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EFFECT OF VACUUM AGING AND INFLUENCE OF SIRE ON PALATABILITY OF BEEF *LONGISSIMUS* FROM GRASS-FED F1 SENEPOL X ZEBU BULLS

Nelson O. Huerta-Leidenz[1], Argenis R. Rodas-González[2] and Gary C. Smith[3]

[1]Facultad de Agronomía, Núcleo Agropecuario, La Universidad del Zulia, Apartado 15205. Maracaibo 4005, Estado Zulia, Venezuela. carnit@telcel.net.ve. [2]Facultad de Ciencias Veterinarias, Núcleo Agropecuario, La Universidad del Zulia, Apartado 15252. Maracaibo 4005-A, Estado Zulia, Venezuela. [3]Department of Animal Sciences, Colorado State University, Fort Collins, CO 80523-1171.USA.

ABSTRACT

Fourteen carcasses from grass-fed F1 Senepol crossbred bulls (from 3 Senepol bulls mated to 14 Nellore-influenced cows) were electrically stimulated, and longissimus muscle samples were aged for three periods (2, 7 or 14 d) to study cooking traits, Warner-Bratzler shear force (WBS) values and sensory panel ratings for palatability attributes. Sire affected (P=0.001) WBS values. As compared to control (2-d aged) steaks, those steaks aged 7 or 14 d cooked slower (P<0.05), had lower WBS values (P<0.05), and rated as more tender (P<0.01), with lesser amounts of connective tissue (P<0.01), and more intense in flavor (P<0.01). In the control group, 42.9% of the steaks were classified as Tender (WBS<3.88 kg), 21.4% Intermediate (WBS= 3.88 to 4.98 kg) and 35.7% Tough (WBS>4.98 kg). By d 14, 71.4% of the steaks were Tender, 21.4% Intermediate and 7.1% Tough. Aging of steaks from these grass-fed bulls reduced the proportion of tough steaks from 35.7% (d 2, control) to 21.4% (d 7) and 7.1% (d 14).

Key words: Senepol, sire, *longissimus*, aging, shear force.

Efecto de maduración al vacío e influencia del semental sobre la palatabilidad del *longissimus* de toros F1 Senepol x Cebú producidos a pastoreo

RESUMEN

Se sacrificaron 14 toros F1 Senepol x Cebú (descendientes de 3 sementales Senepol en 14 vacas predominantes Nellore) producidos a sabana. Sus canales se electro-estimularon, y bistés retirados del músculo *longissimus* sirvieron para determinar los efectos del período de maduración en bolsas al vacío (2, 7 y 14 días) sobre las características de culinaria, fuerza de corte Warner Bratzler (FCWB) y atributos de palatabilidad calificados por catadores. Se detectó efecto de semental (P=0,001) sobre los valores FCWB. Teniendo por testigos bistés madurados por dos días (2d), los madurados por mas tiempo (7 y 14 días) tardaron mas en cocerse (P<0,05), tuvieron valores FCWB mas bajos (P<0,05), y fueron calificados por los catadores como mas tiernos (P<0,01), con menor cantidad de tejido conectivo (P<0,01) y de sabor mas intenso (P<0,01). En el grupo de bistés testigo, el 42,9% clasificaron como Tiernos (WBS<3,88kg), 21,4% Intermedios (WBS<3,88 a 4,98kg) y 35,7% Duros (WBS>4.98). Para el día 14, el 71,4% de los bistés resultaron Tiernos, 21,4% Intermedios y 7,1% Duros. La maduración de bistés de toros de este tipo racial y producidos a sabana de la manera descrita, redujo la proporción de lomos duros, de 35,7% (2d, testigos) a 21,4% (7d) y 7,1% (14d).

Palabras clave: Senepol, semental, *longissimus*, maduración, fuerza de corte.

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INTRODUCTION

Based on the extensive literature review conducted by Huerta and Ríos [4], there is enough information to affirm that beef derived from post-pubertal bulls is less tender than that derived from castrated males (steers) or intact females (heifers or heiferettes) of the same age. Advantages perceived in meat production/marketing with the use of bulls in Venezuela make it doubtful that castration would be implemented on a regular basis. In 1998, 49% of the total slaughter cattle (68% of the bovine males) in the Venezuelan grading program were bulls or bullocks (Venezuelan Ministry of Agriculture, unpublished data).

Grass feeding and predominance of Zebu genetics (to impart adaptability to the tropical environment) are largely responsible for the high variability observed in tenderness of Venezuelan beef [5]. Satisfactory tenderization by aging is more difficult to accomplish in beef derived from cattle with a high proportion of *Bos indicus* genetics [13, 18, 20]. Little improvement in tenderness has been gained, in beef from grazing bulls, by diluting, up to 50%, the Brahman genetics with those of native and traditional *Bos taurus* types [5].

In an effort to improve growth and carcass characteristics, some Venezuelan herds have recently introduced heat-tolerant *Bos taurus* genetics (e.g., those of the Senepol breed). Crossbreeding Senepol with Zebu types has been suggested as an effective strategy to improve tenderness of beef from heat-tolerant cattle [18]. In Venezuela, there is little scientific information about the combined use of electric stimulation of the carcass and aging of the meat to improve the tenderness of beef from Zebu-type bulls, but promising results had been reported by Riera *et al*. [13]. Huerta-Leidenz and Rodas-Gonzalez [6] used a sensory data-set gathered in Venezuela for calculating tenderness thresholds for rib steaks. The present study evaluated the effects of different periods of postmortem vacuum aging of beef rib cuts on cookery traits and palatability characteristics of *longissimus* muscles from electrically stimulated carcasses of grass-fed crossbred (F1 Senepol X Zebu) bulls. Additionally, the effects of Senepol sires were examined and palatability data for rib steaks were segregated into tenderness groups (Tender, Intermediate, Tough) within aging periods.

MATERIALS AND METHODS

Animals

Fourteen 39- to 40-mo-old bulls were used in this study. The animals were born in september-october 1994 in Hato Paraima (Agropecuaria San Francisco Co.). Hato Paraima (45,000 ha) is located at Cojedes state and is in a life zone considered to be tropical dry forest. In that State, annual precipitation (april to november) and temperature average 1380 mm and 27.5°C, respectively. Commercial Zebu cows (high percentage Nellore) were artificially inseminated at the ranch with semen from three Senepol sires (sire No. 424 for six cows, sire No. 593 for three cows and sire No. 770 for five cows) in the same breeding season. After parturition, cows in Hato Paraima spent the entire raising phase (10 mo) in native savannahs predominantly composed of *Leersia hexandra* grass with some spots of *Hymenachne amplexicaulis*.

Weaning occurred at 10 mo of age; at that time, the average live weight was 230 kg for the entire weanling herd of that season. Adjusted (205 d) weaning weight (based on an estimated birth weight of 30 kg) for the entire weanling herd was 167 kg. Grazing management during the stocking period was accomplished in four phases by moving bull calves to native or improved pastures in an alternate manner, according to the season.

During the first phase of the stocking period (4 mo in Hato Paraima), bull calves were allowed continuous grazing of a *Brachiaria humidicola* pasture. At the initiation of the first dry season, bull calves were moved to a neighboring ranch of the same cattle company (Hato Piñero) to graze continuously a native savannah area (4,000 ha composed, in order of predominance, of *Paspalum fasciculatum, Leersia hexandra* and *Hymenachne amplexicaulis* grasses) up to the completion of a 7 mo phase. After that, bull calves spent the third 5-mo phase on *B. humidicola* pastures of Hato Paraima and then moved back, at the initiation of the second dry season, to the Hato Piñero native savannahs to complete the final phase (6 mo) of stocking. Thereafter, the fattening phase (lasting 7 mo) was completed in Hato Piñero by assigning the bull calves to a grazing module. The calf group, as a single herd, was rotated among four pastures (total area of 115 ha) of *Brachiaria plantaginea*, with minerals but no other supplementation.

Slaughter and carcass evaluation

All animals were weighed off test on january 16, 1998 and transported on the same day to the Matadero Industrial Centro Occidental (MICO) beef processing facility (in Barquisimeto city, Lara state) where they were slaughtered the following day. Identity of each carcass was maintained throughout the slaughter process. After evisceration, all carcasses were electrically stimulated with a Lectro-Tender™ unit (Le-Fiell Company Inc.), within approximately one hour postmortem, with 18 impulses (of 1.8 sec duration; with 1.8 sec intervals between impulses) of 550 V, 60 Hz (AC), 1 to 2 amps. After 24-h chilling (0°C), right sides were ribbed (between the 12th and 13th ribs) and placed on a single rail in the storage cooler (4°C) for carcass data collection according to USDA quality grade and yield grade standards [19]. Carcasses were also graded according to Venezuelan standards [3].

Sample procurement and aging treatments

A section (extending caudally from the sixth rib to the 12th rib) of the *longissimus dorsi thoracis* muscle (ribeye) was removed from the right side of each chilled carcasses 2 d postmortem. The ribeye (wholesale cut) was fabricated to yield 12, 2.5 cm-thick steaks, in four segments of three steaks each, for palatability studies (FIG 1). Each steak was immediately packaged in a multilaminar, thermo-shrinkable, B620 CryO-Vac® bag by use of a Koch Ultravac® vacuum packaging machine, and identified with the animal number, the assigned designation/treatment and the test date. Control steaks (2 d aging time) were blast-frozen immediately (-30°C), and stored at that temperature for subsequent analysis; steaks assigned to the 7 d or 14 d aging treatments were placed in a refrigerator at 4°C for the appropriate time, blast-frozen (-30°C) and stored at that temperature for subsequent analysis. Anatomical-position bias was avoided by alternating designations (sensory tests vs. shear tests) and by rotating postmortem aging period treatments (2 d, 7 d or 14 d) within trios of steaks (FIG. 1).

LONGISSIMUS DORSI THORACIS MUSCLE

Cranial portion (6^{th} rib)	Aging treatment [a]	
1. Sensory test	2d	First segment
2. Shear test	7d	
3. Sensory test	14d	
4. Shear test	7d	Second segment
5. Sensory test	14d	
6. Shear test	2d	
7. Sensory test	14d	Third segment
8. Shear test	7d	
9. Sensory test	2d	
10. Shear test	14d	Fourth segment
11. Sensory test	2d	
12. Shear test	7d	
Caudal portion (12^{TH} rib)		

FIGURE 1. ANATOMICAL LOCATIC PROCEDURE OF STEAKS FOR SENSORY EVALUATION AND SHEAR FORCE TESTS.

[a] In each segment, the three aging treatments were rotated in all possible combinations using three codes just as it is exemplified here. 2d = control (2 days of aging); 7d =7 days of aging; 14d = 14 days of aging.

Cookery, sensory evaluation and shear force determinations

Groups of samples were removed from frozen storage (15 d maximum storage) each day, in random order, and allowed to thaw in a retail display unit at 4°C for 24 h prior to sensory or shear tests. Preparation and cooking of the samples for sensory evaluation were carried out in four consecutive days following the general recommendations of the American Meat Science Association [1]. Details of environmental conditions and equipment at the MICO laboratory for sensory analysis were described by Jerez-Timaure et al. [7]. The steaks were weighted in the raw state and a thermometer was inserted in their geometric center in order to register the internal temperature. The steaks were cooked on an electric grill, which was preheated (approximately at 165°C). When steaks were placed on the grill, the exact time (h, min) was recorded. Steaks were turned once with tongs during broiling and removed from the grill when they reached the desired internal temperature (70°C). Upon completion of the cooking process, the exact time was recorded and the steaks were weighted in their cooked state. Cooking time and losses were calculated by difference.

The taste panel was comprised of five highly trained judges [7] that tasted a maximum of 15 samples (in two sessions) per day. Two or three, cubed samples taken from steaks of each animal, were served warm to each judge. Judges scored the samples for muscle fiber tenderness, overall tenderness, juiciness, amount of connective tissue and flavor intensity using an 8-point structured rating scale for each attribute (where 1 = extremely tough, extremely tough, extremely dry, an abundant amount of connective tissue, extremely bland, respectively, and 8 = extremely tender, extremely tender, extremely juicy, no connective tissue, extremely intense, respectively) [1, 7].

Cooked rib steaks for shear tests were allowed to cool down to room temperature and four to ten core samples (1.27cm in diameter) depending on the area of the *longissimus* muscle, were removed parallel to the muscle fiber orientation, taking care not to include pieces of fat or chunks of connective tissue in the core. Each core was sheared once using a Warner-Bratzler shear machine (G-R Elec. Mfg. Co, Manhattan, KS). The four to ten Warner-Bratzler Shear force (WBS) values were recorded and averaged to obtain a single shear force value for each steak.

Data Analysis

Simple descriptive statistics were computed for carcass traits using PROC MEANS [17] to characterize the animals in the experiment. Analyses of variance were performed by the GLM procedure of SAS [17] using sire, aging period and the sire x aging period interaction as sources of variation of WBS values, sensory ratings, and cooking traits. Furthermore, WBS value and sensory rating data were subjected to covariate analyses using weight loss per cooking time (g/min) as a covariate. When an F-test was statistically significant, least squares means were compared using LSD tests. Additionally, for each treatment, a frequency analysis of the observations allowed for describing the proportion of Tender (WBS value = <3.88 kg), Intermediate (WBS value = 3.88 to 4.98 kg) and tough (WBS value = >4.98 kg) steaks, using values for tenderness thresholds described by Huerta-Leidenz and Rodas-Gonzalez [6]

RESULTS AND DISCUSSION

Carcass traits

Means, standard deviations (SD), and minimum/maximum values for carcass traits of grass-fed bulls reveal that this was a quite homogeneous lot (TABLE I). On the average, bull carcasses were of "B" overall physiological maturity which corresponded well with their chronological age. According to the Venezuelan grading criteria [3] 71.4% of the carcasses was in the B category (also named "Selecta") and the rest graded A

("Excelente"). According to USDA [19] quality grade standards, all of the carcasses graded Standard.

TABLE I

STATISTICS FOR CARCASS TRAITS OF GRASS-FED BULL CARCASSES

Trait	Mean	SD	Min.	Max.
Leg muscle profile [a]	3.00	0.39	2.00	4.00
Distribution external finish [b]	3.50	0.51	3.00	4.00
Back fat thickness, mm [c]	2.50	1.22	1.00	5.00
Marbling score [d]	T^{05}	22.43	Pd^{50}	T^{20}
Ribeye area, cm^2	76.90	8.77	60.64	90.32
Bone maturity [e]	A^{99}	9.97	A^{90}	B^{20}
Lean maturity [e]	B^{05}	22.08	A^{80}	B^{40}
Adipose maturity [f]	2.14	0.53	1.00	3.00
Final maturity [g]	B^{06}	9.20	A^{96}	B^{26}
Carcass weight, kg	279.57	17.38	248.00	311.00
Chronological age, mo	39.64	0.49	39.00	40.00
Venezuelan grade,% [h]	A: 28.58 B: 71.42			
USDA quality grade,%	Standard			

SD: standard deviation. [a] According to Decreto Presidencial No. 181 (1994): where 1 = very convex, 2 = convex, 3 = straight, 4 = concave and 5 = very concave. [b] According to Decreto Presidencial No. 181 (1994): where 1 = very abundant, 2 = abundant, 3 = moderate, 4 = slight and 5 = devoid. [c] Measured at the $12^{th}/13^{th}$ rib interface. [d] Marbling scores according to USDA (1989), where Pd = Practically devoid and T = traces; degrees 0-99. [e] Maturity scores according to USDA (1989). Where A= younger maturity; B=older maturity; degrees 0-99. [f] Adipose tissue maturity based on fat color, according to Decreto Presidencial No. 181 (1994); where 1 = ivory white, 2= creamy white, 3 = yellowish, 4 = yellow, and 5 = orange. [g] According to Decreto Presidencial No. 181 (1994). [h] Carcass grade according to Decreto Presidencial No. 181 (1994); where A=Excelente; B=Selecta.

Sire and interaction effects

Because this experiment was not designed to investigate progeny testing *per se,* the number of sons was low and unequal among sires. Nevertheless, significant differences for WBS values (P=0.0001) existed among the Senepol sires used in this study. These differences remained significant at constant cooking loss per cooking time. With or without adjustment for the covariate, Sire had no effect on sensory panel ratings or cooking traits of rib steaks from grass-fed bulls. No significant variation in rib steak characteristics was attributed to Sire x Aging treatment interaction.

Information on progeny testing of the Senepol sires for meat quality traits was not provided by the breeder. Other authors have also detected the significant effect of sire on WBS of their progeny using data from steers and/or heifers [14, 18]. In the study of Tatum et al. [18] based on WBS values, a Red Brangus sire and two Simbrah sires produced offspring that yielded meat that was more tender (P<0.05) on d 1 than was beef generated by other crossbred cattle; however, after four days of aging, differences in WBS value among meat from cattle of different sires was not readily evident.

This study is the first attempt to explore such effects in the Senepol breed using a non-castrated male progeny. If this effect is demonstrated in further, well designed studies then sire selection could become a strategy to reduce the tenderness (WBS) variation in beef from cattle of Senepol x Nellore ancestry.

Effects of aging treatments on sensory characteristics and Warner-Bratzler shear force

In data not presented in tabular form, analyses of variance revealed highly significant effects of the postmortem vacuum aging period on muscle fiber tenderness (P= 0.0007), overall tenderness (P= 0.0008), amount of connective tissue (P = 0.0006), and flavor intensity (P = 0.0008). The aging period also affected WBS values (P = 0.02) but did not affect juiciness (P=0.6) of steaks. When data were subjected to adjustment for the covariate (steak loss per cooking time) analyses of variance-covariance detected again, highly significant effects of the postmortem vacuum aging period on muscle fiber tenderness (P= 0.002), overall tenderness (P= 0.001), amount of connective tissue (P = 0.001), and flavor intensity (P = 0.007). Again, the aging period affected WBS values (P = 0.01) but did not affect juiciness (P=0.3) of steaks.

Least squares means for WBS values and palatability ratings for steaks subjected to different periods of postmortem vacuum aging are presented in TABLE II. Mean values for WBS, by treatment, with or without adjustment for the covariate, show a decrease in the kilograms of pressure required to sever a core of cooked muscle when the time of vacuum aging was prolonged beyond 2 d (P<0.05). Comparison of non-adjusted WBS values indicate that steaks aged 14 d were 17.4% lower in WBS value than control steaks but they were not significantly different from the steaks aged 7 d. However, at constant steak loss (g) per cooking time (min), differences in WBS values between steaks aged 14 d and steaks aged 7 d reached statistical significance (P=0.02). LS means for sensory ratings, with or without adjustment for steak loss per cooking time, showed that steaks aged 7 or 14 d were more tender, had less connective tissue, and were more intense in flavor, as compared to control (2 d) steaks. Even though there were statistically significant differences in flavor ratings among aging periods, all steaks were assigned mean ratings in the same descriptive level (approaching "slightly intense"). For juiciness, steaks from cuts in all three postmortem vacuum aging periods were assigned ratings of "slightly dry." Panelists did not detect any significant differences in sensory attributes between steaks aged 7 vs. 14 days. Regardless of feeding regimen, Bidner et al. [2] observed a decrease of 18.6% for WBS values and more desirable ratings for tenderness and amount of connective tissue in beef strip loin steaks aged for 21 days from Hereford x Angus steers.

Savell et al. [15], investigating beef from grass-fed Hereford x Angus steers, found a significant decrease of 15.95% in WBS values in *longissimus* steaks after 6 days (but not thereafter) of vacuum aging as compared to beef from control animals.

TABLE II

EFFECT OF DIFFERENT PERIODS OF POSTMORTEM VACUUM AGING ON WARNER-BRATZLER SHEAR FORCE VALUES, SENSORY PANEL RATINGS AND COOKING TRAITS OF RIB STEAKS FROM GRASS-FED BULLS

	Aging period (d)		
Trait	2	7	14
Non-adjusted values [z]			
Warner-Bratzler shear force, kg	4.48 ± 0.20[a]	4.29 ± 0.20[ab]	3.70 ± 0.20[b]
Juiciness [y]	4.79 ± 0.19	4.55 ± 0.19	4.70 ± 0.19
Muscle fiber tenderness [y]	3.48 ± 0.22[a]	4.63 ± 0.22[b]	4.72 ± 0.22[b]
Connective tissue amount [y]	3.00 ± 0.22[a]	4.20 ± 0.22[b]	4.19 ± 0.22[b]
Overall tenderness [y]	3.22 ± 0.22[a]	4.41 ± 0.22[b]	4.42 ± 0.22[b]
Flavor intensity [y]	5.44 ± 0.08[a]	5.78 ± 0.08[b]	5.94 ± 0.08[b]
Cooking loss,%	33.25 ± 0.79	34.94 ± 0.82	35.44 ± 0.79
Cooking time, min.	103.19 ± 7.51[a]	122.15 ± 7.51[ab]	135.97 ± 9.69[b]
Values at constant cooking loss/min			
Warner-Bratzler shear force, kg	4.54 ± 0.19[a]	4.28 ± 0.20[a]	3.50 ± 0.25[b]
Juiciness [y]	4.82 ± 0.19	4.54 ± 0.24	4.41 ± 0.24
Muscle fiber tenderness [y]	3.50 ± 0.24[a]	4.62 ± 0.24[b]	4.86 ± 0.31[b]
Connective tissue amount [y]	3.01 ± 0.23[a]	4.20 ± 0.23[b]	4.39 ± 0.30[b]
Overall tenderness [y]	3.24 ± 0.24[a]	4.42 ± 0.23[b]	4.64 ± 0.31[b]
Flavor intensity [y]	5.48 ± 0.08[a]	5.77 ± 0.08[b]	5.94 ± 0.10[b]

[a,b] LS means within a row with different superscripts ([a, b]) differ ($P<0.05$). [y] Based upon 8-point scales (1= extremely dry, extremely tough, an abundant amount of connective tissue, extremely tough, extremely bland, respectively, and 8= extremely juicy, extremely tender, no connective tissue, extremely tender, extremely intense, respectively, for juiciness, muscle fiber tenderness, connective tissue amount, overall tenderness and flavor intensity). [z]LS means without the use of weight loss of steaks per cooking time (g/min) as a covariate.

Martin et al. [11] reported that aging decreased WBS values in steaks from bulls, steers and heifers during 6 days aging, between 14.8% and 15.3%. Johnson et al. [9] observed that aging for 10 days postmortem, of steaks from Angus and ¼ Brahman steers diminished WBS values by 37% and 27%, respectively, in contrast to results for steaks from ½ Brahman and ¾ Brahman steers that decreased by only 9.4% and 16.0%, respectively.

Savell et al. [16], studying Santa Gertrudis grain-fed bulls, did not find any beneficial ($P>0.05$) response in either WBS values or palatability ratings with the use of vacuum aging (4-day or 18-day aging periods). Johnson et al. [8] and Maria et al [10], however, demonstrated that prolonging the aging period, by more than 13 days, improved panelist scores and decreased WBS values in steaks from young bulls.

Tatum et al. [18], comparing three breed types of 3/8 *Bos indicus* (Braford, Red Brangus and Simbrah) with *Bos taurus* (Red Angus, Simmental and Hereford), found that steaks from the *Bos indicus* group were less tender at 4, 7, 14, 21 and 35 days postmortem than steaks from *Bos taurus* cattle. Steaks from 3/8 *Bos indicus* cattle were tender when the aging period was longer than 21 days, and there was no difference in tenderness of steaks from cattle sired by different breeds that were 3/8 *Bos indicus* [16]. In a Venezuelan experience, Riera [12] studied 50 young grass-fed bulls from five breed types (Brahman, F1 Angus, F1 Chianina, F1 Romosinuano, F1 Simmental) and found that panelists assigned higher scores to meat aged for 10 vs. 0 days. Aging significantly decreased WBS values, by 13.3% (WBS value of 4.96 kg in the control group) in the latter study [12].

Effects of aging period on cookery traits

Analysis of variance detected a significant effect of aging period on cooking time (P = 0.03) but aging period had no significant effect on cooking loss (TABLE II). Control steaks required less time to reach the final endpoint cooking temperature than did steaks aged for longer periods (approximately 19 min and 38 min shorter than times for those aged 7 days or 14 days, respectively). Neither cooking time nor cooking loss differed (P>0.05) between steaks aged for 7 vs. 14 days, but cooking losses tended (P= 0.14) to increase as the aging period was prolonged. Jerez-Timaure et al. [7] reported that cooking loss increased at cooking times of over 60 minutes for non-aged beef (2 d postmortem). The findings of the present study do not agree with conclusions of Wheeler et al. [20] indicating that cooking loss and cooking time decreased significantly as aging time increased from 7 d to 14 d postmortem.

Tenderness classification for postmortem vacuum aging period

Numbers and percentages of rib steaks in each of three tenderness classes from grass-fed bulls, arrayed according to postmortem aging period are presented in TABLE III. Percentage of tender steaks did not increase from 2 d to 7 d of aging (42.9% vs. 42.9%) but increased 28.5% between 7 d and 14 d of aging. More consistent, and perhaps more important, was the progressive decrease in percent of tough steaks -from 35.7% to 21.4% to 7.1%- associated with aging for 2 d compared to 7 d or 14 d, respectively (TABLE III).

TABLE III
NUMBERS AND PERCENTAGES OF RIB STEAKS IN EACH OF THREE TENDERNESS CLASSES FROM GRASSFED BULLS, ARRAYED ACCORDING TO POSTMORTEM VACUUM AGING PERIODS

	Tenderness class		
Aging period (d)	Tender	Intermediate	Tough
2	6 (42.9%)	3 (21.4%)	5 (35.7%)
7	6 (42.9%)	5 (35.7%)	3 (21.4%)
14	10 (71.4%)	3 (21.4%)	1 (7.1%)

Tender: Warner-Bratzler shear force value less than 3.86 kg. Intermediate: Warner-Bratzler shear force value between 3.88 kg and 4.98 kg. Tough: Warner-Bratzler shear force value higher than 4.98 kg.

Tatum et al. [18] found a WBS value of 3.85 kg to be the threshold to distinguish tough from tender beef *longissimus*; that WBS value is very similar to the one reported by Huerta-Leidenz and Rodas-Gonzalez [6] and used in the present study. Additionally, Huerta-Leidenz and Rodas-Gonzalez [6] described another threshold (WBS value > 4.98 kg) that could be used to distinguish intermediate from tough *longissimus* samples. Tatum et al. [18] also reported that *longissimus* muscles derived from 3/8 *Bos indicus* steers, compared to those from *Bos taurus* steers, required longer periods of aging (a minimum of 21 d) to produce steaks of acceptable tenderness (i.e., to reach WBS values lower than 3.85 kg).

CONCLUSIONS

The effect of Sire within the Senepol breed, for expected Warner-Bratzler shear force of beef from their progeny is strongly suggested under the limitations of the present study. However, these findings must be corroborated in further studies, utilizing an adequate number of observations per cell.

Postmortem vacuum aging improves the tenderness of beef from grass-fed Senepol X Nellore bulls. To guarantee that a high proportion of such beef acquires an acceptable tenderness level (WBS value less than 3.88 kg), the aging period should be at least 14 days.

Cooking of the aged beef for more than two days takes longer, but the longer cooking period does not increase cooking loss.

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