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Evaluation of Meat Tenderness of Forage-Finished Cattle Produced in Hawai'i, and Factors Affecting the Tenderness

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Summary

The objective of this study was to evaluate the current status of meat tenderness of forage-finished cattle produced in Hawai'i and to determine what production factors affect the meat tenderness of forage-finished cattle. Two ribeye steak samples from the 12th rib were obtained from 191 forage-finished cattle harvested at two slaughterhouses on Hawai'i. The steak samples were individually vacuum-packaged in Kapak pouches and aged for 2 weeks at 4°C, then were stored at –20°C for later proximate analysis and measurement of shear force values of cooked steaks. The vacuum-packaged steak samples were thawed and cooked in a water bath at 70°C for 1 hour, cooled to room temperature, and shear force values were measured from 1.3-cm core samples (six per steak). Information on animal age, breed, carcass weight, and sex was obtained during sample collection from the slaughterhouses. Carcass weight ranged from 353 lb to 939 lb with a mean value of 601.8 lb. Intramuscular fat content ranged from 0.19% to 14.11% with a mean value of 4.49%. Shear force value ranged from 2.41 kg to 9.41 kg with a mean value of 5.21 kg. The shear force value of heifers (5.52 ± 0.133 kg) was higher ($P < 0.05$) than that of steers (4.96 ± 0.148 kg). The shear force value of the age group between 24 and 36 months (4.97 ± 0.137 kg) was lower ($P < 0.05$) than that of the age group over 36 months (5.51 ± 0.149 kg) or the age group below 24 months (5.23 ± 0.321 kg). The shear force value of the Hereford breed (n = 19, 6.24 ± 0.288 kg) was higher ($P < 0.05$) than that of Angus (n = 53, 5.19 ± 0.172 kg), or Bos taurus crosses (n = 76, 5.06 ± 0.144 kg), or other breeds (n = 25, 4.91 ± 0.251 kg). Correlation coefficient of shear force value with intramuscular fat was 0.025, indicating that intramuscular fat is not a good indicator for meat tenderness of forage-finished beef produced in Hawai'i. In conclusion, the results of this study indicate that meat tenderness of forage-finished cattle can be improved by younger age at harvest and possibly by selection of breed types.

Introduction

Hawai'i has been shipping most of its feeder calves to the U.S. mainland and Canada and has imported concentrate-finished beef for consumption in the state. Because of the lack of grain production and economies of scale and an inefficient processing segment, the Hawai'i beef industry has difficulty competing against the concentrate-finished beef that dominates the U.S. beef industry, resulting in the current situation of shipping calves out of Hawai'i. Recently, finishing cattle on pasture has drawn a lot of interest among ranchers and end-users, such as restaurants and supermarkets, as a sustainable alternative to concentrate-finishing of cattle.

Forage-finished beef in general, compared to concentrate-finished beef, has a much lower amount of intramuscular fat and higher amounts of omega-3 fatty acids, unsaturated fatty acid, and conjugated linoleic acid (Bowling et al. 1977, French et al. 2000). Therefore, it appears that forage-finished beef produced in Hawai'i has the potential to be marketed as natural, health-promoting food, particularly for people seeking animal products produced in natural conditions without much intervention on the animals' dietary intake or the use of growth-promoting agents. However, studies have indicated that forage-based beef is generally less tender and less palatable than concentrate-finished beef (Melton 1983, Kim 1995, Fukumoto et al. 1999). While we previously examined the meat tenderness of forage-finished cattle harvested at a young age (Fukumoto et al. 1995) and the effect of aging on meat tenderness of forage-

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finished cattle (Fukumoto et al. 1999), there has been no extensive survey of the meat tenderness of forage-finished beef produced in Hawai‘i. Therefore, the objectives of this study were (1) to examine the current status of meat tenderness of forage-finished cattle produced in various subtropical environments on the island of Hawai‘i, and (2) to examine whether any production factors are related to meat tenderness of forage-finished beef.

Materials and methods

Meat samples

Ribeye steak samples from 191 forage-finished cattle harvested from two slaughterhouses on Hawai‘i were collected between May 2005 and February 2006. Two ribeye steaks from the 12th rib were individually vacuum-packaged and aged for 2 weeks in a refrigerator, then were stored at –20°C for later proximate analysis of ribeye muscle and shear force value of cooked steak. Information on animal age, breed, carcass weight, and sex was obtained during sample collection from the slaughterhouses. The samples were from forage-finished cattle destined for the quality forage-finished market, but not from culled cattle destined for the processed beef market.

Proximate analysis

Ribeye muscles were removed without subcutaneous fat, then ground three times for proximate analysis using a meat grinder. Moisture and lipid contents were determined according to AOAC methods (1980). Ash content was determined as the residue after combustion at 600°C for six hours. Protein concentration was estimated by the difference between the weight of moisture, ash and lipid, and the total sample weight.

Cooking and shear force measurement

Steak samples were thawed overnight in a refrigerator, then the steak slices were trimmed to less than 2 mm of subcutaneous fat, weighed, packed, and vacuum-sealed in Kapak pouches (Kapak Corporation, Minneapolis, MN). The packages were heated in a water bath at 70°C for one hour, then cooled at room temperature for one hour. The pouches were unwrapped and cooked steaks were gently dried with paper towels. For shear force measurement, six core samples (1.3 cm diameter) were taken from the slice after cooking. Each core sample was cut at a speed of 180 mm/min with a Warner-Bratzler blade attached to a TA.XT2 Texture Analyzer (Texture Technologies Group, Scarsdale, New York). The shear force value was the mean of the maximum forces required to shear each set of core samples.

Data analyses

To examine the shear force value as affected by age, three age groups were established: Group 1, less than 24 months old; Group 2, 24–36 months; and Group 3, greater than 36 months old. Breed types were categorized into four groups to examine the shear force value as affected by breed types: Angus, Hereford, Bos taurus crosses, and others. Data analyses were done using JMP software (SAS Institute, Cary, NC). The effects of age, breed types, and sex classes on shear force value were determined using the GLM procedure.

Results and discussion

Distribution of sex class, age, and breed type

Figure 1 presents the distributions of sex classes, age groups, and estimated breed types of forage-finished cattle sampled from Hawai‘i island. Steers and heifers composed 45.2 and 54.8 percent of the forage-finished cattle, respectively. The proportions of cattle harvested at <24 months, 24–36 months, and >36 months were 9.2, 48.9, and 41.9 percent, respectively. In our previous study with samples collected on Hawai‘i in 1997, we found that about 10 percent of the cattle were harvested at age >30 months (Fukumoto and Kim 2007). Thus, the 41.9 percent of forage-finished cattle being harvested at age >36 months suggests that a large proportion of forage-finished beef is coming from relatively old animals in recent years. Angus, Hereford, Bos taurus crosses and other breed type composed 30.6, 10.9, 43.9 and 14.6 percent, respectively, of the forage-finished cattle harvested in this study.

Carcass traits

Table 1 summarizes hot carcass weight, intramuscular fat content, muscle pH, and shear force value of forage-finished cattle. Carcass weight ranged from 353 lb to 939 lb with a mean of 601.8 lb. In our previous study of samples collected in 1997 (Fukumoto and Kim 2007), the mean carcass weight was 621 lb. The distribution of carcass weight is summarized in Figure 2. The coefficient of variation (CV) that measures sample dispersion and is defined as the ratio of the standard deviation to the mean was 18.4 percent for carcass weight in this study. In 1997

Figure 1. Sex, age and breed type distributions of forage-finished cattle slaughtered in Hawai‘i.

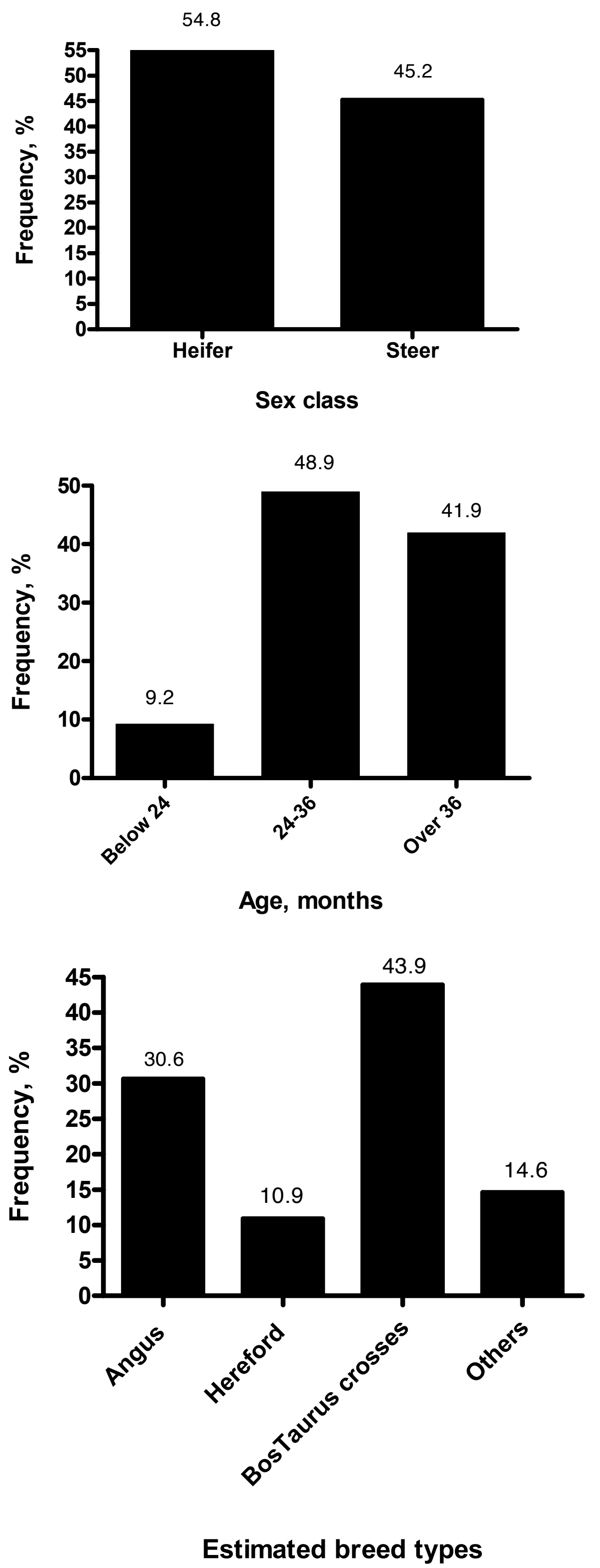
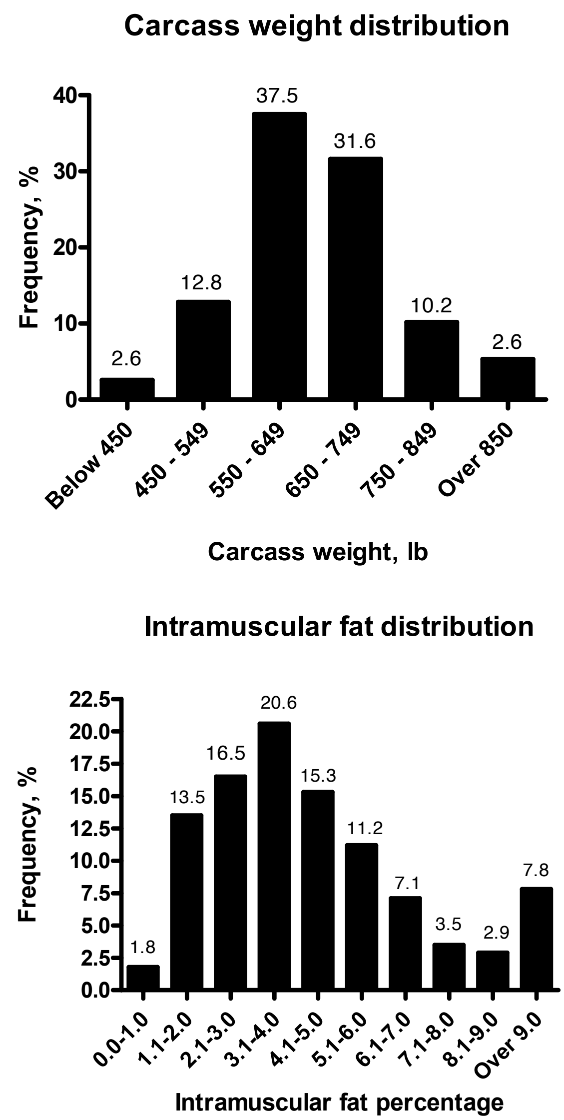


Table 1. Carcass weight, intramuscular fat content, muscle pH, and shear force value of cooked steaks.

Trait	Mean	SD	Min.	Max.
Hot carcass weight, lb	601.8	110.8	353	939
Intramuscular fat content, %	4.49	2.68	0.19	14.11
Muscle pH	5.73	0.16	5.29	6.73
Shear force value, kg	5.21	1.30	2.45	9.41

SD = standard deviation

Figure 2. Carcass weight and intramuscular fat distributions of forage-finished cattle.



samples, it was 12.1 percent (Fukumoto and Kim 2007), indicating that carcass size has become more variable in recent years.

Intramuscular fat content ranged from 0.19 to 14.11 percent with a mean value of 4.49 percent. The distribution of intramuscular fat content is summarized in Figure 2. The CV of intramuscular fat content was 59.7 percent, indicating a wide variation of intramuscular fat content of the forage-finished beef. Intramuscular fat content is a good measure of marbling. Intramuscular fat content of the USDA Choice average grade is usually above 6 percent (Davis et al. 1979), and about 21.3 percent of our samples had more than 6 percent of intramuscular fat content, indicating that approximately 21.3 percent of the forage-finished beef can be graded as Choice or better if the cattle were less than 3 years old.

Muscle pH ranged from 5.29 to 6.73 with a mean value of 5.73. The CV of muscle pH was 2.8 percent. The pH range of 5.3-5.8 is considered to be normal meat pH, and meat pH exceeding 6.0 usually produces dark, firm, and dry (DFD) meat condition, which is not favored by consumers. In our sample, only 3.5 percent of samples (6 of 171) had muscle pH exceeding 6.0, indicating that most of the forage-finished cattle reached normal muscle pH after harvest.

Shear force value

The shear values ranged from 2.41 kg to 9.41 kg with a mean value of 5.21 kg and CV of 25.0 percent. Figure 3 shows the distribution of shear force values. According to a study by Miller et al. (2001), shear force values of 3.4, 4.0, and 4.3 kg for strip loin steaks cooked in electric broiler would result in 99, 94, and 86 percent of consumer satisfaction for beef tenderness. About 35 percent of our samples had shear values below 4.4 kg in water bath cooking. The diameter of meat core samples collected for shear force measurement and the steak cooking temperature in our study were the same as the above study. Thus, assuming that shear force value would not be much affected by cooking method (water bath vs. oven broiling), this result suggests that only 35 percent of ribeye steaks from the forage-finished beef produced in Hawai‘i would be sufficiently tender to satisfy consumers.

Carcass traits and shear force values within sex classes

Carcass trait means and shear force values within sex classes are summarized in Table 2. Steers had a significantly heavier mean carcass weight (619.1 lb vs. 582.9 lb) than heifers, but no difference was observed in intramuscular fat content and muscle pH between the two

Figure 3. Shear force value distribution of ribeye steaks from forage-finished cattle.
(A study by Miller et al. (2001) found that 86% of consumers expressed satisfaction of their steaks when the shear force values of steaks were less than 4.3 kg. Assuming that shear force value would not be much affected by cooking method, only 35% of ribeye steaks (inside the rectangle) from the forage-finished beef produced in Hawaii would be sufficiently tender to satisfy consumers.)

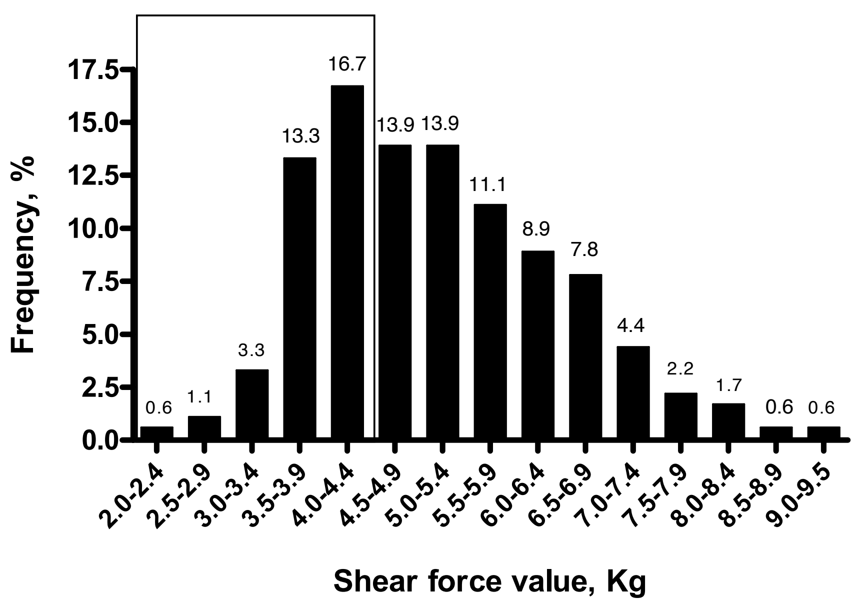


Table 2. Carcass weight, intramuscular fat content, muscle pH, and shear force values within sex classes.

	Sex class	
Trait	Heifer	Steer
Hot carcass weight, lb	582.9 [a] (11.96)	619.1 [b] (13.41)
Intramuscular fat content, %	4.15 (0.314)	4.88 (0.339)
Final muscle pH	5.73 (0.019)	5.72 (0.020)
Shear force value, kg	5.52 [a] (0.133)	4.96 [b] (0.148)

Data are means, with standard error in parentheses.
a, b: Means within a row not sharing a common letter differ significantly (*P* <0.05).

Table 3. Carcass weight, intramuscular fat content, muscle pH and shear force values within age groups.

	Age group (months)		
Trait	< 24	24–36	> 36
Hot carcass weight, lb	518.9 [a] (25.02)	581.2 [b] (10.87)	640.8 [c] (11.75)
Intramuscular fat content, %	5.04 (0.718)	4.27 (0.284)	4.54 (0.307)
Muscle pH	5.68 (0.041)	5.73 (0.018)	5.73 (0.019)
Shear force value	5.23 [a, b] (0.321)	4.97 [a] (0.137)	5.51 [b] (0.149)

Data are means, with standard error in parentheses.
a, b, c: Means within a row not sharing a common letter differ significantly (*P* <0.05). Mean difference was analyzed by Tukey honestly significant difference (HSD) test.

sex classes. Heifers had a significantly higher shear force value than steers (5.52 kg vs. 4.96 kg). Regarding the effect of sex on beef tenderness, results from other studies with grain-finished beef are not consistent. Some studies reported no effect of sex on beef tenderness (Gracia et al. 1970, Prost et al. 1975), while others reported that heifers had higher shear force values than steers (Choat et al. 2006, Wulf et al. 1996).

Carcass traits and shear force values within age groups

Mean carcass traits and shear force values within age groups are summarized in Table 3. As was expected, with the increase of animal age, carcass weight became heavier: 518.9, 581.2, and 640.8 lb for age groups <24 months, 24–36 months, and >36 months, respectively. No significant difference in intramuscular fat content and muscle pH was observed among age groups. It is generally known that meat from younger animals is tenderer than that from older animals. In agreement with this, the age group 24–36 months had a significantly lower shear force value of cooked steaks than the age group over 36 months (4.97 kg vs 5.51 kg). In contrast, the age group below 24 months has a numerically higher shear force value of cooked steaks than the age group 24–26 months. In our previous study, we observed that the shear force value of cooked steaks from 9-month-old, forage-finished steers was significantly lower than that from 36-month-old, forage-finished steers (Fukumoto et al. 1999).

Carcass traits and shear force values within estimated breed groups

Table 4 presents mean carcass traits and shear force values within estimated breed types. Hot carcass weight of Bos taurus crosses was significantly lower than that of Angus (570.7 lb vs. 619.7 lb) and numerically lower than Hereford (61.6 lb) and other breed types (630.7 lb). No significant difference in intramuscular fat content and muscle pH was observed among breed groups. Hereford had significantly higher shear force value (6.24 kg) than Angus (5.19 kg), Bos taurus crosses (5.06 kg), and other breeds (4.91 kg). Considering that meat from Bos taurus cattle is generally tenderer than that from Bos indicus cattle (Crouse et al. 1987, 1989; O'Connor et al. 1997), it is somewhat surprising that Hereford had the highest shear force value among the breed groups. Since Hereford cattle represented only 10 percent of the sample, and the breed information was collected from the slaughterhouses, caution probably needs to be exercised in interpreting the results. Furthermore, previous studies about the effect of breed types on meat tenderness were mostly with cattle finished with concentrate diet. Thus, future studies need to carefully evaluate the effect of breed types on meat tenderness of forage-finished cattle produced in Hawai'i.

Correlation between intramuscular fat content and shear force value

The effect of marbling/intramuscular fat content on meat

Table 4. Carcass weight, intramuscular fat content, muscle pH, and shear force values within estimated breed types.

Trait	Estimated breed type			
	Angus	Hereford	Bos taurus crosses	Others
Hot carcass weight, lb	619.7 [a] (14.25)	612.6 [a, b] (23.64)	570.7 [b] (11.82)	630.7 [a, b] (21.14)
Intramuscular fat content, %	5.02 (0.383)	3.67 (0.638)	4.22 (0.309)	4.97 (0.638)
Muscle pH	5.74 (0.023)	5.74 (0.036)	5.71 (0.018)	5.79 (0.038)
Shear force value	5.19 [a] (0.172)	6.24 [b] (0.288)	5.06 [a] (0.144)	4.91 [a] (0.251)

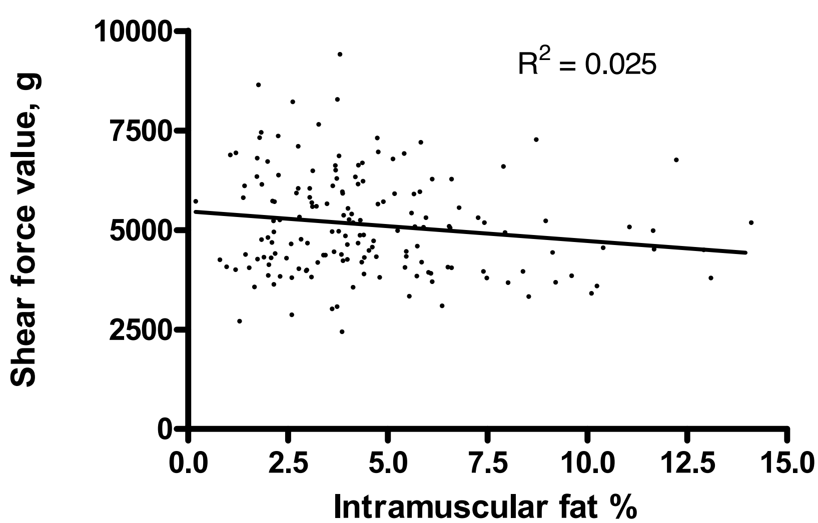
Data are means, with standard error in parentheses. a, b: Means within a row not sharing common letter differ significantly ($P < 0.05$). Mean difference was analyzed by Tukey honestly significant difference (HSD) test.

tenderness has been a subject of numerous studies, and results of those studies generally indicate that marbling has a positive but small effect on meat tenderness, with only 5–10 percent of beef tenderness being accounted for by marbling (Wheeler et al. 1994 and references therein). When we analyzed the relationship of intramuscular fat content to the shear force value of forage-finished beef, no significant relationship was observed between these two parameters (Fig. 4). The result, thus, indicates that intramuscular fat content/USDA quality grade is not a good indicator for meat tenderness of forage-finished cattle.

Conclusion

The results of this study show that meat tenderness of forage-finished beef produced in Hawai‘i is quite variable, and they also indicate that for a large proportion of forage-finished beef, meat tenderness should be improved to better satisfy the consumer experience of eating beef steaks. Controlling age at harvest appears to be a way to improve the meat tenderness of forage-finished beef, while focusing on improved USDA quality grade does not appear to lead to improved meat tenderness. The forage-beef industry in Hawai‘i probably needs to focus on improving tenderness through the establishment of

Figure 4. Correlation between intramuscular fat and shear force value.



standards to address maximum harvest age and minimum carcass weight targets, as well as to incorporate available tenderness technologies to improve the level of consumer satisfaction as related to tenderness. The current study could not clearly define the role of breed types on the meat tenderness of forage-finished beef; thus, future research needs to examine the role of breed types and their interaction with other parameters on meat tenderness. In addition, a future taste panel study is recommended to evaluate consumer acceptance and the overall palatability of forage-finished beef produced in Hawai‘i.

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