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Enhancing the shelf life of minced beef with sumac extract

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ABSTRACT

The present study investigated the effect of Sumac Water Extract (SWE) on microbial growth and chemical changes in minced meat during refrigerated storage. Therefore, SWE used at three concentrations (4, 5, and 6%) to determine their effect on the sensory attributes, chemical parameters (pH, total volatile nitrogen, and thiobarbituric acid), and bacteriological status including total bacterial count, *Enterobacteriaceae* count, total staphylococcus count of minced meat stored at 4°C for 12 days. The study's results suggest that incorporating different concentrations of SWE improved the sensory attributes of the treated minced meat samples compared to the control samples. Furthermore, the use of SWE with different concentrations led to a decrease in pH, TVN, and TBA values in the treated minced meat as compared to the control group. Among the different concentrations tested, the 6% concentration of SWE exhibited the most significant impact on improving the sensory, chemical, and bacterial quality, surpassing the effects observed with the 4 and 5% concentrations. Consequently, the study concluded that the utilization of SWE as a natural antioxidant and antibacterial preservative for refrigerated minced meat could prolong its shelf life for up to 12 days, in contrast to the control group, which became spoiled completely within 6 days.

Introduction

Beef mince is a rich source of protein, zinc, and vitamins B3 and B12. Meat and meat products create an optimal environment for bacterial growth due to their high moisture content, abundance of essential amino acids and proteins, minerals, vitamins, and other growth factors. Additionally, their pH levels are conducive to microorganism growth (Alahakoon *et al*., 2015).

The sale of chilled minced meat at temperatures between 2-5°C has raised concerns among retailers, consumers, and public health officials regarding its microbiological quality and safety. However, refrigerating minced meat within this temperature range can result in undesirable changes due to microbial growth, leading to a decline in quality, meat spoilage, and economic losses (Elabbasy *et al*., 2014).

According to Bisholo *et al*. (2018), the consumption of contaminated meat and meat products presents a notable global risk, resulting in illnesses and a significant number of fatalities. To address this issue, scientists have explored various methods, including radiation and inorganic chemicals, to reduce contamination in meat products. However, research has shown that chemical preservatives can have harmful effects, such as being carcinogenic, teratogenic, and having residual toxicity (Costa *et al*., 2019). Consequently, there is a growing trend towards the use of natural additives, like sumac extract, as safer alternatives to chemical additives.

Sumac, a member of the Anacardiaceae family and the genus Rhus, is an antioxidant spice known for its various beneficial properties (Tohma *et al*., 2019). It is comprised of various compounds including tannins, phenolic compounds, anthocyanins, organic acids, fatty acids, vitamins, and minerals. These elements contribute to its antioxidant, antibacterial, antifungal, antilipidemic, hypoglycemic, and therapeutic properties (Diler *et al*., 2021; Khalil *et al*., 2021). Beyond its medicinal applications, sumac is also used as a spice, food coloring, food preservative, and finds application in the cosmetic and pharmaceutical industries (Reidel *et al*., 2017; Ozcan *et al*., 2021).

Research by Aliakbarlu and Mohammadi (2014) revealed that water extract of sumac effectively slowed down the oxidation of lipids and the formation of metmyoglobin in ground sheep meat. Furthermore, no toxic effects have been reported for various sumac extracts in hypercholesterolemic rats, as stated by Shafiei *et al*. (2011).

The aim of this study was to examine the influence of sumac water extract on the quality and safety of chilled minced meat. This was achieved through sensory evaluation, analysis of chemical indices (pH, TBA, and TVN), and bacteriological examination including total bacterial count, *Staphylococcus aureus* count, and *Enterobacteriaceae* count during storage at 4°C throughout 12 days of chilled storage.

Materials and methods

Preparation of Sumac Water Extract (SWE)

The extraction of water extract of sumac was done in Scientific Research City in Burj Al Arab; In summary, 100 grams of ground sumac were combined with one liter of distilled water and refluxed at 100°C for 60 minutes. The resulting extract was then filtered through Whatman filter paper (Sigma-Aldrich, St. Louis, MO) and the filtrate was concentrated using a rotary evaporator (Heidolph, Laborata 4003, Schwabach, Germany) before being lyophilized. The lyophilized extracts were sealed in bottles and stored at 4°C. Prior to use, the extract was dissolved in distilled water according to Aliakbarlu and Tajik (2012). The lyophilized extracts were then mixed into ground meat at concentrations of 4, 5, and 6% (w/w) and homogenized at 260 rpm for 2 minutes to ensure even distribution within

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the ground meat.

Collection, preparation, and treatment of minced meat samples with SWE according to Barbosa et al. (2009)

A total of 14 kilograms of minced meat were procured from butcher shops in Damanhour city, El-Behira governorate, Egypt. The gathered samples were placed in sterile polyethylene bags, stored in an ice box, and then transported to the laboratory of the Food Hygiene Department at the Animal Health Research Institute, El-Behira government, Egypt. The minced meat samples were divided into 4 groups, with each group comprising approximately 3.5 kilograms and containing 35 samples of 100 grams each. The first group served as the control (untreated group), while the other 3 groups were treated with 4, 5, and 6% sumac extract, respectively. The treated minced meat samples were individually labeled and packaged in polyethylene bags. The experiment spanned 12 days of refrigerated storage at 4°C, during which each group underwent sensory, chemical, and bacteriological evaluations daily until signs of decomposition appeared in any of the groups. This experimental procedure was replicated 5 times.

Sensory evaluation of treated minced meat samples with different concentrations of SWE according to Lawless and Heymann (2010)

Twenty adults who were untrained and unaware of the experimental approach were given 100±10 grams of minced meat for each concentration. The samples were assigned specific codes, and the panelists were instructed to evaluate the overall acceptance, including color, odor, and texture, while the samples were fresh and uncooked. Subsequently, the samples were cooked without any additives and presented to the panelists for the assessment of their sensory characteristics. Between each sample, the panelists consumed warm water and utilized a ten-point descriptive scale. Ratings of 7-10 denoted ''very good' quality, 4.0-6.9 denoted ''good' quality, and 1.0-3.9 denoted "spoiled". This scoring system was employed to assess appearance, smell, texture, taste, and overall acceptability.

Evaluation of chemical indices of treated minced meat

Potential of hydrogen ion concentration (pH) measurement according to EOS 63-11/(2020)

Ten milliliters of neutralized distilled water and 10 grams of minced beef samples were mixed. The mixture was shaken continuously at room temperature for 10 minutes, then it was left to stand. The pH value was then measured using a pH electrical meter (Bye model 6020, USA). The pH meter was calibrated using two buffer solutions with accurately defined pH values (alkaline pH 7.01, acidic pH 4.01). Neutralized water was utilized to clean the pH electrode, and it was introduced to the samples after the temperature correction system was adjusted.

Determination of total volatile nitrogen "TVN" according to EOS: 63-9/(2006)

In a clean distillation flask, 300 ml of distilled water and 10 grams of minced meat samples were combined and thoroughly mixed. The resulting mixture was then enriched with two grams of magnesium oxide and an anti-foaming agent. Subsequently, 25 ml of 2% boric acid and a few drops of indicator were added to a 500 ml receiving flask, with the receiver tube positioned such that it extended below the boric acid solution. Within 10 minutes, the distillation flask reached boiling temperature, and distillation continued for an additional 25 minutes. Following this, titration of TVN (Total Volatile Nitrogen) against H2SO4 M 0.1 was carried out until a pink color appeared, TVN was calculated according to the following formula:

TVN/l00grams= (mls H_2So_4 n 0.1 for sample – ml H_2So_4 n 0.1 for Blank)x14

Determination of thiobarbituric acid number "TBA" according to EOS: 63-10/(2006)

The test relies on measuring malonaldehyde (MDA) as a byproduct of lipid peroxidation. To summarize, 50 ml of distilled water were mixed with ten grams of prepared minced meat samples and transferred to a distillation flask. An antifoaming agent and 50 ml of diluted hydrochloric acid were then added to the flask. The distillation flask was heated to distill 50 ml of the diluted hydrochloric acid within 10 minutes of reaching boiling. Subsequently, 5 ml of the distilled solution was placed in a covered tube, and 5 ml of prepared thiobarbituric acid was added. The tube was covered, placed in a water bath, boiled for 35 minutes, and then cooled using water for 10 minutes. The absorbance of the sample at a wavelength of 538 nm was measured using a Spectrophotometer (UNICAM969AA Spectronic, USA).

TBA value= absorbance of sample x 7.8 (malonaldehyde (mg) /Kg).

Bacteriological examination of minced meat treated with different concentrations of SWE

Twenty-five grams of minced beef samples were weighed under aseptic condition and homogenized for 1 min in a laboratory blender containing 225 ml of 0.1 % a sterile peptone water (Oxide CM0009) for preparation of an original dilution of 1: 10. Ten-fold serial dilutions up to 106 were prepared. using plate count agar for estimation of the total aerobic bacterial count, plates were incubated at 30°C for 24 hours according to ISO 4833-1 (2013). According to FDA (2001) the staphylococcal count was performed using the Baird Parker agar medium supplemented with egg yolk tellurite emulsion and incubated at 37°C for 48 hours. Identification of Staph. aureus was done according to MacFaddin (2000). Finally, according to ISO 21528-2 (2004), *Enterobacteriaceae* were quantified using violet red bile glucose agar medium and plates were incubated at 37°C for 24 hours, Suspected colonies, characterized by purplish-red appearance surrounded by a red zone of precipitated bile acid, were counted to determine the total *Enterobacteriaceae* counts per gram.

Statistical Analysis

The statistical analysis system (SAS, 2014), Cary, USA, Version 9.3) software was used to statistically analyze the data. The mean and standard deviation "SD" of the organoleptic, chemical, and bacteriological parameters were displayed. Tukey's Studentized Range (HSD) post-hoc test (p0.05) and a nested procedural model ($p<0.05$) were used to compare significant means.

Results and Discussion

Overall acceptability of treated minced meat treated with SWE

The control minced meat sample was completely spoiled on the sixth day of storage at 4°C which was observed during overall acceptance of minced meat. The addition of SWE at 4, 5, and 6% improved the overall acceptability for the sensory properties in minced meat significantly. Samples treated with 4, and 5% SWE maintained their overall acceptability until the 10^{th} and 11^{th} days, respectively, while samples treated with 6% SWE kept their overall acceptability until the 12^{th} day. Moreover, samples containing 6% SWE had the highest acceptability, while those with 4 and 5% SWE had the least enhancement as shown in Table 1.

In our study, it was observed that the application of SWE had a positive impact on the overall acceptability of minced meat and, in turn, increased the shelf life of minced meat. The results indicated that the effect was dependent on the concentration of the extract. These findings align with Aliakbarlu and Mohammadi (2014) who also reported that the application of a water extract of sumac not only improved the sensory characteristics of meat but also extended its shelf life. In addition, Wang *et al*. (2023) reported that addition of sumac (2%−5%) to ground beef increased anthocyanin contents of ground beef which responsible for the color stability of minced meat.

Table 1. Overall acceptance mean values of minced beef treated with varying concentrations of Sumac extract during a storage period at 4°C.

Storage period	Control	Sumac extract concentrations		
		4.00%	5.00%	6.00%
1st day	8.32±0.05^{Da}	8.72±0.02^{Ca}	8.89±0.05^{Ba}	8.99±0.06^{Aa}
2nd day	6.96±0.04^{Db}	8.69±0.06^{Ca}	8.78±0.04^{Bb}	8.96±0.03^{Aa}
3rd day	6.65±0.05^{Db}	8.65±0.05^{Ca}	8.76±0.03^{Bb}	8.93±0.04^{Aa}
4th day	5.49±0.02^{Dc}	8.62±0.09^{Cb}	8.74±0.05^{Bb}	8.88±0.09^{Ab}
5th day	4.19±0.08^{Dd}	7.57±0.07^{Cc}	8.57±0.08^{Bc}	8.83±0.05^{Ab}
6th day	Decomposed	7.54±0.05^{Cc}	8.37±0.02^{Bd}	8.81±0.04^{Ac}
7th day	Decomposed	6.51±0.05^{Cd}	7.94±0.05^{Be}	8.75±0.05^{Ac}
8th day	Decomposed	6.50±0.07^{Cd}	7.68±0.03^{Bf}	7.79±0.02^{Ad}
9th day	Decomposed	6.47±0.09^{Ce}	6.75±0.06^{Bg}	7.52±0.06^{Ae}
10th day	Decomposed	6.45±0.05^{Cf}	6.71±0.03^{Bg}	7.48±0.07^{Af}
11th day	Decomposed	Decomposed	6.70±0.02^{Bg}	7.36±0.04^{Ag}
12th day	Decomposed	Decomposed	Decomposed	7.25±0.09^{Ah}

Results are expressed as Mean±SD

Chemical evaluation of minced meat treated with SWE

Effect of SWE on pH of treated minced meat

The data presented in Table 2 indicated that minced meat samples treated with varying levels of SWE had lower pH values compared to the control samples throughout the different periods of the experiment. Additionally, it was observed that different concentrations of SWE had a significant impact on reducing pH values, particularly at a concentration of 6%.

Different concentration of SWE (4, 5, and 6%) decreased the pH values as compared with control samples. pH Increases of pH in control minced meat may be attributed to the degree of meat spoilage because of protein breakdown into free amino acids, which results in the generation of NH3 and amines, which are alkaline reaction chemicals (Karabagias *et al*., 2011), while decrease in pH values in minced meat treated with SWE can be attributed to that sumac is known to contain organic acids, which can contribute to the acidity of the extract. The application of the extract to minced meat leads to the presence of organic acids such as malic, citric, and fumaric acids, which can effectively decrease the pH of meat. Consequently, this pH reduction can enhance the microbial stability and prolong the shelf life of the meat, as reported by Gulmez *et al*. (2006) and Kossah *et al*. (2011).

Our finding was supported by Aliakbarlu and Mohammadi (2014) who reported that minced sheep meat treated with water extract showed significant reduction in pH values at the end of experiment (day 9) in comparison with control untreated sample. In addition, our results are dose dependent and this in consistent with Wang *et al*. (2023) who reported that the addition of increasing amounts of sumac was found to consistently reduce the pH values of ground beef samples in a dose-dependent manner.

Effect of SWE on TVN content of treated minced meat

The Total Volatile Nitrogen (TVN) content can be used as a measure of the nitrogen released due to protein decomposition caused by microorganisms and/or tissue proteolytic enzymes during storage (Gibriel *et al*., 2007). TVN is frequently used to estimate the rate of deterioration and shelf life of different types of meat (Morshdy *et al*., 2021). TVN mean values of control minced samples was increased as shown in Table 2 and were exceed the permissible limits established by EOS-1694 (2005) (The TVN level should remain below 20 mg/100 grams) by the 5th day, this might be growth of spoilage bacteria which caused protein breakdown and the production of free amines such trimethylamine and dimethylamine as well as ammonia (Rukchon *et al*., 2011). Treated minced meat with different concentration of SWE showed significant decrease in TVN values as compared with control samples. Comparing lower concentrations of sumac water extract (SWE) (4 and 5%) with higher concentration (6%), it was found that SWE 6% was more effective in reducing the TVN value, as indicated in Table 2.

Table 2. Average pH values, TVN, and TBA of minced meat subjected to various concentrations of Sumac extract throughout refrigerated storage at 4°C.

Storage periods	Control	pH value		
		SWE 4%	SWE 5%	SWE 6%
1st day	6.43±0.15^{Ae}	6.23±0.12^{Bj}	6.10±0.10^{Ci}	5.96±0.05^{Dl}
2nd day	6.53±0.23^{Ad}	6.30±0.20^{Bi}	6.10±0.10^{Ci}	6.03±0.06^{Dk}
3rd day	6.70±0.17^{Ac}	6.33±0.15^{Bh}	6.20±0.10^{Ch}	6.06±0.05^{Dj}
4th day	6.76±0.25^{Ab}	6.38±0.20^{Bg}	6.24±0.02^{Cg}	6.10±0.02^{Di}
5th day	6.86±0.21^{Aa}	6.43±0.15^{Bf}	6.26±0.01^{Cg}	6.16±0.05^{Dh}
6th day	Decomposed	6.46±0.21^{Ae}	6.30±0.03^{Bf}	6.20±0.02^{Cg}
7th day	Decomposed	6.53±0.15^{Ad}	6.33±0.10^{Be}	6.23±0.05^{Cf}
8th day	Decomposed	6.56±0.20^{Ac}	6.41±0.10^{Bd}	6.26±0.06^{Ce}
9th day	Decomposed	6.66±0.03^{Ab}	6.45±0.03^{Bc}	6.31±0.02^{Cd}
10th day	Decomposed	6.75±0.06^{Aa}	6.54±0.10^{Bb}	6.36±0.05^{Cc}
11th day	Decomposed	Decomposed	6.83±0.10^{Aa}	6.44±0.06^{Bb}
12th day	Decomposed	Decomposed	Decomposed	6.67±0.02^{Aa}
		TVN		
1st day	1.37±0.06^{Ae}	1.22±0.05^{Bj}	1.07±0.04^{Ck}	1.03±0.03^{Dl}
2nd day	14.03±0.15^{Ad}	12.33±0.08^{Bi}	10.46±0.55^{Cj}	9.33±0.49^{Dk}
3rd day	14.36±0.37^{Ac}	12.53±0.80^{Bh}	10.63±0.08^{Ci}	9.43±0.58^{Dj}
4th day	14.60±0.60^{Ab}	12.80±0.72^{Bg}	10.90±0.40^{Ch}	9.53±0.58^{Di}
5th day	23.01±0.13^{Aa}	12.90±0.71^{Bf}	11.10±0.08^{Cg}	9.66±0.73^{Dh}
6th day	Decomposed	13.03±0.68^{Ae}	11.23±0.40^{Bf}	9.85±0.04^{Cg}
7th day	Decomposed	13.13±0.57^{Ad}	11.43±0.46^{Be}	9.92±0.81^{Cf}
8th day	Decomposed	13.32±0.49^{Ac}	11.53±0.12^{Bd}	11.11±0.08^{Ce}
9th day	Decomposed	13.73±0.06^{Ab}	11.60±0.05^{Bc}	10.68±0.04^{Cd}
10th day	Decomposed	13.68±0.09^{Aa}	11.80±0.48^{Bb}	11.10±0.08^{Cc}
11th day	Decomposed	Decomposed	12.85±0.12^{Aa}	11.36±0.05^{Bb}
12th day	Decomposed	Decomposed	Decomposed	11.83±0.04^{Aa}
		TBA		
1st day	0.076±0.01^{Ad}	0.054±0.01^{Bi}	0.056±0.01^{Bi}	0.046±0.01^{Cl}
2nd day	0.67±0.03^{Ac}	0.62±0.06^{Bh}	0.58±0.03^{Ch}	0.45±0.11^{Dk}
3rd day	0.86±0.01^{Ab}	0.66±0.03^{Bg}	0.60±0.05^{Cg}	0.47±0.12^{Dj}
4th day	0.87±0.01^{Aa}	0.71±0.01^{Bf}	0.61±0.01^{Cg}	0.49±0.11^{Di}
5th day	0.88±0.01^{Aa}	0.73±0.02^{Be}	0.63±0.02^{Cf}	0.51±0.02^{Dh}
6th day	Decomposed	0.73±0.01^{Ae}	0.67±0.01^{Be}	0.54±0.01^{Cg}
7th day	Decomposed	0.76±0.03^{Ad}	0.69±0.02^{Be}	0.57±0.02^{Cf}
8th day	Decomposed	0.78±0.07^{Ac}	0.71±0.03^{Bd}	0.59±0.03^{Ce}
9th day	Decomposed	0.81±0.01^{Ab}	0.73±0.01^{Bc}	0.63±0.01^{Cd}
10th day	Decomposed	0.86±0.03^{Aa}	0.77±0.02^{Bb}	0.69±0.02^{Cc}
11th day	Decomposed	Decomposed	0.81±0.03^{Aa}	0.73±0.03^{Bb}
12th day	Decomposed	Decomposed	Decomposed	0.79±0.01^{Aa}

SD= Standard deviation Means carrying different superscript capital letter on the same row are significantly different ($P<0.05$). while means carrying different superscript small letter on the same column are significantly different ($P<0.05$).

Our findings showed that the addition of SWE decreased TVN values until day 12 of the storage period. Our results were consistent with Langroodi *et al*. (2018), who found that TVN values of treated mined meat with sumac extract were significantly lower in the treated group with 4% sumac extract compared to the control groups during storage time. In addition, Goneim (2012) reported a low TVN value of fresh sausage incorporated with sumac during storage for five days.

Impact of SWE on thiobarbituric acid content of treated minced meat

The measurement of lipid oxidation indicators, such as TBA values, is considered a key factor in determining the shelf-life of ground meat (Valerio *et al*., 2020).

In our study, TBA values of control minced meat exceeded the permissible limits established by EOS-1694 (2005) (not more 0.9 mg MDA/kg) on the 6th day of storage but minced meat treated with different concentration of SWE did not exceed the same permissible limit during different periods of storage. Control samples started to develope a rancid flavor on the 6th day of storage. On the other hand, minced meat samples treated with 4% and 5% SWE maintained a normal flavor until the 10th and 11th days of storage, respectively. The samples treated with 6% SWE remained suitable for consumption until the end of the experiment without any signs of rancidity, as indicated in Table 2. These results suggest that SWE possesses antioxidant properties, which is supported by a study conducted by Aliakbarlu *et al*. (2013) who found that water extract of sumac have the highest antioxidant properties.

The antioxidant properties of sumac may be attributed to compounds that include phenolic hydroxyl groups and double bonds, such as gallic acid, hydrolysable tannins, and flavonoids. Phenolic compounds are known to inhibit lipid oxidation by scavenging active radicals to impede radical chain reactions, as well as by chelating transition metal ions during the oxidation process (Wang and Zhu, 2017).

Our results are dose dependent and this consistent with Wang *et al*. (2023) found that the TBA values in ground beef treated with sumac (3, 4, and 5%) were notably lower than those of both the control sample and the treated samples (with 0.5, 1, and 2% sumac) after the end of storage period. In addition, Aliakbarlu and Mohammadi (2014) reported that SWE significantly retarded TBARS formation in ground sheep meat.

Impact of SWE on microbiological quality of minced meat

Effect of SWE on total bacterial counts of minced meat

The microbial contamination level of the ground beef samples was evaluated by employing the total aerobic plate count (TAPC), a crucial indicator for assessing the quality and safety of raw beef (Valerio *et al*., 2020).

The aerobic bacterial count in the untreated minced meat samples was higher compared to the minced meat treated with various concentrations of sumac water extract (SWE) until the sixth day of storage. The average aerobic bacterial count in the minced meat treated with 6% SWE was lower than that of the minced meat treated with 4 and 5% SWE, respectively. Decomposition of the minced meat treated with 4% SWE began on the 11th day of storage, while minced meat treated with 5% SWE decomposed on the 12th day. However, minced meat treated with 6% SWE remained suitable for consumption until the conclusion of the experiment. The higher concentration of 6% SWE proved more effective in reducing the bacterial count compared to the lower concentration of 4% SWE, as indicated in Table 3.

Our findings are consistent with Wang *et al*. (2023) who observed that treating ground beef samples with a 5% concentration of sumac resulted in a decrease in microbial population. Additionally, the antimicrobial properties of sumac against food spoilage and pathogenic bacteria have been documented by Wang and Zhu (2017). Gabr (2014) also reported that the addition of sumac extracts to meat can extend its shelf life by reducing the total microbial counts. Aliakbarlu and Mohammadi (2014) reported that samples treated with SWE, the total viable count (TVC) were reduced by 4.2 and 3.2 log cfu/g on days 6 and 9, respectively.

Table 3. Average aerobic bacterial counts (log10 cfu/g) of minced meat subjected to varying concentrations of Sumac extract during refrigerated storage at 4°C.

Storage period	Control	Sumac extract concentrations		
		4.00%	5.00%	6.00%
1st day	4.82±0.15^{Ae}	4.58±0.07^{Bi}	4.46±0.11^{Cj}	4.32±0.13^{Dk}
2nd day	5.01±0.05^{Ad}	4.65±0.12^{Bh}	4.54±0.09^{Ci}	4.47±0.05^{Dj}
3rd day	5.27±0.34^{Ac}	4.92±0.13^{Bg}	4.85±0.11^{Ch}	4.72±0.08^{Di}
4th day	5.47±0.01^{Ab}	5.17±0.08^{Bf}	5.03±0.01^{Cg}	4.96±0.01^{Dh}
5th day	5.48±0.00^{Aa}	5.19±0.23^{Be}	5.14±0.22^{Cf}	5.02±0.17^{Dg}
6th day	Decomposed	5.25±0.24^{Ad}	5.22±0.22^{Be}	5.16±0.23^{Cf}
7th day	Decomposed	5.31±0.20^{Ac}	5.25±0.22^{Bd}	5.19±0.23^{Ce}
8th day	Decomposed	5.44±0.02^{Ab}	5.40±0.02^{Bc}	5.36±0.01^{Cd}
9th day	Decomposed	5.45±0.01^{Aa}	5.42±0.01^{Bb}	5.37±0.01^{Cd}
10th day	Decomposed	5.46±0.04^{Aa}	5.43±0.01^{Ba}	5.39±0.01^{Cc}
11th day	Decomposed	Decomposed	5.44±0.04^{Ba}	5.41±0.01^{Cb}
12th day	Decomposed	Decomposed	Decomposed	5.43±0.02^{Aa}

Results are expressed as Mean±SD

Effect of SWE on *Staphylococcus aureus* count of minced meat

The data presented in Table 4 showed that the average counts of *Staphylococcus aureus* in untreated minced meat samples were higher than those in minced meat treated with various concentrations of sumac water extract (SWE) until the sixth day of storage, at which point decomposition began. The average counts of staphylococci in the minced meat treated with 6% SWE were lower than those treated with 4 and 5% SWE. These results suggest that higher concentration of SWE (6%) was more effective at reducing the staphylococcal count compared to the lower concentrations (4 and 5%).

The results elucidated that minced meat samples treated with higher concentration of SWE had lower *Staphylococcus aureus* count, but the samples that treated with lower concentration of SWE showed a higher *Staphylococcus aureus* count level. Our results were confirmed by Nasar-Abbas and Halkman (2004) who discovered that water extract of sumac exhibited a moderate level of antibacterial activity against *Staphylococcus aureus*. In addition, Fazeli *et al*. (2007) reported that *Staphylococcus aureus* was the most sensitive food-borne bacteria to sumac extract.

Table 4. Average *Staphylococcus aureus* counts (log_{10} cfu/g) of minced meat subjected to varying concentrations of Sumac extract during refrigerated storage at 4°C.

Storage period	Control	Sumac extract concentrations		
		4.00%	5.00%	6.00%
1st day	3.81±0.19^{Ae}	3.67±0.17^{Bj}	3.50±0.17^{Ci}	3.31±0.27^{Dk}
2nd day	4.18±0.16^{Ad}	4.02±0.15^{Bi}	3.83±0.20^{Ch}	3.66±0.31^{Dj}
3rd day	4.48±0.08^{Ac}	4.31±0.14^{Bh}	4.22±0.13^{Cg}	4.15±0.14^{Di}
4th day	4.71±0.00^{Ab}	4.56±0.05^{Bg}	4.54±0.06^{Cf}	4.46±0.05^{Dh}
5th day	5.20±0.08^{Aa}	4.94±0.03^{Bf}	4.91±0.01^{Ce}	4.81±0.04^{Dg}
6th day	Decomposed	5.05±0.58^{Ae}	5.07±0.22^{Bd}	4.99±0.01^{Cf}
7th day	Decomposed	5.23±0.03^{Ad}	5.25±0.03^{Bc}	5.16±0.23^{Ce}
8th day	Decomposed	5.31±0.20^{Ac}	5.26±0.04^{Bc}	5.23±0.07^{Cd}
9th day	Decomposed	5.32±0.02^{Ab}	5.31±0.01^{Bb}	5.29±0.01^{Cc}
10th day	Decomposed	5.51±0.01^{Aa}	5.32±0.01^{Bb}	5.31±0.01^{Cb}
11th day	Decomposed	Decomposed	5.45±0.01^{Aa}	5.33±0.02^{Bb}
12th day	Decomposed	Decomposed	Decomposed	5.39±0.02^{Aa}

Results are expressed as Mean±SD

Impact of SWE on *Enterobacteriaceae* count of treated minced meat

Data in Table 5 revealed that *Enterobacteriaceae* count in the untreated minced meat samples was notably higher than in minced meat treated with various concentrations of sumac water extract (SWE) until the sixth day of refrigerated storage. The untreated samples began to decompose on the sixth day of storage. The average *Enterobacteriaceae* count in the minced meat treated with 6% SWE was lower than those treated with 4 and 5% SWE, respectively. These results indicated that as the concentration of SWE increases, the count of *Enterobacteriaceae* decreases. Additionally, minced meat samples treated with the highest concentration of SWE exhibited lower *Enterobacteriaceae* counts compared to untreated samples or samples with lower concentrations of SWE. This outcome may be attributed to the presence of phenolic compounds and tannic acids in sumac, which have antibacterial effects (Langroodi *et al*. 2018).

Table 5. Average *Enterobacteriaceae* counts (log_{10} cfu/g) of minced meat subjected to varying concentrations of Sumac extract during refrigerated storage at 4°C.

Storage period	Control	Sumac extract concentrations		
		4.00%	5.00%	6.00%
1st day	$4.08{\pm}0.13^{Ae}$	$3.94{\pm}0.09^{Bi}$	$3.83{\pm}0.12^{Cj}$	$3.69{\pm}0.08^{Dk}$
2nd day	$4.37{\pm}0.04^{Ad}$	$4.21{\pm}0.05^{Bh}$	$4.12{\pm}0.04^{Ci}$	$3.99{\pm}0.04^{Dj}$
3rd day	$4.67{\pm}0.01^{Ac}$	$4.52{\pm}0.04^{Bg}$	$4.42{\pm}0.05^{Ch}$	$4.33{\pm}0.09^{Di}$
4th day	$4.96{\pm}0.02^{Ab}$	$4.87{\pm}0.08^{Bf}$	$4.69{\pm}0.14^{Cg}$	$4.67{\pm}0.03^{Dh}$
5th day	$5.47{\pm}0.01^{Aa}$	$5.12{\pm}0.03^{Be}$	$5.06{\pm}0.01^{Cf}$	$4.98{\pm}0.01^{Dg}$
6th day	Decomposed	$5.26{\pm}0.03^{Ad}$	$5.21{\pm}0.03^{Be}$	$5.13{\pm}0.05^{Cf}$
7th day	Decomposed	$5.33{\pm}0.01^{Ac}$	$5.30{\pm}0.01^{Bd}$	$5.21{\pm}0.04^{Ce}$
8th day	Decomposed	$5.40{\pm}0.03^{Ab}$	$5.33{\pm}0.02^{Bc}$	$5.28{\pm}0.03^{Cd}$
9th day	Decomposed	$5.39{\pm}0.01^{Aa}$	$5.36{\pm}0.01^{Bb}$	$5.30{\pm}0.02^{Cd}$
10th day	Decomposed	$5.40{\pm}0.01^{Aa}$	$5.38{\pm}0.01^{Ba}$	$5.32{\pm}0.02^{Cc}$
11th day	Decomposed	Decomposed	$5.38{\pm}0.03^{Aa}$	$5.34{\pm}0.01^{Bb}$
12th day	Decomposed	Decomposed	Decomposed	$5.36{\pm}0.01^{Aa}$

Results are expressed as Mean±SD

Our findings demonstrated that the percentage of reduction in *Enterobacteriaceae* count is dependent on the concentration of sumac water extract (SWE). Specifically, higher concentrations of SWE resulted in greater reduction in *Enterobacteriaceae* count. These results are consistent with the findings of Ahmed *et al*. (2020) who reported that the highest percentage of reduction in *Enterobacteriaceae* count was achieved with sumac extract at a concentration of 5%, followed by concentrations of 2.5%, while the lowest effect was observed with sumac extract at a concentration of 1%.

Conclusion

Sumac water extracts improved the sensory attributes and caused a decline in the pH, TVN, and TBA values in treated minced meat samples. Additionally, sumac water extract at various concentrations during chilling of minced meat can enhance its shelf life and reduce the presence of *Staphylococcus aureus* and *Enterobacteriaceae*, thus minimizing microbial contamination during storage. The findings were dependent on the concentration, as the impact on the sensory, chemical, and bacteriological characteristics became more pronounced with the rise in SWE concentration from 4 to 6%. This highlights the potential of sumac water extract as a natural and safe option for preserving minced meat.

Conflict of interest

The authors declare that they have no conflict of interest.

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