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Comparison of *longissimus thoracis* physical quality traits and the expression of tenderness-related genes between Goudali zebu breed and Italian Simmental × Goudali crossbreed

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ABSTRACT

The aim of this trial was to compare some meat physical quality traits and the expression of some tenderness-related genes between Goudali (G, *Bos indicus*) breed and Italian Simmental × Goudali (SimGoud, SG, *Bos taurus* × *Bos indicus*) crossbreed. Ten G and 12 SG bulls, aged 31 ± 0.49 months, bred in the same farm and conditions in Western Highland Plateau Savannah of Cameroon were considered. Physical quality traits of *longissimus thoracis* (LT) muscle such as water losses, colour parameters and rheological properties were determined together with ultimate pH (pHu). The mRNA early *post-mortem* abundance of calpain-1 (Capn1), calpain-2 (Capn2), calpastatin (Cast), caspase 3 (Casp3), caspase 9 (Casp9), αB-crystallin (Cryab), heat shock proteins 27 (Hsp27), 40 (Hsp40) and 70 (Hsp70) was detected by qPCR. The Capn1, Cast, Hsp27 and Hsp70, early *post-mortem* protein content was determined by ELISA. The meat of G bulls had greater values of lightness ($p < .05$) and cooking loss ($p < .05$) than SG. The expression of Hsp70 in G was greater at mRNA ($p < .05$) level than SG. None of the other variables considered was significantly different between G and SG breeds. Whereas crossbreeding with Italian Simmental breed changed the colour and ameliorated the water retention capacity of G meat, tenderness and the expression of tenderness-related genes, both at mRNA and at protein level, were not significantly different between the pure local breed and the crossbreed. In comparison with pure Goudali, crossbreeding Goudali with Italian Simmental breed has a limited impact on meat traits in tropical conditions.

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Introduction

The Goudali (G) is a *Bos indicus* breed widespread in Cameroon, with good tolerance to heat, resistance to local parasites and high foraging ability (Nfor et al. 2014). However, these animals present limitations in carcass and meat quality. In the past, in order to improve carcass and growth performance of *Bos indicus* breeds, various successfully experiences of crossbreeding between *Bos indicus* and *Bos taurus* were conducted (Williams et al. 2001).

Considering meat quality, it is widely recognised that one of the most important characteristic for consumers is tenderness. In general, as the percentage of *Bos indicus* increases in crossbreeds, the variability of tenderness tends to increase and tenderness tends to decrease, although there are some contrary findings.

Indeed, Frylinck and Heinze (2003) reported similar values of shear force between Simmental and Brahman loins, whereas Frylinck et al. (2009) showed higher values for Simmental *longissimus* muscle.

Many enzymatic systems are known to control the quality traits of meat and its tenderness in particular, among which the calpain system has been considered the most important. The quantity of calpains and the ratio between calpain-1 and its inhibitor calpastatin seems to be the cause for meat hardness of *Bos indicus* breeds (Wheeler et al. 1990). Becila et al. (2010) provided evidences that cell death in *post-mortem* muscle occurs via an apoptotic process, in which caspase 3 and caspase 9 operate. Although caspases are the main effectors of apoptosis, their importance in meat tenderisation process is still debated (Saccà et al. 2015a). For their physiological role as chaperones, anti-

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apoptotic and anti-oxidative factors, heat shock proteins are involved in the transformation of muscle to meat (Cassar-Malek and Picard 2016). Among these, alphaB-crystallin and heat shock protein 27 (Hsp27) have been shown to be involved in myofibrillar proteins protection (Guillemin et al. 2011; Lomiwes et al. 2014) and Hsp27 was reported as related to tenderness (Bernard et al. 2007; Saccà et al. 2015a). Besides having a significant role in cell thermotolerance, Hsp70 has been shown to inhibit the apoptotic pathways and appears to be a good biomarker of low tenderness (Kregel 2002; Picard et al. 2014).

A crossbreeding programme between the African Goudali and the Italian Simmental (IS, *Bos taurus*) breeds was initiated in the year 2008 (Bessong et al. 2011) to obtain the SimGoud (SG) crossbreed, with the positive result of increasing meat yield (Bessong et al. 2018).

The aim of this trial was to compare some physical meat quality traits and the expression, at mRNA and at protein level, of some tenderness-related genes between G breed and SG crossbreed, to evaluate the effect of the crossbreeding in tropical pastures conditions on important aspects of meat quality.

Materials and methods

Animals and treatments

The experimental procedures followed the requirements of the European Community Directive 2010/63/EU regarding the protection of animals used for experimental and other scientific purposes. Twenty-two male bulls, aged 31 ± 0.49 months, of two genotypes, 10G and 12 SG crossbred, born and reared in Cameroon (Latitude 060 42' North, Longitude 0100 25' East), in the same conditions, were considered. The SG bulls were F1-crossbred originated using G cows and semen of IS bulls, whereas the G bulls originated from pure G cows and bulls (Bessong et al. 2018). All the experimental animals were fed by grazing natural herbage of the Western Highland Plateau Savannah, plus NaCl supplementation. At the end of the trial, the animals were initially moved on-foot for 208 km and then were moved by an animal transport truck for 306 km. After the journey, to allay stress, the animals were rested for five weeks at the Douala Cattle market lairage. During this period, they grazed every day from sunrise to sunset on native pastures, close to the market. After this, the animals were slaughtered in the slaughterhouse at Douala, following standard industrial procedures.

Sample collection and physical measurements

Five-g samples of *longissimus thoracis* (LT) muscle were obtained within 30 min of slaughter, frozen in liquid N₂ and stored at -80°C until proteomic and transcriptomic analysis. After chilling for 24 h, the LT muscle was extracted from the carcass. The ultimate pH (pHu) was measured by a pH-meter (HI 8424; Hanna Instruments, Padua, Italy). Approximately, 100 g of muscle was cut and weighed; after that, the cuts were suspended for 24 h at 4°C and then weighed again to determine the drip loss (48 h of ageing). After 48 h of ageing at 4°C , the colour of muscle was measured using a portable spectrophotometer Minolta CM 2600d (Konica Minolta, Tokyo, Japan). The values recorded, according to the standard conditions of the Commission International d'Eclairage (CIE 1976) included L* (Lightness), a* (Redness) and b* (Yellowness). Samples of muscle were aged at 4°C for 5 days after slaughtering until cooking loss determination. Slices of muscle of 2 cm thickness were cooked in plastic bags, according to the procedure described by Honikel (1998). The cooking loss (5 days of ageing) was calculated by difference between the weight before and after cooking and expressed as a percentage of the initial weight. After two days at 4°C (7 days of ageing), the Warner-Bratzler Shear Force test was performed on cooked meat. Cylinders of 15 mm in diameter were sheared perpendicularly of muscle fibres using a Warner-Bratzler (WB) device, mounted on a Lloyd TA Plus texture analyser (Lloyd, Borgnor Regis, UK). From the WB deformation curves, two parameters were recorded: the peak yield force (PY, in N) and the final yield (FY, in N). The first peak is taken as a measurement of the myofibrillar component of tenderness and the second is taken as a measurement of the connective tissue component of tenderness (Møller 1981).

RNA content analysis

RNA content analysis was performed in accordance with Corazzin et al. (2013). Briefly, total RNA was extracted using RNeasy Fibrous Tissue Mini Kit (Qiagen, Hilden, Germany) according to the manufacturer's protocol. Concentration and purity of RNA extracted were assessed using spectrophotometer NanoDrop 2000c (Thermo Fisher Scientific, Waltham, MA). Integrity of RNA (the presence of intact 18S and 28S rRNA bands) and absence of genomic DNA were assessed by agarose gel (1% in Tris-borate-EDTA buffer [TBE]) electrophoresis, comparing with molecular

Table 1. Primers sequence, amplification product and amplification efficiency of genes in exam and reference genes.

Gene ^a	Primers sequence ^b , 5' to 3'	Amplicon length, bp	Accession Number	Efficiency	R ²
Capn1	F: AACCGGATCCGGAATTACCTGTCCATCTTC R: GTAACCACTTAAACAAGTCAAAGTCCACCA	282	NM_174259	0.979	0.986
Capn2	F: CGAGGACATGCACACCAATTGGCTTCG R: TCCTCGCTGATGTCAATCTCGTCAATGTTG	314	NM_001103086.1	0.968	0.997
Cast	F: CACAGAAGCCAAGGCTATTCC R: TTTACAGCCTGTTTTTGTGTCTTTTC	87	NM_001030318	0.978	0.997
Casp3	F: AGAACTGGACTGTGGTATTGAGA R: CACAAAGAGCCTGGATGAAC	167	NM_001077840.1	0.957	0.996
Casp9	F: CCTGTGGTGGAGAGCAGAAAG R: CATCTGGCTCGTCAATGGAA	134	NM_001205504.1	0.945	0.980
Cryab	F: CCGCCTCTTTGACCAAGTT R: AGAGGCCAGTGTCAATCC	134	NM_174290	0.991	0.997
Hsp27	F: CGTTGCTTCACTCGCAAATA R: TACTTGTTCCGGCTGTTCG	210	NM_001025569.1	0.936	1.000
Hsp40	F: GGAAGTACCAATGCTGCTG R: CAAACCCACCTGTGAATAGC	138	NM_001034458.1	0.984	0.998
Hsp70-1A	F: AACCAAGATCACCATCACCAACG R: TCCTTCTCCGCAAGGTGTTG	274	NM_00174550	1.015	0.996
Cyclophilin	F: GGATTTATGTGCCAGGGTGGTGA R: CAAGATGCCAGGACCTGTATG	119	NM_00178320	0.992	0.998
β-actin	F: CTCTTCCAGCCTTCTCTCT R: GGCAGTGATCTCTTCTGCTC	177	NM_00173979	0.961	0.997
GAPDH	F: TCATCCCTGCTTCTACTGGC R: CCTGCTTACCACCTTCTTG	177	NM_001034034	0.974	0.999
RPLP0	F: CAACCCTGAAGTGCTTGACAT R: AGGCAGATGGATCAGCCA	226	NM_001012682	0.987	0.999

^aCapn1: calpain-1; Capn2: calpain-2; Cast: calpastatin; Casp3: caspase 3; Casp9: caspase 9; Cryab: αB-crystallin; Hsp27: heat shock protein 27; Hsp40: heat shock protein 40; Hsp70: heat shock protein 70. Cyclophilin, β-actin, Glyceraldehyde 3-phosphate dehydrogenase (GAPDH), Ribosomal Protein Large P0 (RPLP0): reference genes.

^bF: Forward; R: Reverse.

weight standards. To obtain cDNA, the iScript cDNA Synthesis kit (BioRad, Hercules, CA) was used according to the manufacturer's protocol and with a volume of RNA solution to have 50 ng/μL RNA final concentration. A qualitative PCR was carried out to validate primers pair specificity for all the genes in exam (calpain-1 [Capn1], calpain-2 [Capn2], calpastatin [Cast], caspase 3 [Casp3], caspase 9 [Casp9], αB-crystallin [Cryab], heat shock proteins 27 [Hsp27], 40 [Hsp40], 70 [Hsp70] and reference genes [Table 1]). The amplification was performed using the Bio-Rad CFX96 system (BioRad) including 1 cycle of 3 min at 95 °C, 40 PCR cycles of 15 s at 95 °C, 30 s at 60 °C and 30 s at 72 °C, then 1 min at 95 °C, followed to a melt curve of 55-95 °C with 0.5 °C increments every 5 s. Amplicons length (Table 1) was verified by agarose gel (1.5% in TBE buffer) electrophoresis, comparing with molecular weight standards. The quantitative PCR (qPCR) was performed using the same instrument, volumes and conditions of the qualitative PCR, for each sample, in triplicate. The relative gene expression was calculated according to the efficiency-corrected method (Pfaffl 2001). Among considered genes, only β-actin and GAPDH were treated as reference genes and used for normalisation of qPCR data, since they showed the highest stability ($M < 1.50$; Vandesompele et al. 2002). Data were presented in fold-change ratio having G breed as reference.

Enzyme-linked immunosorbent assay (ELISA) analysis

Proteins extraction and quantification

Protein extraction for Capn1 and Cast analysis was made according to Geesink and Koohmaraie (1999), experiment 1, using pre-rigor extraction buffer, with 10 μL of Protease Inhibitor Cocktail (P8340, Sigma-Aldrich, Saint Louis, MO). Protein extraction for Hsp27 and Hsp70 analysis was made according to Pulford et al. (2008), using 10 μL of Protease Inhibitor Cocktail (P8340, Sigma-Aldrich) in the extraction buffer. Protein concentration of muscle extracts was determined by the method of Bradford (1976) using Bradford reagent (Sigma-Aldrich).

Quantification of Capn1 and Cast was made according to Doumit et al. (1996), whereas quantification of Hsp27 and Hsp70 was made according to Lomiwes et al. (2014), using 96 well Costar high binding polystyrene plates (Corning Inc., 3590). The primary antibodies used were mouse monoclonal antibodies: anti-calpain antibody (C0355, Sigma-Aldrich) diluted 1 μg/mL for Capn1; anti-calpastatin antibody (C270, Sigma-Aldrich) diluted to 1:5000 for Cast; anti-Hsp27 antibody (Hytest 4HSP27, Hytest, Turku, Finland) and anti-Hsp70 (Hytest 4HSP70; Hytest), each diluted to 1:10,000, for Hsp27 and Hsp70, respectively. The secondary antibody utilised was a goat anti-mouse IgG

Table 2. Characteristics of *longissimus thoracis* muscle belonging to *Goudali* (G) and *Simmental* × *Goudali* (SG) crossbreed cattle.

Trait ¹	G	SG	SEM ²
Colour			
L*	36.8 ^a	32.2 ^b	1.04
a*	11.1	14.3	0.97
b*	14.0	14.9	0.80
pHu	5.61	5.58	0.021
WBSF			
PY (N)	52.9	60.1	2.21
FY (N)	48.1	53.1	2.03
Water losses			
Drip loss, %	3.85	2.97	0.272
Cooking loss, %	36.64 ^b	32.80 ^a	0.682

¹pHu: Ultimate pH; WBSF: Warner Bratzler Shear Force; PY: Peak yield force; FY: Final yield force; L*: Lightness; a*: Redness; b*: Yellowness.

²SEM: Standard Error of the Mean.

*,**,**p* < .05.

Horseradish Peroxidase (HRP) conjugate (A4416, Sigma-Aldrich). The absorbance was measured at 450 nm using a Tecan Sunrise plate reader (Tecan Group Ltd., Männedorf, Switzerland). Relative quantity of *Capn1*, *Cast*, *Hsp27* and *Hsp70* was measured by optical density. Data were presented as fold-change ratio having G breed as reference.

Statistical analysis

Stability of genes expression was assessed using R software (v 3.2.1; R core team, Vienna, Austria), package SLqPCR (Kohl 2007). The other statistical analyses were performed using SPSS for Windows (v. 7.5.21; SPSS Inc., Chicago, IL). The normality of the data distribution was tested using Shapiro–Wilk test. Where appropriate, non-parametrically-distributed data were transformed for parametric testing. The effect of genotype on the characteristics of *longissimus thoracis* muscle was evaluated by one-way ANOVA considering the genotype (G vs. SG) as fixed factor. The effect of genotype on mRNA and protein abundance was evaluated by one-way ANCOVA considering the genotype (G vs. SG) as fixed factor and the age of the animals as covariate. Data are presented as mean ± standard error.

Results and discussion

Physical characteristics of meat

Table 2 presents the characteristics of LT muscle of G and SG. G showed a greater lightness (L*) value with respect to SG (*p* < .05). The L* value of SG crossbreed is not so far from that declared by Corazzin et al. (2012; 33.6) for IS bulls, but below the lowest value reported by Muchenje et al. (2009a; 33.2) that considered both European and African breeds in their review.

The lightness of G appeared high for a *Bos indicus* breed, as showed by other authors (Bressan et al. 2011; 32.3; Nfor et al. 2014; 29.5 on average), even if Strydom (2008) reported greater values of L* (39.0) for a *Bos indicus* crosses (Brahman) with respect to Simmental crosses (37.8). Moreover, Gama et al. (2013) found a reduction of lightness as effect of crossbreeding between *Bos indicus* and *Bos taurus* bred at pasture. Taylor (2004) suggested that differences in fibre characteristics found between breeds would rather relate to differences in meat colour between breeds than to differences in meat tenderness. Although we did not give the characterisation of muscle fibre composition in G and SG, we can suppose a higher presence of large, white fibres in G type (Strydom 2008) that can lead to a brighter colour and a higher water loss. Redness (a*) and yellowness (b*) were similar between genotypes (*p* > .05). The redness in G was greater than the values reported by Nfor et al. (2014) for zebu breeds (7.2 on average), but lower than redness recorded by Bressan et al. (2011) for *Bos indicus* breeds (19.8). In any case, our values of redness, both for G and for SG, were within the limits showed by Muchenje et al. (2009a; 11.1 to 23.6).

The pHu of all the animals was below the value of 5.87 considered the cut-off between normal and dark-cutting beef carcasses (Page et al. 2001). The five weeks of rest before slaughter seem to be effective in reducing the stress of the travel from the farm to the slaughterhouse and to reconstitute the glycogen stores. Similarly to our trial, other authors did not find pH differences between *Bos taurus* and *Bos indicus* (Bressan et al. 2011; 5.86 on average) or between these genotypes and their crosses (Gama et al. 2013). Also Muchenje et al. (2008, 2009b) did not find pHu differences between *Bos taurus* and *Bos taurus* × *Bos indicus* breeds (5.7 on average).

Concerning the rheological parameters, differences between G and SG were not found (*p* > .05), neither for the myofibrillar nor for the connective component of the shear force. To this regards, the literature shows controversial results. Some authors highlighted that *Bos taurus* gives more tender meat compared to *Bos indicus* (Wheeler et al. 1990), conversely, Strydom (2008) and Frylinck et al. (2009) reported higher WBSF for Simmental crosses in comparison with Brahman crosses (*Bos indicus*) and Nguni crosses (*Bos taurus africanus*). Du Plessis and Hoffman (2007) also reported no differences in shear force resistance of three days aged loin muscle from Nguni, Brahman and Simmental crosses aged between 18 and 30 months, showing that breed effect on meat shear force was not significant in natural pasture of South African arid

subtropics. Also in our condition (tropical climate, natural pasture feeding, high physical activity) differences between genotypes have not been highlighted. Moreover, the tenderness of SG bulls may have been reduced by a food restriction suffered during transfer and lairage time, when the pasture allowance was likely not sufficient to satisfy their feeding requirements. Indeed, as reported for the largest group of bulls comprising the animals of this experiment (Bessong et al. 2018), it is interesting to note that the more performing SG bulls showed a marked loss of weight during transfer and lairage time (6.1%), while G ones, during this period, were able to increase their body weight of 4.4%.

The values of WBSF for G (PY, maximum peak yield) are much lower than the values reported for the same breed by Nfor et al. (2014; 112 N), probably because of the lower average age and better-controlled management conditions of animals in our study. Corazzin et al. (2012) reported values of WBSF of 47.9 N for IS breed reared in stable, whereas our values of WBSF were 56.9 N on average between G and SG. The slightly higher shear force values in loin of bulls finished on pasture may have been also due to increased collagen cross-linking associated with increased exercise. In any case, our values were fully ranged between limits reported by Muchenje et al. (2009a), both at 2 and at 21 days of ageing. In a number of studies in South Africa (De Bruyn 1991; Frylinck and Heinze 2003; Marais 2007), the poor tenderness quality of Simmental meat was questioned. In particular, De Bruyn (1991) found no significant differences between shear force resistance of Afrikaner, Bonsmara, Charolais and Hereford meat, whereas the toughness values were significantly higher for Brahman and Simmental meat. Moreover, Frylinck et al. (2009) hypothesised that, under specific environmental challenges, both Simmental and *Bos indicus* contributed to the poor tenderness of the crossbreed meat.

Muchenje et al. (2008, 2009b) found no differences in drip and cooking losses of *longissimus* muscle meat between *Bos Taurus*, *Bos indicus* × *Bos Taurus* and *Bos taurus africanus*. On the contrary, in our trial, cooking losses were different between the two genotypes, with SG having lower values than G ($p < .05$). The low water loss of fresh meat is considered a positive commercial characteristic. Even if the pH was comparable between the two genotypes, the differences in meat colour and water losses could be related to a different muscle fibres type composition, as already observed. The value of cooking loss for G was slightly lower than the values reported by Nfor et al. (2014) for the Cameroonian *Bos indicus* breeds (38.4% on average).

Conversely, the values of cooking loss were greater for both genotypes than those showed by Corazzin et al. (2012) in young bulls of Simmental breed (30.4%).

RNA and protein expression of considered genes

The values of mRNA expression for G and SG LT muscles are shown in Table 3. Many proteins systems are known to control the quality traits of meat and its tenderness in particular, among which the calpain system has been considered the most important. It consists of two calcium-dependent proteases, Capn1 and Capn2 and their competitive inhibitor Cast. Concerning the mRNA expression of calpains and Cast our results are in accordance with the rheological measurements. In fact, no significant differences occurred between the two genotypes for both shear force values and the expression levels of genes related with tenderness. The ELISA analysis (Table 4) confirmed the lack of difference in the expression for both Capn1 and Cast between the two breeds that was

Table 3. Fold change ratio in relative mRNA expression of genes in *longissimus thoracis* muscle belonging to *Goudali* (G) and *Simmental* × *Goudali* (SG) crossbreed cattle.

Gene ^a	G	SG	SEM ^b
Capn1	1	0.84	0.329
Capn2	1	0.81	0.380
Cast	1	1.21	0.282
Capn1/Cast	1	0.94	0.234
Casp3	1	0.69	0.361
Casp9	1	0.74	0.267
Cryab	1	0.71	0.310
Hsp27	1	0.64	0.335
Hsp40	1	0.86	0.213
Hsp70	1**	0.41*	0.348

^aCapn1: calpain-1; Capn2: calpain-2; Cast: calpastatin; Casp3: caspase 3; Casp9: caspase 9; Cryab: α -crystallin; Hsp27: heat shock protein 27; Hsp40: heat shock protein 40; Hsp70: heat shock protein 70.

^bSEM: Standard Error of the Mean.

*, ** $p < .05$.

Table 4. Fold change ratio in relative protein quantity of *longissimus thoracis* muscle belonging to *Goudali* (G) and *Simmental* × *Goudali* (SG) crossbreed cattle.

Protein ^a	G	SG	SEM ^b
Capn1	1	1.03	0.081
Cast	1	1.02	0.025
Capn1/Cast	1	1.00	0.084
Hsp27	1	1.37	0.271
Hsp70	1	0.87	0.075

^aCapn1: calpain-1; Capn2: calpain-2; Cast: calpastatin; Hsp27: heat shock protein 27; Hsp70: heat shock protein 70.

^bSEM: Standard Error of the Mean.

highlighted by mRNA analysis. Some authors reported a higher Cast activity and/or a lower Capn1 expression in *Bos indicus* than *Bos taurus*, resulting in lower rates and amount of *post-mortem* tenderisation (Wheeler et al. 1990). The lack of difference between SG and G in the expression of Capn and Cast genes, sustained by the absence of difference in share force values, may be related to the extreme environmental factors (climate, feeding regime and management stresses) that characterised our experimental conditions and that, as already discussed, may have particularly affected the more performing and demanding SG genotype during the transfer and lairage time. Similarly, Marais (2007) considering Brahman, Nguni and Simmental crosses highlighted a failure in the correspondence between the genotypic makeup and the phenotypic expression of tenderness genes caused by environmental factors.

In recent years, Becila et al. (2010) provided evidences that cell death in *post-mortem* muscle occurs via an apoptotic process. Casp3 and Casp9 are involved in the intrinsic pathway of apoptosis. In spite of their central role in apoptosis, the involvement of caspases in meat tenderisation, by means of proteolytic degradation, is still debated (Saccà et al. 2015a, 2015b). In our trial, no significant differences were found between G and SG in the expression of Casp3 and Casp9 mRNA (Table 3), in line with Capn and Cast genes expression.

The anoxic state that characterises *post-mortem* condition also activates cell survival processes, such as the increase in the concentration of several Hsp. Because of their anti-apoptotic function, their protective actions on myofibrillar proteins and their anti-oxidative role, Hsp have been proposed to have a potential role in meat tenderisation process (Cassar-Malek and Picard 2016). In particular, alphaB-crystallin and Hsp27 are known to stabilise and protect myofibrillar proteins (Lomiwes et al. 2014). Concerning the expression of Hsp genes at mRNA level, the two genotypes showed not significant differences (Table 3), except for Hsp70 that is more expressed in G ($p < .05$). The ELISA analysis (Table 4) confirmed the lack of difference in the expression of Hsp27 between the two breeds, but G showed only numerically higher Hsp70 protein abundance than SG. Because of the environmental adaptation, zebu breeds of cattle are better able to regulate body temperature in response to heat stress than European breeds (Beatty et al. 2006). Hsp70 is abundantly induced in response to cellular stress, possibly due to its function to preserve proteins (Gagaoua et al. 2015). Moreover, Hsp70 has a significant role in cell thermotolerance and animal survival

(Kregel 2002). Hsp70 has been also reported as a good marker of meat hardness regardless of the type of muscle and the breed considered (Picard et al. 2014), but in our study, it seems to be more related to environmental stress resistance.

Moloto et al. (2017) underline that the complexity of the tenderisation process and the different metabolic pathways involved in the transformation of muscle to meat, lead to the difficulty to identify definite markers for meat tenderness. Moreover, in our study, the extreme environmental and breeding conditions may have influenced the expression of mRNA and proteins in muscle cell (Guillemin et al. 2011) and particularly that of the more performing and demanding SG bulls, leading to a flattening of the differences between the two genetic types.

Conclusions

In conclusion, in comparison to pure G breed, the crossing between IS and G seems to have limited impact on meat traits, at least in tropical environment. Indeed, although it caused a reduction of cooking losses of meat, it had no effects on meat tenderness and on the expression of the related genes. Based on its greater Hsp70 expression, the local Goudali breed should respond better to the tropical climate, where it has evolved over the years, with respect to the SimGoud crossbreed.

Disclosure statement

No potential conflict of interest was reported by the authors.

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