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Influence of temperament on performance and carcass quality of commercial Brahman steers in a Colombian tropical grazing system

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ABSTRACT

Temperament is defined as individual behavioral responses to potentially fear-eliciting or challenging situations related to human presence and handling. A total of 190 steers of commercial Zebu Brahman (*Bos indicus*) were used in this study, selected when they were between 10 and 11 months of age, fattened for 24 months (720 days) and slaughtered between 34 and 35 months of age. Using a temperament index (based on two tests: chute and exit score), animals were classified as calm, restless, or nervous. In general, calm animals had a longer carcass, a higher slaughter and fasting weight, and a normal pH^{24} (<5.7). However, carcass yield was significantly higher in nervous than in restless animals, but did not differ from that of calm steers. It is important to note that these results were obtained under experimental conditions, therefore, effects could have a greater impact on carcass quality under commercial conditions.

1. Introduction

Temperament is a key issue in beef cattle production systems, as it defines individual behavioral responses to potentially fear-eliciting or challenging situations related to production conditions, including human presence and handling (Estévez-Moreno et al., 2021; Haskell, Simm, & Turner, 2014). Cattle responses during handling can pose a risk for the animals and stockpeople (Cafe, Robinson, Ferguson, Geesink, & Greenwood, 2011). Cattle with more excitable temperaments are thought to have a stronger negative reaction to handling and suffer more adverse effects, with subsequent negative effects on their performance, carcass and meat quality traits (King et al., 2006). However, results from the scientific literature are inconsistent, with some studies finding no impact of temperament on production, and others showing a direct (and negative) effect of more nervous temperaments on dry matter intake and weight gain, hot carcass weight and fat coverage, and meat quality traits (i.e. Braga et al., 2018). These inconsistencies can be due to a series of factors that affect temperament such as breed, sex, age, experience, production system, handling routines and the attitudes of stock-people towards their animals during handling (Estévez-Moreno et al., 2021).

Extensive grazing systems used for beef cattle in tropical and subtropical areas are mainly based on warm-season perennial C4 grasses, and their availability, quality and management strategies have a significant influence on animals' productivity (Cooke et al., 2020). Assessing animal temperament under these conditions could help to improve handling and management practices for *Bos indicus* and crossbred cattle. During handling, *B. indicus* cattle have been classified as being more excitable than *Bos taurus* cattle (Crouse, Cundiff, Koch, Koohmaraie, & Seideman, 1989; Wulf, O'Connor, Tatum, & Smith, 1997). Under tropical conditions, the temperament of Zebu animals has been associated with improved growth performance and carcass and meat quality (Petherick, Holroyd, Doogan, & Venus, 2002; Silveira et al., 2012). In Australia, daily gain in nervous Brahman steers is lower than in docile steers, while cattle adapted to tropical conditions lose less weight during long distance transport and regain weight more rapidly afterwards (Burrow & Dillon, 1997). In Brazil, Zebu cattle with greater reactivity to handling tended to present lower ADG and meat with higher pH and lower tenderness (Ribeiro et al., 2012).

Colombia has the fourth largest cattle herd in Latin America, which in 2020 represented 28 million heads with an annual beef production of

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933 million kg (González-Quintero et al., 2020). Beef production there is largely extensive and primarily based on *B. indicus* and *B. taurus* × *B. indicus* cattle, where *B. indicus* is represented by Brahman and commercial Zebu, and *B. taurus* breeds are Angus, Limousin, Simmental, and Creole breeds -Blanco Orejinegro, Romosinuano, Sanmartinero, and Casanare- (Vergara, Elzo, & Cerón-Muñoz, 2009). Excitable temperament is noticed more frequently in *B. indicus* cattle compared with *B. taurus* and *B. taurus* crosses (Voisinet, Grandin, Tatum, O'Connor, & J., & Struthers, J., 1997), and studies that evaluate temperament and its consequences on performance and carcass quality in *B. indicus* breeds, such as Brahman cattle, are still limited. In this context, studies of temperament are relevant for the management of herds in grazing systems as they give information on individual susceptibility to handling stress under this type of environment (Miranda-De La Lama et al., 2013). In recent years, the importance of meat production systems based on sustainable grazing has been highlighted in tropical areas. Colombia has great potential in this respect, due to its geographical position, the quality of the pastures and a rich landscape that can be positive aspects for potential international consumers. However, it is possible that the temperament of Zebu cattle may have detrimental effects on carcass or meat quality, which could discourage consumption and thus affect exports. Thus, the aim of this study was to assess the effects of temperament on performance and carcass traits of Zebu Brahman cattle under grazing and tropical conditions.

2. Materials and methods

The study was carried out in the Department of Meta (central Colombia, in the *Orinoquía* region) at the Experimental Station "*La Libertad*" of AGROSAVIA (9°6′N 73°34′W).The station has an area of 1332 ha (https://www.agrosavia.co/nosotros/sedes/centro-de-investigación-la-libertad), with agroecological zones of humid alluvial valleys, acid soils of low fertility and agricultural vocation classified as oxisols. Its landscape is made up of high, medium and low terraces, typical of the Oriental Plains subregion. The station is in the Villavicencio Municipality and is characterized by a tropical rainforest climate at 336 above mean sea level with a precipitation of 2458 mm/year, average annual temperature of 26 °C, relative humidity of 80% and 1478 h of annual sunshine. This study was approved by the scientific committee of AGROSAVIA according to the protocols for care and use of research animals (FUA Care and use of research animals GA-F-191).

2.1. Study description

A total of 190 commercial Brahman steers -including seven genotypes from crosses of Brahman with Angus, Simmental, Limousin, Sanmartinero, Romosinuano, Blanco Orejinegro and Casanare- (242.47 ± 41.37 kg) from the cow-calf system of the experimental field were used in this study. The animals were selected at 10–11 months of age, fattened for 24 months (720 days) and slaughtered at 34–35 months of age. Animal ages and fattening times were similar to those of commercial production in the Colombian tropics. The 190 animals were kept in a single group for the duration of the fattening period in a rotational grazing system in an area of 68 ha (2.8 animals/ha) of *Brachiaria* pastures (Brachiaria decumbens and Brachiaria humidicola), with ad libitum access to water and mineralized salt. During the dry season (January to March), animals were supplemented with a concentrate formula. The animals consumed approximately 1 kg of feed supplement per animal per day, which had a metabolizable energy of 2.35 Mcal/kg DM. This supplement contained a mixture of corn meal (30%), rice meal (30%), soybean meal (14%), palm oil cake (20%), sugar cane molasses (3%) and mineral salt (3%). Table 1 shows the nutritional composition of the pasture and supplement, as well as the calculation of the total ration, using the LRNS software of Texas A&M University (https://www.nutritionmodels.com/lrns.html).

Table 1
Nutritional composition of *Brachiaria* pastures and supplement and total ration.

Composition	*Brachiaria pastures*[7]	*Supplement*[8]
Dry matter, %	26.0	89.6
Crude Protein, (%DM)	8.3	17.5
NDF[1], (%DM)	62.3	33.7
ADF[2], (%DM)	26.0	12.3
Ash, (%DM)	5.9	7.4
In situ dry matter digestibility, (%)	75.8	83.4
Ration calculated composition		
Dry Matter, (%)	29.0	
Crude Protein (%DM)	9.3	
NDF[1], (%DM)	59.3	
Apparent TDN[3], %	61.0	
ME[4], (Mcal/kg DM)	2.2	
NEm[5], (Mcal/kg DM)	1.3	
Neg[6], (Mcal/kg DM)	0.7	

[1] Neutral detergent Fiber.
[2] Acid detergent Fiber.
[3] TDNTotal digestible nutrients.
[4] ME: metabolizable energy.
[5] NEm: net energy maintenance.
[6] NEg: net energy growth.
[7] pastures of *B. decumbens* and *B. humidicola*.
[8] Supplement composed by a mixture of corn meal (30%), rice meal (30%), soybean meal (14%), palm oil cake (20%), sugar cane molasses (3%) and mineral salt (3%).

2.2. Temperament assessment and growth

For each animal, three temperament assessment periods were conducted. The first was at the start of the study (day 1), when the animals were between 10 and 11 months of age. The second assessment was midway through the study (day 360), when animals were between 22 and 23 months of age. The third and final assessment (day 720) was between 34 and 35 months of age. Each evaluation period was composed of two tests: chute score and exit velocity. The chute score was evaluated in a squeeze chute by a group of three evaluators before weighing, who were located between 1 and 2 m away from the right side of the pen. The evaluators remained still at the time of the assessment and did not touch the animals at any time. Each evaluator determined the temperament score for a period of two minutes, according to the method described by Grandin (1993), which includes a scale of 1 to 5, where 1 = calm, no movement; 2 = slightly agitated; 3 = wriggling, sporadically shaking the squeeze chute; 4 = continuous, very strong movement and shaking of the squeeze chute; 5 = rearing, twisting of the body and struggling violently. For each animal evaluated, the scores of each evaluator were averaged. The exit velocity was determined according to the methods described by Burrow, Seifert, and Corbet (1988), using an infrared electronic system, which was connected to a registration unit (Farm Tec, Inc., North Wylie, TX). Sensors (sensor 1 and 2) were located 1 m from the chute exit and placed 1.83 m apart. Once an animal passed by sensor 1, a chronometer was automatically started, and was stopped when the same animal passed by sensor 2. Using the time lapse in seconds, the exit velocity was calculated in meters per second.

The weight of the animals was monitored every 28 days, starting on day 0 (beginning of fattening) until day 720 (end of fattening, and shipment to the slaughterhouse), totaling 23 weighings for each of the 190 animals in the study. On weighing days, the animals were led to a holding pen in the morning and taken individually to a handling squeeze chute equipped with an electronic scale (Tru-Test, New Zealand). Average daily gain (ADG) was calculated for each animal using the difference between the weight collected on day 0, divided by the 720 days since day 0.

2.3. Slaughter and carcass assessment

The 190 animals were slaughtered in four groups on the same day, with each group consisting of 45–50 animals. The animals in each group had the same degree of finishing (4–5), which was estimated using a 1–5 body condition scale. Four journeys were required to transport each group, all of which took place on the same day. Slaughter groups were randomly formed according to the final live weight of the animals at the end of the fattening period. These slaughter groups could include animals from one or more temperament groups. Steers were transported by lorry to a nationally approved abattoir (Friogan, Villavicencio) in groups of 13–14 animals, located 22 km away from the Research Center. The livestock trucks used during this study complied with Colombian standards for cattle transport and were of the type most commonly used in Colombia, i.e., 10-ton capacity (room for approximately 14 animals), two-axle with a rigid chassis (combined wood and steel), passive ventilation and a canvas roof (see Romero, Uribe-Velásquez, Sánchez, & Miranda-de La Lama, 2013). The concrete un-loading ramps had nonslip floors that were about as wide as the livestock lorries. Each transport group was housed in separate lairage pens for 24 h with metallic fences, non-slip floors and equipped with Polyshade TM roofing (high density polyethylene screen) and water misters to cool the animals. Animals were given ad-libitum access to water while resting. Feed was not provided, to avoid carcass contamination at slaughter. On the day of slaughter, cattle were stunned with a pneumatic pistol and immediately bled by cutting the jugular vein and carotid artery. After exsanguination, each animal was suspended by a hind leg, bled, and transferred to the production line to begin the process of removing the head, feet, skin, viscera, and the quartering of the carcass. Loading, transportation, unloading and slaughter procedures were performed under commercial conditions, but monitored by project personnel.

On the same day, hot carcass weight was evaluated. After 24 h of chilling, carcass characteristics were evaluated according to the methodology established in the national beef carcass and cut classification system ICTA - FEDEGAN (Amador, Palacios, & Maldonado, 1995). Carcass measurements were measured in all animals using a measuring tape and a compass. The following parameters were measured: carcass length, thorax depth, loin fat thickness, rump fat thickness forearm length, leg length, leg circumference, carcass compactness index and leg compactness index. Additionally, rib eye area (REA) was calculated by making a cut between the 12th to 13th intercostal space and measuring the area using a grid with 1 cm × 1 cm squares. At 0 and 24 h after slaughter, carcass temperature and pH were evaluated in the geometric center of the *Longissimus thoracis* muscle with a digital thermometer (Checktemp 1 Digital Thermometer, Mod. HI98509, Hanna Instrument, Limena, Padova, Italy) and a portable HACCP compliant pH meter for meat (Model HI 99163; Hanna Instruments, Woonsocket, RI) respectively. The thermometer had a built-in self-calibration system and was pre-calibrated using an internal metrology protocol. The pH meter had an automatic calibration at two points with a set of standard buffers (pH 7.01 / 10.01) and automatic temperature compensation from −5.0 to 105.0 °C.

2.4. Statistical analysis

For each animal, the three measurements from the chute scores and exit velocity tests were averaged. A temperament index (TI) was calculated as proposed by King et al. (2006). Animals were classified into three categories (calm, restless and nervous) according to the TI. Animals with a TI greater than the average plus one standard deviation were classified as nervous. Animals with a TI value lower than the average minus one standard deviation were classified as calm. The remaining animals were classified as restless. Covariance analyses were performed for each of the variables, using a generalized linear mixed model, using the GLIMMIX procedure of SAS Enterprise (8.3), according to the following statistical model:

$$Yij = \mu + Ri + Tj + \text{Covariate (pij)} + eij$$

where: Yij = random variable observed; μ = intercept; R*i* = random effect for the *i*th genotype; T*j* = fixed effect for the *j*th temperament; pij = covariate effect for the initial live weight; eij = residual error; Ri ~NIID (0, σb2), eij ~NIID(0, σe2). This analysis was complemented by Tukey's multiple comparison tests (Alpha = 0.05), to compare the means of each of the temperaments considered, adjusted by least squares. All values were expressed in terms of least-squares means ± standard error. These measurements were separated using the PDIFF option. The significance was obtained at 0.05 level of probability of type I error.

3. Results

Regardless of breed, animals were grouped and classified into three temperament categories according to chute score, exit velocity, and temperament index (Table 2). (16) After that classification, we measured the expected differences between categories ($P < 0.001$) for temperament variables, indicating the adequate classification of cattle within each category.

3.1. Temperament and growth

The least-squares means of slaughter age, initial weight, slaughter weight, total average daily gain, fasting weight and fasting loss are presented in Table 3 based on temperament during the growing and finishing periods. Nervous cattle had a lower final weight and fasting weight ($P < 0.05$) compared to calm cattle, but there were no differences with restless cattle ($P > 0.05$). There was no effect of temperament category on slaughter age, initial weight, total ADG, or fasting loss in percentage or kg ($P > 0.05$).

3.2. Temperament effects on carcass quality and meat pH

The least-square means and standard errors of carcass measurement are presented in Table 4. Nervous animals had a shorter carcass length compared to calm animals ($P < 0.05$), but not compared to restless animals ($P > 0.05$). Additionally, calm and nervous animals had lower leg length ($P > 0.05$), compared to restless animals. There was no effect of temperament on fat thickness, forearm length, leg circumference, carcass or leg compactness or ribeye area. The least-square means and standard errors of carcass characteristics of cattle classified by temperament are presented in Table 5. The mean pH differences were not large, but nervous cattle had a higher carcass pH at 24 h postmortem compared to restless animals ($P < 0.05$), but there were no differences between nervous and calm animals ($P > 0.05$). There was no effect of temperament ($P > 0.05$) on hot carcass weight, cold carcass weight, carcass chilling loss (kg), carcass chilling loss (%), carcass pH (0 h), or carcass temperature (0 h and 24 h). Nervous animals had higher cold and hot carcass yields than restless animals (P < 0.05), but similar to calm animals.

Table 2
Least-square mean (±SE) values of chute score exit velocity and temperament index of beef cattle classified by temperament ($n = 190$).

Variable	Temperament Category[1]		
	Calm (n = 26)	Restless (n = 132)	Nervous (n = 32)
Chute score	1.0 ± 0.1^a	1.6 ± 0.1^b	3.2 ± 0.1^c
Exit velocity, m/s	1.0 ± 0.1^a	1.7 ± 0.1^b	2.3 ± 0.1^c
Temperament index	1.0 ± 0.1^a	1.7 ± 0.1^b	2.9 ± 0.1^c

a,b, c: means with different letters in the same row are significantly different ($P \leq 0.05$).

Table 3
Least-square mean (±SE) values of slaughter age, initial and final weight, total average daily gain (ADG, kg / day), fasting weight and fasting loss in beef cattle classified by temperament (n = 190).

Variable	Temperament type		
	Calm (n = 26)	Restless (n = 132)	Nervous (n = 32)
Slaughter age (months)	35.3 ± 1.7	34.3 ± 0.7	34.1 ± 1.4
Initial weight (kg)	254.5 ± 9.6	243.1 ± 3.6	240.6 ± 9.5
Slaughter weight (kg)	509.6 ± 7.8[a]	500.9 ± 2.9[ab]	486.4 ± 6.1[c]
Total ADG (kg)	0.44 ± 0.02	0.44 ± 0.01	0.45 ± 0.01
Fasting weight (kg)	471.4 ± 6.5[a]	464.6 ± 2.5[ab]	451.5 ± 5.1[c]
Fasting loss (kg)	38.1 ± 2.6	36.3 ± 1.1	36.0 ± 2.1
Fasting loss (%)	7.5 ± 0.5	7.2 ± 0.2	7.4 ± 0.4

a,b means with different letters in the same row are significantly different ($P \leq 0.05$).

Table 4
Least-square mean (±SE) values of carcass measures of beef cattle classified by temperament (n = 190).

Variable	Temperament type		
	Calm (n = 26)	Restless (n = 132)	Nervous (n = 32)
Carcass length (cm)	142.3 ± 1.5[a]	140.0 ± 0.6[ab]	136.8 ± 1.2[b]
Thorax depth (cm)	79.5 ± 0.9	80.4 ± 0.4	81.4 ± 0.8
Loin fat thickness (cm)	0.6 ± 0.1	0.7 ± 0.1	0.7 ± 0.1
Rump fat thickness (cm)	0.7 ± 0.1	0.7 ± 0.1	0.7 ± 0.1
Forearm length (cm)	63.7 ± 0.7	62.7 ± 0.3	63.4 ± 0.6
Leg length (cm)	76.9 ± 1.2 [a]	79.3 ± 0.5 [b]	77.5 ± 0.9 [a]
Leg circumference (cm)	79.9 ± 1.4	79.7 ± 0.5	79.4 ± 1.1
Carcass compactness index	1.9 ± 0.1	1.8 ± 0.1	1.9 ± 0.1
Leg compactness index	1.0 ± 0.1	1.0 ± 0.1	1.0 ± 0.1
Ribeye area (cm^2)	73.3 ± 2.8	71.0 ± 1.1	71.0 ± 2.2
Ribeye area/cwt	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1

a,b means with different letters in the same row are significantly different ($P \leq 0.05$).

Table 5
Least-square mean (±SE) values of carcass quality traits of beef cattle classified by temperament (n = 190).

Variable	Temperament type		
	Calm (n = 26)	Restless (n = 132)	Nervous (n = 32)
Hot carcass weight (kg)	272.3 ± 4.6	264.3 ± 1.7	263.1 ± 3.6
Cold carcass weight (kg)	268.5 ± 4.3	259.3 ± 1.6	258.2 ± 3.5
Carcass chilling loss (kg)	4.2 ± 0.5	5.0 ± 0.1	4.9 ± 0.4
Carcass chilling loss (%)	1.5 ± 0.1	1.9 ± 0.1	1.9 ± 0.1
Hot carcass yield (%)	57.3 ± 0.6[ab]	56.8 ± 0.2[b]	58.2 ± 0.4[a]
Cold carcass yield (%)	56.7 ± 0.6[ab]	55.8 ± 0.2[b]	57.1 ± 0.4[a]
Meat pH (0 h)	6.46 ± 0.15	6.56 ± 0.10	6.52 ± 0.10
Meat pH (24 h)	5.59 ± 0.05 [ab]	5.51 ± 0.02 [b]	5.62 ± 0.04 [a]
Carcass temperature °C (0 h)	38.9 ± 0.5	38.1 ± 0.2	38.8 ± 0.4
Carcass temperature °C (24 h)	5.0 ± 0.9	6.0 ± 0.4	6.2 ± 0.9

a,b means with different letters in the same row are significantly different ($P \leq 0.05$).

4. Discussion

Cattle temperament is important for the cattle industry since it is related to productive and reproductive performance, work safety, and animal welfare (Estévez-Moreno et al., 2021). There has also been a trend towards the genetic selection of docile and safe-to-handle animals, which has further promoted research on cattle temperament, mostly based on the observation of specific parameters with different levels of participation by observers and the incorporation of precision measuring devices (Parham, Tanner, Wahlberg, Grandin, & Lewis, 2019; Valente et al., 2017). Overall, our results show the existence of three temperament phenotypes in cattle (calm, restless and nervous), which are consistent with the scientific literature. In general, our results show that quiet animals had a longer carcass, higher slaughter and fasting weights, and normal pH. However, carcass yield was significantly higher in the nervous animals than in the restless ones, but did not differ from that of calm steers. These results are relevant since a few recent studies have underlined the importance of animal temperament in beef cattle produced in tropical and subtropical regions on grazing systems (Guimarães et al., 2020; Paredes-Sánchez et al., 2020). In this context, cattle temperament is a trait that exerts a marked influence on the beef cattle grazing production system in Colombia because handling on farms has direct repercussions on the profitability of rural enterprises, implying less labor and improved work safety, with consequent benefits for animal welfare (Barrozo et al., 2012). Considering that livestock farming in Colombia (and in countries with similar agroecosystems) is characterized by intense pre-slaughter management that involves long-distance transport, auction markets, collection centers, and prolonged lairage times (Romero et al., 2013), temperament could be a risk factor that can potentially aggravate animal welfare problems.

4.1. Temperament and growth

The high chute scores for nervous animals in the present study were due to their sudden escape movements when restrained in the chute. Nervous animals may react in such a manner because they associate confinement in the chute, and the presence of people, with stressful handling experiences such as castration, branding and vaccination (Pérez-Torres et al., 2014). The results for each temperament category are probably due to different levels of psychological stress, as described by several authors (i.e. Cooke et al., 2017; Lees, Salvin, Colditz, & Lee, 2020; Parham et al., 2021). Our results show that calm cattle had a higher slaughter and fasting weight, compared to nervous cattle. According to Voisinet et al. (1997), both *B. indicus* and *B. taurus* cattle that become nervous during handling have significantly lower weight gain. It seems that a greater activity and alertness in nervous cattle increases maintenance energy, which can have a negative impact on slaughter and fasting weight. Increased physical activity in nervous animals is related to greater metabolism and catabolism, which increases nutrient expenditure for processes other than growth (Cafe et al., 2011). Similar results regarding the effect of temperament on slaughter weight have been reported previously (Bruno et al., 2018; Cafe, Robinson, Ferguson, McIntyre, et al., 2011; Fell, Colditz, Walker, & Watson, 1999; Müller & von Keyserlingk, 2006).

4.2. Temperament effects on carcass quality and meat pH

Body measurements are essential and useful in assessing cattle growth, especially the values of thorax circumference, hip height, and carcass length (Kamchen, dos Santos, Lopes, Vendrusculo, & Condotta, 2021). In our study, we observed that carcasses of nervous animals were shorter than calm animals, but similar to restless animals. The influence of temperament on carcass dimensions has been reported previously by Olson et al. (2019) and Yang et al. (2019). Temperament may have an effect on carcass dimensions since nervous animals are more susceptible to stress throughout fattening, which can exert a catabolic effect not seen in the other two temperament profiles. According to Restle, Vaz, Pascoal, and de Senna (1999), linear objective measures such as carcass length are related to bone growth, which occurs more intensely during the first months of age; while the measurements of the perimeter are associated with the development of the muscles that appear throughout the different phases of growth. Also, a greater availability of net energy during supplementation will improve growth and fat cover (Rezende et al., 2013), favoring bone and muscle development, resulting in a longer carcass.

It is possible that the good conditions of extensive management, the short transport, and calm handling may have contributed to keeping the animals calm in this study, such that we found only subtle effects on carcass quality, even for cattle with more reactive temperaments. In that regard, Yang et al. (2019) did not find an effect of temperament on back fat, ribeye area, or yield grade in cattle purchased from auction markets, however, excitable temperament was associated negatively with final carcass weight and carcass yield grade. Hall et al. (2011) report that cattle with a faster exit velocity (excitable) have a larger ribeye area, but Sant'Anna et al. (2019) report that Nellore bulls classified as nervous (exit velocity) produce carcasses with a smaller ribeye area. In another temperament study with Angus and Brahman commercial heifers, Olson et al. (2019), found that carcasses from heifers categorized as excitable had 6% less backfat depth and 4% less carcass hot weight compared to heifers categorized as calm. In the same study, calm heifers had 8% higher dry matter intake along with 12% higher ADG and 4% higher gain on feed. Similar results on back fat depth were observed in grazing cattle in Australia (Della-Rosa, Pavan, Maresca, Spetter, & Ramiro, 2018).

At the feedlot level, calm temperament is important because it facilitates herd management, avoids animal abuse and benefits meat and carcass quality (King et al., 2006). However, our results obtained under tropical grazing conditions with Brahman cattle indicate that nervous animals had higher hot and cold carcass yield compared to restless animals, but similar to that of calm animals. These results challenge the long-held assumption that calm animals are more efficient compared to those with a more excitable temperament. However, these results should be taken with some caution because the proportion of animals characterized as restless was much higher than both calm and nervous animals. It is important to note that there are several factors that affect cold carcass performance, although the most important are the thickness of fat cover (loin and rump) and the degree of muscle conformation (Francisco et al., 2015). In our study, we did not find that these two variables differed between the phenotypes studied. Therefore, the major explanation for this result is that restless and nervous animals are more susceptible to other risk factors that affect cold carcass yield, such as gut fill, increased visceral fat, water consumption or susceptibility to coat soiling from mud or manure (Aberle, Forrest, Gerrard, & Mills, 2001). It is important to note that these results have been obtained under experimental conditions, so it is possible that under commercial conditions these effects may be aggravated and have a greater impact on carcass quality.

In beef cattle, one of the most common problems associated with meat quality is dark cutting beef (Miranda-de la Lama, 2013). This condition is generally unacceptable for consumers because it is visually unappealing and its pH 24 $\geq$ 6.0 reduces shelf-life, causing significant losses for the meat industry in many countries (Jerez-Timaure et al., 2019). Dark cutting beef is generally linked to a low muscle glycogen content at slaughter caused by elevated glycogenolysis induced by on-farm nutrition, stress and exercise in the pre-slaughter period (Fuente-Garcia, Sentandreu, Aldai, Oliván, & Sentandreu, 2020). In our study the pH at 24 h of the loin muscle from nervous cattle was greater than restless cattle, although within commercially acceptable ranges. However, recent evidence indicates that meat with a pH over 5.7 may have some dark-cutting beef characteristics (Ponnampalam et al., 2017). These results highlight the importance of the quality of pre-slaughter handling, since nervous animals are more susceptible to emotional reactivity, which can affect the final pH. Consequently, minimizing aversive handling and poor conditions during pre-slaughter operations will potentially improve carcass quality, this is why it is important to maintain friendly welfare handling throughout the fattening period (Losada-Espinosa et al., 2021). Ribeiro et al. (2012) found a positive correlation between temperament evaluation and loin muscle pH at 24 h in Brahman cattle, suggesting that there was greater glycogen expenditure in nervous cattle which would prevent an effective decrease of muscle pH during the first 24 h postmortem. In Nellore bulls Sant'Anna et al. (2019) reported that cattle with a high exit velocity (faster and reactive cattle) produced carcasses with higher meat pH. However, King et al. (2006) in feedlot cattle classified by temperament did not find differences of pH at 24 h in loin muscle. Contrary to the present study, Silveira et al. (2012) in Nellore steers classified by temperament as calm animals, had a higher pH measured one-hour postmortem compared with more reactive steers. In addition, negative correlations were reported between exit velocity and pH measured 24 h postmortem.

5. Conclusions

Overall, our study found that calm animals had a longer carcass, a higher slaughter and fasting weight, and a normal pH. However, hot and cold carcass yields were significantly higher in nervous animals than in restless animals, but did not differ from that of calm steers. These results show that even under experimental conditions of handling, grazing and pre-slaughter handling, temperament had repercussions on productivity and meat quality. Our study emphasizes the importance of implementing best handling and management practices during farm and pre-slaughter operations of cattle in order to modulate any possible risk factor for emotional stress. Furthermore, handling facilities, stock handling and the training of stock-people could be improved to diminish the negative effect of temperament. These improvements should be regulated through appropriate legislation as well as an enforcement infrastructure based on scientific results and market demand.

CRediT authorship contribution statement

Leandro M. León-Llanos: Conceptualization, Methodology, Validation, Investigation. **Hernando Flórez-Díaz:** Conceptualization, Methodology, Validation, Investigation, Project administration, Funding acquisition. **Luis G. Duque-Muñoz:** Data curation, Formal analysis. **Morris Villarroel:** Writing – review & editing, Visualization. **Genaro C. Miranda-de la Lama:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing, Visualization.

Declaration of Competing Interest

None of the authors of this paper has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.

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