Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Role of Edible Flowers on Reducing Lipid and Protein Oxidation in Ground Beef

Krishna Brunda Duggirala
University of Georgia
Anand Mohan
anandmohan@uga.edu
University of Georgia

Research Article

Keywords: Edible Flower, Ground Beef, Lipid and Protein Oxidation; TBARS; DPPH; Textural properties; Scavenging activity

Posted Date: June 7th, 2024

DOI: https://doi.org/10.21203/rs.3.rs-4468791/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

This study examined the antioxidant, physicochemical, and sensory characteristics of raw ground beef patties, including those augmented with varying percentages of roselle (*Hibiscus sabdariffa* L.) and rose (*Rosa canina* L.) powders, and stored at 4°C for 7 days. The analysis encompassed parameters such as 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, 2-thiobarbituric acid reactive substances (TBARS), carbonyls, Schiff bases, free thiols, water holding capacity, pH, color, and texture. The incorporation of roselle and rose powders led to heightened scavenging activity, resulting in reduced oxidative activity, carbonyls, Schiff bases, and free thiols during storage. Enhanced water holding capacity and decreased pH were observed in raw ground beef patties treated with these powders. While minimal impact on texture was noted across all samples, color attributes of patties treated with roses remained acceptable by the 7th day. Overall, the inclusion of rose powder exhibited more favorable effects than untreated raw ground beef patties and those treated with roselle. Consequently, raw ground beef patties treated with rose powders demonstrated greater efficacy in enhancing the quality attributes under investigation.

INTRODUCTION

In recent years, there's been a notable shift towards healthier eating habits, with consumers increasingly opting for natural or processed foods to address health concerns associated with unhealthy diets. (Scollan et al., 2006;Cabrera & Saadoun, 2012). This change has impacted the meat industry, prompting exploration into alternative protein sources and innovative production methods to meet evolving consumer preferences. Despite meat's historical significance, perceptions around it have shifted, leading to a rise in demand for healthier meat options. (OECD/FAO, 2023).

Ground beef, particularly in developing nations and the U.S., has seen a surge in demand. To address challenges like supply fluctuations and rising costs, technological advancements are being integrated into beef production. These technologies aim to improve efficiency, satisfy consumer needs, and address health considerations by incorporating dietary fiber. Various plant-derived ingredients are being explored to enhance the texture, taste, and shelf life of beef products, aligning with sustainability goals (Drouillard, 2018).

Concerns over synthetic additives, low dietary fiber, and high cholesterol, salt, and saturated fat levels in beef have spurred the search for alternatives. It's crucial to maintain high-quality protein while mitigating these negative aspects. Oxidation processes can compromise beef quality, leading to off-flavors and decreased nutritional value (Kerth & Miller, 2015). Thus, proper processing and preservation methods are essential for maintaining consumer satisfaction and extending shelf life (Mishra et al., 2023).

Dietary fiber, lacking in meat, is vital for health. To address this, the industry adds fibers from various sources to meat products to enhance their nutritional value. Additionally, the use of antioxidants is crucial for extending shelf life and preventing spoilage. Natural antioxidants from plants, including edible flowers, offer a promising alternative to synthetic ones (Dujmović et al., 2022). Edible flowers, rich in antioxidants, have been used in traditional medicine and food for centuries and show potential for preserving meat products (Fernandes et al., 2020).

Among edible flowers, roses and hibiscus stand out for their antioxidant properties. Roses, known for their various health benefits, effectively inhibit lipid oxidation in meat products (Vinokur et al., 2006). Similarly, hibiscus extracts, rich in phytochemicals, combat oxidative damage and enhance meat quality and taste (Rodriguez et al., 2020; Efosa et al., 2023).Incorporating these flowers into beef products offers improved quality and nutritional value, making them valuable additions to the industry (Santos et al., 2022).

This study evaluates the impact of rose and hibiscus flowers on lipid and protein oxidation in fresh ground beef stored under simulated retail conditions for seven days. By understanding the mechanisms behind oxidation in beef products and exploring natural antioxidants, this research aims to enhance the quality and shelf life of meat-based products. Ultimately, it provides valuable insights into the potential applications of edible flowers in meat preservation and quality enhancement.

MATERIALS AND METHODS

2.1 Raw materials and chemicals

Fresh raw ground beef (lean/fat blend ratio of 80/20, serving as the experimental unit) was procured from a local beef supplier, FPL Foods, in Augusta, GA. A certificate of analysis was provided with the purchased ground beef blend, verifying its composition and lean/fat ratio. Food-grade rose, and hibiscus flowers were acquired from organic edible flower selections available from a local purveyor and were subsequently freeze-dried before being finely ground into powders. Analytical grade chemicals, including Thiobarbituric acid (TBA), trichloroacetic acid (TCA), 1,1,3,3-tetraethoxypropane (TEP), diethylenetriaminepentaacetic acid (DTPA), butylated hydroxytoluene (BHT), 2,4-dinitrophenylhydrazine (DNPH), 5,5'-dithiobis (2-nitrobenzoic acid) (DTNB), and bicinchoninic acid (BCA), were sourced from Sigma-Aldrich, Co. (based in St. Louis, MO). Additionally, chemical standards of deuterated 4-oxo-2-nonenal-d3 and the derivatization reagent amino oxyacetic acid (AOA) were purchased from the Cayman Chemical Company, headquartered in Ann Arbor, MI.

2.2 Processing of raw ground beef patties, packaging, and retail storage

The raw ground beef patties were mixed with the treatment ingredients and molded into patties. The ground beef patties were subsequently placed in foam trays on absorbent pads and overwrapped with polyvinyl chloride film (oxygen transmission rate of 14000 cc/mm^2/24 h/L atm; Koch Supplies, Inc., Kansas City, Mo., U.S.A.). The ground beef patties were stored and displayed under retail display conditions (4 ± 1°C; continuous deluxe warm white, fluorescent lighting; 1600 lx; Phillips, Inc., Somerset, N.J., U.S.A.) for 7 d in a retail display case. The experiment was repeated three times independently on three separate occasions. This entails dividing the raw ground beef into seven treatments, each consisting of 30 grams: raw ground beef patties (control), raw ground beef patties mixed with 1% hibiscus powder, ground beef patties mixed with 2% hibiscus powder, ground beef patties mixed with 3% hibiscus powder, raw ground beef patties mixed with 1% rose powder, ground beef patties mixed with 2% rose powder, and ground beef patties mixed with 3% rose powder. All preparation procedures, including mixing, patty formation, packaging, and storage, were conducted at 4 ± 1°C. The packages were rotated daily to minimize any potential effects due to localized conditions. For analysis, 5.0 grams of ground beef patties were homogenized using an Ultra Turrax homogenizer at 3000 rpm

with 35 mL of 20 mM phosphate buffer containing 0.6 M NaCl and adjusted to a pH of 6.5. These aliquots were then stored at -80°C for future analysis.

2.3 pH

The pH of raw ground beef patties was assessed using a pH meter (Thermo Scientific Athens, Georgia, USA) equipped with a pierced probe. Measurements were taken after processing the raw ground beef patties for 7 days stored at 4°C. The pH readings were taken three times for each sample and averaged for statistical analysis (Mohan et al., 2016a).

2.4 Water Holding Capacity

The moisture-holding capacity of the uncooked product was assessed in triplicate following the method described by (Hughes et al., 1997). Initially, 10 grams of the batter (W1) was weighed and placed into a glass jar. The jar was then heated in a water bath at 90°C for 10 minutes. Subsequently, after allowing the samples to cool to room temperature, they were wrapped in cotton cheesecloth and centrifuged at 1400 rpm for 15 minutes. After centrifugation, the samples were reweighed (W2). The water holding capacity (WHC) was calculated using the following equation:

$\%WHC = 1 - \frac{T}{M} \times 100 = 1 - \frac{((W1) - (W2))}{M} \times 100$ where T is the amount of water lost after heating and centrifugation, and M is the total moisture content of the sample.

2.5 Instrumental color analysis

The L*, a*, and b* color values were assessed using a Hunter Lab colorimeter (McKinley Scientific Reston, Virginia, USA). Positive values of L*, a*, and b* signify the product's brightness, whereas negative values indicate dullness. Color measurements for each patty were taken at three random locations and averaged for statistical analysis. The ground raw beef patties (control) were rotated daily to minimize positional effects (Mohan et al., 2016b).

2.6 Texture analysis

This experiment used a TAXT2i texture analyzer;(Stable Micro Systems Ltd., Surrey, UK) equipped with a 40 mm diameter glass probe. The objective was to assess the texture of the sample under specified conditions. The sample was positioned directly beneath the instrument on a plate, and a Tpa compression test was conducted using a 50 kg load cell and a 2 kg weight for calibration purposes. The samples were divided into three equal parts and placed in the center of the compression plate for texture measurement. Two consecutive compressions were performed, with the instrument set at 50% strain and a crosshead speed of 250 mm/min. A platen probe with a diameter of 100 mm was utilized to compress the sample and evaluate various textural parameters between the two compressions, including force (N)-distance (mm) curve, hardness (g), springiness (%), resilience (%), cohesiveness (%), and gumminess (%). The test was conducted in duplicate to ensure accuracy, with three measurements taken for each replicate (Bermúdez et al., 2023a). Subsequently, the data collected from the three measurements were averaged to mitigate any potential anomalies or measurement errors (Mohan et al., 2016c).

2.7 Determination of TBARS

The MDA measurement in raw ground beef patties, as free MDA equivalents, was conducted following the procedures outlined by (Reitznerová et al., 2017) with some modifications. Initially raw, homogenates (400 μL) or standard solutions (400 μL) were transferred to a 1.5 mL microtube, and the volume was adjusted to 1 mL using a 7.5% (w/v) solution of trichloroacetic acid. The samples were vortexed and then sonicated for 5 minutes to release the MDA from the matrix and precipitate the proteins. Following centrifugation at 3000 g for 5 minutes, the supernatant (500 μL) was mixed with 500 μL of TBA (40 mM, prepared in glacial acetic acid), vortexed, and heated in a water bath at 90°C for 45 minutes. After cooling in an ice bath for 10 minutes and centrifuging at 3000 *g* for 1 minute, the absorbance was measured at 532 nm using a UV1800 Spectrophotometer. MDA levels were quantified using a standard TEP curve (0 to 10 μmol). The results were expressed as nmol MDA per gram of sample.

2.8 Determination of Protein Carbonyl Content

Total protein carbonyls were performed using the DNPH method as outlined by (Levine et al., 1994), with certain adjustments. Initially, 400 μL of raw sample was mixed with 1 mL of ice-cold 10% trichloroacetic acid (TCA) and stored at 4°C for 15 minutes. From the homogenized samples, 400 μL of thawed digest was transferred to 1.5-mL Eppendorf test tubes, combined with 1 mL of ice-cold 10% TCA, and then incubated at 40°C for 15 minutes to release the digested proteins from the lipid particles. Subsequently, one set of meat samples undergo 2,4-dinitrophenylhydrazine (DNPH) derivatization, while blank samples will be treated with 2.0 M HCl instead of DNPH. The carbonyl concentration (nmol/mg protein) will be determined using the absorbance values at 280 nm and 370 nm, respectively, employing the following equation:

$$\frac{\varvec{C}\text{hydrazone}}{\varvec{C}\text{protein}} = \frac{\varvec{A}_{370}}{\varepsilon_{\varvec{h}\varvec{y}\varvec{d}\varvec{r}\varvec{a}\varvec{z}\varvec{o}\varvec{n}\varvec{e},370} \times \left(\varvec{A}_{280} - \varvec{A}_{370}\right) \times 0.43} \times 10^6$$

where $\varepsilon_{\text{hydrazone},370}$ is 22,000 $M^{-1}\,cm^{-1}$ and the carbonyl concentrations obtained from the blanks will be subtracted from the corresponding treated sample.

2.9 Determination of Free Thiols Concentration

A modified Ellman's method utilizing 5,5'-dithiobis (2-nitrobenzoic acid) (DTNB) was employed to determine the concentration of thiol oxidation. Initially, raw ground beef homogenates (5 mL) and 5 mL digests were centrifuged (10000 g, 15 min) to eliminate insoluble protein. Subsequently, 0.5 mL of 10 mM DTNB was added to 4.5 mL aliquots of the supernatant. All mixtures were shielded from light and allowed to react at room temperature for 30 minutes. A reagent blank of 0.5 mL of 20 mM phosphate buffer (pH 6.5) was also prepared. The absorbance will be spectrophotometrically measured at 412 nm, and the thiol concentration was determined using the Lambert-Beer formula (ε412 = 14000 M–1 cm–1), expressed in nanomoles of thiol per milligram of protein. Protein content was determined spectrophotometrically at 280 nm using a BSA standard curve. (Hu et al., 2018).

2.10 Determination of Schiff bases

The fluorescence emission of Schiff bases was evaluated following the protocol outlined by (Sobral et al., 2020) with minor adjustments. Initially, a meat sample weighing 1 g was homogenized for 30 seconds with 5 mL of phosphate buffer solution (20 mM, NaCl 0.6 M, pH 6.5). Subsequently, 2 mL of the extract was diluted with 8 mL of solvent (dichloromethane: ethanol in a 2:1 v/v ratio) and vortexed for 30 seconds. After

centrifugation at 4000 g for 10 minutes, the upper phase was collected, and 200 µL of the supernatant was transferred to a cuvette to measure the fluorescence intensities (FI). Emission spectra were recorded from 390 to 600 nm with the excitation wavelength set at 360 nm using ;(Cary Eclipse Fluorimeter from Agilent, USA). All measurements were performed in triplicate, and the fluorescence intensities will be expressed in arbitrary units (AU).

2.11 Determination of 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity assay

Samples were prepared, and the DPPH radical scavenging activity was assessed following the protocol outlined by(Soriano et al., 2018) with minor adjustments. Initially, 3 g of the refrigerated stored patty was weighed using an analytical balance and homogenized in 6 mL of methanol: water (80:20, v/v) using a homogenizer at 10,000 rpm for 1 minute. Subsequently, the mixture was centrifuged at 9,840 g for 10 minutes using a refrigerated centrifuge. The supernatant was filtered through Whatman filter paper No. 1. An aliquot (200 μL) of the supernatant was mixed with 800 μL of distilled water and 1 mL of 0.2 mM methanolic DPPH solution, followed by vertexing using a test tube shaker at high speed for 2 minutes. The mixture was left in the dark for 20 minutes before the absorbance was measured at 517 nm using a UV-Vis spectrophotometer. The percentage of DPPH radical scavenging activity was calculated using the following equation:

Radical Scavenging Activity = [(Absorbance Control – Absorbance Sample) / Absorbance Control] × 100

3. Statistical analysis

The findings were evaluated using descriptive statistical analysis (mean ± SD), one-way ANOVA, and post hoc comparison using the Tukey honest significant difference (HSD) test to discover substantial changes between experiments (p-value $\leq$ 0.05). All analyses were carried out by using JMP analytic software (SAS Institute Inc, Cary, NC, USA).

RESULTS

4.1 pH

The influence of rose and hibiscus edible flower powders on the pH of raw ground beef patties is depicted in Fig. 2. The pH values of raw ground beef patties (control) and those treated with rose at 1% and 2% concentrations exhibited significant differences on days 0 and 7 of storage ($p < 0.05$). However, there were no significant differences in pH values among the raw ground beef patties treated with 1%, 2%, and 3% hibiscus powders and 3% rose powder between the 0th and 7th day of storage.

On day 0, the pH of raw ground beef patties (control) was 5.7, which increased to 5.9 by the 7th day ($p < 0.05$). In contrast, patties treated with 1% hibiscus powder showed a pH of 5.5 on day 0, which remained the same at 5.5 by day 7 with no significant difference ($p < 0.05$). Also, patties treated with 2% hibiscus powder had a pH of 5.3 on day 0, which remained almost unchanged at 5.3 on day 7 ($p < 0.05$). Likewise, those treated with 3% hibiscus powder maintained a pH of 5.0 on days 0, 5, and 7 ($p < 0.05$). On the other hand, patties treated

with 2% rose powder exhibited similar pH results on both days, 0 and 7. Patties treated with 1% rose powder showed a pH of 5.6 on day 0, which remained the same as 5.6 by day 7 ($p < 0.05$). However, those treated with 2% rose powder had a pH of 5.5 on day 0, which decreased to 5.4 on day 7 ($p > 0.05$). Also, patties treated with 3% rose powder had the lowest pH on day 0 compared to control and patties treated with 1% and 2% rose powders, with pH values of 5.4 on day 0 remained the same which was 5.4 on day 7 ($p < 0.05$).

4.2 Water holding capacity

The impact of rose and hibiscus on raw ground beef patties is illustrated in Fig. 3. Water holding capacity (WHC) values of raw ground beef patties (control) and those treated with 2% and 3% rose powder exhibited significant differences on both the 0th and 7th day of storage ($p < 0.05$). Conversely, there were no significant differences in WHC values among patties treated with 1%, 2%, and 3% hibiscus powders and 1% rose powder between the 0th and 7th day of storage.

On day 0, raw ground beef patties (control) had a WHC of 97.8%, which remained to be 97.8% by the 7th day ($p > 0.05$). However, patties treated with 1% hibiscus powder exhibited a WHC of 97.3% on day 0, slightly increasing to 97.5% by the 7th day with no significant difference ($p < 0.05$). Similarly, those treated with 2% hibiscus powder had a WHC of 96.8% on day 0 and 97.3% on the 7th day, showing no significant difference ($p > 0.05$). Likewise, patties treated with 3% hibiscus powder maintained a consistent WHC, with values of 96.5% on day 0 and 96.6% on day 7 ($p < 0.05$).

However, patties treated with 2% and 3% rose powder showed significant differences in WHC on days 0 and 7. This rise in WHC could be due to the higher dietary fiber content of rose powder added to raw ground beef patties, with higher concentrations further enhancing WHC, unlike those treated with 1% rose powder, which exhibited no significant difference. For instance, patties treated with 2% rose powder had a WHC of 96.3% on day 0, which increased to 97.2% by the 7th day ($p > 0.05$). Similarly, those treated with 3% rose powder had the lowest WHC on day 0 compared to control and other treatments, with 96.1% and 97.3% on days 0 and 7, respectively ($p < 0.05$).

4.3 Color

The L^*-mean values of raw ground beef patties (control) and those treated with hibiscus powders 1%, 2%, and 3%, and rose powders 1%, 2%, and 3%, are presented in Table 1. On day 0, the L^* value for raw ground beef patties (control) was 45.27 ± 0.82, which increased to 50.11 ± 0.02 on day 7, indicating a significant difference ($p < 0.05$). Similarly, raw ground beef patties treated with hibiscus powder 1% exhibited a lightness of 40.95 ± 0.97 on day 0, which increased to 46.57 ± 0.65 on day 7, showing a significant difference ($p < 0.05$). Comparable trends were observed for raw ground beef patties treated with hibiscus powder 2% and 3%, with initial lightness values of 39.11 ± 0.62 and 33.95 ± 0.68 on day 0, respectively, increasing to 43.63 ± 0.12 and 40.81 ± 0.3 on day 7, respectively ($p < 0.05$).

Table 1

The table represents Lightness (*L**), red/green coordinate (*a**), and yellow/blue coordinate (*b**) from the data obtained from Day 0 to Day 7, with treatments shown in the first column. P-value is < 0.05. Letters connected by different letters are significantly different.

	L*				
	Day 0	***Day 1***	***Day 3***	***Day 5***	***Day 7***
Control	45.27 ± 0.82^{cd}	46.57 ± 0.9^{bc}	48.54 ± 0.57^{ab}	50.05 ± 1.09^{a}	50.11 ± 0.02^{a}
Hibiscus 1%	40.95 ± 0.97^{fghijk}	41.76 ± 0.75^{efghij}	44.45 ± 0.41^{cde}	45.46 ± 0.12^{bcd}	46.57 ± 0.65^{bc}
Hibiscus 2%	39.11 ± 0.62^{jklmno}	40.41 ± 0.4^{hijklm}	42.78 ± 0.08^{defghi}	43.26 ± 0.06^{defgh}	43.63 ± 0.12^{cdefg}
Hibiscus 3%	33.95 ± 0.68^{p}	37.54 ± 0.21^{mno}	39.99 ± 0.35^{ijklm}	40.02 ± 0.03^{ijklm}	40.81 ± 0.3^{ghijkl}
Rose 1%	45.29 ± 0.9^{cd}	44.82 ± 0.21^{cde}	44.02 ± 0.74^{cdef}	38.34 ± 0.24^{klmno}	37.78 ± 0.4^{lmno}
Rose 2%	44.49 ± 0.21^{cde}	44.23 ± 0.1^{cde}	44.42 ± 0.43^{cde}	37.81 ± 1.22^{klmno}	35.29 ± 1.06^{op}
Rose 3%	44.43 ± 0.02^{cde}	43.56 ± 0.04^{cdefgh}	42.09 ± 0.12^{efghij}	36.25 ± 0.07^{nop}	34.16 ± 0.48^{p}
	a*				
Control	19.34 ± 0.77^{a}	16.42 ± 0.7^{bc}	7.64 ± 0.36^{ijklmno}	6.71 ± 0.38^{lmnop}	7.12 ± 0.3^{jklmno}
Hibiscus 1%	11.11 ± 0.41^{fg}	10.17 ± 0.62^{gh}	6.63 ± 0.24^{lmnop}	4.45 ± 0.08^{qr}	3.81 ± 0.12^{r}
Hibiscus 2%	9.22 ± 0.3^{ghi}	7.95 ± 0.24^{ijklmn}	6.15 ± 0.17^{nopq}	6.2 ± 0.19^{mnopq}	5.09 ± 0.16^{pqr}
Hibiscus 3%	9.18 ± 0.32^{ghi}	7 ± 0.03^{klmnop}	6.46 ± 0.08^{lmnop}	6.01 ± 0.16^{nopq}	5.91 ± 0.19^{opq}
Rose 1%	19.62 ± 0.55^{a}	15.2 ± 0.63^{cd}	9.42 ± 0.36^{ghi}	9.46 ± 0.19^{ghi}	6.77 ± 0.17^{klmnop}
Rose 2%	17.72 ± 0.09^{ab}	13.66 ± 0.22^{de}	9.33 ± 0.21^{ghi}	9.02 ± 0.39^{hij}	8.16 ± 0.39^{ijklm}
Rose 3%	17.03 ± 0.51^{bc}	13.05 ± 0.46^{ef}	8.69 ± 0.23^{hijk}	8.38 ± 0.06^{hijkl}	7.59 ± 0.29^{ijklmno}
	b*				
Control	15.15 ± 0.05^{f}	16.05 ± 0.04^{ef}	16.93 ± 0.05^{bcdef}	17.91 ± 0.05^{abcde}	18.22 ± 0.17^{abcde}

	*L**				
	Day 0	***Day 1***	***Day 3***	***Day 5***	***Day 7***
Hibiscus 1%	11.37 ± 0.21^{g}	11.26 ± 0.34^{g}	11.33 ± 0.65^{g}	11.41 ± 0.74^{g}	8.52 ± 0.29^{hi}
Hibiscus 2%	8.72 ± 0.22^{h}	8.56 ± 0.19^{hi}	8.45 ± 0.28^{hi}	7.22 ± 0.47^{hij}	6.32 ± 0.12^{ijk}
Hibiscus 3%	6.14 ± 0.06^{jk}	4.41 ± 0.19^{kl}	3.78 ± 0.15^{l}	3.12 ± 0.18^{l}	3.81 ± 0.03^{l}
Rose 1%	18.22 ± 0.62^{abcde}	16.48 ± 0.62^{def}	19.09 ± 0.94^{ab}	18.6 ± 0.12^{abcd}	16.97 ± 0.08^{bcdef}
Rose 2%	18.08 ± 0.14^{abcde}	16.73 ± 0.33^{cdef}	19.52 ± 0.49^{a}	18.97 ± 0.71^{abc}	16.53 ± 0.75^{def}
Rose 3%	18.02 ± 0.34^{abcde}	16.65 ± 0.53^{def}	16.9 ± 0.32^{bcdef}	17.96 ± 0.03^{abcde}	17.06 ± 0.58^{bcdef}

In contrast, raw ground beef patties treated with rose powder 1%, 2%, and 3% displayed different results. For instance, those treated with rose powder 1% had a lightness of 45.29 ± 0.9 on day 0, which decreased to 37.78 ± 0.4 on day 7 ($p > 0.05$). Similarly, patties treated with rose powder 2% exhibited a lightness of 44.49 ± 0.21 on day 0, which decreased to 35.29 ± 1.06 on day 7 ($p > 0.05$). Likewise, patties treated with rose powder 3% showed a lightness of 44.43 ± 0.02 on day 0, decreasing to 34.16 ± 0.48 on day 7 ($p > 0.05$). Thus, patties treated with rose powder 3% on days 0 and 7 also displayed significant differences, like raw ground beef patties (control) and those treated with hibiscus 1%, 2%, and 3%, as well as rose 1% and 2%. Consequently, this experiment suggests that lightness was higher on day 7 in raw ground beef patties (control) compared to those treated with hibiscus 1%, 2%, and 3%, and rose 1%, 2%, and 3% powder percentages.

The *a** -mean values of raw ground beef patties (control) and those treated with hibiscus powders 1%, 2%, and 3%, as well as rose powders 1%, 2%, and 3%, are presented in Table 1. On day 0, the *a** value for raw ground beef patties (control) was 19.34 ± 0.77, which decreased to 7.12 ± 0.3 on day 7, indicating a significant difference ($p > 0.05$). Similarly, raw ground beef patties treated with hibiscus powder 1% exhibited a redness of 11.11 ± 0.41 on day 0, which decreased to 3.81 ± 0.12 on day 7, showing a significant difference ($p > 0.05$). Comparable trends were observed for raw ground beef patties treated with hibiscus powder 2% and 3%, with initial redness values of 9.22 ± 0.3 and 9.18 ± 0.32 on day 0, respectively, decreasing to 5.09 ± 0.16 and 5.91 ± 0.19 on day 7, respectively ($p > 0.05$).

In addition, raw ground beef patties treated with Rose powder 1%, 2%, and 3% displayed comparable results. For instance, those treated with rose powder 1% had a redness of 19.62 ± 0.55 on day 0, which decreased to 6.77 ± 0.17 on day 7 ($p > 0.05$). Similarly, patties treated with rose powder 2% exhibited a redness of 17.72 ± 0.09 on day 0, which decreased to 8.16 ± 0.39 on day 7 ($p > 0.05$). Likewise, patties treated with rose powder 3% showed a redness of 17.03 ± 0.51 on day 0, decreasing to 7.59 ± 0.29 on day 7 ($p > 0.05$). Thus, patties

treated with rose powder 3% on days 0 and 7 also displayed significant differences, like raw ground beef patties (control) and those treated with hibiscus 1%, 2%, and 3%, as well as rose 1% and 2%.

Consequently, this experiment suggests that retention of redness on day 7 was higher in raw ground beef patties treated with rose powder 3% compared to raw ground beef patties (control) and those treated with hibiscus 1%, 2%, 3%, and rose 1%, 2% powders.

The *b** -mean values of raw ground beef patties (control) and those treated with hibiscus powders 1%, 2%, and 3%, as well as rose powders 1%, 2%, and 3%, are presented in Table 1. On day 0, the *b** value for raw ground beef patties (control) was 15.15 ± 0.05, which increased to 18.22 ± 0.17 on day 7, indicating a significant difference ($p < 0.05$). Similarly, raw ground beef patties treated with hibiscus powder 1% exhibited a yellowness of 11.37 ± 0.21 on day 0, which decreased to 8.52 ± 0.29 on day 7, showing a significant difference ($p > 0.05$). Comparable trends were observed for raw ground beef patties treated with hibiscus powder 2% and 3%, with initial yellowness values of 8.72 ± 0.22 and 6.14 ± 0.06 on day 0, respectively, decreasing to 6.32 ± 0.12 and 3.81 ± 0.03 on day 7, respectively ($p > 0.05$).

In contrast, raw ground beef patties treated with rose powder 1%, 2%, and 3% showed different results. For instance, those treated with rose powder 1% had a yellowness of 18.22 ± 0.62 on day 0, which slightly decreased to 16.97 ± 0.08 on day 7, with no significant difference observed between the two days ($p > 0.05$). Similarly, patties treated with rose powder 2% exhibited a yellowness of 18.08 ± 0.14 on day 0, which slightly decreased to 16.53 ± 0.75 on day 7, with no significant difference observed ($p > 0.05$). Likewise, patties treated with rose powder 3% showed a yellowness of 18.02 ± 0.34 on day 0, which slightly decreased to 17.06 ± 0.58 on day 7, with no significant difference observed ($p > 0.05$).

Therefore, this experiment suggests that yellowness was lower on day 7 in raw ground beef patties treated with hibiscus powder 3% compared to raw ground beef patties (control) and those treated with hibiscus powder 1%, 2%, and rose powder 1%, 2%.

4.4 Texture

The textural property of hardness in beef patties is illustrated by the mean values presented in Table 2. Table 2 compares the hardness of raw ground beef patties (control) with patties treated with various percentages of hibiscus and rose powders (1%, 2%, 3%). On day 0, raw beef patties (control) exhibited a hardness of 2696.34 ± 574.62, which increased to 4734.1 ± 576.55 by day 7 ($p < 0.05$), indicating a significant difference over the storage period. In contrast, raw ground beef patties treated with hibiscus powder 1% showed a decrease in hardness from day 0 to day 7, with values decreasing from 5150.17 ± 531.04 to 4278.76 ± 763.02 ($p > 0.05$). Similarly, patties treated with hibiscus powder 2% and 3% exhibited a decrease in hardness over the same period, with values decreasing from 5853.81 ± 874.01 to 4841.29 ± 201.56 and from 6837.73 ± 341.99 to 5150.17 ± 531.04, respectively ($p > 0.05$).

Table 2

The table represents Hardness obtained from Day 0 to Day 7, with treatments shown in the first column. P-value is < 0.05. Letters connected by different letters are significantly different.

	HARDNESS(g)				
	Day 0	**Day 1**	**Day 3**	**Day 5**	**Day 7**
Control	2696.34 ± 574.62 ^{g}	3846.32 ± 128.38 ^{bcdef}	4535.49 ± 256.07 ^{abcdef}	4685.48 ± 93.72 ^{abcdef}	4734.1 ± 576.55 ^{abcdef}
Hibiscus 1%	5150.17 ± 531.04 ^{abcdef}	3243.89 ± 272.72 ^{cdef}	4379.01 ± 550.32 ^{bcdef}	3071.89 ± 457.14 ^{def}	4278.76 ± 763.02 ^{bcdef}
Hibiscus 2%	5853.81 ± 874.01 ^{abcde}	4824.41 ± 653.5 ^{abcdef}	6118.2 ± 724.69 ^{abcd}	4298.7 ± 491.33 ^{bcdef}	4841.29 ± 201.56 ^{bcdef}
Hibiscus 3%	6837.73 ± 341.99 ^{af}	4325.66 ± 249.66 ^{bcdef}	5820.19 ± 536.11 ^{abcde}	4199.51 ± 352.05 ^{bcdef}	5150.17 ± 531.04 ^{abcdef}
Rose 1%	5461.37 ± 716.71 ^{abcde}	4398.11 ± 47.23 ^{bcdef}	5629.83 ± 952.17 ^{abcde}	5027.67 ± 477.46 ^{abcdef}	4249.32 ± 653.61^{bcdef}
Rose 2%	5629.83 ± 952.17 ^{abcde}	4292.46 ± 147.8 ^{bcdef}	4535.49 ± 256.07 ^{abcdef}	3939.75 ± 656.32 ^{bcdef}	3399.18 ± 643.03 ^{bcdef}
Rose 3%	5853.81 ± 874.01 ^{abcde}	2567.12 ± 34.41 ^{ef}	6452.82 ± 2035.06 ^{abc}	3286.35 ± 276.99 ^{bcdef}	3093.71 ± 348.34 ^{bcdef}

In comparison, raw ground beef patties treated with rose powder 1% did not exhibit a significant difference, with hardness values decreasing from 5461.37 ± 716.71 on day 0 to 4249.32 ± 653.61 on day 7 ($p > 0.05$). Similarly, patties treated with rose powder 2% and 3% showed similar trends, with hardness values decreasing from 5629.83 ± 952.17 to 3399.18 ± 643.03 and from 5853.81 ± 874.01 to 3093.71 ± 348.34, respectively ($p > 0.05$).

Overall, the hardness analysis indicates that raw ground beef patties treated with rose powder 3% had the lowest hardness value on day 7 compared to raw ground beef patties (control) and those treated with hibiscus and rose powders (2%, 3%). However, no significant difference was observed between raw ground beef patties (control) and those treated with hibiscus and rose powders (1%, 2%, 3%) on both day 0 and day 7 of the analysis.

Table 3 presents the mean cohesiveness values in beef patties, indicating the cohesion percentage in raw ground beef patties (control) and patties treated with hibiscus and rose powders (1%, 2%, 3%). Cohesiveness increased in raw ground beef patties compared to those treated with hibiscus powders 1%, 2%, 3%, and rose powder 2%, 3%.

Table 3

The table represents and Cohesion % obtained from Day 0 to Day 7, with treatments shown in the first column. P-value is < 0.05. Letters connected by different letters are significantly different.

	COHESION%				
	Day 0	**Day 1**	**Day 3**	**Day 5**	**Day 7**
Control	41.78 ± 2.52^{cdef}	42.54 ± 1.36^{cdef}	41.45 ± 1.41^{cdef}	44.68 ± 2.72 cdef	49.96 ± 2.59 cdef
Hibiscus 1%	47.25 ± 3.25^{cdef}	44.82 ± 1.65^{cdef}	44.31 ± 2.45^{cdef}	42.74 ± 1.15^{cdef}	42.06 ± 0.91^{cdef}
Hibiscus 2%	42.42 ± 1.02^{cdef}	40.38 ± 1.55^{ef}	42.16 ± 0.61^{cdef}	41.14 ± 0.74^{cdef}	37.67 ± 0.67^{f}
Hibiscus 3%	46.18 ± 2.01 cdef	48.29 ± 0.37^{ef}	47.02 ± 1.85^{def}	37.22 ± 0.74^{f}	38.04 ± 1.22^{f}
Rose 1%	47.66 ± 2.34 cdef	44.76 ± 2.43^{cdef}	41 ± 1.33$_{def}$	45.97 ± 2.21^{cdef}	40.45 ± 2.28^{ef}
Rose 2%	44.12 ± 1^{bcde}	41.34 ± 1.05^{cdef}	38.66 ± 0.51^{ef}	42.12 ± 1.31^{cdef}	38.45 ± 2.94^{ef}
Rose 3%	48.81 ± 5.13^{cdef}	43.04 ± 1.91^{cdef}	40.7 ± 0.97^{ef}	37.75 ± 1.49^{f}	37.67 ± 0.67^{f}

On day 0, raw beef patties (control) exhibited a cohesiveness of 41.78 ± 2.52, which increased slightly to 49.96 ± 2.59 on the 7th day, showing no significant difference ($p < 0.05$). However, raw ground beef patties treated with hibiscus powder 1% showed a decrease in cohesiveness from 47.25 ± 3.25 on day 0 to 42.06 ± 0.91 on day 7 ($p > 0.05$). Similarly, patties treated with hibiscus powder 2% decreased cohesiveness from 42.42 ± 1.02 on day 0 to 37.67 ± 0.67 on day 7 ($p > 0.05$).

Comparable results were observed for patties treated with hibiscus powder 3%, with cohesiveness decreasing from 46.18 ± 2.01 to 38.04 ± 1.22 from day 0 to day 7 ($p > 0.05$), raw ground beef patties treated with rose powder 1% showed a significant decrease in cohesiveness from 47.66 ± 2.34 on day 0 to 40.45 ± 2.28 on day 7 ($p > 0.05$). Likewise, patties treated with rose powder 2% and 3% exhibited comparable results to those treated with rose powder 1%, with cohesiveness decreasing from 44.12 ± 1 on day 0 to 38.45 ± 2.94 on day 7 ($p > 0.05$) and from 48.81 ± 5.13 on day 0 to 37.67 ± 0.67 on day 7 ($p > 0.05$), respectively. In conclusion, the analysis of cohesiveness suggests that raw ground beef patties (control) and those treated with hibiscus and rose powder 1,2 and 3 percentages were not significantly different when observed from day 0 to day 7.

The mean value in Table 4 indicates the springiness percentage in raw ground beef patties (control) and patties raw ground beef patties treated with hibiscus and rose powders 1,2,3 percentages. Springiness increased in raw ground beef patties (control) than in raw ground beef patties treated with hibiscus powders 1,2,3 and rose powders 1,2,3 percentages. On the day of 0, raw ground beef patties (control) had (42.26 ± 1.11 of springiness, which increased to 54.54 ± 1.04 on the 7th day, which also showed that the springiness in raw ground beef patties was significantly not different; $p < 0.05$).

Table 4

The table represents Springiness% and Gumminess% obtained from Day 0 to Day 7, with treatments shown in the first column. P-value is < 0.05. Letters connected by different letters are significantly different.

	SPRINGINESS%				
	Day 0	**Day 1**	**Day 3**	**Day 5**	**Day 7**
Control	42.26 ± 1.11^{ef}	43.25 ± 0.53^{def}	44.27 ± 3.66^{def}	51.71 ± 1.99 cdef	54.54 ± 1.04 ^{cdef}
Hibiscus 1%	48.91 ± 2.83 cdef	44.69 ± 1.7^{def}	38.66 ± 1.61^{f}	50.76 ± 4.56^{cdef}	47.99 ± 2.44 ^{cdef}
Hibiscus 2%	50.27 ± 1.38^{cdef}	42.75 ± 0.86^{def}	47.28 ± 4.14 cdef	47.77 ± 1.38^{cdef}	46.47 ± 2.17 ^{cdef}
Hibiscus 3%	52.45 ± 1.18 cdef	43.52 ± 3.11^{def}	41.88 ± 2.15^{ef}	40.86 ± 0.74^{f}	47.86 ± 1.29 ^{cdef}
Rose 1%	47.56 ± 1.32 cdef	40.77 ± 3.27^{f}	48.81 ± 8.07^{cdef}	45.68 ± 1.74^{def}	46.47 ± 2.17 ^{cdef}
Rose 2%	51.52 ± 3.38 cdef	44.66 ± 2.57^{def}	45.68 ± 1.74^{def}	40.86 ± 0.74^{f}	43.52 ± 3.11^{def}
Rose 3%	54.23 ± 1.44 cdef	40.43 ± 0.82^{f}	38.74 ± 0.82^{f}	43.21 ± 7.5^{def}	45.07 ± 5.12 ^{cdef}
	GUMMINESS%				
	Day 0	**Day 1**	**Day 3**	**Day 5**	**Day 7**
Control	109810.62 ± 16510.7 ^{c}	163300.93 ± 1981.76 ^{abc}	200206.18 ± 23450.06 ^{abc}	139217.19 ± 11486.19 ^{c}	125050.7 ± 4003.89^{c}
Hibiscus 1%	215659.34 ± 18151.57 ^{abc}	142404.37 ± 3948.71 ^{bc}	194427.18 ± 17829.78 ^{abc}	130929.36 ± 19025.95 ^{c}	164877.17 ± 24421.49 ^{abc}
Hibiscus 2%	249414.59 ± 40987.32 ^{abc}	203894.61 ± 30002.16 ^{abc}	248750.69 ± 37941.55 ^{abc}	177500.68 ± 22971.38 ^{abc}	186344.36 ± 10421.96 ^{abc}
Hibiscus 2%	297894.21 ± 4146.04 ^{ab}	176580.22 ± 4384.23 ^{abc}	228993.47 ± 23082.25 ^{abc}	155882.51 ± 10737.79 ^{abc}	250807.07 ± 11783.06 ^{abc}
Rose 1%	146878.18 ± 9942.14 ^{bc}	105213.78 ± 3169.53 ^{c}	307923.96 ± 110601.17 ^{a}	171800.16 ± 21091.27 ^{abc}	129559.08 ± 23101.4^{c}
Rose 2%	191752.64 ± 15662.73 ^{abc}	165954.41 ± 6377.45 ^{abc}	187011.88 ± 6600.09 ^{abc}	181937.76 ± 32017.27 ^{abc}	165838.63 ± 29305.76^{abc}
Rose 3%	221515.7 ± 27296.9 ^{abc}	165890.32 ± 4890.05 ^{abc}	228133.96 ± 35556.99 ^{abc}	217535.78 ± 28074.84 ^{abc}	184323.91 ± 16079.01^{abc}

Contrast results were obtained in raw ground beef patties treated with hibiscus 1 percentage showed different results to that of raw ground beef patties as the springiness decreased from day 0 to 7 (48.91 ± 2.83 to 47.99 ± 2.44; $p > 0.05$) in raw ground beef patties treated with hibiscus powder 1 percentage; $p > 0.05$) was not significantly different. Whereas patties treated with hibiscus powder two percent resulted in (50.27 ± 1.38 on the 0th day and 46.47 ± 2.17 springiness on the 7th day; $p > 0.05$) also showed that patties treated with hibiscus powder 2 percent were not significantly different.

Similar results were obtained from raw ground patties treated with hibiscus powder three percentage as the results showed (52.45 ± 1.18 on the 0th day and 47.86 ± 1.29 on the 7th day; $p > 0.05$). For raw ground beef patties treated with rose powder, one percentage was not significantly different from day 0 to 7 as the results on the 0th day were (47.56 ± 1.32) decreased to 46.47 ± 2.17 on the 7th day; $p > 0.05$). Raw ground beef patties treated with rose powder two percentage showed results of (51.52 ± 3.38 on the 0 day, which decreased to 43.52 ± 3.11 on the 7th day; $p > 0.05$) was also not significantly different, whereas raw ground beef patties treated with rose powder three percentage showed (54.23 ± 1.44 on 0th day increased to 45.07 ± 5.12 on 7th day; $p > 0.05$) was also not significantly different. Hence, through this experiment, according to the mean values of springiness, we can conclude that raw ground beef patties (control) and patties treated with hibiscus and rose powder 1,2 and 3 percentages were not significantly different when seen on the 0th to 7th day of analysis.

In addition, Table 4 also includes the mean values of gumminess % in raw ground beef patties, including both the control group and patties treated with various percentages of hibiscus and rose powders (1%, 2%, 3%). Gumminess increased in raw ground beef patties (control) compared to those treated with hibiscus 1%, 2%, 3%, and rose 1%, 2%, and 3% powder percentages. On day 0, raw beef patties (control) exhibited a gumminess of 109810.62 ± 16510.7, which increased to 125050.7 ± 4003.89 on the 7th day, showing no significant difference ($p < 0.05$). However, raw ground beef patties treated with hibiscus 1% powder showed a decrease in gumminess from 215659.34 ± 18151.57 on day 0 to 164877.17 ± 24421.49 on day 7 ($p > 0.05$), which was not significantly different. Similarly, patties treated with hibiscus 2% powder decreased gumminess from 249414.59 ± 40987.32 on day 0 to 186344.36 ± 10421.96 on day 7 ($p > 0.05$), also not significantly different. The same trend was observed for patties treated with 3% of hibiscus powder, with gumminess decreasing from 297894.21 ± 4146.04 on day 0 to 250807.07 ± 11783.06 on day 7 ($p > 0.05$), also not significantly different. Raw ground beef patties treated with rose 1% powder showed similar results to those treated with hibiscus powder 1%, 2%, and 3% when observed from day 0 to day 7, with gumminess decreasing from 146878.18 ± 9942.14 on day 0 to 129559.08 ± 23101.4 on day 7 ($p > 0.05$). Likewise, patties treated with rose 2% powder exhibited a decrease in gumminess from 191752.64 ± 15662.73 on day 0 to 165838.63 ± 29305.76 on day 7 ($p > 0.05$), not significantly different.

Similarly, patties treated with rose 3% powder showed gumminess decreasing slightly from 221515.7 ± 27296.9 on day 0 to 184323.91 ± 16079.0 on day 7 ($p > 0.05$), also not significantly different. In conclusion, according to the mean gumminess values, there was no significant difference observed between raw beef patties (control) and those treated with hibiscus powders 1%, 2%, 3%, and rose powders 1%, 2%, 3% when observed on day 0 and day 7 of analysis.

Table 5 presents the mean chewiness values in raw ground beef patties, including the control group and patties treated with various percentages of hibiscus and rose powders (1%, 2%, 3%). Chewiness increased from the 0th day to the 7th day of analysis in raw ground beef patties and in those treated with hibiscus powders, 1%, 2%, 3%, and rose 1%, 2%, and 3% percentages.

Table 5
The table represents Chewiness obtained from Day 0 to Day 7, with treatments shown in the first column. P-value is < 0.05. Letters connected by different letters are significantly different.

	CHEWINESS %				
	Day 0	**Day 1**	**Day 3**	**Day 5**	**Day 7**
Control	46034.47 ± 5758.71 ^{b}	70626.3 ± 1409.78 ^{ab}	87107.72 ± 5502.34 ^{ab}	101194.74 ± 9938.55 ^{ab}	100069.6 ± 10541.27 ^{ab}
Hibiscus 1%	110186.93 ± 14772.77 ^{ab}	63513.08 ± 1224.24 ^{ab}	75710.72 ± 9882.55 ^{ab}	68168.77 ± 16306.75 ^{ab}	99596.83 ± 11805.62 ^{ab}
Hibiscus 2%	126482.05 ± 23531.03 ^{ab}	86816.27 ± 11511.53 ^{ab}	120659.3 ± 29504.38 ^{ab}	85042.07 ± 11871 ^{ab}	86695.83 ± 7197.83 ^{ab}
Hibiscus 3%	138466.07 ± 5397.6 ^{ab}	76664.6 ± 4655.57 ^{ab}	96821.29 ± 14449.42 ^{ab}	63678.84 ± 4370.63 ^{ab}	122847.71 ± 18308.6 ^{ab}
Rose 1%	118937.18 ± 21704.82 ^{ab}	145876.19 ± 26999.5 ^{ab}	167032.83 ± 86670.47 ^{ab}	43036.76 ± 4492.52 ^{b}	55360.12 ± 5368.62 ^{b}
Rose 2%	125373.92 ± 36546.08 ^{ab}	120712.71 ± 23049.01 ^{ab}	73791.95 ± 1823.14 ^{ab}	85624.11 ± 6135.23 ^{ab}	80181.21 ± 11777.99 ^{a}
Rose 3%	105357.28 ± 15572.55 ^{ab}	67044.93 ± 2041.9 ^{ab}	88788.16 ± 14919.52 ^{ab}	119723.07 ± 32114.95 ^{ab}	103135.75 ± 18667.74 ^{ab}

On the 0th day, raw ground beef patties (control) exhibited a chewiness of 46034.47 ± 5758.71, which increased to 100069.6 ± 10541.27 on the 7th day, indicating that raw beef patties were significantly different ($p < 0.05$). Similarly, raw ground beef patties treated with hibiscus 1% powder showed a similar increase in chewiness from 99596.83 ± 11805.62 to 110186.93 ± 14772.77 on the 7th day ($p < 0.05$). However, patties treated with hibiscus 2% powder decreased chewiness from 126482.05 ± 23531.03 on the 0th day to 86695.83 ± 7197.83 on the 7th day ($p > 0.05$). The same trend was observed for patties treated with hibiscus 3% powder, with chewiness decreasing from 138466.07 ± 5397.6 on the 0th day to 122847.71 ± 18308.6 on the 7th day ($p > 0.05$).

In contrast, raw ground beef patties treated with rose 1% powder did not show a significant difference when observed from the 0th to the 7th day, with values increasing from 55360.12 ± 5368.62 on the 0th day to 118937.18 ± 21704.82 on the 7th day ($p < 0.05$). Likewise, patties treated with rose 2% powder exhibited an increase in chewiness from 80181.21 ± 11777.99 on the 0th day to 125373.92 ± 36546.08 on the 7th day ($p < 0.05$), not significantly different. Similarly, patties treated with rose 3% powder showed chewiness values decreasing from 105357.28 ± 15572.55 on the 0th day to 103135.75 ± 18667.74 on the 7th day ($p > 0.05$).

In conclusion, according to the mean values of chewiness, raw ground beef patties (control) and raw ground beef patties treated with hibiscus and rose powders 1%, 2%, and 3%, were not significantly different when observed from the 0th to the 7th day of analysis.

4.5 MDA

Figure 4 illustrates the impact of MDA development in raw ground beef patties (control) compared to those treated with various percentages of hibiscus and rose powders over 0, 1, 3, 5, and 7 days of analysis. Throughout the analysis period, oxidative changes in lipids occurred in all raw beef patties, resulting in notably higher MDA values in raw ground beef patties (control) compared to those treated with hibiscus and rose powders 1,2 and 3 percentages.

MDA equivalents per μg/kg in raw ground beef patties on the 0th day were 50.0 per μg/kg, escalating to 309.8 per μg/kg on day 7 ($p < 0.05$), significantly different from those treated with hibiscus 1% powder, with MDA equivalents per μg/kg starting at 43.2 and gradually increasing to 97.2 on the 7th day ($p < 0.05$). The results on days 0 and 7 were significantly different. Similarly, patties treated with hibiscus 2% powder showed MDA equivalents of 38.8 per μg/kg on day 0, which increased to 87.2 on the 7th day ($p < 0.05$), also significantly different.

Likewise, raw ground beef patties treated with hibiscus 3% powder exhibited significant differences on days 0 and 7, with MDA equivalents of 33.7 per μg/kg on day 0 and 80.7 on day 7 ($p < 0.05$). Raw ground beef samples treated with rose 1%, 2%, and 3% powders also displayed notably lower MDA values. Rose 1% powder resulted in MDA equivalents per μg/kg of 22.3 on the 0th day, increasing to 63.4 on the 7th day ($p < 0.05$). Similarly, rose 2% powder showed lower MDA equivalents, with values of 18.0 on the 0th day and 53.8 on the 7th day ($p < 0.05$). Likewise, patties treated with rose 3% powder showed lower MDA equivalents per μg/kg on days 0 and 7, with values of 17.4 and 48.3, respectively ($p < 0.05$), as depicted in Fig. 4.

In conclusion, this experiment establishes that raw ground beef patties (control) and those treated with hibiscus 1%, 2%, and 3% and rose 1%, 2%, and 3% were significantly different when observed on days 0 and 7 of the analysis, as indicated alphabetically.

4.6 Carbonyls

Figure 5 presents the findings regarding protein carbonylation in raw ground beef patties and those treated with varying percentages of hibiscus and rose powders (1%, 2%, and 3%). Protein carbonyl levels increased significantly in raw ground beef patties (control) compared to those treated with powders.

On day 0, raw ground beef patties (control) exhibited 27.3 nmol per mg of protein carbonyls, which significantly increased to 59.7 nmol per mg on the 7th day ($p > 0.05$). Figure 4 indicates different alphabets on days 0 and 7, representing significant differences in protein carbonyl levels. Raw ground beef patties treated with hibiscus 1% powder displayed results like the control group, with a similar increase in protein carbonyl content on both days 0 and 7 (24.01 nmol per mg protein on day 0 and 56.76 nmol per mg protein on day 7; $p > 0.05$). Similarly, patties treated with hibiscus 2% powder showed increased protein carbonyl content from 21.98 nmol per mg protein on day 0 to 53.03 nmol per mg protein on day 7 ($p > 0.05$). Comparable results

were observed for raw ground beef patties treated with hibiscus 3% powder, with levels increasing from 18.7 nmol per mg protein on day 0 to 50.8 nmol per mg protein on day 7 ($p > 0.05$).

Raw ground beef patties treated with rose 1% powder exhibited an increase in protein carbonyl content from 25.4 nmol per mg protein on day 0 to 51.7 nmol per mg protein on day 7 ($p > 0.05$). Similarly, patties treated with rose 2% and rose 3% powders showed similar trends, with protein carbonyl levels from day 0 to day 7 (20.4 nmol per mg protein to 53.91 nmol per mg protein for rose 2% powder and 19.3 nmol per mg protein to 48.8 nmol per mg protein for rose 3% powder; $p > 0.05$).

In conclusion, based on the mean values of protein carbonyls, raw ground beef patties and raw ground beef patties treated with hibiscus and rose powders (1%, 2%, and 3%) exhibited similar trends on both days 0 and 7, except for the control group. The protein carbonyl retention in raw ground beef patties (control) on the 7th day was comparatively lower than in those treated with hibiscus and rose powders.

4.7 Schiff bases

Figure 6 illustrates another marker of protein oxidation in raw ground beef patties (control) and those treated with varying percentages of hibiscus and rose powders (1%, 2%, and 3%). Schiff bases showed a significant increase in raw ground beef patties (control) compared to those treated with powders.

On day 0, raw ground beef patties (control) exhibited 264.0 nmol per mg of protein of Schiff bases, which significantly increased to 315.6 nmol per mg on the 7th day ($p < 0.05$). The alphabets in Fig. 6 denote significant differences in Schiff bases from day 0 to day 7. Raw ground beef patties treated with hibiscus 1% powder displayed results like the control group, significantly increasing Schiff bases content from day 0 to 7 (221.3 to 264.0 nmol per mg protein; $p < 0.05$). Similarly, patties treated with hibiscus 2% powder showed an increase from 202.2 to 247.8 nmol per mg protein ($p < 0.05$), and those treated with hibiscus 3% powder increased from 169.9 to 192.5 nmol per mg protein ($p < 0.05$).

Raw ground beef patties treated with rose 1% powder exhibited similar results to those treated with hibiscus powders, with increased Schiff bases content from 57.4 on day 0 to 100.0 nmol per mg protein on day 7 ($p < 0.05$). Additionally, patties treated with rose 2% and rose 3% powders showed comparable trends, with increases from 19.2 to 48.2 nmol per mg protein ($p < 0.05$) for rose 2% powder and from 11.5 to 21.3 nmol per mg protein ($p < 0.05$) for rose 3% powder. In conclusion, based on the mean values of Schiff bases, raw ground beef patties (control) and those treated with hibiscus and rose powders (1%, 2%, and 3%) exhibited alphabetical differences on both days 0 and 7, as indicated in Fig. 6. Additionally, the Schiff base content increased daily during the analysis week in raw ground beef patties(control) and those treated with hibiscus and rose powders. Notably, patties treated with these powders showed lower Schiff base content on the 7th day than raw ground beef patties (control).

4.8 Free Thiols

Figure 7 illustrates another aspect of protein oxidation in raw ground beef patties and those treated with varying percentages of hibiscus and rose powders (1%, 2%, and 3%). Free thiol levels significantly decreased in raw ground beef patties (control) compared to the treated samples.

On day 0, raw ground beef patties had a free thiol level of 1.0 nmol per mg protein, significantly decreasing to 0.3 nmol per mg on the 7th day. The alphabets in the figure indicate that the free thiols from day 0 to 7 were significantly different ($p > 0.05$). Raw ground beef patties treated with hibiscus 1% powder showed comparable results to the control, with a significant decrease in free thiol content from day 0 to 7 (0.8 to 0.3 nmol per mg protein; $p > 0.05$). This difference is also evident in the figure, showing that raw ground beef patties treated with hibiscus 1% were significantly different from day 0 to 7.

Similarly, patties treated with hibiscus 2% powder decreased from 0.4 to 0.2 nmol per mg protein from day 0 to day 7 ($p > 0.05$). The same trend was observed in patties treated with hibiscus 3% powder, decreasing from 0.6 to 0.1 nmol per mg protein ($p > 0.05$). Raw ground beef patties treated with rose 1% powder also showed similar trends to those treated with hibiscus powders, decreasing from 0.8 to 0.2 nmol per mg protein on days 0 to 7 ($p > 0.05$). Likewise, patties treated with rose 2% and rose 3% powders exhibited similar trends, with decreases from 0.9 to 0.2 nmol per mg protein ($p > 0.05$) and from 0.9 to 0.2 nmol per mg protein ($p > 0.05$), respectively.

In conclusion, based on the mean values of free thiols, raw ground beef patties treated with hibiscus and rose powders (1%, 2%, and 3%) showed similar trends on days 0 and 7, except for the control. This indicates that the retention of free thiols in raw ground beef patties (control) on the 7th day was lower, suggesting higher protein oxidation than those treated with hibiscus and rose powders.

4.9 Radical scavenging activity

Figure 8 depicts an assessment of antioxidant capacity in both raw ground beef patties and those treated with varying percentages of hibiscus and rose powders (1%, 2%, and 3%). Radical scavenging activity exhibited a significant decrease in raw ground beef patties (control) compared to the treated samples.

On day 0, raw ground beef patties (control) displayed a radical scavenging activity of 8.8, which significantly decreased to 5.8 on the 7th day ($p > 0.05$). The alphabets, in the figure denotes that the radical scavenging activity from day 0 to 7 did not significantly differ. In contrast, raw ground beef patties treated with hibiscus 1% powder showed significantly different results than the control, with radical scavenging activity increasing from 43.2 on day 0 to 56.1 on day 7 ($p < 0.05$).

Similarly, patties treated with hibiscus 2% powder exhibited an increase from 43.0 to 57.8 ($p < 0.05$), and those treated with hibiscus 3% powder showed an increase from 44.6 to 58.3 ($p < 0.05$). Raw ground beef patties treated with rose 1% powder also showed comparable results to those treated with hibiscus powders, with radical scavenging activity increasing from 45.7 on day 0 to 55.2 on day 7 ($p < 0.05$).

Additionally, patties treated with rose 2% and rose 3% powders demonstrated similar trends to those treated with rose 1% powder, with radical scavenging activity increasing from 45.1 to 58.5 ($p < 0.05$) for rose 2% powder and from 47.7 to 59.4 ($p < 0.05$) for rose 3% powder.

In conclusion, based on the mean values of radical scavenging activity, raw ground beef patties treated with hibiscus and rose powders (1%, 2%, and 3%) significantly differed from days 0 to 7 during the analysis. Notably, the radical scavenging activity content in raw ground beef patties (control) on the 7th day was comparatively lower than that of the treated samples.

DISCUSSION

This study undertakes a pioneering investigation into the degradation of physicochemical properties and the formation of LOPs and POPs in raw ground beef patties. It compares raw beef patties with ground beef patties treated with hibiscus and rose 1,2 and 3 percentages, stored at 4°C for intervals of 0, 1, 3, 5, and 7 days. Various experiments assessed the physicochemical deterioration of untreated raw ground beef patties and those treated with hibiscus. They rose 1,2 and 3 percentages, focusing on parameters such as pH, water holding capacity (WHC), textural attributes, and color. Additionally, the study evaluated oxidative degradation using four oxidation markers (MDA, protein carbonyls, Schiff bases, and free thiols), and antioxidant capacity was determined using the DPPH assay.

The pH levels of raw ground beef patties exhibited notable changes over the storage period, with untreated patties and those treated with hibiscus and rose powders showing distinct trends. Initially, untreated patties had a pH of 5.7 on day 0, which increased to 5.9 by day 7. Similarly, treated patties showed a slight pH increase from day 0 to day 7, though not statistically significant (Youssef, 2014). However, there were intriguing differences between the effects of hibiscus and rose powders on pH levels. While hibiscus-treated patties showed a marginal increase in pH, those treated with rose powders exhibited a decrease in pH, particularly at higher concentrations. This variation in pH response could be attributed to the different chemical compositions of hibiscus and rose powders, including the presence of various acids and non-extractable polyphenols. (Rocha et al., 2014; Vega et al., 2020; Villasante et al., 2020). Concurrently, water-holding capacity (WHC) values showed significant differences between untreated patties and those treated with rose powders, particularly at higher concentrations. Untreated patties maintained a consistent WHC throughout the storage period, while those treated with rose powders demonstrated an increase in WHC, especially at 2% and 3% concentrations. This rise in WHC could be linked to the lower pH from adding rose powders or the higher dietary fiber content in the rose powder (Turp & Serdarglu, 2010). Conversely, the WHC values of patties treated with hibiscus powders did not significantly differ from untreated patties, suggesting that these treatments did not restrict water movement within the patties. The interplay between pH levels and WHC in treated beef patties underscores the complex relationship between chemical composition and physical properties. The observed changes in pH may have influenced the water-binding capacity of the patties, as evidenced by the variations in WHC. Additionally, the presence of acids and polyphenols in the botanical powders could have contributed to these effects, highlighting the multifaceted nature of food preservation and quality enhancement (Cortés et al., 2018).

Further research is warranted to elucidate the mechanisms underlying these interactions and optimize the use of edible flower additives in meat products for enhanced shelf life and sensory attributes.

Color and texture are fundamental attributes that significantly influence the perception of food products, including raw ground beef patties. This study investigated the impact of hibiscus and rose powders on color and texture parameters, revealing interesting interconnections between these properties. Regarding color, it was observed that raw ground beef patties treated with hibiscus powders exhibited reduced yellowness compared to untreated patties and those treated with rose powders. This reduction in yellowness was particularly pronounced in patties treated with 3% hibiscus powder, indicating a remarkable preservation of color over the storage period. The presence of anthocyanins, abundant in hibiscus, was identified as a critical

factor contributing to this color stability. These natural pigments impart various shades of red, purple, and blue colors to foods, enhancing their visual appeal (Zhang et al., 2019). Furthermore, in the studies by (Prejsnar et al., 2018; Viana et al., 2017), it was reported that the antioxidative properties of hibiscus flowers, evidenced by lower levels of lipid oxidation (MDA), played a crucial role in color retention by inhibiting metmyoglobin formation, which prevents meat discoloration says (Wang et al., 2021).

Additionally, the increase in lightness observed in patties treated with 3% hibiscus powder further supported the color-stabilizing effect of hibiscus, highlighting the contribution of anthocyanins to color stability, changes in color parameters were also linked to texture properties, particularly hardness. Adding hibiscus and rose powders reduced patty hardness, with higher concentrations correlating with a more significant decrease in hardness by the 7th day of analysis in a study conducted by (Jung et al., 2013). This trend also suggests a potential relationship between color preservation and texture modification induced by the flower powders. The lower pH exhibited by patties treated with hibiscus and rose powders could influence the formation and stability of protein gels within the meat matrix, consequently contributing to reduced hardness. (Banerjee et al., 2020; Baez et al., 2021b). Additionally, the higher water-holding capacity (WHC) and fiber retention abilities of patties treated with hibiscus and rose powders could further contribute to the observed texture changes. Furthermore, including hibiscus and rose powders did not significantly affect springiness and cohesiveness compared to untreated patties; reductions in these parameters were noted. (Guevara et al., 2020). In addition, a decrease in springiness and cohesiveness is usually a common effect observed in meat products when non-meat ingredients are added, resulting in less cohesive structures (Akesowan, 2016).

In conclusion, the study demonstrates the intricate relationship between color and texture in raw ground beef patties treated with hibiscus and rose powders (Kurt & Gençcelep, 2018). The preservation of color stability, attributed to the antioxidative properties of anthocyanins, was accompanied by modifications in texture properties, influenced by the chemical composition and functional attributes of the edible flower powders (Banerjee et al., 2020; Baez et al., 2021). Further research is needed to fully elucidate the mechanisms underlying these interconnections and optimize the use of botanical additives to enhance color and texture attributes in meat products.

The antioxidant activity, lipid oxidation, and protein oxidation are interconnected processes that influence the quality and preservation of raw ground beef patties. Figure 8 demonstrates the antioxidant capacity of beef patties treated with different percentages of hibiscus and rose powders. Notably, the radical scavenging activity decreased in control patties compared to those treated with hibiscus and rose powders, indicating the antioxidative properties of these additives (Tyburcy & Kozyra, 2010). This effect was attributed to phenolic compounds present in hibiscus and rose powders (Mohamed et al., 2007). Raw ground beef patties treated with rose powder at 3% exhibited the highest scavenging activity, consistent throughout the analysis, supported by previous research highlighting the superior antioxidative effects of rose products. Additionally, similar antioxidative effects were observed in beef patties treated with hibiscus powders, indicating their potential to mitigate lipid oxidation, as evidenced by TBARS values. Figure 4 illustrates the impact of malondialdehyde (MDA) development, a marker of lipid oxidation, in raw ground beef patties (Zhang et al., 2016). Control patties showed significantly higher MDA values than those treated with hibiscus and rose powders, indicating increased lipid oxidation in the control group. The reduction in TBARS values observed in

treated patties suggests the antioxidative effects of hibiscus and rose powders in mitigating lipid oxidation, supported by previous studies conducted by (Malelak et al., 2017; Bozkurt & Belibağlı, 2009b).

Protein oxidation, assessed through protein carbonylation, exhibited a significant increase in control patties compared to treated patties (Fig. 8). This reduction in protein carbonylation in treated patties may be attributed to the presence of phenolic-rich extracts and antioxidants in hibiscus and rose powders (Stadtman & Levine, 2003;Ganhão et al., 2010; Haak et al., 2009), the reduction in protein carbonylation could be influenced by cold storage conditions, emphasizes the importance of considering storage conditions when evaluating protein oxidation in beef products. (Filgueras et al., 2010; Lindahl et al., 2010; Rowe et al., 2004). The Schiff bases, another marker of protein oxidation, showed a significant increase in control patties compared to treated ones (Fig. 6). The maintenance of Schiff base levels in treated patties may be attributed to the robust antioxidant activities in hibiscus and rose powders(Utrera et al., 2015; Ganhão et al., 2010; Vossen et al., 2012). The examination of free thiols, indicative of protein oxidation, revealed a significant decrease in control patties compared to treated ones reported in the study (Estévez & Cava, 2006). The higher protein oxidation rate in control patties is also consistent with previous research highlighting the protective effects of phenolic and antioxidant properties in preserving free thiols (Jongberg et al., 2011).In conclusion, adding hibiscus and rose powders to raw ground beef patties shows promising effects in reducing lipid oxidation and protein oxidation, thereby maintaining quality, and enhancing nutritional value. Hence, the antioxidative properties of these additives play a crucial role in preserving the quality characteristics of beef patties, suggesting potential applications in meat preservation (Jia et al., 2012).

Declarations

Author contribution

Krishna Brunda Duggirala: Investigation, Methodology, Writing – original draft.

Anand Mohan: Conceptualization, Supervision, Visualization, Funding acquisition, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare no conflict of interest in this paper.

Declaration of funding

This work was supported by the Georgia Beef Commission Grant (RGABF000176260A), Georgia, United States of America.

References

1. Augustyńska-Prejsnar, A., Ormian, M., & Sokołowicz, Z. (2018). Physicochemical and sensory properties of broiler chicken breast meat stored frozen and thawed using various methods. *Journal of Food Quality*, *2018*, 1–9.

2. Banerjee, D. K., Das, A. K., Banerjee, R., Pateiro, M., Nanda, P. K., Gadekar, Y. P., Biswas, S., McClements, D. J., & Lorenzo, J. M. (2020). Application of enoki mushroom (Flammulina Velutipes) stem wastes as functional ingredients in goat meat nuggets. *Foods*, *9*(4), 432.
3. Bermúdez, R., Rangel-Vargas, E., Lorenzo, J. M., Rodríguez, J. A., Munekata, P. E. S., Teixeira, A., Pateiro, M., Romero, L., & Santos, E. M. (2023). Effect of Partial Meat Replacement by Hibiscus sabdariffa By-Product and Pleurotus djamor Powder on the Quality of Beef Patties. *Foods*, *12*(2), 391.
4. Bozkurt, H., & Belibağlı, K. B. (2009). Use of rosemary and Hibiscus sabdariffa in production of kavurma, a cooked meat product. *Journal of the Science of Food and Agriculture*, *89*(7), 1168–1173.
5. Cerón-Guevara, M. I., Rangel-Vargas, E., Lorenzo, J. M., Bermúdez, R., Pateiro, M., Rodriguez, J. A., Sanchez-Ortega, I., & Santos, E. M. (2020). Effect of the addition of edible mushroom flours (Agaricus bisporus and Pleurotus ostreatus) on physicochemical and sensory properties of cold-stored beef patties. *Journal of Food Processing and Preservation*, *44*(3), e14351.
6. Da-Costa-Rocha, I., Bonnlaender, B., Sievers, H., Pischel, I., & Heinrich, M. (2014). Hibiscus sabdariffa L.–A phytochemical and pharmacological review. *Food Chemistry*, *165*, 424–443.
7. Drouillard, J. S. (2018). Current situation and future trends for beef production in the United States of America—A review. *Asian-Australasian Journal of Animal Sciences*, *31*(7), 1007.
8. Dujmović, M., Radman, S., Opačić, N., Fabek Uher, S., Mikuličin, V., Voća, S., & Šic Žlabur, J. (2022). Edible flower species as a promising source of specialized metabolites. *Plants*, *11*(19), 2529.
9. Efosa, J. O., Omage, K., & Azeke, M. A. (2023). Hibiscus sabdariffa calyx protect against oxidative stress and aluminum chloride-induced neurotoxicity in the brain of experimental rats. *Toxicology Reports*, *10*, 469–480.
10. Estévez, M., & Cava, R. (2006). Effectiveness of rosemary essential oil as an inhibitor of lipid and protein oxidation: Contradictory effects in different types of frankfurters. *Meat Science*, *72*(2), 348–355.
11. Fernandes, L., Casal, S., Pereira, J. A., Saraiva, J. A., & Ramalhosa, E. (2020). An overview on the market of edible flowers. *Food Reviews International*, *36*(3), 258–275.
12. Filgueras, R. S., Gatellier, P., Aubry, L., Thomas, A., Bauchart, D., Durand, D., Zambiazi, R. C., & Santé-Lhoutellier, V. (2010). Colour, lipid and protein stability of Rhea americana meat during air-and vacuum-packaged storage: Influence of muscle on oxidative processes. *Meat Science*, *86*(3), 665–673.
13. Ganhão, R., Morcuende, D., & Estévez, M. (2010). Protein oxidation in emulsified cooked burger patties with added fruit extracts: Influence on colour and texture deterioration during chill storage. *Meat Science*, *85*(3), 402–409.
14. Gómez-Cortés, P., Guerra-Rivas, C., Gallardo, B., Lavín, P., Mantecón, A. R., De la Fuente, M. A., & Manso, T. (2018). Grape pomace in ewes diet: Effects on meat quality and the fatty acid profile of their suckling lambs. *Food Research International*, *113*, 36–42.
15. Hu, L., Ren, S., Shen, Q., Ye, X., Chen, J., & Ling, J. (2018). Protein oxidation and proteolysis during roasting and in vitro digestion of fish (Acipenser gueldenstaedtii). *Journal of the Science of Food and Agriculture*, *98*(14), 5344–5351. https://doi.org/10.1002/JSFA.9075
16. Hughes, E., Cofrades, S., & Troy, D. J. (1997). Effects of fat level, oat fibre and carrageenan on frankfurters formulated with 5, 12 and 30% fat. *Meat Science*, *45*(3), 273–281. https://doi.org/10.1016/S0309-1740(96)00109-X

17. Izquierdo-Vega, J. A., Arteaga-Badillo, D. A., Sánchez-Gutiérrez, M., Morales-González, J. A., Vargas-Mendoza, N., Gómez-Aldapa, C. A., Castro-Rosas, J., Delgado-Olivares, L., Madrigal-Bujaidar, E., & Madrigal-Santillán, E. (2020). Organic acids from Roselle (Hibiscus sabdariffa L.)—A brief review of its pharmacological effects. *Biomedicines*, *8*(5), 100.
18. Jia, N., Kong, B., Liu, Q., Diao, X., & Xia, X. (2012). Antioxidant activity of black currant (Ribes nigrum L.) extract and its inhibitory effect on lipid and protein oxidation of pork patties during chilled storage. *Meat Science*, *91*(4), 533–539.
19. Jongberg, S., Skov, S. H., Tørngren, M. A., Skibsted, L. H., & Lund, M. N. (2011). Effect of white grape extract and modified atmosphere packaging on lipid and protein oxidation in chill stored beef patties. *Food Chemistry*, *128*(2), 276–283.
20. Jung, E., Kim, Y., and, N. J.-J. of the S. of F., & 2013, undefined. (2013). Physicochemical properties and antimicrobial activity of Roselle (Hibiscus sabdariffa L.). *Wiley Online Library EK Jung, YJ Kim, N JooJournal of the Science of Food and Agriculture, 2013•Wiley Online Library*, *93*(15), 3769–3776. https://doi.org/10.1002/jsfa.6256
21. Kerth, C. R., & Miller, R. K. (2015). Beef flavor: A review from chemistry to consumer. *Journal of the Science of Food and Agriculture*, *95*(14), 2783–2798.
22. Kurt, A., & Gençcelep, H. (2018). Enrichment of meat emulsion with mushroom (Agaricus bisporus) powder: Impact on rheological and structural characteristics. *Journal of Food Engineering*, *237*, 128–136.
23. Lindahl, G., Lagerstedt, Å., Ertbjerg, P., Sampels, S., & Lundström, K. (2010). Ageing of large cuts of beef loin in vacuum or high oxygen modified atmosphere–Effect on shear force, calpain activity, desmin degradation and protein oxidation. *Meat Science*, *85*(1), 160–166.
24. Malelak, G. E. M., Lalel, H. J. D., Kale, P. R., & Jelantik, I. G. N. (2017). The Sensory properties, color, microbial, lipid oxidation, and residual nitrite of se'i marinated with lime and roselle calyces extracts. *Media Peternakan*, *40*(3), 194–201.
25. Mishra, B. P., Mishra, J., Paital, B., Rath, P. K., Jena, M. K., Reddy, B. V, Pati, P. K., Panda, S. K., & Sahoo, D. K. (2023). Properties and physiological effects of dietary fiber-enriched meat products: a review. *Frontiers in Nutrition*, *10*, 1275341.
26. Mohamed, R., Fernandez, J., Pineda, M., & Aguilar, M. (2007). Roselle (Hibiscus sabdariffa) seed oil is a rich source of γ-tocopherol. *Journal of Food Science*, *72*(3), S207–S211.
27. Mohan, A., Jaico, T., Kerr, W., & Singh, R. (2016a). Functional properties of bicarbonates on physicochemical attributes of ground beef. *LWT*, *70*, 333–341. https://doi.org/10.1016/J.LWT.2016.02.053
28. Mohan, A., Jaico, T., Kerr, W., & Singh, R. (2016b). Functional properties of bicarbonates on physicochemical attributes of ground beef. *LWT*, *70*, 333–341. https://doi.org/10.1016/J.LWT.2016.02.053
29. Mohan, A., Jaico, T., Kerr, W., & Singh, R. (2016c). Functional properties of bicarbonates on physicochemical attributes of ground beef. *LWT*, *70*, 333–341. https://doi.org/10.1016/J.LWT.2016.02.053
30. Perez-Baez, A. J., Camou, J. P., Gonzalez-Aguilar, G., Lucas-Gonzalez, R., Valenzuela-Melendres, M., & Viuda-Martos, M. (2021). Roselle (Hibiscus sabdariffa L.) extracts added to Frankfurt-type sausages:

Effects on chemical, physicochemical, and sensorial properties. *Journal of Food Processing and Preservation*, *45*(10), e15782.

31. Reitznerová, A., Uleková, M., Nagy, J., Marcinčák, S., Semjon, B., Čertík, M., & Klempová, T. (2017). Lipid Peroxidation Process in Meat and Meat Products: A Comparison Study of Malondialdehyde Determination between Modified 2-Thiobarbituric Acid Spectrophotometric Method and Reverse-Phase High-Performance Liquid Chromatography. *Molecules 2017, Vol. 22, Page 1988*, *22*(11), 1988. https://doi.org/10.3390/MOLECULES22111988
32. Rowe, L. J., Maddock, K. R., Lonergan, S. M., & Huff-Lonergan, E. (2004). Influence of early postmortem protein oxidation on beef quality. *Journal of Animal Science*, *82*(3), 785–793.
33. Santos, E. M., Sánchez-Ortega, I., Lorenzo, J. M., Domínguez, R., Munekata, P. E. S., Falfán-Cortés, R. N., Ibarra, I. S., & Rangel-Vargas, E. (2022). Use of Hibiscus sabdariffa calyxes in meat products. *Frontiers in Animal Science*, *3*, 876042.
34. Scollan, N., Hocquette, J.-F., Nuernberg, K., Dannenberger, D., Richardson, I., & Moloney, A. (2006). Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. *Meat Science*, *74*(1), 17–33.
35. Selene Marquez-Rodriguez, A., Nevarez-Baca, S., Cesar Lerma-Hernandez, J., Raul Hernandez-Ochoa, L., Virginia Nevarez-Moorillon, G., Gutierrez-Mendez, N., Nayzzel Munoz-Castellanos, L., & Salas, E. (2020). In Vitro Antibacterial Activity of Hibiscus sabdariffa L. Phenolic Extract and Its In Situ Application on Shelf-Life of Beef Meat. *Foods*, *9*(8).
36. Sobral, M. M. C., Casal, S., Faria, M. A., Cunha, S. C., & Ferreira, I. M. P. L. V. O. (2020). Influence of culinary practices on protein and lipid oxidation of chicken meat burgers during cooking and in vitro gastrointestinal digestion. *Food and Chemical Toxicology : An International Journal Published for the British Industrial Biological Research Association*, *141*. https://doi.org/10.1016/J.FCT.2020.111401
37. Soriano, A., Alañón, M. E., Alarcón, M., García-Ruíz, A., Díaz-Maroto, M. C., & Pérez-Coello, M. S. (2018). Oak wood extracts as natural antioxidants to increase shelf life of raw pork patties in modified atmosphere packaging. *Food Research International*, *111*, 524–533.
38. Stadtman, E. R., & Levine, R. L. (2003). Free radical-mediated oxidation of free amino acids and amino acid residues in proteins. *Amino Acids*, *25*, 207–218.
39. Utrera, M., Morcuende, D., Ganhão, R., & Estévez, M. (2015). Role of phenolics extracting from Rosa canina L. on meat protein oxidation during frozen storage and beef patties processing. *Food and Bioprocess Technology*, *8*, 854–864.
40. Viana, F. M., Canto, A., Costa-Lima, B. R. C., Salim, A., & Junior, C. A. C. (2017). Color stability and lipid oxidation of broiler breast meat from animals raised on organic versus non-organic production systems. *Poultry Science*, *96*(3), 747–753.
41. Villasante, J., Ouerfelli, M., Bobet, A., Metón, I., & Almajano, M. P. (2020). The Effects of pecan shell, roselle flower and red pepper on the quality of beef patties during chilled storage. *Foods*, *9*(11), 1692.
42. Vinokur, Y., Rodov, V., Reznick, N., Goldman, G., Horev, B., Umiel, N., & Friedman, H. (2006). Rose petal tea as an antioxidant-rich beverage: cultivar effects. *Journal of Food Science*, *71*(1), S42–S47.
43. Vossen, E., Utrera, M., De Smet, S., Morcuende, D., & Estévez, M. (2012). Dog rose (Rosa canina L.) as a functional ingredient in porcine frankfurters without added sodium ascorbate and sodium nitrite. *Meat*

Science, *92*(4), 451–457.

44. Wang, X., Wang, Z., Zhuang, H., Nasiru, M. M., Yuan, Y., Zhang, J., & Yan, W. (2021). Changes in color, myoglobin, and lipid oxidation in beef patties treated by dielectric barrier discharge cold plasma during storage. *Meat Science*, *176*, 108456.
45. Yıldız-Turp, G., & Serdaroglu, M. (2010). Effects of using plum puree on some properties of low fat beef patties. *Meat Science*, *86*(4), 896–900.
46. Zakrys, P. I., O'sullivan, M. G., Allen, P., & Kerry, J. P. (2009). Consumer acceptability and physiochemical characteristics of modified atmosphere packed beef steaks. *Meat Science*, *81*(4), 720–725.
47. Zhang, H., Wu, J., & Guo, X. (2016). Effects of antimicrobial and antioxidant activities of spice extracts on raw chicken meat quality. *Food Science and Human Wellness*, *5*(1), 39–48.
48. Zhang, J., Zou, X., Zhai, X., Huang, X., Jiang, C., & Holmes, M. (2019). Preparation of an intelligent pH film based on biodegradable polymers and roselle anthocyanins for monitoring pork freshness. *Food Chemistry*, *272*, 306–312.

Figures

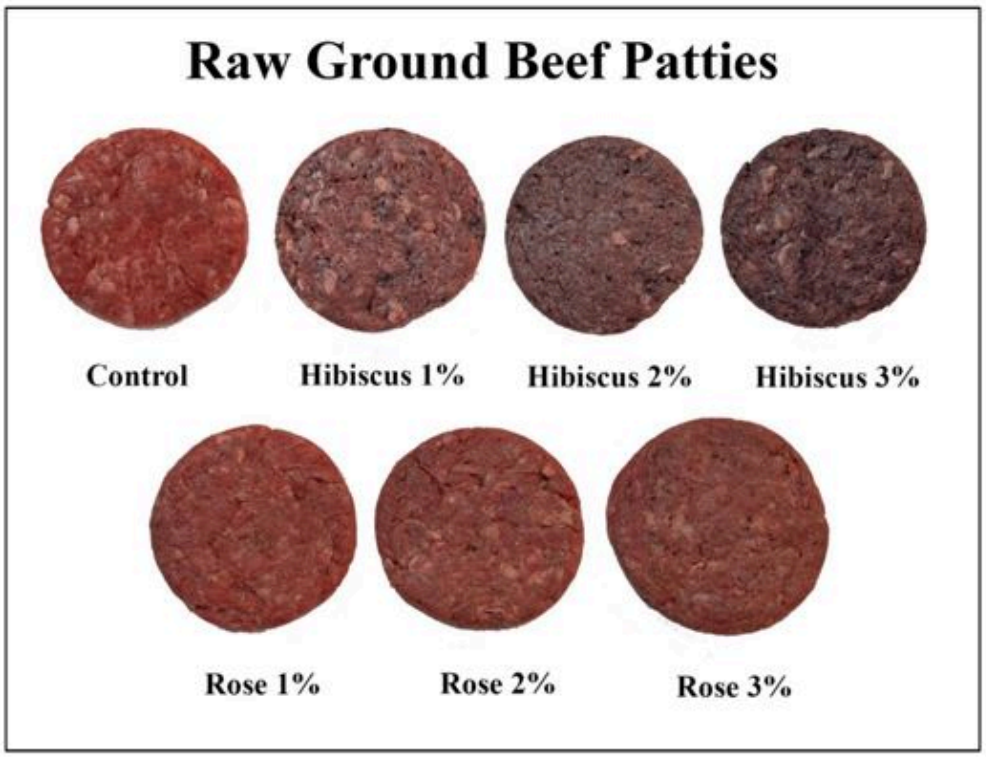


Figure 1

The visual appearance of the raw ground beef patties is evaluated after preparation, considering the seven treatments: Raw ground beef patties (control), Raw ground beef patties treated with 1% Hibiscus sabdariffa L. powder, Raw ground beef patties treated with 2% Hibiscus sabdariffa L. powder, Raw ground beef patties treated with 3% Hibiscus sabdariffa L. powder, Raw ground beef patties treated with 1% Rosa canina L.

powder, Raw ground beef patties treated with 2% Rosa canina L. powder, Raw ground beef patties treated with 3% Rosa canina L. powder.

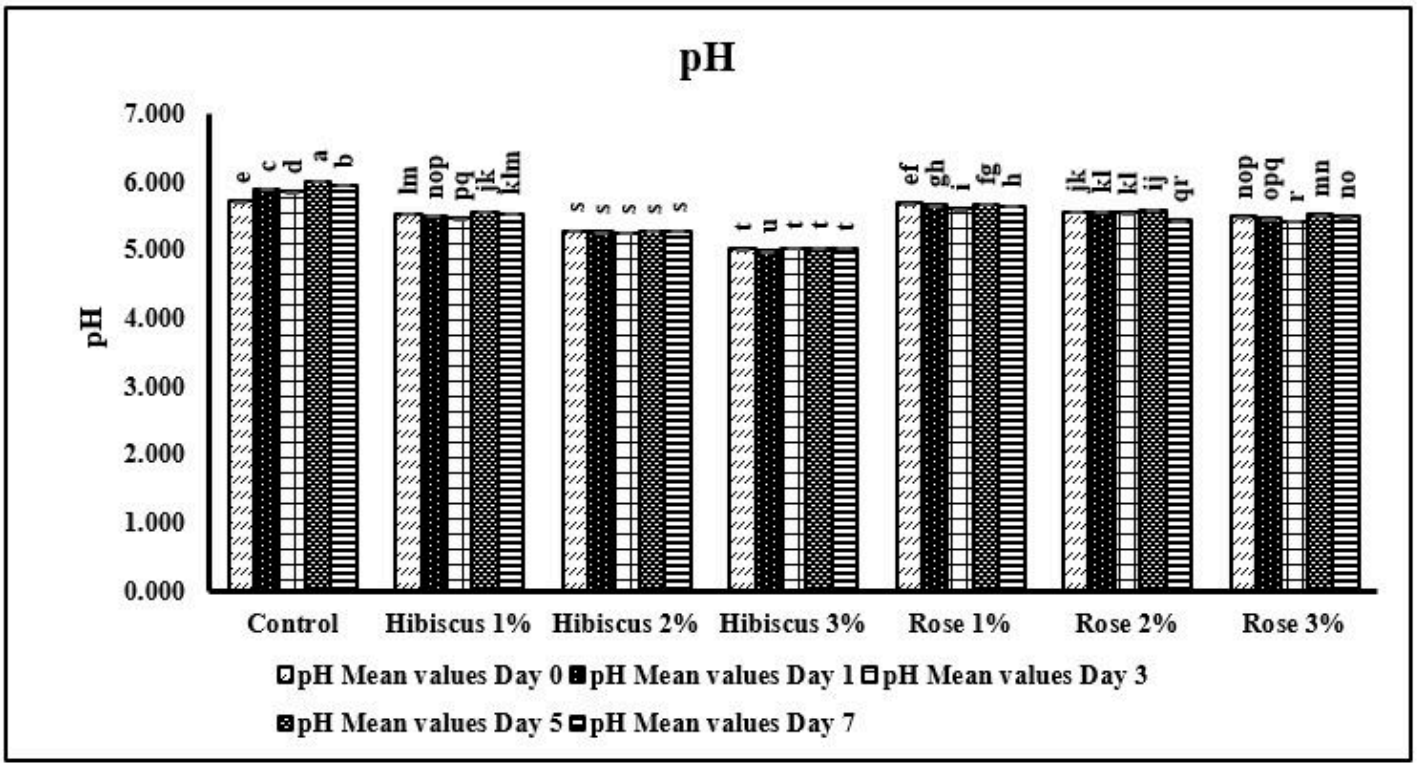


Figure 2

The graph represents the concentration of pH obtained from Day 0 to Day 7, with various treatments. P-value is < 0.05. Letters connected by different letters are significantly different.

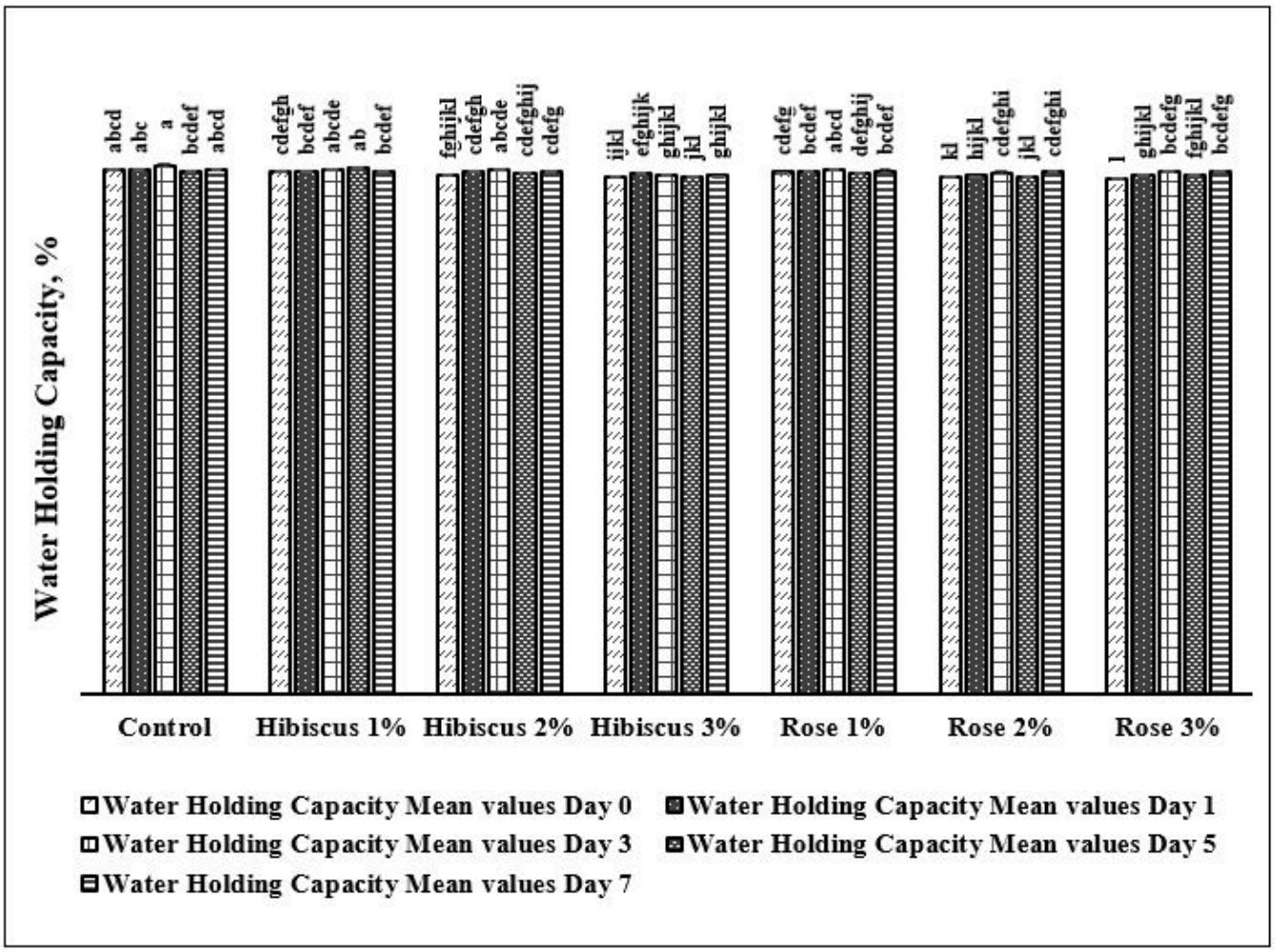


Figure 3

The graph represents the concentration of Water holding capacity obtained from Day 0 to Day 7, with various treatments. The P-value is < 0.05. Letters connected by different letters are significantly different.

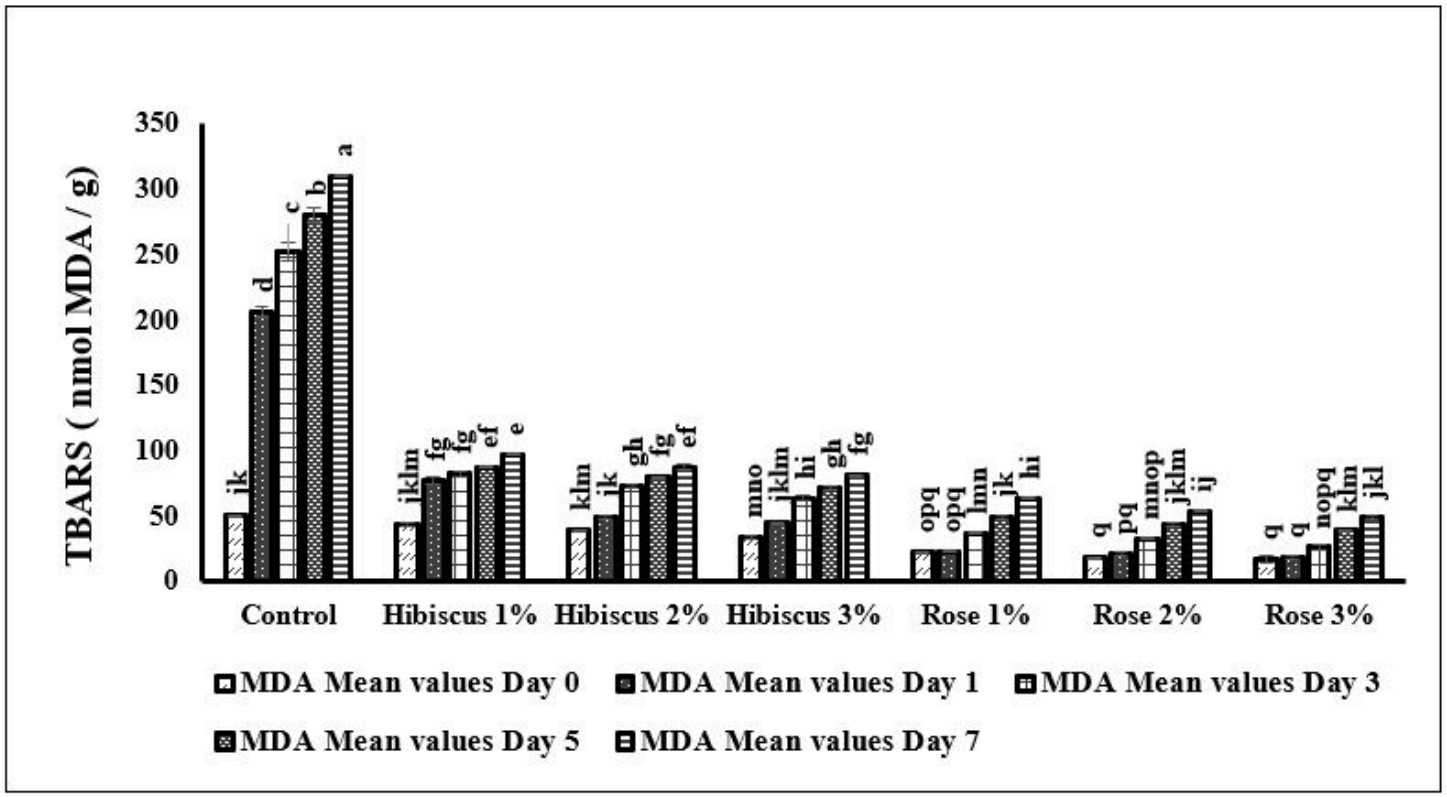


Figure 4

The graph represents the concentration of MDA (TBARS, nmol MDA / g) obtained from Days 0 - 7 with different treatments. Results are presented as mean ± SD of three independent determinations. Letters connected by different letters are significantly different. Significant difference within the treatment ($p < 0.05$).

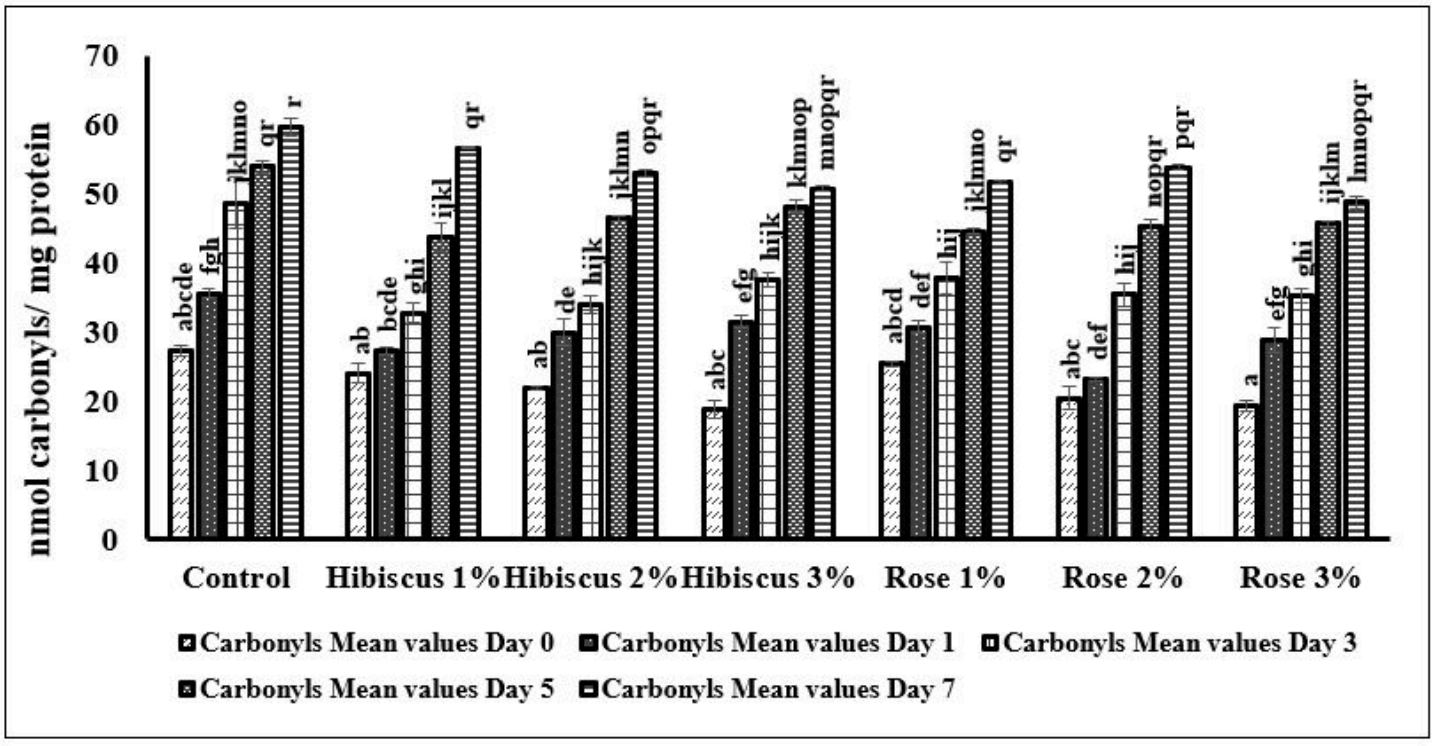


Figure 5

The graph represents the concentration of Carbonyls obtained from Day 0 to Day 7, with various treatments. P-value is < 0.05. Letters connected by different letters are significantly different.

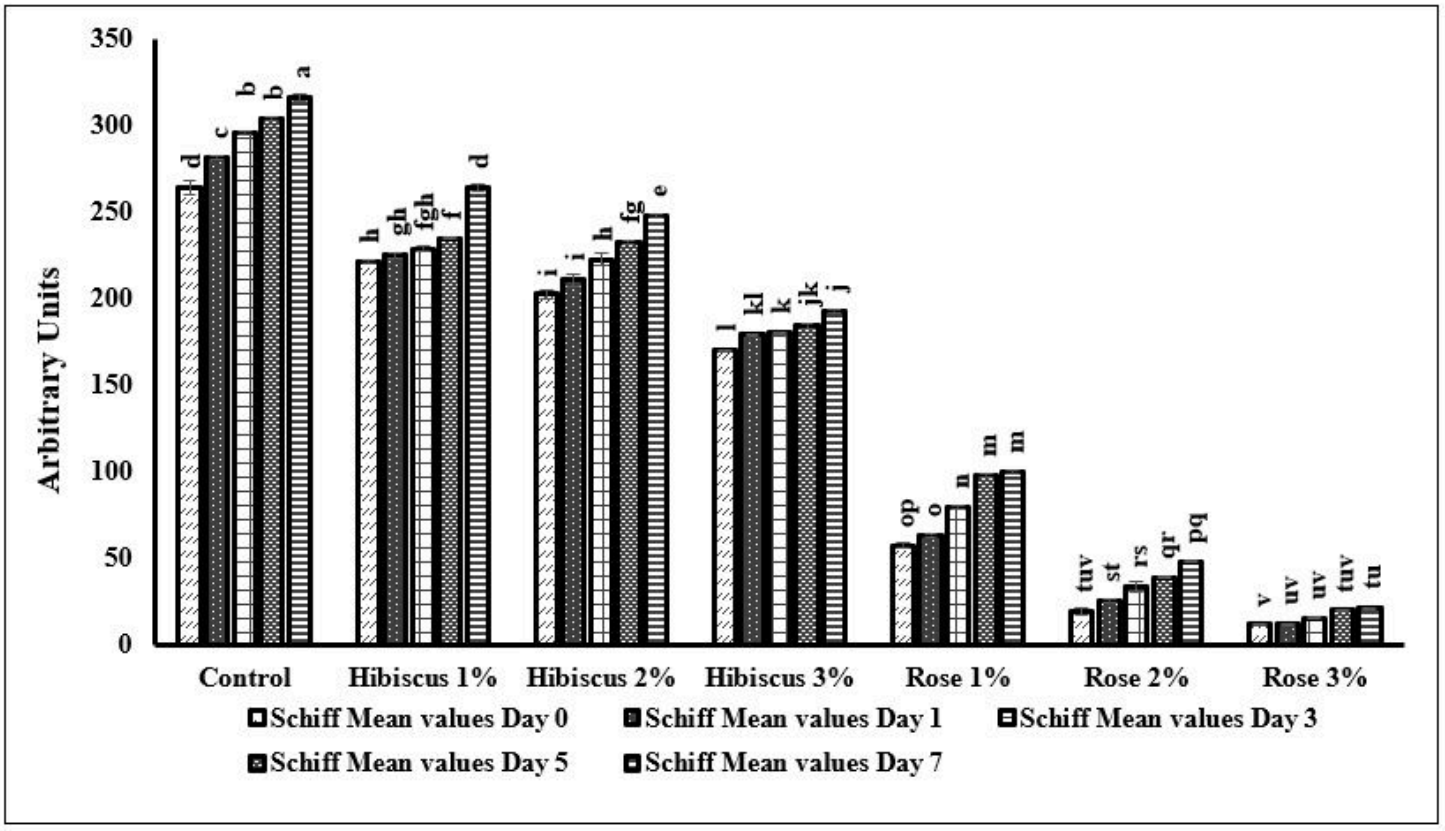


Figure 6

The graph represents the concentration of Schiff bases obtained from Day 0 to Day 7, with various treatments. P-value is < 0.05. Letters connected by different letters are significantly different.

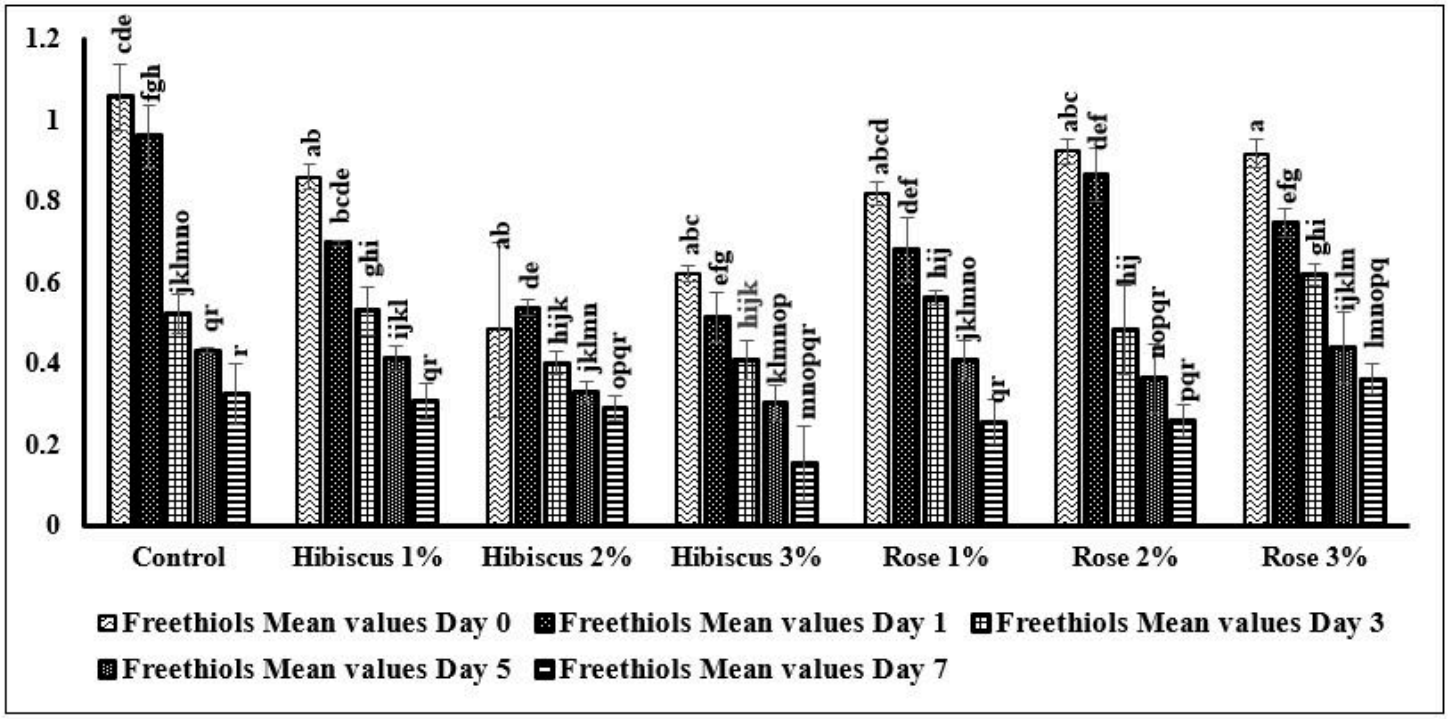


Figure 7

The graph represents concentration of Free thiols obtained from Day 0 to Day 7, with various treatments. P-value is < 0.05. Letters connected by different letters are significantly different.

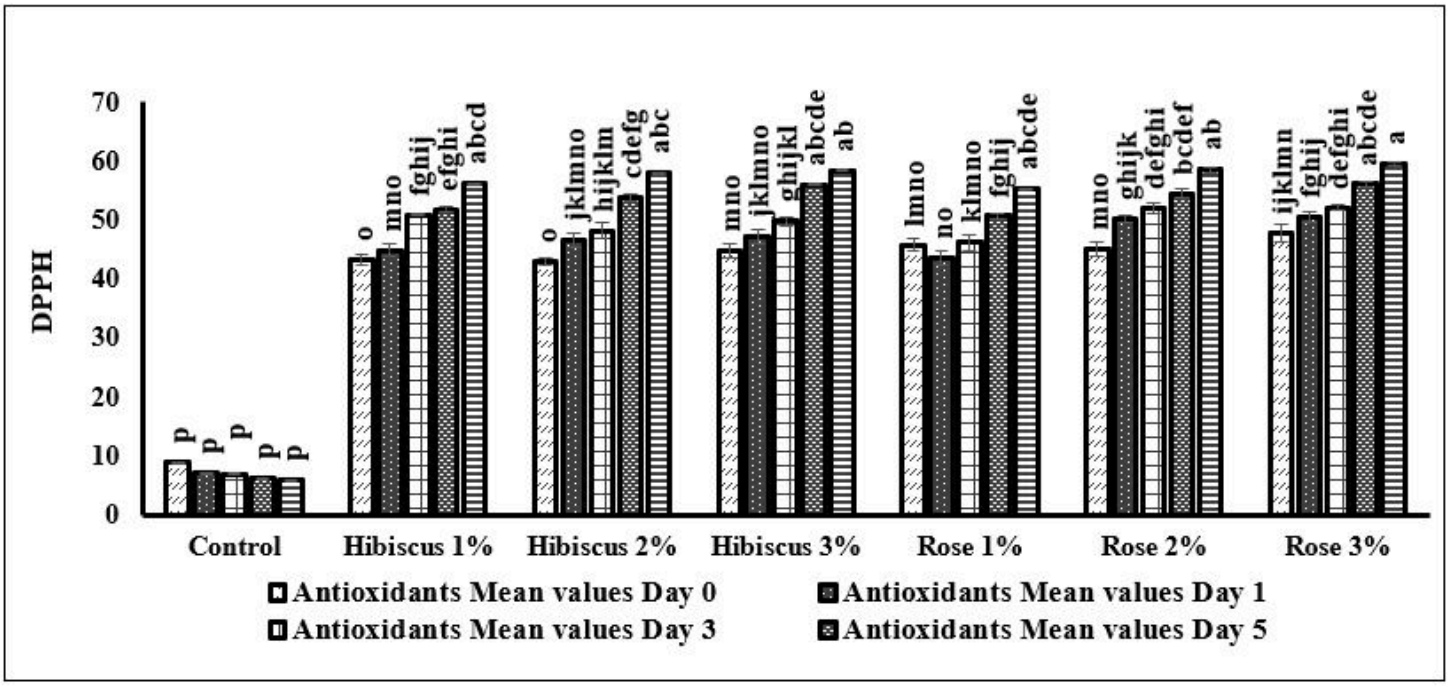


Figure 8

The graph represents the concentration of Free radical scavenging activity assay obtained from Day 0 to Day 7, with various treatments. P-value is < 0.05. Letters connected by different letters are significantly different.