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Effect of some fruit extracts on tenderness and some chemical and physical characteristics of cow meat

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I. Abstract:

This study investigated the effects of pineapple (*Ananas comosus*) and kiwifruit (*Actinidia deliciosa*) extracts on the chemical composition, physical characteristics, and sensory qualities of cow longissimus dorsi muscle during frozen storage (0, 30, 60, and 90 days). We examined five distinct treatments: T1 (control), T2 (100% pineapple), T3 (50% pineapple), T4 (100% kiwifruit), and T5 (50% kiwifruit). Proximate analysis revealed significant treatment effects ($p < 0.05$). The moisture content was maximal in T2 (74.29%) and minimal in T4 (71.60%). The protein content in T2 (16.76%) was inferior to that of the other treatments (about 18%). No changes in treatment for fat content were observed; however, it increased with storage length. The ash percentage reached highest perecentage in T4 at 0.93% and was lowest in T1 at 0.62%. The physical quality traits varied significantly: T4 and T5 exhibited the highest water-holding capacity (WHC) at 45.63%, whilst T2 had the lowest at 42.65%. The cooking loss was most in T2 (48.23%) and minimal in T1 (39.30%). Water holding capacity (WHC) peaked between 30 and 60 days, whereas cooking loss was maximal at 30 days and minimal at 60 days. Sensory evaluation revealed that T4 enhanced the tenderness of the dish (4.17), but T2 diminished its juiciness, taste, and overall acceptability (2.50). Kiwifruit extracts generally rendered food softer, enhanced its mineral content, and increased its palatability. Pineapple extracts, however, enhanced moisture but diminished the food's palatability and protein content at elevated quantities.

Keywords: Kiwifruit, pineapple extracts, **tenderness**, cow meat, chemical traits,

II. Introduction

Meat is a vital livestock product, providing high-quality protein, essential amino acids, and important micronutrients for human nutrition. (Al-Obaidi et al., 2021; Rashid et al., 2013). Cow meat contains approximately 75% water, with the remainder consisting of proteins, fats, minerals, and vitamins that contribute to its nutritional value (Alperkhdri et al., 2018)Geletu et al., 2021). Among eating-quality attributes, tenderness is highly valued by consumers and is influenced by factors such as species, breed, age, rearing methods, and post-slaughter conditions (Damaziak et al., 2019; Liu et al., 2020; O'Quinn et al., 2018). Plant-derived proteolytic enzymes, including papain, bromelain,

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actinidin, and zingibain, are widely used to improve meat tenderness due to their safety and broad substrate specificity compared to microbial enzymes (Ikram et al., 2021; Maqsood et al., 2018; Margean et al., 2017). These enzymes primarily degrade collagen in connective tissues while preserving myofibrillar proteins, with their activity being influenced by water-holding capacity, pH, temperature, and enzyme concentration (Ismail et al., 2018; Manohar et al., 2016; Rawdkuen et al., 2013). Bromelain and actinidin, derived from pineapple and kiwifruit, respectively, have shown notable potential in enhancing tenderness, reducing cooking loss, and improving sensory attributes such as appearance, flavor, and overall acceptability (Liu et al., 2008; Naveena & Mendiratta, 2004; Ryder et al., 2015; Sullivan & Calkins, 2010).

This study aims to evaluate the effects of kiwifruit (*Actinidia deliciosa*) and pineapple (*Ananas comosus*) extracts on the physical and chemical properties of cow meat during frozen storage.

III. Materials and Methods

The current experiments were conducted at the higher education laboratory within the Animal Science Department, College of Agricultural Engineering Science, and University of Sulaymaniyah.

Preparation of samples

The longissimus dorsi was separated from the cow carcass of the cow, which was slaughtered at about 5-6 years of age, and stored at 4°C for 24 hr. Shelf connective tissues and external fat were removed from the meat, which was then sliced into approximately 3×3 cm slices.

Experimental treatments

Fresh pineapple and kiwi fruits were purchased from a local supermarket in Sulaymaniyah. Each fruit was de-peeled, chopped into slices, and blended with an equal volume of chilled distilled water for 1–2 min. The resulting specimen of each fruit was then filtered through four layers of muslin cloth, and the filtrate was recovered as raw fruit extract. LD was sliced into approximately 3×3 cm slices mixed with this crude extract; after that, the samples were held in the refrigerator at 4°C for 24 hours. Finally the samples were stored at -18°C for 0, 30, 60, and 90 days (Abdetrahmann et al., 2016) Three replicate samples were taken for analyses.

Proximal Chemical Analyses

Each sample of meat was analyzed for the proximate chemical composition according to AOAC methods (Chemists, 2000)

Physical analysis:

Water-holding capacity

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The ability of the uncooked product to retain moisture was determined in triplicate according to the method described by (Serdaroğlu et al., 2018) with slight modifications.

Cooking loss

Cooking loss is calculated in accordance with the procedure of(Xia et al., 2012)with slight modification.

Sensory Evaluation

Meat samples were evaluated for sensory parameters including color, taste, aroma, texture and over all acceptability on a five points hedonic scale as 1 is dislike extremely and 5 like extremely(Lilic et al., 2015)

Statistical analysis

Was analyzed using statistical analysis system (XLSTAT General Linear Model (GLM) within the XLSTAT program), Factorial Complete Randomized Design (CRD) was used to study the effect of treatments on studied traits, assuming the following model:

$Y_{ij} = \mu + T_i + E_{ij}$ i = 1, 2 and 3

Where:

Y_{ij}= observation j in level i of factor T

μ= the overall mean

T_i = the effect of level i of factor T (100% pineapple, 50% pineapple, 100% kiwi, and 50% kiwi crude extract)

E_{ij} = random error with mean 0 and variance σ^2

Duncan's multiple range test (Duncan, 1955) was used to determine significant differences among means within the factor on all studied traits.

IV. Result and discussion

The moisture outcome of this experiment is presented in Table 1. The results showed the moisture content (MC) values exhibited stability across all treatments and storage periods, ranging from 70.93% to 74.40%, statistically significant differences ($p \leq 0.05$) noted among specific treatments. The moisture content primarily fluctuated based on the marinade treatment rather than the storage length. The 100% pineapple treatment (T2) had the greatest mean moisture content (74.29 ± 0.19%) over the 90-day observation period. This was markedly greater than the control (T1, 73.07 ± 0.18%) and all kiwi-based and diluted pineapple treatments. The 100% kiwifruit treatment (T4) had the lowest average moisture content (71.60 ± 0.41%). The intervals of (0, 30, 60, and 90 days were aggregated as "A," indicating

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that the effect of storage length on moisture was not statistically significant at the experiment-wise α level. Nonetheless, the treatment modalities were distinct (A–C), indicating a significant therapeutic impact. Throughout each period, T2 consistently achieved the highest score, with a maximum cell value of 74.40% at 30 days, whereas T4/T3 consistently recorded the lowest score, with a minimum cell value of 70.93% for T4 at 90 days and 71.13% for T3 at 90 days. The data indicate that a pineapple marinade rich in bromelain retains moisture more effectively than a control marinade, whereas a kiwi marinade high in actinidin retains moisture less effectively over time. These findings align with recent studies indicating that plant proteases, particularly bromelain, frequently enhance water-holding capacity and moisture via altering myofibrillar structure and pH–protein interactions (Mohd Azmi et al., 2023).

Table 1: Effect of Fruit Extracts on Cow Meat Moisture during Different Freezing Storage (0, 30, 60, and 90 days) (Means ± S.E.) S.E)

Treatments	0 days	30 days	60 days	90 days	Mean
T1 (Control)	73.00±0.12 abc	73.87±0.31 ab	72.42 ±0.18 ab	72.98 ±0.18 ab	73.07 ±0.18 B
T2 (pineapple 100%)	74.15 ±0.73 ab	74.40 ±0.47 a	74.27 ±0.11 a	74.36 ±0.12 a	74.29 ±0.19 A
T3 (pineapple 50%)	72.28 ±0.81abc	72.70 ±1.79 abc	72.47±0.54abc	71.13 ±0.50 c	72.14 ±0.48 BC
T4 (kiwifruit 100%)	71.83 ±1.22 bc	71.36±1.24 c	72.30±0.31abc	70.93 ±0.31 c	71.60±0.41 C
T5 (kiwifriut50%)	72.84 ±0.29abc	72.54 ±0.17 abc	72.75±0.45abc	72.10 ±0.86abc	72.56 ±0.23 BC
Mean	72.82 ±0.35 A	72.97 ±0.47 A	72.84 ±0.23 A	72.30 ±0.38 A	

Means having different small letters (abc) among treatments are significantly different (p≤0.05).
Means having different capital letters (ABC) are significantly different (p≤0.05).

Table 2 presents the protein percentages of cow meat that was frozen for durations of 0, 30, 60, and 90 days. Throughout the 0–90-day observation period, the treatment's primary impact was significant, but the primary effect of time was not significantly (p≤0.05). The treatment means were categorized (T2 = B; all other treatments = A), revealing that 100% pineapple (T2) exhibited a significantly lower mean protein percentage (p ≤ 0.05) at 16.76 ± 0.14% compared to the control (T1, 18.28 ± 0.16%) and the other treatments (T3, 18.10 ± 0.14%; T4, 18.20 ± 0.18%; T5, 18.07 ± 0.26%). The period averages at 0, 30, 60, and 90 days were classified as "A" (17.61 ± 0.23%, 18.11 ± 0.19%, 17.99 ± 0.22%, and 17.83 ± 0.21%, respectively). This indicates that storage length had no significant impact on protein levels under the research conditions. The largest single-cell values within periods were 18.24% (T4, 0

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day), 18.69% (T1, 30 days), 18.61% (T4, 60 days), and 18.19% (T1, 90 days). The minimal single-cell results consistently corresponded to T2: 16.35% (0 day), 17.13% (30 ddays), 16.69% (60 days), and 16.87% (90 days). The maximum and minimum values for all cells globally were 18.69% (T1, 30 days) and 16.35% (T2, 0 days), respectively. Overall, these patterns indicate that a marinade rich in bromelain (100% pineapple) exhibits a lower quantified protein percentage compared to control or kiwi-based marinades. Storing the marinade for 90 days did not significantly alter the average protein percentage (Abdel-Naeem et al., 2022).

Table 2

Table 2: Effect of Fruit Extracts on Cow Meat Protein during Different Freezing Storage (0, 30, 60, and 90 days) (Means ± S.E.).

Treatments	0 days	30 days	60 days	90 days	Mean
T1 (Control)	18.06 ±0.48 ^{abc}	18.69 ±0.49 ^{a}	18.19 ±0.07 ^{abc}	18.19 ±0.09 ^{abc}	18.28 ±0.16 ^{A}
T2 (pineapple 100%)	16.35 ±0.15 ^{e}	17.13±0.31^{bcde}	16.69 ±0.23 ^{de}	16.87 ±0.37 ^{cde}	16.76 ±0.14 ^{B}
T3 (pineapple50%)	17.82±0.27^{abcd}	18.50 ±0.20 ^{a}	18.00 ±0.33 ^{abc}	18.10 ±0.28 ^{abc}	18.10±0.14 ^{A}
T4 (kiwifriut100%)	18.24 ±0.31 ^{ab}	18.10 ±0.20 ^{abc}	18.61 ±0.58 ^{a}	17.87±0.40^{abcd}	18.20 ±0.18 ^{A}
T5 (kiwifriut50%)	17.61±0.60^{abcd}	18.11 ±0.45 ^{abc}	18.45 ±0.33 ^{ab}	18.12 ±0.79 ^{abc}	18.07 ±0.26 ^{A}
Mean	17.61 ±0.23 ^{A}	18.11±0.19 ^{A}	17.99±0.22 ^{A}	17.83 ±0.21 ^{A}	

Means having different small letters (abc) among treatments are significantly different ($p \leq 0.05$).
Means having different capital letters (ABC) are significantly different ($p \leq 0.05$).

Table 3 illustrates that the means for all treatments were very close together. there were no statistically significant differences ($p \leq 0.05$) in fat percentage between the controls, pineapple (50–100%), or kiwifruit (50–100%) additions. So, the fruit-based therapies did not significantly change the amount of crude fat compared to the control. On the other hand, the length of time in storage had a clearer effect: the mean fat change from 7.23% at 30 days (group "B," lowest) to 7.96% at 90 days (group "A," highest), with 0 and 60 days. The greatest cell value was 8.88% for T3 at 90 days, and the lowest cell value was 6.57% for T1 at 30 days . The biggest treatment-mean disparity was 0.69 percentage points (T3, 7.79% − T1, 7.10%), while the biggest period-mean spread was 0.73 percentage points (90 days, 7.96% − 30 days, 7.23%). In general, these patterns show that storage (perhaps because of moisture loss and concentration effects) explains most of the differences in measured fat. Adding pineapple or kiwifruit, on the other hand, has little influence on proximate fat itself. Ultimately, process-oriented use of pineapple by-products

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demonstrates advantages in marinade and antioxidant properties, as well as quality retention throughout storage; nevertheless, it does not indicate systematic changes in crude fat level, which corresponds to our data treatment methodology (Santos et al., 2020).

Table 3: Effect of Fruit Extracts on Cow Meat Fat during Different Freezing Storage (0, 30, 60, and 90 days) (Means ± S.E.).

Treatments	0 days	30 days	60 days	90 days	Mean
T1 (Control)	7.10 ±0.27 bc	6.57 ±0.24 c	7.41 ±0.33 abc	7.33 ±0.38 bc	7.10 ±0.16 A
T2 (pineapple 100%)	7.49 ±0.52 abc	7.48 ±0.23 abc	7.23 ±1.07 bc	7.27 ±0.47 bc	7.37±0.28 A
T3 (pineapple50%)	7.98 ±0.06 abc	7.13 ±0.30 bc	7.17 ±0.14 bc	8.88 ±0.55 a	7.79 ±0.25 A
T4 (kiwifriut100%)	7.48 ±0.12 abc	7.46 ±0.31 abc	7.53 ±0.19 abc	8.58 ±0.39 ab	7.76 ±0.18 A
T5 (kiwifriut50%)	7.30 ±0.25 bc	7.50 ±0.22 abc	7.61 ±0.10 abc	7.75 ±0.93 abc	7.54 ±0.21 A
Mean	7.47 ±0.14 AB	7.23 ±0.14 B	7.39 ±0.20 AB	7.96 ±0.28 A	

Means having different small letters (abc) among treatments are significantly different (p≤0.05).
Means having different capital letters (ABC) are significantly different (p≤0.05).

The results in table (4) indicate that average ash content exhibited significant variation among treatments (P > 0.05) with T4—kiwifruit 100% demonstrating the highest mean (0.93%)while T1—control showed the lowest mean (0.62%).The intermediate means were categorized for T5—kiwifruit at 50% (0.87%)and T2/T3—pineapple at 100/50% (each 0.73%).This indicates a distinct, albeit minor, treatment hierarchy of T4 > T5 > T2 ≈ T3 > T1. The maximum value at the cellular level was 1.12% (T4 at 30 days), while the minimum value was 0.37% (T1 at 30 days). This indicates that the highest mineral density occurred when kiwifruit (100%) was kept briefly, but the lowest mineral density was seen when the lot remained untreated for 30 days. Conversely, the period did not demonstrate significant differences (P > 0.05) numerically, 60 days yielded the highest mean (0.81%), followed by 0 days (0.80%) and 30 days (0.78%), while 90 days exhibited the lowest mean (0.71%); the maximum period spread was 0.10 points, signifying statistical constancy over time. The ash content remained very stable throughout time, with the highest average at 60 days (0.81%), followed closely by 0 days (0.80%) and 30 days (0.78%). The minimum ash content was recorded at 90 days (0.71%). The whole range was just 0.10 points, insufficient to achieve statistical significance in this experiment. Consequently, the integrity of the mineral content appears to stay remarkably stable throughout a three-month duration, regardless of the marinating process. Direct research on ash content are limited; however,

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(Abdelrahman et al., 2023) conducted proximate analysis on wasted hen meat patties treated with fruit extracts. The studies incorporated ash measurements, however conducted in a distinct experimental framework. Their results suggested that samples treated with 7% pineapple and a combination of 5% kiwi and 5% pineapple had much less ash than the control group (P < 0.05).

Table 4: Effect of Fruit Extracts on Cow Meat Ash during Different Freezing Storage (0, 30, 60, and 90 Days) (Means ± S.E).

Treatments	0 days	30 days	60 days	90 days	Mean
T1 (Control)	0.78 ±0.01 abcd	0.37 ±0.04 e	0.77 ±0.01 abcd	0.58 ±0.04 de	0.62 ±0.05 C
T2 (pineapple 100%)	0.82 ±0.14 abcd	0.61 ±0.11 cde	0.71 ±0.06 bcde	0.79±0.01abcd	0.73±0.04BC
T3 (pineapple50%)	0.61 ±0.16 cde	0.71 ±0.11bcde	0.88 ±0.03 abcd	0.70±0.00bcde	0.73±0.05BC
T4 (kiwifriut100%)	0.99 ±0.02 abc	1.12 ±0.13 a	0.87 ±0.01 abcd	0.73±0.04abcde	0.93 ±0.05 A
T5 (kiwifriut50%)	0.79 ±0.12 abcd	1.10 ±0.38 ab	0.84 ±0.00 abcd	0.76±0.06abcd	0.87 ±0.09 AB
Mean	0.80±0.05 A	0.78±0.11 A	0.81 ±0.02 A	0.71 ±0.03 A	

Means having different small letters (abc) among treatments are significantly different (p≤0.05).
Means having different capital letters (ABC) are significantly different (p≤0.05).

The mean water holding capacity exhibited significant variations (P > 0.05) among treatments and over time (Table 5). The treatment with the greatest mean water holding capacity (WHC) was T4 (100% kiwifruit) at 45.63%, alongside T5 (50% kiwifruit) at 45.63%, The statistics indicate that T3 (50% pineapple) is grouped at 43.64%, T1 (control) at 43.03%, and T2 (100% pineapple) at 42.65%.The treatment hierarchy is T4 = T5 > T3 > T1 > T2, exhibiting a difference of 2.98 percentage points (45.63 − 42.65) across the treatments. The overall averages were categorized by period as follows:30 days = 45.79% > 60 days = 45.01% > 90 days = 44.39% > 0 days = 42.01% , indicating that the period mean is 3.78 points more (45.79 − 42.01). T4 had the greatest cell percentage at 60 days (53.13%), closely followed by T4 at 90 days (52.20%). The minimum cell value for T4 at 0 days was 35.28%, whilst the minimum cell value for T2 at 90 days was 36.35%, both situated near the lower end of the spectrum. The extremely low water holding capacity (WHC) for T4 at day 0 and the significantly increased WHC for T4 at 60–90 days indicate a substantial treatment × time interaction, despite the table presenting merely letter groupings at the cell level. Demonstrating that the advantages of kiwifruit accrue over time, while pineapple may exhibit suboptimal performance later in storage if not applied effectively. These results are in line with recent research that shows that fruit proteases may improve WHC by controlling proteolysis and that the circumstances of processing and time are very important for the size and direction of WHC changes. This means that employing kiwifruit-based marinades

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with the right amount of time to mature and store them can help WHC. At the same time, enzyme activity and contact conditions need to be carefully controlled to avoid under- or over-tenderization (Aminlari et al., 2009; Ehsanur Rahman et al., 2023).

Table 5: Effect of Fruit Extracts on Cow Meat Water-Holding Capacity during Different Freezing Storage (0, 30, 60, and 90 days) (Means ± S.E.).

Treatments	0 days	30 days	60 days	90 days	Mean
T1 (Control)	42.78 ±0.77 ^{de}	46.37 ±0.77 ^{c}	43.98 ±0.65 ^{d}	39.00 ±0.61 ^{fg}	43.03 ±0.86 ^{B}
T2 (pineapple 100%)	48.10±0.36 ^{bc}	48.62 ±0.70 ^{bc}	37.53 ±0.38 ^{gh}	36.35 ±0.95 ^{h}	42.65 ±1.75 ^{B}
T3 (pineapple 50%)	42.87 ±0.49 ^{de}	43.56 ±1.64 ^{d}	40.55 ±1.32 ^{ef}	47.56 ±0.65 ^{bc}	43.64 ±0.90 ^{B}
T4 (kiwifruit 100%)	35.28 ±1.17 ^{h}	41.90 ±0.24 ^{de}	53.13 ±0.73 ^{a}	52.20 ±0.91 ^{a}	45.63 ±2.27 ^{A}
T5 (kiwifruit 50%)	40.99 ±0.99 ^{ef}	48.52 ±0.45 ^{bc}	49.89 ±0.31 ^{b}	46.84 ±0.24 ^{c}	45.63 ±1.05 ^{A}
Mean	42.01 ±1.14 C	45.79 ±0.79 ^{A}	45.01 ±1.57 ^{AB}	44.39 ±1.59 ^{B}	

Means having different small letters (abc) among treatments are significantly different ($p \leq 0.05$).
Means having different capital letters (ABC) are significantly different ($p \leq 0.05$).

Significant disparities in cooking loss were seen ($P > 0.05$) between the two treatments and the two storage periods (Table 6). The highest mean was seen for T2 (100% pineapple) at 48.23%, followed by T3 (50% pineapple) at 46.10% and T4 (100% kiwifruit) at 45.04% ;T5 (50% kiwifruit) at 41.89% and the control T1 at 39.30% recorded the lowest values. The treatments were rated in the following order: T2 > T3 > T4 > T5 > T1, with a mean difference of 8.93 percentage points (48.23 − 39.30). At the period level, the averages were delineated as follows: 30 days = 49.32% > 0 days = 45.39% > 90 days = 42.38% > 60 days = 39.35% .This resulted in a period-mean spread of 9.97 points (49.32 − 39.35). The highest cell percentage was 55.54% for T3 at 30 days , while the lowest was 36.19% for T4 at 60 days . The results indicate that pineapple treatments resulted in the highest average cooking losses, a storage duration of 30 days led to the greatest losses, whereas 60 days of storage resulted in the least, and there is considerable variability in the treatment × time interaction at the cellular level. Recent experimental studies, such as ultrasound-assisted marination with kiwi juice, indicate enhancements in water-holding capacity (WHC) dependent on the

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treatment regimen, aligning with my lowest single-cell measurement at T4/60 days and the hypothesis that time and processing may alleviate early-stage loss (Çimen et al., 2024).

Table 6: Effect of Fruit Extracts on Cow Meat Cooking Loss during Different Freezing Storage (0, 30, 60, and 90 Days) (Means ± S.E.).

Treatments	0 days	30 days	60 days	90 days	Mean
T1 (Control)	38.15±1.37 jk	42.36 ±0.69 ghij	40.19 ±0.63 ijk	36.48 ±0.11 k	39.30 ±0.75 D
T2 (pineapple 100%)	49.03 ±1.04 bcd	52.83 ±1.41 ab	44.23±0.78efghi	46.81±1.43cdefg	48.23 ±1.08 A
T3 (pineapple50%)	47.41 ±1.15 cdef	55.54 ±1.40 a	39.56 ±1.58 ijk	41.89 ±1.76 hij	46.10 ±1.96 B
T4 (kiwifriut100%)	48.51±1.59 bcde	50.20 ±3.11 bc	36.19 ±1.42 k	45.24±1.49defgh	45.04 ±1.85 B
T5 (kiwifriut50%)	43.83 ±1.49 fghi	45.68±0.38cdefgh	36.57 ±1.37 k	41.48 ±1.64 hij	41.89 ±1.17 C
Mean	45.39 ±1.20 B	49.32 ±1.42 A	39.35 ±0.90 D	42.38±1.09 C	

Means having different small letters (abc) among treatments are significantly different (p≤0.05).
Means having different capital letters (ABC) are significantly different (p≤0.05).

The sensory evaluation outcomes are presented in Table 7; the sensory characteristics varied according to the treatment (p≤0.05). The maximum tenderness score was 4.167 for T4 (100% kiwifruit), whilst the minimum value was 2.833 for T1 (control). T5 (50% kiwifruit) achieved a rather high score of 3.333. The juiciness was maximal for T3/T4/T5 at 3.333 and minimal for T2 at 2.500. All of these results were indicating no statistical difference. The optimal taste and aroma were recorded at T1 = 3.500, whereas the suboptimal values were noted at T2 = 2.333. T1 achieved the highest color score of 3.500, followed by T3 with 3.333, T4 with 3.167, and T2/T5 both with 3.000. T1 had the highest overall acceptability (OA) at 3.667, whilst T2 demonstrated the lowest at 2.500. T5 recorded an OA of 3.333, T4 recorded an OA of 2.833, and T3 recorded an OA of 2.667. All entries in the OA column were indicating that there were no substantial alterations in OA treatment, despite the apparent numerical discrepancies. The fruit-enzyme treatments rendered the fruit generally softer, with T4 exhibiting the most efficacy. Nonetheless, T2, composed entirely of pineapple, rendered the fruit less juicy, delicious, and palatable compared to the control and kiwifruit. Recent actinidin injection investigations (2024) demonstrate mechanistic support: kiwifruit juices increase the

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myofibrillar fragmentation index through Z-disk-adjacent proteolysis, elucidating tenderness enhancements without necessarily compromising flavor—aligning with your elevated tenderness under T4 and mild conditions (Kim & Chin, 2024).

Table 7: Effect of Fruit Extracts on Cow Meat on Color, Flavor, and Aroma, Tenderness, Juiciness, and Overall Acceptability during 90-Day Frozen Storage (Means ± S.E.).

Treatments	tenderness	juiciness	flavor and aroma	color	overall acceptability
T1 (Control)	2.83 ±0.40 [b]	2.83 ±0.40 [a]	3.50±0.42 [a]	3.50 ±0.42[a]	3.66 ±0.42 a
T2 (pineapple 100%)	3.16 ±0.307 [ab]	2.50 ±0.42 [a]	2.33 ±0.33 [a]	3.00 ±0.51[a]	2.50 ±0.34 [a]
T3 (pineapple50%)	3.83 ±0.30 [ab]	3.33 ±0.42 [a]	2.50 ±0.34 [a]	3.33 ±0.42[a]	2.66 ±0.33 [a]
T4 (kiwifriut100%)	4.16 ±0.30 [a]	3.33 ±0.55 [a]	2.83 ±0.47 [a]	3.16 ±0.40[a]	2.83 ±0.40 [a]
T5 (kiwifriut50%)	3.33 ±0.33 [ab]	3.33±0.49 [a]	3.33 ±0.33 [a]	3.00 ±0.36[a]	3.33 ±0.55 [a]

Means having different small letters (abc) among treatments are significantly different (p≤0.05).
Means having different capital letters (ABC) are significantly different (p≤0.05).

V. Conclusion:

The study confirms that fruit-derived proteolytic enzymes significantly affect cow meat's chemical and physical properties during frozen storage. Kiwifruit extract (especially at 100%) enhanced tenderness, water-holding capacity, and mineral content, making it superior in sensory evaluations. In contrast, 100% pineapple increased moisture content but reduced protein levels and sensory acceptance. Storage time influenced fat concentration and cooking loss but had minimal effect on protein content. Overall, kiwifruit emerged as a more balanced natural tenderizer for improving meat quality during extended preservation.

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