loss of samples was estimated by heating 20 g of minced meat sample placed in polyethylene bags for 20 mins at 80°C using a water bath. Samples were cooled for 10 mins under running tap water. The samples were removed from the bags, dried on filter paper and weighed. Cooking loss percentage was described by Honikel (1998).

$$\text{Cooking loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

2.5 Determination of drip loss

Drip loss was measured according to the method described by Honikel (1998). Approximately 5 g minced meat was placed and vacuumed by using a chamber vacuum (CHTC-520LR, USA) before being labelled and kept at 5°C. After 24 hrs, the samples were dried using tissue paper and then weighed. The percentage of weight change is used to quantify drip loss.

$$\text{Drip loss (\%)} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100$$

2.6 Determination of pH

Each sample (10 g) was mixed with 10 mL of phosphate-buffered saline and homogenized for 20 s using a homogenizer (Wiggen Hauser® D-500, Germany). The mixture was filtered with Whatman No.1 filter paper before the pH was measured using a pH meter.

2.7 Determination of myoglobin

Myoglobin was determined according to the method described by Zessin *et al*. (1961). Where the absorption factor is 0.452, the wavelength is 525 nm, and the coefficient mitigation is 2.4.

$$\text{Myoglobin (mg/g)} = \frac{\text{absorbability} \times 2.4}{\text{sample weight} \times 0.452} \times 100$$

2.8 Statistical analysis

The data were subjected to analysis of variance (ANOVA) using GLM (version 9.1, SAS Inst. Inc., U.S.A.). The green tea extract was applied as treatment while individual samples were experimental units. Duncan multiple range tests were used to compare differences of means among the treatments ($p<0.05$).

3. Results and discussion

Meat quality traits including tenderness, water holding capacity and colour, have long been associated with ultimate pH. High pH meat often has a coarse texture, higher water holding capacity, less attractive colour and reduced shelf life. Table 1 presents the effect of green tea extract on the pH of chilled minced mutton. The pH of minced mutton was similar in all treatment groups at day 0. As the duration of chilled storage increased, the pH of the minced mutton increased significantly in all treatment groups. There was a significant difference ($p<0.01$) in the effects of different concentrations of green tea extract on the pH of minced mutton at all the chilled storage duration. TGE5 had the highest pH and followed by TGE4, TGE3, and TGE2. Meanwhile, TGE1 had the lowest pH among the treatment groups on days 3, 6, 9 and 12. The present study was consistent with the findings of Abdullah and Qudsieh (2009) that ageing has an impact on the pH of meat. Present findings were also in agreement with

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Salem *et al*. (2016) and Nath *et al*. (2016) that meat products treated with green tea extract have higher pH than those untreated control group. The higher pH in the meat products may be due to the active compounds present in the green tea extracts such as catechins and other phenolic compounds that inhibit oxidation and maintain cell membranes (Saeed, Kee, Sazili *et al*., 2019; Yu *et al*., 2020).

Table 1. Effect of different concentrations of green tea extract on the pH of minced mutton during chilled storage.

Treatments	Chilled duration (days)				
	0	3	6	9	12
TGE1	5.41	5.47^{e}	5.52^{e}	5.60^{e}	5.78^{e}
TGE2	5.41	5.54^{d}	5.62^{d}	5.71^{d}	5.91^{d}
TGE3	5.4	5.59^{c}	5.75^{c}	5.88^{c}	6.00^{c}
TGE4	5.4	5.62^{b}	5.81^{b}	5.92^{b}	6.14^{b}
TGE5	5.41	5.66^{a}	5.90^{a}	6.13^{a}	6.33^{a}
SEM	0.002	0.029	0.06	0.081	0.084
P-value	0.34	0.01	0.01	0.01	0.01

Values are presented as mean. Values with different superscripts are significantly different.

Myoglobin is largely responsible for the red colouration of meat. Green tea extract has been used as natural antioxidant to improve the shelf life and colour of fresh minced meat on a large scale in the meat industry (Borzi *et al*., 2019). The effect of green tea extract on the myoglobin content of minced mutton during chilled storage is presented in Table 2. The myoglobin content of all samples was similar (p>0.05) in all treatment groups at day 0, and these values decreased with the duration of chilled storage. The addition of green tea extracts decreased the reduction rate of myoglobin content in the minced meat. The concentration of green tea extract is negatively associated with the reduction rate of myoglobin content. In this study, TGE5 had the highest (p<0.05) myoglobin content, followed by TGE4, TGE3, TGE2 and TGE1 on days 3, 6, 9 and 12.

Table 2. Effect of different concentrations of green tea extract on the myoglobin content (mg/g) of minced mutton during chilled storage.

Treatments	Chilled duration (days)				
	0	3	6	9	12
TGE1	4.77	4.17^{e}	3.90^{e}	3.67^{e}	3.08^{e}
TGE2	4.75	4.24^{d}	4.07^{d}	3.85^{d}	3.54^{d}
TGE3	4.76	4.31^{c}	4.21^{c}	4.01^{c}	3.80^{c}
TGE4	4.77	4.45^{b}	4.33^{b}	4.19^{b}	4.05^{b}
TGE5	4.76	4.57^{a}	4.47^{a}	4.33^{a}	4.21^{a}
SEM	0.003	0.064	0.088	0.105	0.178
P-value	0.13	0.01	0.01	0.01	0.01

Values are presented as mean. Values with different superscripts are significantly different.

Decreased myoglobin concentration may be due to the myoglobin oxidation and transformation of myoglobin into metmyoglobin (King *et al*., 2011). The addition of natural antioxidants may stop the oxidation of hydrogen atoms of myoglobin (Huang and Ahn, 2019). The present finding was consistent with a study conducted by Bellés *et al*. (2017) and Bora *et al*. (2018) that supplementation of green tea extract had reduced metmyoglobin production and subsequently limited the colour deterioration of meat.

The WHC is the ability of meat to retain inherently or added water during storage, manufacturing, processing or preparation (Van Oeckel *et al*., 1999). The majority of water in meat is held within the muscle structures and immobilized by muscle proteins. Any changes influencing the muscle structure including the rate and extent of pH decline during the postmortem, as well as the degradation and oxidation of proteins will affect the ability of meat to retain water (Honikel, 2004). Different concentrations of green tea extracts affected the WHC, drip loss and water loss of minced mutton during chilled storage (Table 3). There was an insignificant difference (p>0.05) in the WHC, drip loss and cooking loss among the treatment groups at day 0. The WHC and cooking loss of the meat were decreased with the duration of chilled storage. TGE5 had the highest (p<0.05) WHC and cooking loss among the treatment groups on days 3, 6, 9 and 12, while TGE1 had the lowest percentage. The concentration of green tea extract is negatively associated with the reduction rate of WHC and cooking loss. Drip loss measures extracellular water exuding from the meat, without applying external force. Water loss is expected during storage as a result of rigour mortis-induced alterations in muscle fibres and myofibrillar structural changes (Monteschio *et al*., 2021). The present study observed that drip loss of the meat was increased with the chilled storage duration in all treatment groups. Green tea extracts improved the drip loss of the minced mutton during chilled storage. TGE5 had the lowest (p<0.05) drip loss while TGE1 had the highest percentage on days 3, 6, 9 and 12.

The addition of green tea extracts improved the WHC of meat during chilled storage (Salem *et al*., 2016; Manessis *et al*., 2020). This may be due to the increase in meat pH and the inhibition of protein and lipid oxidation (Cornet *et al*., 2021). In this study, the effect of green tea extract on the pH of the minced mutton was complemented with the WHC. Meat pH is one of the most critical elements that determine drip loss and WHC. Lower pH reduces the ability of muscle proteins to bind to water, producing myofibril shrinkage and thus resulting in higher drip loss and lower WHC.

Minced meat is highly susceptible to oxidation as the grinding process increased the exposure of lipids and protein to air. Lipid and protein oxidation may disrupt

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muscle cell membrane integrity, decrease membrane stability and eventually contribute to water loss from the meat. Reduction of lipid oxidation raises the MUFE and PUFA proportions in the meat, which decreases drip loss and improves colour and odour (Saeed, Sazili, Akit *et al*., 2019). As mentioned in the literature review the utilization of 2% green tea extract as a natural antioxidant was effective in preventing protein and lipid oxidation without altering the meat quality (Beya *et al*., 2021).

Table 3. Effect of different concentrations of green tea extract on the water holding capacity (%), drip loss (%) and cooking loss (%) of minced mutton during chilled storage.

Treatments	Chilled duration (days)				
	0	3	6	9	12
Water holding capacity (%)					
TGE1	45.42	39.88^e	34.35^e	30.56^e	24.52^e
TGE2	46.43	42.32^d	37.02^d	34.25^d	30.13^d
TGE3	46.43	43.85^c	38.44^c	36.88^c	33.22^c
TGE4	46.44	43.96^b	40.35^b	38.10 ^{b}	34.57^b
TGE5	45.44	44.23^a	42.03^a	40.87^a	36.15^a
SEM	0.219	0.727	1.187	1.568	1.837
P-value	0.76	0.01	0.01	0.01	0.01
Drip loss (%)					
TGE1	2.76	3.33^a	3.81^a	4.26^a	5.87^a
TGE2	2.79	3.10^b	3.62^b	3.93^b	5.22^b
TGE3	2.77	2.97^c	3.48^c	3.64^c	4.85^c
TGE4	2.77	2.88^d	3.26^d	3.33^d	4.04^d
TGE5	2.77	2.80^e	3.03^e	3.11^e	3.86^e
SEM	0.004	0.083	0.121	0.183	0.333
P-value	0.36	0.01	0.01	0.01	0.01
Cooking loss (%)					
TGE1	35.24	33.03^a	30.44^a	28.33^a	24.52^a
TGE2	35.25	32.16^b	28.24^b	26.03^b	22.32^b
TGE3	35.23	31.31^c	27.34^c	24.82^c	21.02^c
TGE4	35.24	30.88^d	26.78^d	23.13^d	20.75^d
TGE5	35.25	28.54^e	25.45^e	20.51^e	18.93^e
SEM	0.003	0.677	0.743	1.181	0.829
P-value	0.89	0.01	0.01	0.01	0.01

Values are presented as mean. Values with different superscripts are significantly different.

In this study, the WHC is higher on day 0 when compared to the chilled storage samples on days 3, 6, 9, and 12. This pattern is analogous to variations in protein solubility, implying that WHC rises in tandem with protein solubility and vice versa. The reduction in WHC with storage duration suggests that cold storage causes biochemical changes and protein denaturation (Marapana *et al*., 2018; Beya *et al*., 2021). Protein denaturation will disrupt the cellular structure and subsequently release the water bound in the meat. The application of thermal force in cooking will denature the meat protein and release water in the meat. Green tea extract lowered the cooking loss in the present study indicating a higher volume of water was retained in the meat, which will be perceived as juiciness by consumers.

4. Conclusion

The present study was conducted to determine the effects of different concentrations of green tea extract on the water holding capacity, drip loss, cooking loss, myoglobin content and pH of minced mutton during chilled storage. Minced mutton added with green tea extract had significantly higher ($p<0.05$) pH, myoglobin content and WHC than the untreated control group at days 3, 6, 9 and 12. In addition, minced mutton with added green tea extract also had significantly lower ($p<0.05$) drip and cooking loss than the control group. The present study showed that a high concentration of green tea extract (2%) had a significant improvement in the meat quality traits measured. In conclusion, the present findings suggest that green tea extract could be used to improve the quality of meat and meat products.

Conflict of interest

The authors declare no conflict of interest.

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