Sixty Hereford (H) and Braford (B: 3/8 Zebu and 5/8 H) steers were finished on: D1) rangeland plus corn grain (1% of live weight) (H n=15, B n=15); and D2) high quality pasture (H n=15, B n=15) to study the effect of diet, temperament and lairage time on carcass and meat quality. Steers were slaughtered the same day in two groups, spending 15 and 3 h in pens, respectively (50% from D1, 50% from D2 in each group). Animals from D1 had better carcass performance without effect of the diet on meat quality. Regardless of breed, calmer steers showed higher average daily gain and lower shear force values. Carcasses from animals in the long lairage group had a better rate of pH decline and more tender meat, suggesting that more than 3 h preslaughter time should be necessary to rest and recover, mainly depending on lairage conditions.

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Braford n = 15, with 380 ± 38.89 kg in average). Braford is a synthetic breed, about 3/8 Zebu (Bos taurus indicus) and 5/8 Hereford (Bos taurus taurus). The area for each finishing strategy was divided in two plots by electric fencing and animals alternated plots every 14 days. Pasture height, availability, and quality were registered for each plot every grazing period (pre and post grazing). The same data were collected for the pasture remaining in each plot. Pasture results are not presented in this paper.

Chemical composition of feeds offered is reported in Table 1.

2.2. Field determinations

2.2.1. Productivity measurements

Animals were weighed without previous fasting every 14 days. For D1, amounts of corn grain were provided once a day early in the morning (6 AM) and were adjusted at this time according to LW. Animals from both diets had ad libitum access to water.

2.2.2. Temperament

Temperament was individually assessed every 14 days by both non-restrained and restrained tests: 1) Crush score (CS) which is the behaviour of each animal when put into a crush using a 1 (calm) to 5 (combative) scale, 2) Flight-time (FT) is the amount of time, in seconds, it takes an animal to cover a fixed distance (5 m) after it leaves the restraining device and 3) Exit speed (ES) is the speed for leaving the squeeze chute and was ranked as 1 = walked, 2 = trotted, and 3 if the animal ran out of the chute. A multicriterial average temperament index (average Tindex) was built with FT, CS and ES.

2.3. Transport and slaughter plant

Animals were slaughtered the same day in two groups, in a commercial abattoir licensed for exporting meat. Each slaughter group was composed of 50% of animals from D1 and 50% from D2. Both groups were transported for 4 h in a commercial truck with two compartments, allowing 420 kg/m² (1–1.2 m²/head) according to protocols from the abattoir (based on international recommendations) and remained in lairage pens for 15 and 3 h respectively. The first group waited during the whole night and the second one waited 3 h during the morning, being the first and the last group sacrificed that day in the abattoir, respectively. Steers from different diets (and different slaughter groups) were not mixed either in the truck or in the abattoir.

2.4. Slaughter and sampling procedures

2.4.1. Carcass traits

Carcasses were graded using the Uruguayan Grading System (INAC, 1997) based on conformation and fatness scores. Carcass conformation was based on a visual assessment of muscle mass development, with lower numbers indicating better conformation (1 = good muscle development and 6 = poor muscle development). The conformation score system for Uruguay is: I(1), N(2), A(3), C(4), U(5), and R(6). Fat finishing was based on the amount and distribution of subcutaneous fat, using a five grade scale, where lower numbers indicate lack of fat cover and higher numbers, excessive covering. The scores used in Uruguay are: 0, 1, 2, 3, and 4.

Hot carcass weight (HCW) was registered. Carcass pH and temperature were measured at 1, 3, 6, 12 and 24 h post mortem (pm) at the Longissimus dorsi (LD) muscle between the 12th and 13th rib, using a thermometer (Barnant 115) with type E thermocouple and pH meter (Orion 210A) with gel device. Subcutaneous fat thickness (SFT) and instrumental fat colour were recorded at 50 h pm, the last based on L* (lightness), a* (redness/greenness) and b* (yellowness/blueness) colour space, using a colorimeter (Minolta C10) with an 8 mm diameter measurement area. At 36 h pm carcasses were ribbed between the 10th and 11th rib, obtaining primal cuts. The fabrication process was carried out according to a European common commercial standard (United Kingdom). From the pistola cut1 (PC), 7 boneless cuts were obtained, striploin (Longissimus dorsi, Multifidus dorsi, and Spinalis dorsi), tenderloin (Psoas major), rump (Gluteus medius and Biceps femoris), topside (Biceps femoris and Semitendinosus), silverside (Semimembranosus, Sartorius, Adductor, Gracilis, and Pectineus), knuckle (Rectus femoris, Vastus lateralis, Vastus medialis, and Vastus intermedialis), tail of the rump (Tensor fasciae latae), and the weight of trimmings and bones was recorded separately. Retail cuts were weighed and retail yields were calculated. Muscle, fat and bone percentages were calculated from the (PC) using the UK commercial standard (cuts with 5% of fat cover).

2.4.2. Meat quality

Two steaks per animal from the LD muscle were vacuum packaged individually and transported to INIA Tacuarembó Meat Laboratory. The first steak (1 cm thickness) was immediately frozen at −20 °C and used for lipid content determination. The second steak (2.54 cm thickness) was aged for 7 days at 2–4 °C. Meat colour, marbling and toughness were measured in that steak after the aging period.

2.4.2.1. Instrumental colour. Meat bags were opened and the exudation on the steak surface was removed with a paper towel. Muscle colour was measured on the LD after seven days of aging at the L*, a* and b* colour spaces, using a Minolta C10 colorimeter with an 8 mm diameter measurement area, after 1 h of blooming. Values were registered from three different locations on the upper side of the steaks in order to obtain a representative average value of meat colour.

2.4.2.2. Marbling and lipid content. Subjective marbling was determined after 1 h of blooming in the 2.54 cm thickness LD steak, by the USDA quality grade system (USDA, 1997). Total lipid content was measured in the 1 cm thickness LD steak, by solvent extraction, based on Folch, Lees, and Sloane Stanley (1957).

2.4.2.3. Shear force. The second LD steak (2.54 cm) was placed inside a polyethylene bag and cooked in a water bath until an internal temperature of 70 °C was achieved, using a Barnant 115 thermometer with type E thermocouple. Six cores, 1.27 cm diameter, were removed from each steak parallel to the muscle fiber orientation. Shear force measurement (WBSF) was obtained for each core using Warner Bratzler (Model D 2000) and an average value was calculated for each steak.

2.4.2.4. Cooking loss. Cooking loss was determined as the percentage difference between the raw steak (pre-cooked weight) and its weight after cooking.

---

1 Pistola cut: The pistola cut was prepared from the hindquarter by the removal of the thin flank, lateral portion ribs and a portion of the navel end brisket. A cut was made from the superficial inguinal lymph node, separating the Rectus abdominus and following the hip contour, running parallel to the body of the vertebra and the Longissimus dorsi muscle (eye muscle) to the specified ribs.

---

Table 1
Chemical composition of feeds offered.

<table>
<thead>
<tr>
<th></th>
<th>OMD (%)</th>
<th>CP (%)</th>
<th>ADF (%)</th>
<th>NDF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved pasture</td>
<td>60.00</td>
<td>21.98</td>
<td>36.42</td>
<td>54.85</td>
</tr>
<tr>
<td>Native pasture</td>
<td>34.39</td>
<td>9.22</td>
<td>46.29</td>
<td>80.25</td>
</tr>
<tr>
<td>Corn grain</td>
<td>81.25</td>
<td>8.93</td>
<td>13.90</td>
<td>22.65</td>
</tr>
</tbody>
</table>

2.5. Statistical analysis

Exploratory analyses were performed with the Statgraphics and SAS programmes.

2.5.1. Productive variables

A general linear model (PROC GLM; SAS, 2007) was used to evaluate the effect of diet, liage time, breed and temperament on ADG. All interactions were considered and when they were not significant they were removed from the model.

2.5.2. Temperament

Relationships between the initial and subsequent temperament measurements were analyzed in order to verify the consistency of each method. The three initial temperament appraisals were positively correlated with subsequent temperament assessments. Based on this exploratory analysis, a multicriterial temperament index (Tindex) was built from FT, CS and ES. A standardised ranking was created for each variable in a 1–100 scale was created by:

\[ \text{Tindex} = \sum W \cdot d, \]

where “W” is the weight assigned to each variable estimated by the Analytic Hierarchy Process-AHP (Saaty, 1980); and “d” is each individual record, standardised. Considering that FT is an objective test, it ranked with 80% for the Tindex construction and the other tests (CS and ES), ranked with 10% each. The higher the Tindex, the calmer the animal. A mixed model with repeated measures was used to evaluate treatment effect on Tindex with time (4 consecutive dates) with the animal as a random effect inside each treatment. A regression analysis was performed to study the effect of temperament on ADG.

2.5.3. Carcass traits and meat quality

A general linear mixed model was used to study the effect of diet and breed on carcass conformation and degree of finishing (PROC GLIMMIX; SAS, 2007). The interaction between diet and breed was considered and as it was not significant, it was removed from the model.

A general linear model (PROC GLM; SAS, 2007) was used to evaluate the effect of diet, temperament, liage time and breed on carcass and meat quality traits. Considering differences in initial and final LW between diets, both variables were included in the model as covariates. All interactions were considered and when they were not significant they were removed from the model. A regression analysis was performed to study the effect of different variables and factors on meat tenderness (PROC REG; SAS, 2007).

In order to study the direct relationship between tenderness and temperament, a multiple regression model was fitted, with tenderness as dependent variable, and pH, slaughter group, breed, initial and final live weight as independent variables. Residuals from this regression were plotted versus Tindex and a simple regression analysis was performed with these two variables (Fig. 1). Residual (or error) represents unexplained (or residual) variation after fitting a regression model. It is the difference (or left over) between the observed value of the variable and the value suggested by the regression model.

Several correlation analyses were performed between productive, physiologic and temperament-related data. Means were compared by the LSMEANS procedure (SAS, 2007).

3. Results and discussion

3.1. Productivity and temperament

ADG did not differ between diets (0.63 ± 0.02 in D1 and 0.64 ± 0.02 in D2) but due to differences in initial LW, animals from D1 had lower final LW than those from D2 (436.03 ± 45.43 and 468.46 ± 34.76 kg, respectively). In spite of these differences and considering the experiment main objectives, all animals were slaughtered on the same day. Pasture consumption was not restricted in any diet, crude protein contents were above critical values (6%) and energy restrictions in D1 were released with the energetic supplementation, allowing animals to achieve the targeted daily gain.

Average Tindex did not differ between finishing strategies nor between slaughter groups (p > 0.05), but Braford animals were more excitable, showing a lower average Tindex than Hereford steers (62.10 ± 4.10 in Hereford and 50.90 ± 4.00 in Braford). Genetic differences in tameness are well known (Manteca & Ruiz de la Torre, 1996) and many authors have reported that without exception, Bos indicus (Burrow & Corbet, 2000; Fordyce, Dodt, & Wythes, 1988) and Bos indicus cross breeds (Voisinet, Grandin, Tatam et al., 1997) were more excitable than Bos taurus cattle. Calmer animals had higher ADG within both breeds (p < 0.05) and these results are also consistent with Voisinet, Grandin, Tatam et al. (1997), who reported higher ADG in calmer Bos indicus cross and Bos taurus. A depression of growth is the consequence of a series of acute or chronic responses due to human presence (Barnett, Hemsworth, & Mand, 1983; Hemsworth, Price, & Borgwardt, 1996) being more relevant with temperamental animals. In spite of being more excitable, Braford steers had higher ADG than Hereford ones (0.73 ± 0.05 and 0.53 ± 0.05, respectively; p < 0.05). When feed is not restricted, Braford animals usually have better ADG because they have a higher potential for muscle accumulation and their consumption is higher per unit weight. The use of synthetic breeds like Braford presents the heterosis advantage (hybrid vigor) associated with productive traits (Dickerson, 1969).

3.2. Carcass traits

Animals from D1 had higher HCW and PC weight than D2 (Table 2). This information is consistent to results from Brito et al. (2008) who compared pasture-fed animals and pasture plus grain offered at 1% LW, reporting that animals with grain supplementation showed higher HCW and PC weight. Striploin, tenderloin and rump and loin (R&L) represent most of the commercial value of the carcass and some

![Fig. 1. Residuals (actual minus predicted value) of the multiple regression considering pH, slaughter group, breed, initial and final live weight as dependent variables and shear force as independent, versus Tindex.](image)
markets require a certain weight for each cut. In this experiment, the heaviest carcasses also had the highest seven boneless cuts (7C) weight and R&L weight. However, PC yield (PC/half carcass weight; PCY), valuable cuts yield (7C weight/PC; 7CY) and R&L yield (R&L weight/PC; RLY) did not differ between diets (p < 0.05). Braford animals had higher HCW, 7C and R&L weight than Hereford steers (Table 3) and also had better meat yield (7CY and RLY; p < 0.05). Similar results were found by several authors when comparing meat yield between Bos taurus and Bos indicus crosses (Franco, Feed, Gimeno, Aguilar, & Avendaño, 2002; Joandet, 1989; Wheeler, Cundiff, Koch, Dikeman, & Couse, 1997). Meat yield differences between breeds are generally due to different fat levels. However, when animals are compared at the same fat level, these differences could be explained by the muscle/bone relation (Purchas, 2000). In this experiment, Braford animals had higher muscle percentage and lower bone percentage than Hereford in the PC (p < 0.05). Animals with a high growing potential like Braford, have later maturity and consequently they have more protein than fat deposition (Di Marco, 1994; Joandet, 1990). In general, they accumulate more energy as proteins when compared to fat accumulation (Webster, 1989). This implies a heavier slaughter weight for reaching the same finishing state (Gregory, Cundiff, & Koch, 1982).

Lairage time did not affect PC weight or valuable cuts weight (p < 0.05). According to the literature, during the initial 24 h and 48 h of fasting, the majority of weight lost in cattle originates from excretion of gastrointestinal tract contents and urine. As the duration of food and water deprivation extends beyond 48 h, tissue catabolism and dehydration increase their contribution to liveweight loss (Ferguson & Warner, 2008). Wythes and Shorthose (1984) concluded that carcass weight loss was typically not observed until after 24 h of food and water deprivation in cattle.

Conformation did not differ either between diets or between breeds (p < 0.05) but carcasses from D1 had higher fat grading than those from D2 according to the Uruguayan classification system (p < 0.05; D1: 33% of the animals were grade 1 and 67% grade 2; D2: 55% grade 1 and 45% grade 2).

SFT was also higher in carcass from the supplemented treatment (7.26 ± 0.45 mm vs 4.51 ± 0.47 mm in D2; p < 0.05). In general, higher carcass weight produces higher muscle thickness and fat deposits, meaning that carcass and all its components have greater dimensions (Sañudo, 1997).

Hereford steers had a higher degree of finishing than Braford within the supplemented treatment (p < 0.05), with no differences between breeds in D2. British breeds like Hereford and Angus (early mature breeds) are smaller and begin fat deposition at a lower live weight when compared to continental breeds and others (Brito & Jiménez de Aréchaga, 2004). This condition could be partially explained by the higher level of energy in D1. The energy level of the pasture in D2 was probably not enough to bring about fat differences between breeds. However, in our experiment, Braford and Hereford steers did not differ either in subcutaneous fat thickness (SFT) or in PC fat percentage (p < 0.05).

Muscle percentage did not show differences between diets when PC composition was evaluated. Similar results were found by del Campo et al. (2008) who compared steers finished on pastures vs. supplemented with grain at 0.6 and 1.2% of LW. On the contrary, many studies had reported that a higher grain or concentrate level during finishing periods leads to a lower proportion of muscle and bone in the carcass, along with a higher percentage of fat (Keane, O’Ferrall, & Connolly, 1989). Although there were no differences in muscle percentage, PC from D1 had higher fat percentage than PC from D2. Similar results were obtained by other authors, reporting that fat proportion rises with concentrate-based diets (del Campo et al., 2008; Micol, 1993). Differences in carcass composition are mainly related to differences in the energy density of the diet and, in the end, to the total energy consumed (Cerdeño, Vieira, Serrano, Lavin, & Mantecon, 2006).

3.3. Meat quality

3.3.1. pH and temperature

Higher SFT probably motivated the higher carcass temperature registered in D1 at 1, 3, 6, and 24 h pm (Table 4). However, no differences in pH decline were obtained between diets (p < 0.05). pH and temperature decline showed no differences between breeds (p < 0.05).

On the other hand, lairage time had a significant effect on pH values. Carcasses from the short lairage group had higher pH values at 1, 3, 6, and 24 h pm (Table 5) suggesting that animals were more stressed at slaughter, than those from the long lairage. Prolonged stress is likely to reduce muscle glycogen level in vivo (Warris, 1990) because of energy expenditure due to physical exercise or psychological stress, which may in turn increase ultimate pH of muscles (Gregory & Grandin, 1998). This depletion limits the extent of muscle/meat acidification. Warris (1990) sustains that this is mainly explained by physical exertion associated for example, with agonistic behaviour like mounting and fights, especially in the muscles of the back and legs (M. longissimus dorsi and semitendinosus) (Tarrant, 1989; Tarrant & Sherington, 1980; Tarrant, Kelly, & Harrington, 1988). Stressors appear to be additive (Bray, Graafhuis, & Chrystall, 1989) and multiple stressors in the preslaughter period will result in a greater elevation of ultimate muscle pH than a single stressor alone.

In this study, overnight animals appeared to recover during waiting time and this was reflected on a better rate of pH decline and also on meat tenderness (see shear force discussion further on). Time spent in lairage, the good conditions and the night quietness, probably allowed cattle to replenish muscle glycogen concentrations or at least to rest and recover from some of the previous stressors, holding back glycogen depletion. According to Warris et al. (1984) glycogen resources can be restored at lairage, and cattle can recover from physical exhaustion even if they are not fed. Similar results were found by Mounier et al. (2006) who evaluated 3 main waiting times in final pH: 1, 17, or 40 h before slaughter, reporting that pH decreased accordingly. On the other hand, several authors indicate that the environment itself may inhibit the ability of cattle to rest or recover from the effects of feed and water restriction (Jarvis et al., 1996; Van de Water, Verjans, & Geers, 2003). Differences among authors could be explained not only by the lairage duration evaluated in each

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Hot carcass weight, boneless cuts weight and rump and loin weights in Braford and Hereford steers. Least square means ± standard error and significance.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Braford</td>
</tr>
<tr>
<td>HCW (kg)</td>
<td>222.47 ± 1.20</td>
</tr>
<tr>
<td>7C wt (kg)</td>
<td>29.27 ± 0.27</td>
</tr>
<tr>
<td>R&amp;L wt (kg)</td>
<td>10.07 ± 0.09</td>
</tr>
</tbody>
</table>

HCW: hot carcass weight, 7C: seven boneless cuts, R&L: rump and loin, wt: weight. *p < 0.05, ns: non significant.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Effect of diet and lairage time on the rate of temperature decline after 1, 3, 6, and 24 h post mortem. Least square means ± standard error and significance.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diet 1</td>
</tr>
<tr>
<td>Temp 1</td>
<td>33.80 ± 0.40</td>
</tr>
<tr>
<td>Temp 3</td>
<td>26.10 ± 0.39</td>
</tr>
<tr>
<td>Temp 6</td>
<td>16.70 ± 0.29</td>
</tr>
<tr>
<td>Temp 24</td>
<td>5.00 ± 0.08</td>
</tr>
</tbody>
</table>

Diet 1: pasture + grain, Diet 2: high quality pasture. *p < 0.05, ns: non significant.
experiment but also by differences in animal experience (handling and feeding system), temperament and breed (genetic affiliation), handling procedures from farm to death, transport duration and conditions, facilities of the abattoir, weather conditions, and/or cumulative effects of the different factors. In this study, the negative effect of lairage probably occurred in the short lairage group mainly because animals did not have enough time to get used to the new environment and probably the waiting conditions were more stressful during the day. It is worth noting that 55% of animals from the short lairage group, showed pH values higher than 5.8.

Temperature was related neither to initial nor to final pH. Similarly, no association between temperament and the incidence of ultimate pH was observed in the studies carried out by Fordyce et al. (1988) and Petherick, Holroyd, Doogan, and Venus (2002).

3.3.2. Fat and meat colour

Fat colour was not affected by diet, temperament, breed or lairage time. Cattle produced under extensive grass-based production systems generally have more yellow carcass fat than their intensive-ly-reared, concentrate-fed counterparts, caused by carotenoids from green forage (Dunne, Monahan, O’Mara, & Moloney, 2009). In our experiment, the grain level used in the supplemented treatment was not enough to diminish fat yellowness (b* = 19.70 ± 0.40 and 18.90 ± 0.40, in D1 and D2, respectively). These results are not consistent with those reported by del Campo et al. (2008) who indicated higher fat b* values in pasture-fed animals, as compared to supplemented ones (corn grain at 0.6 and 1.2% of LW). However, the absolute fat b* values from the present experiment were similar to those reported by the above-mentioned authors in the pasture treatment (b* = 18.80 ± 0.40).

Muscle colour measured after 7 aging days was not affected by diet (p > 0.05). Other researchers did not find significant effects of different forage/concentrate ratio diets during finishing on muscle colour (Brito et al., 2008; Cerdeño et al., 2006; French et al., 2001). Diet characteristics do not have capital relevance on meat colour, probably due to transformation processes that take place in the rumen (Alberti et al., 1992; Hedrick et al., 1983). In our experiment, redness and b* values were higher in the long lairage group (Table 6). Lower pH values (long lairage group) were linked to more red (higher a*) and yellow (higher b*) meat. It has been established by several authors that muscle colour is highly correlated with muscle pH (Page, Wulf, & Holroyd, 2000; Page et al., 2001) reported that a* and b* values were more highly correlated with muscle pH (r = −0.58 and −0.56, respectively) than L* values (r = −0.40). In our experiment a* and b* values were also more significantly (p < 0.05) correlated to pH3 (r = −0.33, a*) and pH6 (r = −0.59 and −0.48, a* and b*, respectively) and pH24 (−0.40, b*).

3.3.3. Marbling and lipid content

Subjective marbling and lipid content did not differ either between diets, slaughter groups or between breeds (p > 0.05). These results were consistent with those reported by Schindler, Kedzierski, Pru zio, and De Santa Colomo (2004) who did not find differences in marbling when grain was included in the diet of steers compared at the same finishing state. In this experiment, all carcasses were in the USDA “Slight” category. With regard to lipid content, least square means and standard errors were 2.10 ± 0.10% in D1 and 1.94 ± 0.10% in D2. Similar results were found by Brito et al. (2008) in a study that also included Brahford and Hereford animals, registering 2.3 and 1.9% of lipid content in pastures and supplemented-fed steers, respectively, with no significant differences either between diets or between breeds.

3.3.4. Shear force and cooking loss

Diet did not have an effect on WBSF values (Table 7) but meat from animals in the long lairage group showed lower WBSF values than steers from the short one (Table 7). According to Kaufman and Marsh (1987) glycolytic rate in the first few hours post slaughter is a major determinant of quality. The pre-rigor muscle environment is critical in determining the behaviour of myofibrillar proteins and their subsequent impact on meat quality attributes such as tenderness and colour. According to Dransfield (1994), the effects of calpains and their inhibitors immediately post mortem, depend on pH and temperature and have an important influence on tenderness (review: Koohmaraie, 1996). Muscle pH and temperature also interact continuously during rigor development as they impact on both physical shortening and proteolytic enzyme activity. In our experiment, early differences in pH and temperature rate decline (1, 3 and 6 h) had already probably determined differences in meat tenderness between the two slaughter groups (Tables 4 and 5). Correlations between WBSF and pH values partially confirm this (pH1 = 0.56, pH3 = 0.55, pH6 = 0.47, p < 0.05).

As mentioned, depletion of muscular glycogen reserves because of greater pre-slaughter stress, without having the opportunity to rest, probably had a considerable influence on pH values in carcasses from the short lairage group. Short lairage time increased ultimate pH but also increased shear force. There has also been a controversy in the literature with regard to the ultimate pH-tenderness-relationship. Most researchers have observed a curve-linear relationship between tenderness and pH, with a minimum around pH 5.8–6.0 (Fjelkner-Modig, & Ruderus, 1983; Purchas, 1990). According to Warris (2001), high ultimate pH values favour the proteolysis produced by the calpains which have optimal activity near neutral (pH ≈ 7). Despite the concomitant rapid breakdown of the calpains themselves, the meat can be more tender than meat of lower pH. In fact, the toughest meat tends to occur in the middle range of ultimate pH values,

### Table 5

<table>
<thead>
<tr>
<th>Diet</th>
<th>Long lairage</th>
<th>Short lairage</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH1</td>
<td>6.56 ± 0.06</td>
<td>6.82 ± 0.06</td>
<td>*</td>
</tr>
<tr>
<td>pH3</td>
<td>6.24 ± 0.06</td>
<td>6.74 ± 0.06</td>
<td>*</td>
</tr>
<tr>
<td>pH6</td>
<td>6.02 ± 0.05</td>
<td>6.30 ± 0.05</td>
<td>*</td>
</tr>
<tr>
<td>pH24</td>
<td>5.67 ± 0.03</td>
<td>5.83 ± 0.03</td>
<td>*</td>
</tr>
</tbody>
</table>

### Table 6

<table>
<thead>
<tr>
<th>Diet</th>
<th>Long lairage</th>
<th>Short lairage</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>L*</td>
<td>39.80 ± 0.34</td>
<td>38.90 ± 0.34</td>
<td>ns</td>
</tr>
<tr>
<td>a*</td>
<td>10.20 ± 0.26</td>
<td>9.40 ± 0.26</td>
<td>*</td>
</tr>
<tr>
<td>b*</td>
<td>10.40 ± 0.14</td>
<td>9.90 ± 0.14</td>
<td>*</td>
</tr>
</tbody>
</table>

### Table 7

<table>
<thead>
<tr>
<th>Diet</th>
<th>Long lairage</th>
<th>Short lairage</th>
<th>Diet effect</th>
<th>Lairage effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBSF (N)</td>
<td>54.92 ± 3.82</td>
<td>50.01 ± 3.92</td>
<td>42.17 ± 3.73</td>
<td>62.76 ± 3.73</td>
</tr>
</tbody>
</table>

Diet 1: pasture + grain, Diet 2: high quality pasture. WBSF: Warner Bratzler shear force, N: Newton. *p < 0.05, ns: non significant.
between approximately 5.8 and 6.2 (Purchas & Aungsupakorn, 1993; Warris, 2001; Yu & Lee, 1986). This is consistent to our results, explaining at least in part, the lower average tenderness at intermediate pH values in the short lairage group (Table 5).

Although fat thickness reduced temperature decline and increased pH decline rate in D1, it had no consistent effects on WBSF values which were not significantly different (59.82 ± 6.08 N and 65.70 ± 6.37 N, in D1 and D2, respectively).

In this experiment, Braford steers had higher WBSF values than Hereford (58.15 ± 3.14 vs. 46.87 ± 3.14 N respectively, p < 0.05). Meat from Bos indicus breeds of cattle is often less tender than meat from Bos taurus (Crouse, Seideman, & Cundiff, 1987; Koch, Dikeman, & Crouse, 1982; McKeith, Smith, Smith, Dutson, & Carpenter, 1985). Genetic differences are partly due to a reduced post mortem proteolysis of myofibrillar proteins in Bos indicus associated with a higher activity of calcium dependent protease inhibitor (Whipple et al., 1990). Considering that breed did not have a significant effect on pH decline and final pH values, breed differences in tenderness in our study were not attributable to stress derived from the experimental conditions, but were probably mainly explained by the known genetic factors, in other words, differences in calpastatin activity in the meat (Koo hmariae, 1995). It is worth noting that WBSF values for Bradorf animals in this study were higher than those reported by Brito and Pittaluga (2002) after 7 aging days (WBSF: 44.33 ± 10.70 N) and by O’ Connor, Tatum, Wulf, Green, and Smith (1997) who reported values of 31.18 N after the same aging period.

Shear force was significantly related to temperament (p < 0.05, Fig. 1), implying that calmer animals (higher Average Tindex) had lower WBSF values with 7 aging days. It is well known that stress impairs the meat aging process, generally leading to tougher meat (Ouali et al., 2006). Considering there was no association between temperament and pH as previously mentioned, our results suggested that temperament had an effect on tenderness, in spite of its effect through the rate of pH decline. One possible explanation could be through the anti-apoptotic activity of heat shock proteins (HSPs). When animals are under intense stress, the cells receive the apoptosis-inducing signals via the receptors of cellular death. If the stress is not as severe, cells prepare their defense by synthesis of HSPs for helping in the protection of intracellular components and structures against hazards associated with loss of their biological functions (Beere, 2004). This condition would be accentuated in more temperamental animals. Consequently, the process of cellular death will be slowed down and this will constitute an impediment to good meat ageing (Ouali et al., 2006). In addition, the altered metabolism associated with greater stress responsiveness in the more stressed and excitable cattle may have created conditions that were less favorable to calpain-mediated proteolysis (King et al., 2006).

Diet, temperament and lairage time did not have an effect on cooking loss percentages at 7 days post slaughter (p > 0.05). Similar results were found by other authors when comparing animals from diets with different forage and grain-concentrate rates (Cerdeño et al., 2006; Kerth, Braden, Cox, Kerth, & Rankins, 2007).

4. Conclusions

A more energetic diet implied higher ADG, carcass, PC, 7 boneless cuts and R&I weights, but the grain level used was not enough to determine differences in meat yield, fat yellowness, meat colour, marbling, lipid content and meat tenderness. Regardless of breed, calmer animals had higher ADG and lower WBSF values. Short time in lairage had a significant negative effect on pH values, meat colour and beef tenderness. According to this experiment, a resting period in pens, probably higher than 3 h should be convenient, especially in animals that may have had stressful pre-slaughter conditions. The first few hours post slaughter are critical in determining glycolytic rate and the behaviour of myofibrillar proteins, with the subsequent impact on meat quality attributes such as tenderness. Braford steers had a better performance but animals were more excitable and their meat was tougher.

5. Implications

The addition of low level of grain in a pasture finishing diet should improve carcass weight with no deleterious effect on fat and meat quality. Temperament appears to be an important tool for farmers, regarding ease of animal handling and especially its effect on productivity and also on meat quality. Special consideration should be paid to lairage time and particularly to lairage conditions, with regard to pH and temperature decline, and consequently to shear force values. Braford animals may represent an income increase but their negative temperament and shear force related disadvantages should be considered in case of quality payment.

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