Effect of Shell-Superchilling and Extended Wet-Aging on the Palatability of M. semitendinosus Beef Steaks

Abstract

The effect of Shell-Superchilling Treatment on M. semitendinosus (eye of round) beef steaks was investigated during a 49-day wet-aging process using King Son Constancy IFP Chilling Technology at -1.9°C. The study aimed to enhance the tenderness, flavor, and juiciness of USDA Select grade beef to increase its retail value. Steaks were subjected to Shell-Superchilling at -35°C for 5 minutes to achieve <30% surface ice content, then vacuum-sealed and aged at -1.9°C. Measurements of pH, shear force, sweetness, and sensory attributes were recorded on Days 0, 28, 35, 42, and 49. Shear force decreased from 750.3 g to 342.6–363.4 g by Day 49, indicating improved tenderness. No significant off-flavors (e.g., sour, musty) developed, and sensory evaluations noted enhanced juiciness and aging aroma by Days 42 and 49. The results suggest that Shell-Superchilling combined with IFP Chilling extends shelf life and improves palatability, offering a viable strategy to enhance the economic value of lower-quality beef cuts.

Introduction

Beef palatability, determined by tenderness, flavor, and juiciness, is a primary factor driving consumer preference over other proteins. Tenderness is the most critical attribute, with market surveys indicating consumers are willing to pay a premium for guaranteed-tender beef. High-value cuts (e.g., tenderloin, ribeye) are prized for their tenderness, but economic pressures such as drought, high grain prices, and elevated interest rates have increased beef prices, necessitating the enhancement of lower-value USDA Select grade cuts, such as M. semitendinosus (eye of round), to meet consumer expectations.

The eye of round is a lean cut known for its toughness, often aged for only 17 days on average, with 48.5% receiving less than 14 days, below the recommended aging standard. Wet-aging, involving vacuum-packaging and refrigerated storage, is the most common method to improve tenderness but can lead to off-flavors (e.g., metallic, sour) after 35 days. The King Son Constancy IFP Chilling Technology, which maintains temperatures just above the initial freezing point (IFP) of beef (-1.3°C for M. semitendinosus), offers a novel approach to extend shelf life while preserving freshness.

This study aimed to evaluate the effect of Shell-Superchilling Treatment, involving partial surface ice crystallization, followed by 49-day wet-aging at -1.9°C using King Son IFP Chilling Technology, on the tenderness, flavor, and juiciness of M. semitendinosus steaks, with the objective of enhancing their retail value.

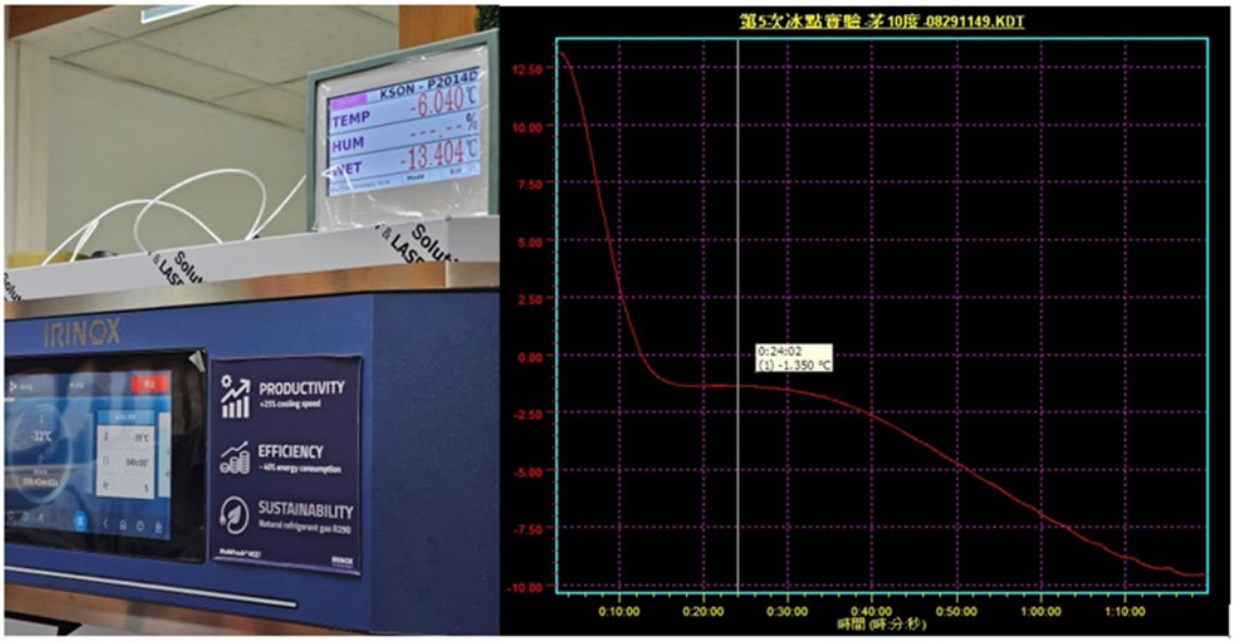
Materials and Methods

Muscle Selection and Preparation

Taiwan Angus M. semitendinosus muscle (1.9 kg), sourced from Farm Around You pasture and slaughtered on February 20, 2025, was used. The muscle, delivered vacuum-packaged on February 25, 2025, was trimmed and sliced into eleven 1.5–2 cm thick steaks. Five steaks were designated for sensory evaluation at Days 0, 28, 35, 42, and 49, with additional samples used for initial freezing point (-1.3°C) and core temperature monitoring.

Shell-Superchilling Treatment

Four steaks underwent Shell-Superchilling using an IRINOX Blast Chiller at -35°C for 5 minutes to achieve <30% surface ice content, minimizing cellular damage. The remaining steaks were stored under standard freezing conditions for comparison. All steaks were vacuum-sealed post-treatment.



Wet-Aging and Storage

Steaks were aged for 49 days in a King Son Convertible IFP Aging Chiller at -1.9°C, utilizing King Son Constancy IFP Chilling Technology. This technology maintains a temperature range between 0°C and the IFP of food with fluctuations of ±0.3°C and humidity fluctuations of ±5%, inhibiting microbial growth while preserving freshness. The chiller incorporates an A7 Intelligent Food-Tech Controller and real-time cloud-based monitoring for precise control.

Measurements

- **pH**: Measured using a calibrated pH meter.
- **Shear Force**: Determined using Warner-Bratzler Shear Force (WBSF) protocol (grams).
- **Sweetness**: Assessed in the exudate (water and myoglobin) using a refractometer (%).
- **Sensory Evaluation**: Conducted by trained panelists assessing color, aroma, tenderness, juiciness, and flavor after pan-frying to medium-well doneness.
- **Microbial Analysis**: Total viable count (TVC) was analyzed by SGS for samples aged 35, 42, and 49 days.

The experiment was conducted from February 25 to April 14, 2025.

Results

Day 0 (February 25, 2025)

The initial pH was 5.28, the shear force was 750.3 g, and sweetness was 16.7%. The raw steak exhibited a slightly dark color with no beefy aroma. When pan-fried, the texture was tough, but the fried aroma was pleasant.

Day 28 (March 24, 2025)

The pH increased to 5.54, with shear forces of 743.4 g, 485.7 g, and 402.0 g across samples. Sweetness decreased to 12.7%. Core temperature ranged from -0.8°C to -1.1°C. Sensory evaluation noted a slight aging aroma in the raw steak and exudate, with marginal tenderness improvement but no significant changes in juiciness or flavor.

Day 35 (March 31, 2025)

The pH was 5.56, with shear forces of 403.5 g, 468.3 g, and 743.1 g. Sweetness rose to 16.5%. Core temperature was approximately -0.4°C. The steak appeared dark red with some browning, and the exudate was dark red with a sweet lactic acid aroma (resembling Yakult or whey). Pan-fried samples showed improved sweetness and juiciness but remained firm.

Microbial Analysis: Total viable count (TVC) analyzed by SGS Taiwan for samples wet aged by day 35 at -1.9°C is 2.0 X 10^3 CFU/g (colony forming units per gram).

Day 42 (April 7, 2025)

The pH was 5.51, with shear forces of 474.3 g, 576.1 g, 711.4 g, and 743.0 g. Sweetness was 12.0%. Core temperature was -1.2°C. The steak and exudate exhibited a dark red to brownish-red color and a pleasant aging aroma (lactic acid and milky cheese notes). Pan-fried samples demonstrated excellent tenderness, juiciness, and flavor, significantly surpassing standard freezer-stored samples.

Microbial Analysis: Total viable count (TVC) analyzed by SGS Taiwan for samples wet aged by day 42 at -1.9°C is 3.8 X 10^3 CFU/g (colony forming units per gram).

Day 49 (April 14, 2025)

The pH reached 5.61, with shear forces of 342.6 g, 363.4 g, and 346.6 g. Sweetness was 16.0%. Core temperature was -1.1°C. Sensory attributes mirrored Day 42, with a slightly more intense flavor and a subtle sweet lactic acid note aftertaste. Tenderness and juiciness were optimal, marking the upper limit of the aging period. The aging quality was superior to freezer-stored samples.

Microbial Analysis: Total viable count (TVC) analyzed by SGS Taiwan for samples wet aged by day 35 at -1.9°C is 1.2 X 10^5 CFU/g (colony forming units per gram).

Microbial Analysis

TVC results (Days 35, 42, 49) confirmed that microbial growth was effectively controlled, supporting the preservation efficacy of IFP Chilling.

Total viable count (TVC) analyzed by SGS Taiwan for samples wet aged at -1.9°C by

- Day 35: 2.0 X 10^3 CFU/g (colony forming units per gram)
- Day 42: 3.8 X 10^3 CFU/g (colony forming units per gram)
- Day 49: 1.2 X 10^5 CFU/g (colony forming units per gram)

Discussion

The Shell-Superchilling Treatment, followed by 49-day wet-aging at -1.9°C, significantly improved the palatability of M. semitendinosus steaks. The reduction in shear force from 750.3 g to 342.6–363.4 g by Day 49 indicates enhanced tenderness, aligning with consumer preferences for tender beef. The absence of significant off-flavors (e.g., metallic, sour, musty) between Days 35 and 49 suggests that the IFP Chilling Technology effectively preserved freshness while allowing flavor development, characterized by sweet lactic acid and cheesy aromas.

The pH increases from 5.28 to 5.61 reflects protein decomposition and amine release, typical of wet-aging. Sweetness fluctuations (16.7% to 12.0–16.5%) correlate with the breakdown of proteins and fats, contributing to flavor complexity. The core temperature range (-0.4°C to -1.2°C) ensured preservation without freezing damage, a key advantage of IFP Chilling over traditional refrigeration or freezing.

Compared to standard freezer storage, the Shell-Superchilling and IFP Chilling combination yielded superior tenderness and flavor, enhancing the retail value of this low-marbled cut. The findings support the commercial viability of this method for USDA Select grade beef, addressing economic pressures by upgrading lower-value cuts.

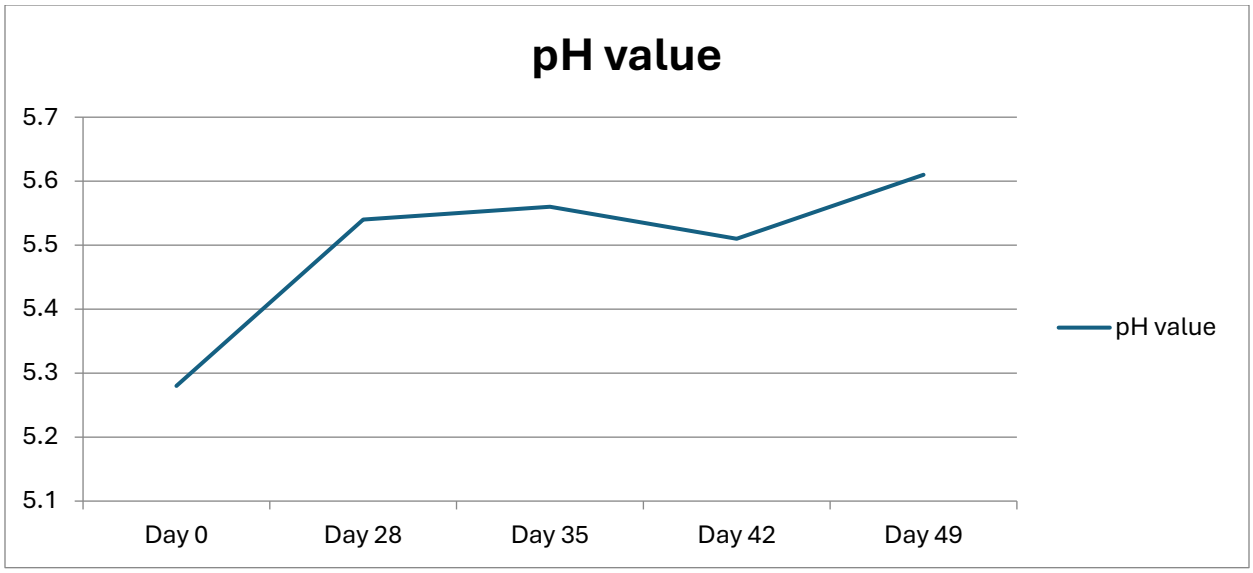
Conclusion

Shell-Superchilling Treatment followed by 49-day wet-aging at -1.9°C using King Son Constancy IFP Chilling Technology significantly improved the tenderness, juiciness, and flavor of M. semitendinosus beef steaks without developing significant off-flavors. This approach extends shelf life and enhances palatability, offering a commercially viable strategy to increase the economic value of USDA Select grade beef cuts for retail markets.

References

- Matrix Education. (n.d.). How to Write a Scientific Report | Step-by-Step Guide. Retrieved from https://www.matrix.edu.au/how-to-write-a-scientific-report/
- [Source data from original report, including King Son Constancy IFP Chilling Technology specifications and sensory evaluation protocols]

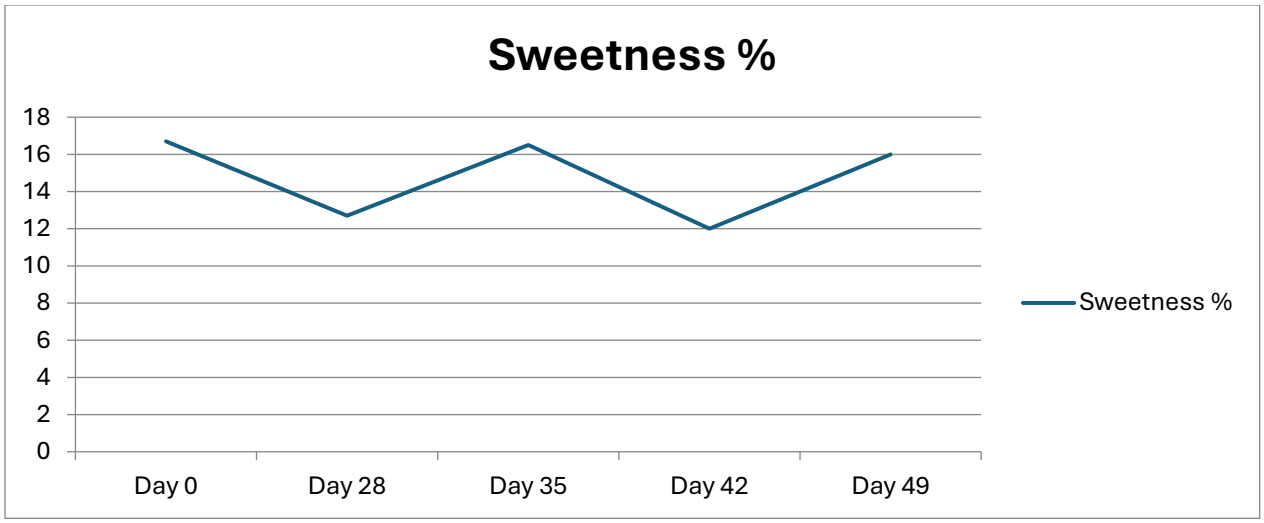
Experimental figure and diagram chart



The pH value evolution chart for M. semitendinosus beef steaks wet ageing processing utilized by King Son Constancy IFP Chilling Technology and Preservation at -1.9℃ storage in King Son Convertible IFP Aging Chiller between day 0 and day 49.

This chart shows the pH changes of wet ageing beef during storage from day 0 to day 49, in which it can be seen that:

- pH value increased from 5.28 to 5.61
- pH value rose slightly between day 28 and day 35
- pH value dropped slightly on day 42, but rose again on day 49
- It shows that after the beef was being by Shell-Superchilling Processing and then transferred to preserve and wet ageing utilized by King Son Constancy IFP Chilling Technology at -1.9℃ storage in King Son Convertible IFP Aging Chiller, that tends to become gradually alkaline during the aging process, which is related to the release of amines due to protein decomposition.



The Sweetness value evolution chart for M. semitendinosus beef steaks wet ageing processing utilized by King Son Constancy IFP Chilling Technology and Preservation at -1.9℃ storage in King Son Convertible IFP Aging Chiller between day 0 and day 49.

Sweetness %

The Sweetness value can be observed from evolution chart, in which

- The Sweetness value dropped significantly between 28 and 42 days.
- But it rebounded significantly on day 35 and day 49, almost approaching the initial Sweetness value
- This may be related to the small molecule compounds produced by the decomposition of proteins and fats, and is also related to the wet ageing flavor and aftertaste.

The sweet value evolution chart for beef

The "sweet value evolution" for beef refers to the change in the perceived value of beef based on factors like flavor, tenderness, and aging process. While there isn't a specific "sweet value evolution chart," several factors contribute to a steak's perceived value:

Factors Influencing "Sweet Value":

- **Aging:**

  Both dry and wet aging significantly impact flavor and texture, leading to a more enjoyable eating experience.

- **Marbling:**

  Marbling, the amount of intramuscular fat, affects the overall taste, juiciness, and USDA quality grade of the beef.

- **Grade:**

  Higher grades of beef (like Prime and Choice) generally have better flavor and tenderness, which contributes to a perceived higher value.

- **Cuts:**
  Different cuts of beef (like strip loin, ribeye, and sirloin) have varying flavor profiles and texture, impacting their perceived value.

How to Understand Evolution:

1. **1. Initial State:**

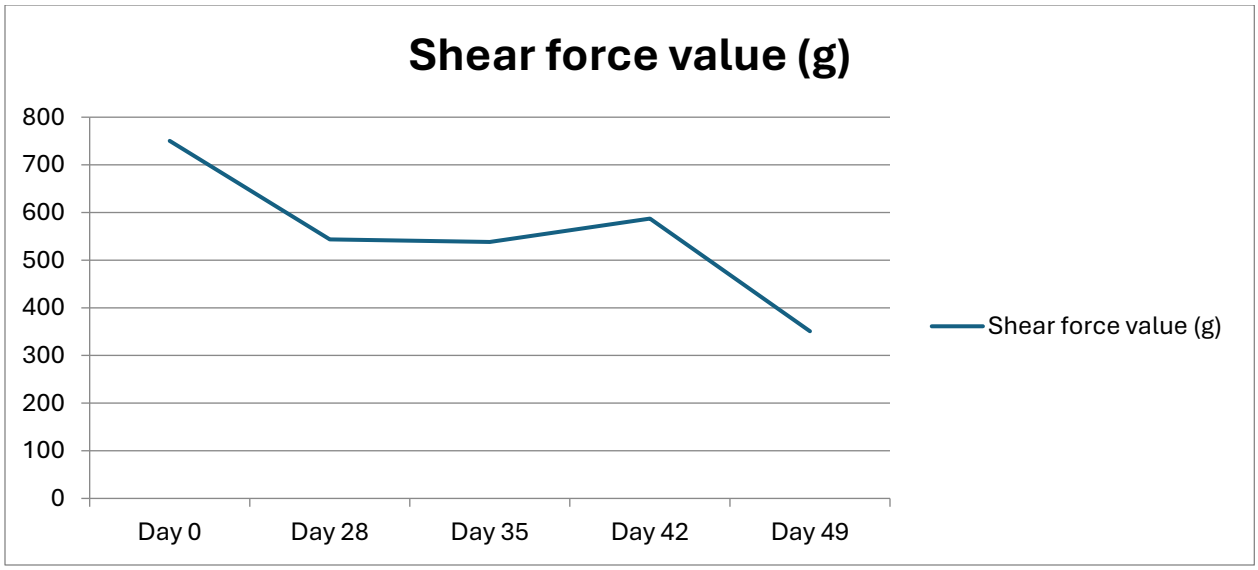
   The perceived value starts with the raw beef cut, influenced by its grade and marbling.

2. **2. Aging:**

   The aging process (dry or wet) transforms the beef, intensifying flavors and tenderizing the meat.

3. **3. Final Product:**
   The steak becomes more flavorful, tender, and potentially higher in perceived value due to the aging process.

In essence, the "sweet value evolution" is the journey of a steak from raw to a highly desirable, flavorful, and tender dish.

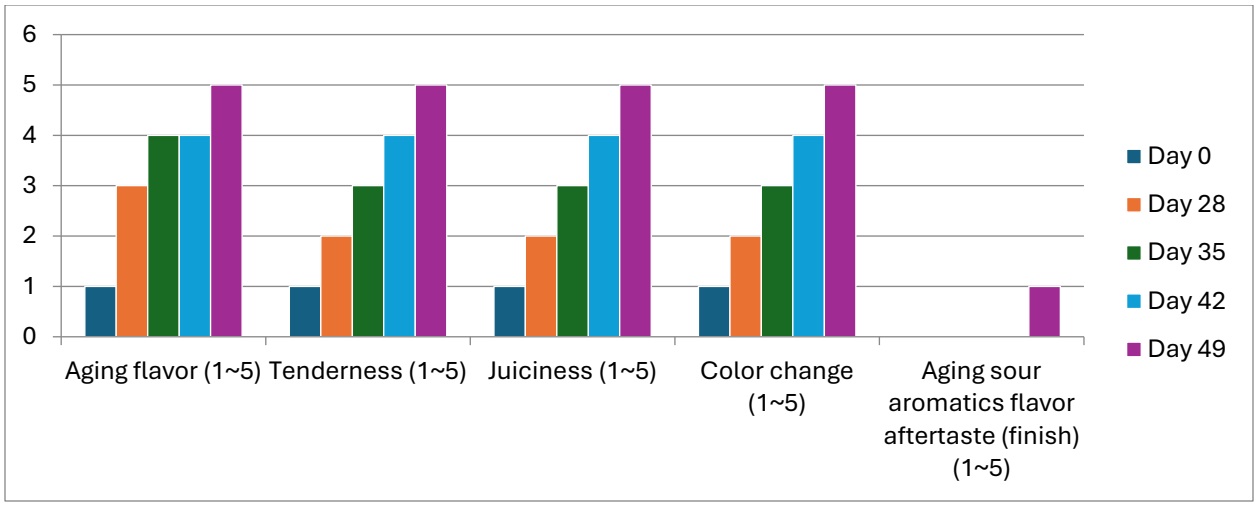


The Shear force value evolution chart for M. semitendinosus beef steaks wet ageing processing utilized by King Son Constancy IFP Chilling Technology and Preservation at -1.9℃ storage in King Son Convertible IFP Aging Chiller between day 0 and day 49.

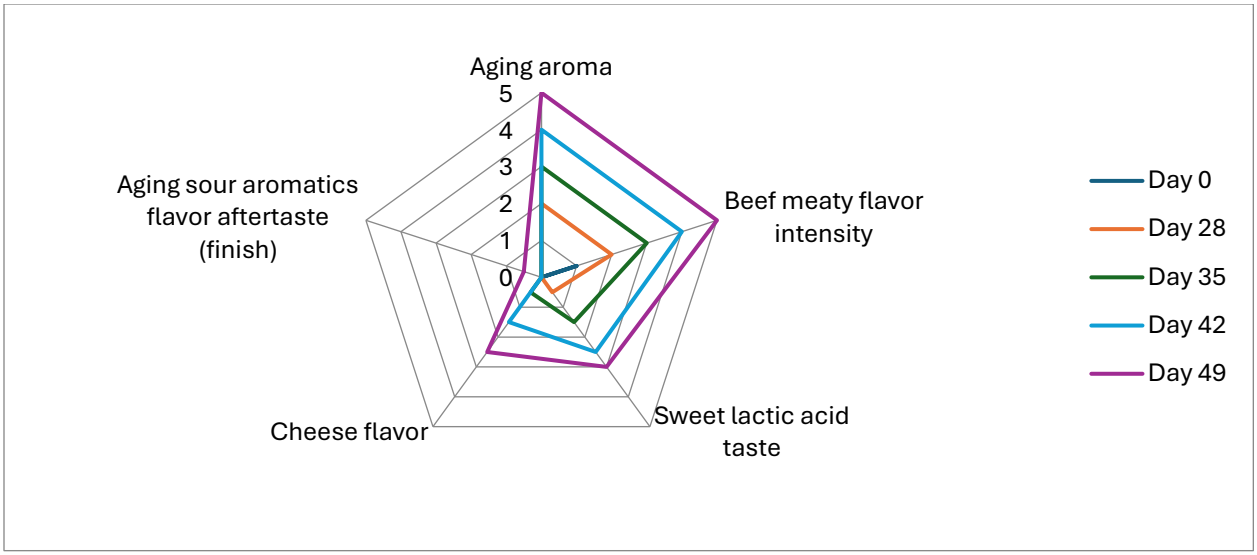
Shear force value (g)

The "Eye of Round" steak, sometimes called "Eye Round", is a boneless cut of beef, specifically the M. semitendinosus muscle, located in the middle of the round. It's a lean cut, often marketed as a lower-value steak due to its inherent toughness, according to New Prairie Press.

The Shear force value on M. semitendinosus beef steaks that was effectively reduced in wet ageing processing utilized by King Son Constancy IFP Chilling Technology and Preservation at -1.9℃ storage in King Son Convertible IFP Aging Chiller between day 35 and day 49 which increases beef tenderness value, texture profile and meet consumer's requirements for wet ageing beef palatability, mouthfeel, and improves purchasing willingness.



The wet aging quality evolution chart for M. semitendinosus beef steaks wet ageing processing utilized by King Son Constancy IFP Chilling Technology and Preservation at -1.9℃ storage in King Son Convertible IFP Aging Chiller between day 0 and day 49.



The aging flavor evolution chart for M. semitendinosus beef steaks wet ageing processing utilized by King Son Constancy IFP Chilling Technology and Preservation at -1.9℃ storage in King Son Convertible IFP Aging Chiller between day 0 and day 49.

Since eye of round (M. semitendinosus; ST) beef steaks is one of the leanest, low marble beefs on the hind leg of the cow, therefore, the aging effect does not have the aroma of fat and meat blended.