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Prediction equations for Warner–Bratzler shear force using principal component regression analysis in Brahman-influenced Venezuelan cattle

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ABSTRACT

A database consisting of 331 beef animals (Brahman-crossbred) was used to determine the multivariate relationships between carcass and beef palatability traits of Venezuelan cattle and to develop prediction equations for Warner–Bratzler shear force (WBSF). The first three principal components (PC) explained 77.53% of the standardized variance. Equations were obtained for each sex class and the total variability observed in WBSF could be explained by its orthogonal regression with carcass weight (CW), fat cover (FC), fat thickness (FT), and skeletal maturity (SM). Prediction equations were: $WBSF_{steers} = 3.566 + 0.003(CW) - 0.033(FC) - 0.015(FT) + 0.0004(SM)$; $WBSF_{heifers} = 4.824 + 0.002(CW) - 0.229(FC) + 0.096(FT) - 0.064(SM)$; $WBSF_{bulls} = 3.516 + 0.009(CW) + 0.154(FC) - 0.129(FT) - 0.006(SM)$. A higher proportion of the variation was explained by the PC when variables of greater weight were selected to define each PC. The equation set presented herein could become an important tool to improve the Venezuelan carcass grading system.

1. Introduction

The current Venezuelan carcass grading system (Decreto Presidencial No. 1896, 1997) mandates a sex classification of cattle (steers, bulls, young bulls, heifers and cows) and two optional grading systems: one by quality and another by yield. Validation studies of the Venezuelan grading system for carcass quality have indicated that it does not provide an accurate mean to segregate carcasses into expected palatability groups (Huerta-Leidenz, Jerez-Timaure, & Morón, 1996; Malaver et al., 2000). In developed countries like the United States, with a vast experience in the use of carcass grading for beef marketing and pricing, the same kind of inconsistency had been reported (Shackelford, Wheeler, & Koohmaraie, 1997).

The quality grading system is perfectible and any improvement must be supported scientifically. In order to obtain a more precise and accurate system to predict beef quality; alternative methods, such as: tenderness thresholds (Shackelford, Morgan, Cross, & Savell, 1991), near infra-red spectroscopy (Mitsumoto, Malda, Mitsubishi, & Ozawa, 1991), ultrasound (Whittaker, Park, Thane, Miller, & Savell, 1992), colorimeter (Wulf, O'Connor, Tatum, & Smith, 1997), video image (Wyle et al., 2003) and more recently, DNA tests (Casas et al., 2006) have been studied; however, most of these approaches are expensive and time consuming, and others are still under experimentation. One sound, analytical approach is to consider the individual and multivariate relationship between a set of carcass characteristics and conventional meat eating quality traits, and hence, to be able to select the best variables to predict such a quality of beef.

Few studies have reported prediction equations for beef quality from carcass traits (Hodgson, Belk, Savell, Cross, & Williams, 1992; Jones & Tatum, 1994); however, the determination coefficients obtained in the equations of both studies were very low ($R^2 < 0.5$). Due to the complex relationship between carcass traits and meat palatability traits, multivariate analysis represents an alternative to obtain reliable predictors for beef tenderness and palatability that could help to improve the quality grading system.

The objectives of this study were: a) to study the multivariate relationships between carcass characteristics and palatability attributes of Venezuelan beef; b) to develop prediction equations for instrumental tenderness using carcass traits.

2. Materials and methods

2.1. Animal and collected data

The database consisted of 331 beef animals selected randomly at one commercial packing company located at Lara state (Midwestern region). This beef slaughter plant kills an average of 950 head per day and represents a major beef packing plant in Venezuela. Because of its strategic location and cattle procurement practices the plant receives animals originated from the main beef producing regions of Venezuela. In general, Venezuelan beef cattle could come from two production systems: a dual-purpose system composed by herds of dairy × zebu genetics, where males are castrated at or before weaning

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and raised in improved pastures until reaching their slaughter weight (450–500 kg); and the beef extensive system composed by herds of heavy *Bos indicus* influence, where young bulls are raised in native savannah and moved to the coastal states to be fattened on improved pastures. For this study, animals derived from both systems, were generally fattened on improved pasture supplemented strategically with minerals, molasses and other locally-sourced feedstuffs (no grains whatsoever).

For the carcass characterization no production information or age records were available. The animals, mostly *Bos indicus* × *Bos taurus* crossbreds were selected in the holding pens (12–14 h of lairage time) according to their apparent breed type (phenotypic predominance, dentition age (incisor eruption; 24–48 mo)) and sex class (44 heifers, 124 steers, and 163 bulls).

2.2. Carcass trait evaluation

Slaughter procedures and postmortem inspection of the carcasses were carried out according to the Regulation 435-82 of the Venezuelan Commission for Industrial Standards (COVENIN, 1982). The pelvic, kidney and heart fat of each carcass was not removed. Hot carcass weights were recorded before the chilling process at 2 °C. At 24 h postmortem, chilled carcasses were ribbed and evaluated according to the Venezuelan quality grading system (Decreto Presidencial No. 1896, 1997). Also, a leg muscular profile score (based on a five-point scale: 1 = very convex, 2 = convex, 3 = rectilinear, 4 = concave, 5 = very concave), and a fat cover score (based on a five-point scale: 1 = extremely abundant, 2 = abundant, 3 = medium 4 = slight, 5 = scarce) were evaluated.

After carcasses were chilled for 48 h, cross-sectional areas for *longissimus dorsi* (LD) muscle at 12th–13th rib interfaces were measured with a plastic grid (LD area, cm^2). The 12th-rib fat thickness (mm) was measured with a metal probe. Marbling, lean maturity (color and texture), and skeletal maturity scores were determined following the United States Department of Agriculture guidelines (USDA, 1997).

2.3. Sensorial evaluation and Warner–Bratzler shear force

At 48 h postmortem, four 2.5-cm thick steaks were obtained from the cranial end of the lumbar portion of the *longissimus dorsi* muscle from each right carcass side. Two steaks were used for the sensory panel evaluation and two for the Warner−Bratzler shear force (WBSF) measurement. Bias due to anatomical position was avoided by alternating designated analysis (i.e. sensory tests and shear force test) among steak locations for each subsequent sub-primal. Steaks were vacuum-packed and frozen at −20 °C immediately and kept frozen until further sensorial and WBSF evaluation (no further aging process).

Steaks were thawed at 4 °C for 24 h prior to sensory or WBSF tests. Cooking procedures were performed according to the guidelines of the American Meat Science Association (AMSA, 1995) in an open electric broil Oster® at 165 °C. The internal temperature of each steak was recorded by inserting a thermocouple Brannan®, with a scale from 20 °C to 110 °C (CFP15SAMA LO-tox™, Brannan & Sons Ltd., Cumbria, England). The bulb of the thermometer was placed in the geometric center of the steak. Steaks were turned once during broiling (35 °C) and removed from the grill when they reached the desired internal temperature (70 °C). Cooked steaks were removed from the broil and allowed to cool to room temperature. Six to ten 1.27-cm cores were taken parallel to the longitudinal axis of the muscle fibers using a drill-press mounted core taking care not to include fat or connective tissue in each core. Cores were sheared perpendicular to muscle fibers using a WBSF device (G-R Electrical Manufacturing Co., Manhattan, KS). The WBSF values were recorded and averaged for each two steaks.

The trained panel was comprised of eight highly trained judges. A detailed description of trained panelists was reported by Huerta-Leidenz, Jerez-Timaure, Rincón-Urdaneta, Morón, and Caro (1996). Preparation and cooking of steaks followed AMSA (1995) guidelines and prepared as described for WBSF. Cooked steaks were trimmed to zero fat cover and 8 to 15 cubed samples (3 cm^3 of size) of LD muscle were derived from strip-loin steaks. Cubed samples from each experimental unit were placed on pre-coded disposable, cardboard plates and stored in a preheated oven (at 50 °C) for 7 min prior serving to panelists. Cubed samples were served warm, unsalted and unspiced, accompanied with a glass of water that was used to rinse the mouth after tasting each sample. Panelists were served in a balanced order according to the experiment (i.e. number of treatments). The laboratory was air conditioned, free of off odors and disturbing noises, and equipped with individual booth seats under red light.

Two cubed samples taken from steaks of each animal were served warm to each judge. Twelve samples were served in two sessions (6 samples per session) in one day and 1-hour break between sessions. Judges scored the samples for juiciness, muscle fiber tenderness, overall tenderness, amount of connective tissue and flavor intensity using an 8-point structured rating scale for each attribute (where 1: extremely dry, extremely tough, extremely tough, an abundant amount of connective tissue, extremely bland, respectively, and 8: extremely juicy, extremely tender, extremely tender, no connective tissue, extremely intense, respectively).

2.4. Statistical analysis

All the data were analyzed using statistical package SAS, Version 9.0, SAS Inc. Institute (SAS, 2002). Analysis of simple descriptive statistics was performed for carcass characteristics. The correlation analysis was done using a multivariate analysis of variance (MANOVA) between the dependent variables standardizing their variances. A preliminary principal component analysis (PCA) was performed including all variables with the purpose to discard those variables that did not contribute to the variation of any principal component (PC); reducing the number of variables, the percentage of variation explained increases (Johnson & Wichern, 2007) the standardized variance. A Gplot procedure was used to plot PC1 and PC2 from the second PCA. Multiple regression analysis was performed using the procedure partial least square (Proc PLS) with the principal component regression (PCR) method of SAS, to predict the variable WBSF. The main components used were those that explained greater than 90% of the variation found.

3. Results and discussion

3.1. Descriptive parameters and correlation analysis

The descriptive parameters of carcass and palatability traits are presented in Table 1. Data correspond to animals evaluated at the commercial slaughterhouse, representing the typical Venezuelan commercial herd, consisting of steers, heifers and bulls of different breed-types and ages (by dentition) between 2 and 4 years. In this group, most of the carcass and meat characteristics showed a high variation, with the exception of marbling, which describes a very narrow distribution of marbling scores for the sample.

The results of multivariate correlation analysis among carcass traits, WBSF and palatability traits are presented in Table 2. The largest associations ($P<0.05$) were found between WBSF and skeletal maturity ($r = 0.58$). The analysis also showed a significant association between WBSF and carcass weight; however, this value was relatively low ($r = 0.27$). Also, WBSF showed a relatively low and significant association with lean ($r = 0.27$) and total maturity ($r = 0.28$). Muscle fiber tenderness, overall tenderness and flavor intensity were associated with the 12th-rib fat thickness ($P<0.05$) but with coefficients of relatively low