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Abstract

Purpose: The aim of this study was to investigate the influence of breed, production system, and feeding type on meat quality, evaluating organoleptic and physicochemical traits and antioxidant status across selected local cattle breeds.

Materials and Methods: The study was carried out on sirloin and blood samples taken in slaughterhouses from the hot carcass of male cattle, divided according to breed, production system and type of feed. The nutritional, organoleptic characteristics and oxidative status was assessed.

Findings: The results revealed that meat from Goudali breed raised in a sedentary system exhibited significantly lower tenderness (p<.) and higher lipid (p<.) and protein (p<.) contents. Additionally, the meat displayed notably lower pH (p=.), reduced cortisol (p<.), and lower catalase (p<.), TAC (p<.), and FRAP (p=.) activities. Consumers preferred the meat of the White Fulani breed due to its color (p<.). In transhumant system, the meat was richer in dry matter (p=.), lipids (p<.), and fibres (p=.), while the sedentary system resulted in more tender (p=.) and red-dark colored meat (p<.), which consumers favored. Meat from cows under commercial feed were preferred by consumers (p<.) compared to grass-fed cows, exhibiting significantly higher lipid (p<.) and protein (p<.) levels as well as intense color (p=.). However, meat from grass-fed cows had significantly higher fibre content (p<.), tenderness (p<.), better taste (p=.), juiciness (p=.), and higher catalase (p=.) and TAC (p<.) activities.

Implications to Theory, Practice and Policy: These findings underscore the importance of considering breed, production system, and feeding type when conserving, selecting, or improving beef breeds for both meat quantity and quality.

Keywords: *Tropical Farming, Beef Cattle Production, Cameroon, Oxidative Stress, Beef Cattle Breeds*

JEL Codes: *Q, Q*

1.0 INTRODUCTION

Rapid population growth in Sub-Saharan Africa and West Africa has led to a sharp increase in demand for food products, including animal products. This demand, which practical technological advancements have not met, has resulted in a significant deficit between supply and demand (Labonne et al., 2003). To ensure food security for its population, Africa must confront the challenge of improving meat production. However, this task faces significant obstacles, including the expansion of cultivated land, reduced access to forage resources and water, increased herd mobility, and conflicts between farmers and nomadic herders. These issues have profoundly affected meat production and public authorities are promoting the sedentarisation of livestock (Sounon et al., 2019).

African cattle breeds are recognised for their limited genetic potential, prompting policymakers to explore crossbreeding with both indigenous and foreign breeds (Blagna et al. 2020). However, these efforts to increase the quantity of African cattle may affect the quality of the meat. Factors such as genetic background, sex, age, rearing conditions, and slaughter methods all play a role in influencing meat quality (Lebret and Picard 2015). Understanding the impact of these measures on meat quality is vital, as it directly influences consumer satisfaction and well-being. Additionally, studies have linked high red meat consumption to health issues such as cardiovascular diseases and colorectal cancer (Sadaka 2011). This may be linked to the high oxidation of beef, as its by-products are known to have potentially carcinogenic and anti-inflammatory effects, contributing to the pathophysiology of these diseases (Huang and Ahn, 2019). This oxidation is exacerbated by factors such as transport conditions, climate, and unfamiliar environments (including unfamiliar noises and odours) (Ferguson and Warner, 2008), which heighten stress in animals, making their muscles more prone to lipid and protein peroxidation.

Lipid peroxidation also contributes to the decline in meat quality, leading to a deterioration in its organoleptic properties and nutritional value (due to the production of toxic compound), key factors in ensuring consumer satisfaction (Gobert et al. 2013). Since efforts to increase livestock production can significantly impact meat quality, it is crucial to understand how these factors affect the meat's nutritional, organoleptic characteristics, and oxidative status. This knowledge is essential for identifying and promoting practices that are best suited to local conditions, ensuring higher-quality livestock production.

This study aims to evaluate the effect of breed, production system, feeding type, and stress on beef's organoleptic, nutritional, and oxidative status properties. By understanding the interactions between these factors, we will gain a clearer understanding of their overall impact on meat quality and help improve the production of high-quality meat, ensuring both consumer satisfaction and health.

2.0 MATERIALS AND METHODS

Study Site

The study was conducted on cattle transported to the Etoudi slaughterhouse in Yaoundé, Cameroon. This slaughterhouse was chosen primarily for its accessibility and proximity to the animal physiology laboratory. The cattle came from two agroecological zones in Cameroon: the Sudano-Sahelian zone and the High Guinea Savannah zone. Animal selection was largely based on the willingness of the owners to collaborate and provide key information about the rearing conditions, including the cattle's origin, diet (grass or feed), and transportation conditions.

Evaluation of the Impact of Breed on Meat Quality

The study was conducted on 30 male beef cattle from the Sudano-Sahelian region, specifically raised for fattening. These animals were fed a commercial ration provided by SODECOTON (Garoua, Cameroon), consisting of 40-45% defatted or full-fat cottonseed cake, 50-55% cotton hulls, 3% crushed limestone, and 1.5% table salt. Three groups of male cattle were used: White Fulani (WF), Red Fulani (RF), and Goudali from Ngaoundere (G). Ten animals, aged 3-4 years, were randomly assigned to each group.

Evaluation of the Impact of the Production System on Meat Quality

The study involved 40 male cattle, divided into two groups of 20 animals each. The transhumant system (TS) group consisted of White and Red Fulani cattle, aged 5 to 9 years, from the Sudano-Sahelian zone. These animals traveled daily over varying distances depending on grass availability, which made up the majority of their diet. The sedentary system (SS) group included White and Red Fulani cattle, aged 3 to 4 years, from the Ngaoundéré region of Cameroon. These animals were raised in confinement and fed a commercial ration provided by SODECOTON.

Evaluation of the Impact of Feeding Type on Meat Quality

Goudali cattle were divided into two groups of 10 animals each to evaluate the impact of feeding type on meat quality. The grass-fed group consisted of cattle raised in confinement and fed exclusively on forage, while the commercially-fed group comprised cattle also raised in confinement but fed a commercial ration provided by SODECOTON

Sampling

The animals were slaughtered at the SODEPA facility. Following the cutting of the throat and exsanguination, blood was immediately collected into labeled EDTA tubes. In the laboratory, the blood was centrifuged at 3500 rpm for 15 minutes, and the resulting serum was stored for cortisol analysis.

The sirloin was taken from the hot carcasses, labeled, and stored in a cooler. The samples were taken to the laboratory and stored at -20°C for 14 days. Then, physicochemical, sensory, and antioxidative tests were carried out.

Physicochemical and Stress Parameters Analysis

Sirloin samples (0.8 g) were crushed and homogenized in 4 ml of Phosphate-buffered saline (PBS), which was used to measure physicochemical and stress parameters. The physical and physicochemical parameters evaluated were dry matter (DM) and water content (Water C.) (AFNOR 1994), proteins (Pietrzak et al. 1997), fat (Folch et al. 1957), ash content (AFNOR 1994), and fibre (Van Soest et al. 1991). The pH was measured using a pH meter (PH Inlab Solid Pro-ISM) by directly reading the sirloin sample.

Stress parameters evaluated were: Catalase (Sinha 1972) malondialdehyde (MDA) (Wilbur et al. 1949), superoxide dismutase (SOD) (Misra and Fridovich 1072) Ferric Reducing Antioxidant Power (FRAP) (Oyaizu 1986), and total antioxidant capacity (TAC) (Prieto et al. 1999), and cortisol (ELISA Kit for bovine cortisol, Elabscience®).

Sensory Analysis

The meat was cut into small pieces (5 to 7cm), threaded onto a stick, and cooked without seasoning or fat in an oven at 180°C for 30 minutes or 15 minutes on each side. The jury consisted of a panel of 25 chosen people who were trained; during the tests, the latter had a glass of water at room temperature to rinse their mouths with bread to pass from one sample to another. Each jury member had a 3-digit coded sample for each breed, comprising 3 pieces per breed. The parameters evaluated were tenderness (Ten), primary juiciness (Jut Ire), secondary juiciness (Jut IIre), fibrous nature (Fib) of the meat, taste, color, and general appreciation of color/Rank color (Color R). Color was evaluated on fresh meat (Maraval et al., 2018).

Statistical Analyses

Data were expressed as mean ± standard error of the mean. They were analyzed using IBM SPSS Statistics software (version 26) and summarized in a table. Differences were considered significant at $p<0.05$. The Kruskal-Wallis test was used to compare the physicochemical, organoleptic characteristics, and stress parameters between the different breeds, while the Mann-Whitney test was employed to compare these parameters across the different production systems and feeding types. Correlations between pH and the oxidative status of the meat were assessed using Pearson's correlation coefficient, calculated with the same software. Multivariate analysis was employed to examine the effects of breed, production system, and nutrition on the various organoleptic parameters through logistic regression.

3.0 FINDINGS

Variation of Physicochemical Characteristics Depending on Breed, Production System and Feeding Type

All results are summarised in Table 1. The physicochemical evaluation of beef by breed shows that the Goudali breed has significantly higher levels of lipids ($p<0.001$), proteins ($p<0.001$), and water content ($p=0.000$), along with a notably lower pH ($p=0.044$) compared to the White and Red Fulani breeds. In contrast, the White Fulani breed exhibits the lowest dry matter content ($p=0.008$).

Transhumant system produces meat with a significantly higher pH ($p=0.013$) than meat from the sedentary system breeds. It is also significantly richer in dry matter ($p=0.002$), lipids ($p=0.000$), and fibre ($p=0.001$) compared to meat from the sedentary system, which is significantly richer in ash ($p=0.008$) and water content ($p=0.001$). However, no significant difference was observed in the protein content between meats from these two systems. Animals fed on commercial feed produced meat significantly richer in lipids ($p<0.001$), proteins ($p<0.001$), and with a substantially higher water content ($p=0.004$) compared to grass-fed animals, whose meat was significantly richer in fibre ($p=0.004$)

Variation of Stress Parameters Depending on Production System and Feeding Type

Goudali breed exhibits the lowest serum cortisol levels, with an average concentration of 64.8 ng/ml, which is significantly lower ($p<0.001$) compared to Red Fulani (78.5 ng/ml) and White Fulani (94.0 ng/ml) breeds (Figure 1). The analysis of oxidative stress among the three breeds shows substantial variations depending on the breed (Table 2). Goudali breed demonstrates significantly lower levels of catalase, TAC, and FRAP, with p-values of <0.001, <0.001, and 0.001, respectively, compared to the other breeds. However, no significant differences were observed in

SOD and MDA levels across the breeds. A bivariate analysis of oxidative stress parameters and meat pH revealed a significant positive correlation between pH and certain oxidative stress markers, particularly catalase and TAC. The correlation was moderate for catalase activity (p=0.023; r=0.531) and strong for TAC activity (p=0.003; r=0.667**).

Regarding the impact of the production system on stress parameters in beef cattle, animals raised in sedentary system showed significantly lower serum cortisol levels (mean: 86.2 ng/ml; p<0.001) compared to those in transhumant system, which had an average concentration of 103.3 ng/ml (Figure II). However, the production system did not affect the oxidative status of the meat. Grass-fed animals had significantly higher levels of catalase and TAC compared to feed-fed animals, with p-values of 0.007 and <0.001, respectively.

Variation of Organoleptic Characteristics of Beef Depending on Breed, Production System

The evaluation of organoleptic parameters (Table 3) revealed that tenderness, fibrousness, color, and overall appreciation are significantly influenced by breed (p<0.001). Meat from Red Fulani breed was found to be the most tender and fibrous, with the lightest color (pale red) and the least favored color by consumers. In contrast, White Fulani breed produced meat with a more intense color (dark red) that received higher appreciation. The Goudali breed produces the toughest meat.

Among the parameters evaluated, the production system significantly influenced only tenderness and color appreciation. The sedentary system produced significantly more tender meat (p<0.001) and meat that was more appreciated for its darker red color (p<0.001). Regarding feeding type, the analysis revealed that grass-fed animals produced significantly more tender meat (p<0.001), with better taste (p=0.03) and juiciness (p=0.015). In contrast, feed-fed animals had more intense coloring (dark red), which was more appreciated by consumers for its visual appeal.

Multivariate Analyzes

Multivariate analysis of tenderness reveals that 7.3 to 10% of meat tenderness is significantly (p=0.01) linked to the breed of the animal and production system. From this model, it appears that the meat of Red Fulani breed has 3.051 times more chance of being tender than Goudali breed (p=0.027), while the meat of White Fulani breed has 2.8 times more chance of being tender (p=0.038) than Goudali breed. Regarding the production system, sedentary system is 3.3 times more likely to produce more tender meat compared to transhumant system (p<0.001).

Results indicate that 20.5% to 27.3% of color variability is significantly (p<0.001) associated with both breed and production system. The analysis suggests that Goudali breed is 3.13 times less likely to produce darker meat compared to the White Fulani breed (p=0.36) and 3.2 times more likely to produce darker meat than Red Fulani breed (p=0.48). However, the production system showed no significant influence on meat color.

Multivariate analysis of color appreciation reveals that 9 to 12% of the variability in meat color appreciation is significantly (p=0.006) linked to breed and especially to production system. Sedentary system would produce meat that is 3.8 times (p=0.001) more likely to be appreciated for its color than beef produced by transhumant system.

Table 1: Variation of Physicochemical Parameters of Sirloin Beef According to Breed, Production System and Feeding Type RF=Red Fulani; G = Goudali; WF=White Fulani; SS= Sedentary System; TS= Transhuman System; Feed=Animals Fed with a Commercial Feed; Grass= Grass-Fed Animals; DM = Dry Matter; Water C. = Water Content; Prot= Protein (µg/ml). Sig=Significance;(*): p < 0.05, (**): p < 0.01, (***): p < 0.001. a=Different from b, c; b= Different from a, c; c=Different from a, c, with p<0.05

		Age	pH	DM	Ash	Lipids	Fibres	Water C.	Prot
Breed	RF	3.7±1.0	6.1±0.1a	93.5±1.5a	3.6±0.2a	26.6±2.0a	2.1±1.1a	5.9±1.3a	048.4±3.2a
	G	4.0±0.0	5.8±0.1b	91.0±2.3a	3.5±0.3a	38.0±8.4b	1.6±0.8a	11.9±1.7b	113.0±3.7b
	WF	4.0±0.0	6.0±0.3a	89.8±1.4b	3.5±0.3a	22.7±2.0a	2.0±0.0a	10.2±1.4c	039.1±3.5c
	Sig	0.156	0.044*	0.008**	0.792	0.000***	0.64	0.000***	0.000***
Production system	SS	4.0±0.0	5.9±0.1	88.6±1.7	3.9±0.3	18.3±2.6	1.4±0.7	11.8±1.8	52.4±18.5
	TS	6.5±1.7	6.1±0.2	91.7±2.4	3.6±0.2	24.6±2.8	2.1±0.7	08.0±2.6	43.8±05.8
	Sig	0.000***	0.013*	0.002**	0.008**	0.000***	0.027*	0.001**	0.272
Feeding type	Feed	3.0±0.0	5.8±0.1	91.0±2.3	3.5±0.3	38.0±8.4	1.6±0.8	11.9±1.7	113.0±3.7
	Grass	3.7±0.5	5.7±0.1	93.4±1.3	3.9±0.3	17.4±0.8	3.0±0.2	05.3±0.4	069.6±3.1
	Sig	0.053	0.113	0.074	0.056	0.000***	0.004**	0.000***	0.000***

Table 2: Variation of Oxidative Stress Parameters of Sirloin Beef According to Breed, Production System and Feeding Type RF=Red Fulani; G = Goudali; WF=White Fulani; SS= Sedentary System; TS= Transhuman System; Feed=Animals Fed With a Commercial Feed; Grass= Grass-Fed Animals; Catalase (mM/g Prot); TAC=Total Antioxidant Capacity (µg EAA/g Prot); FRAP =Ferric Reducing Antioxidant Power (µg EAA/g Prot) ; MDA = Malondialdehyde (nmol/mL); SOD= Superoxide Dismutase (Units of SOD/mg of Protein). Sig=Significance;(*): p < 0.05, (**): p < 0.01, (***): p < 0.001. a=Different from b, c; b= Different from a, c; c=Different from a, c, with p<0.05

		Catalase	TAC	FRAP	MDA	SOD
Breed	RF	48.9±4.5a	102.7±7.5a	52.2±5.6a	32.9±3.5a	3.5±0.5a
	G	36.2±4.8b	038.4±3.0b	29.2±3.4b	34.2±4.0a	3.9±1.0a
	WF	65.6±8.8c	104.9±9.5a	32.7±13.8b	33.2±2.9a	4.5±0.6a
	Sig	0.000***	0.000***	0.001**	0.788	0.147
Production sytem	SS	71.3±29.5a	94.6±30.2a	38.0±11.2a	31.8±3.3a	3.7±1.1a
	TS	57.3±11.0a	98.5±22.7a	42.4±14.3a	33.1±3.1a	4.0±0.7a
	Sig	0.14	0.728	0.418	0.357	0.476
Feeding type	Feed	36.2±4.8a	38.4±3.0a	29.2±3.4a	34.2±4.0a	3.9±1.0a
	Grass	50.1±8.1b	63.8±8.1b	32.3±7.8a	35.5±3.7a	3.3±0.8a
	Sig	0.007**	0.000***	0.415	0.611	0.313

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Table 3: Variation in Organoleptic Characteristics of Sirloin Beef Depending on Breed, Production System and Feeding Type RF=Red Fulani; G = Goudali; WF=White Fulani; SS=Sedentary System; TS=Transhuman System; Feed=Animals Fed with a Commercial Feed; Grass= Grass-Fed Animals; Ten=Tenderness; Jut Ire=Primary Juiciness; Fib= Fibrous Nature; Jut IIre =Secondary Juiciness; R. Color =Rank Color. Sig=Significance;(*): p < 0.05, (**): p < 0.01, (***): p < 0.001. a=Different from b, c; b= Different from a, c; c=Different from a, c, with p<0.05

		Age	Ten	Taste	Jut Ire	Fib	Jut IIre	Color	R. color
Breed	RF	4.0±0.0	6.6±0.9b	3.3±0.8	3.0±0.9	3.9±1.3b	3.6±0.8	3.3±0.9a	3.6±1.1b
	G	3.7±1.0	4.2±1.0a	2.8±1.0	2.7±0.9	2.5±1.0a	3.1±0.8	3.7±1.0a	4.3±0.9a
	WF	4.0±0.0	6.0±1.0c	3.1±1.1	2.8±1.0	3.7±1.2b	3.6±0.8	4.8±0.6b	5.5±0.7c
	Sig	0.154	0.000***	0.057	0.399	0.000***	0.136	0.000***	0.000***
Production sytem	SS	4.0±0.0	6.3±1.0a	3.2±0.1a	2.9±1.0a	3.9±1.2a	3.6±0.8a	4.0±1.1	4.5±1.3a
	ST	6.5±1.7	4.1±1.0b	3.6±1.0a	2.6±1.0a	3.8±1.3a	3.4±1.0a	3.8±1.0	2.8±1.0b
	Sig	0.000	0.000***	0.092	0.111	0.549	0.408	0.099	0.000***
Feeding type	Feed	3.0±0.0	4.2±0.1a	2.8±0.1a	2.7±0.9a	2.5±1.0a	3.1±0.8a	3.7±1.0a	4.3±0.9
	Grass	3.7±0.5	6.3±0.9b	3.2±0.9b	3.2±0.9b	2.2±1.0a	3.6±0.8a	3.1±0.9a	2.1±0.9
	Sig	0.053	0.000	0.03	0.015	0.389	0.059	0.044	0.000

Legends of Figures

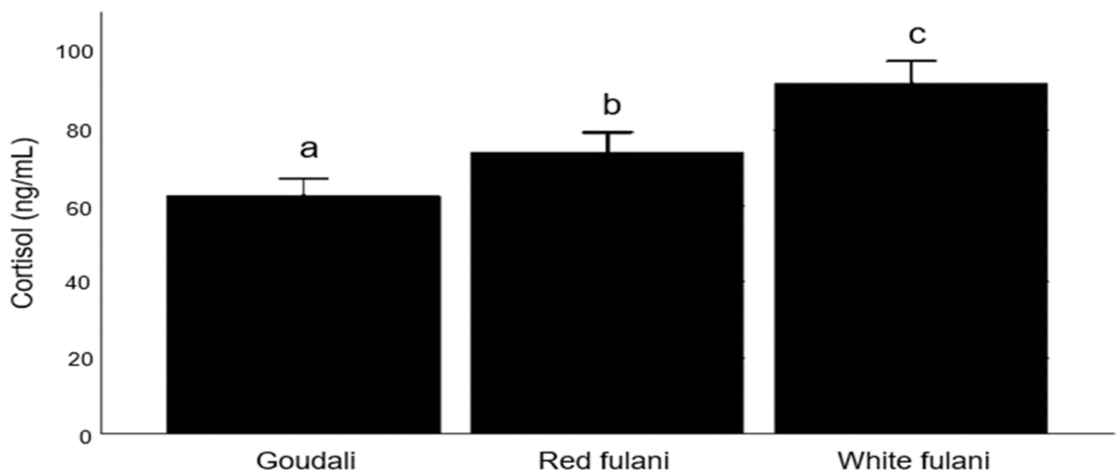

Figure 1: Variation in Serum Cortisol Level According to Breed. a=Different from b, c; b= Different from a, c; c=Different from a, c, with p < 0.001

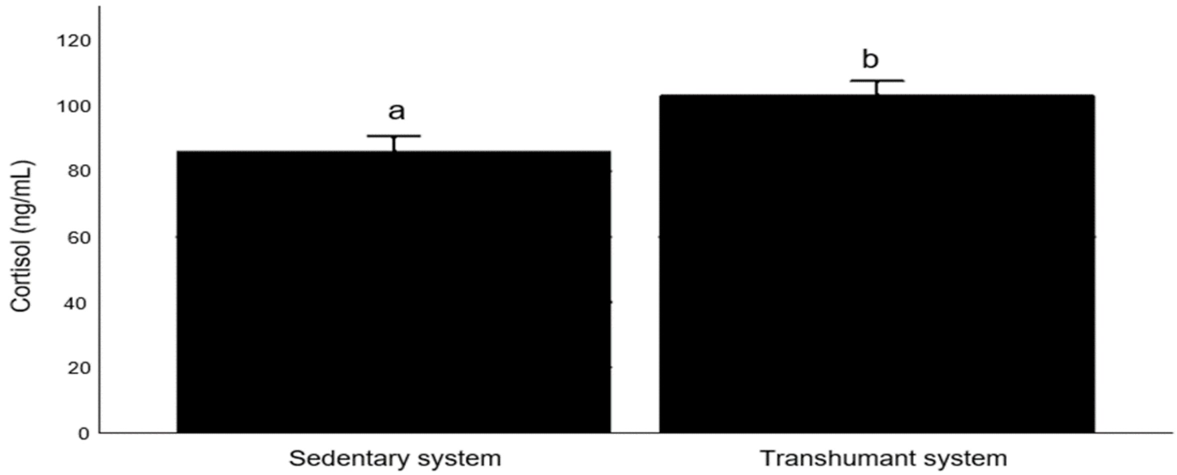

Figure 2: Variation in Serum Cortisol Level According to Production System. a=Different from b, c; b= Different from a, c; c=Different from a, c, with p < 0.001

Discussion

Identifying the optimal combination of breed, production system, and feeding type is crucial for producing high-quality beef. This study seeks to explore the influence of these factors on beef quality, offering valuable insights for the industry. The physicochemical analysis by breed shows that Goudali breed exhibits significantly higher levels of lipids and proteins compared to other breeds. These findings contrast with those of Normand et al. (2005), who assert that protein content in ruminant meats remains relatively constant, regardless of muscle, animal category, breed type, or diet. However, while the effect of breed on various parameters is still widely debated, most studies concur that breed has a significant impact on lipid content (Bauchart et al. 2008; De Barmon et al. 2022).

Meat from transhumant system contains significantly higher levels of dry matter (p=0.002), lipids, and fibre compared to meat from sedentary system, which has notably higher ash content and water levels. These findings do not align with those of Prolio et al., who demonstrated that animals from sedentary system should exhibit higher intramuscular lipid levels due to their energy-rich diets, high nutritional intake, or limited exercise associated with intensive production systems (Priolo et al. 2022). The elevated intramuscular lipid levels in animals from the transhumant system may be attributed to their significantly older age compared to those from the sedentary system. Indeed, according to Hocquette et al. (2015), an animal's capacity to deposit intramuscular fat increases with age (Hocquette et al. 2015; Cassignol 2018).

The lower water content in animals from transhumant system may be linked to their older age compared to those in sedentary system. According to Murat (2009), younger animals have muscle tissue with higher water content. This could be due to the challenges older animals face in maintaining and regulating water balance (Ritz et al. 2004). Additionally, the limited water availability for cattle in Sudano-Sahelian zone, caused by harsh environmental conditions such as high temperatures, scarce water sources, and increased physical activity, further accentuates the differences in meat quality between the two systems. The significantly higher fibre content in meat from transhumant animals is likely related to their diet, which consists mainly of high-fibre grasses.

Animals fed with concentrate exhibited significantly higher lipid levels, likely due to their high-calorie diet, which promotes the deposition of triglycerides in both the carcass and muscle (Bonnet et al. 2010). Moreover, as concentrate is a rich sourceof protein, the increased protein intake stimulates muscle protein synthesis, explaining the significantly higher protein content in these animals. Similarly, grass-fed animals had considerably higher fibre content compared to those fed with concentrate, likely due to their fibre-rich diet.

The evaluation of stress parameters by breed revealed that Goudali meat exhibited significantly lower cortisol levels compared to Red and White Fulani breeds. This difference in serum cortisol concentration, despite the stressful slaughter conditions (such as physical and psychological strain, deprivation of water and food, fatigue or pain, separation from familiar peers, and exposure to unfamiliar environments) may be attributed to the breed's inherent sensitivity to stress, which is influenced by genetic potential and individual animal experience (Terlouw et al. 2008). The significantly lower pH of Goudali meat further supports these findings. According to López-Pedrouso et al. (2020), a pH below 5.8 indicates the absence of stress factors. High levels of stress hormones (catecholamines and cortisol) prior to or during slaughter deplete muscle glycogen reserves, the substrate for lactic fermentation, which is responsible for muscle acidification (Promeyrat 2018; López-Pedrouso et al. 2020). This early depletion of glycogen contributes to lower muscle acidification, resulting in higher pH levels in the White and Red Fulani breeds.

The evaluation of oxidative stress parameters revealed significantly lower catalase, TAC, and FRAP activity in Goudali meat. Bivariate analysis of enzymatic activity in relation to pH showed a positive correlation between pH and the activity of catalase and TAC. The reduced catalase and TAC activity in Goudali breed suggests that these enzymes' activity is negatively impacted by the decrease in pH, unlike FRAP and SOD, which appear unaffected. These findings align with those of Pastsart et al. (2013), who demonstrated that SOD activity is not influenced by pH (Lyons et al. 1996; Pastsart et al. 2013). The decline in antioxidant capacities (in the meat of the Goudali breed) would promote the accumulation of products resulting from the peroxidation of lipids, proteins, and carbohydrates, which could be implicated in various diseases (Huang et al., 2019). This highlights the importance of better preserving the antioxidant status of livestock animals to ensure not only the nutritional quality of the meat but also human health (Sottero et al., 2019). However, no significant differences in MDA production were observed across the groups. Further research is required to better understand the specific role of these enzymes in preventing oxidative damage (Pastsart et al. 2013).

Regarding the impact of production system on stress parameters, the results showed that animals from sedentary system had significantly lower serum cortisol concentrations ($p<0.001$) compared to those from transhumant system. These findings are consistent with those of Hanekon (2010), who demonstrated that lambs from transhumant systems are more sensitive to pre-slaughter stress due to their lack of familiarity with confinement (milking) and handling (herding, transport, and slaughter) (Hanekon 2010).

The evaluation of meat pH based on production system shows that transhumant system produces meat with significantly higher pH levels compared to sedentary system. This may be attributed to the daily movement of animals in the transhumant system, which promotes energy expenditure rather than its storage as reserves. Regarding the impact of feeding type on oxidative stress, the results reveal that despite their lower pH (pH=5.7), grass-fed animals have significantly higher levels of catalase and TAC compared to concentrate-fed animals. This could be due to the grass-based diet being rich in antioxidant compounds. These findings align with Boulefrek (2016), who demonstrated that forage extracts are richer in polyphenols than concentrates (Boulefrek, 2016).

The evaluation of the impact of different breeds on meat taste and texture shows that Goudali breed is significantly less tender than White and Red Fulani breeds. These findings are consistent with those of Olleta et al. (2008), who identified tenderness as the parameter most influenced by breed. Dransfield et al. (2005) also noted that variations in tenderness are linked to differences in muscle fibre composition, connective tissue, and intramuscular lipids, which vary among breeds (Dransfield et al. 2005, Listrat et al. 2015). The perceived difference in tenderness might also be associated with the meat's pH. The lower pH of Goudali meat may inhibit the activity of tenderization enzymes, such as calpains, which function optimally at neutral pH. These proteases break down cytoskeletal proteins, facilitating further and more complete proteolysis (Promeyrat 2018). The reduced activity of these enzymes might explain the decreased tenderness in this breed.

The assessment of fresh meat color revealed that meat from White Fulani breed is significantly darker red compared to that of Goudali and Red Fulani breeds. According to López-Pedrouso et al. (2020), differences in color characteristics can be attributed to genetic factors (Lanari et al. 2002, López-Pedrouso et al. 2020). The judges preferred the darker meat color, which contrasts with the Livestock Institute's report on the "quality of carcasses and beef of large cattle", stating that darker-coloredmeat typically experience substantial commercial devaluation, averaging around 30-35% (Livestock Institute 2007). These results highlight the strong influence of origin, culture, and consumption habits on consumer preferences regarding beef quality.

The evaluation of organoleptic parameters reveals that meat from transhumant system is noticeably less tender than that from sedentary system. This difference can be partly attributed to the older age of animals in the transhumant system, which results in stronger heat-resistant collagen fibre bonds (Hafid 2015). Our findings also confirm a clear consumer preference for darker-colored meats. Animals from sedentary system, which produce meat with significantly more favored coloration, are better aligned with this preference. Multivariate analysis indicates that meat from sedentary system is 3.8 times more likely to be appreciated for its color compared to meat from the transhumant system. This preference for darker meat is not merely a trend but a consumer demand that the meat industry must adapt to in order to remain competitive.

The assessment of the impact of diet on organoleptic parameters reveals intriguing differences. Despite their lower pH, grass-fed animals exhibited significantly greater tenderness compared to fodder-fed animals. However, these findings contradict those of Oury et al. (2007), who found that, given the same feed level, the type of feed (dry or wet forages) has minimal effect on the tenderness and juiciness of the meat. In contrast, Realini et al. (2004) demonstrated that grazing management is more conducive to meat maturation. After 7 to 14 days of maturation, meat from concentrate-fed animals had a shear force 7% higher than that from pasture-grazed animals (Realini et al. 2004).

Furthermore, the findings have significant implications, showing that grass-fed animals produce meat with superior taste and juiciness compared to concentrate-fed animals. This can be attributed to the influence of a grass-based diet, as opposed to a cereal-based one, on the flavour of beef. The composition of tissue fatty acids plays a crucial role, as these acids determine the volatile compounds released during cooking. Aldehydes, ketones, and terpenes, which are more abundant in grass-fed beef, are closely associated with enhanced flavour (Geay et al. 2002).

Meat from animals fed commercial feed, which had a noticeably darker color, was significantly more appreciated than that from grass-fed animals. These findings align with those of Soro et al. (2020), who demonstrated that grain-fed animals produce darker meat compared to grass-fed animals (Soro et al. 2020).

To produce high-quality meat that meets both nutritional and organoleptic expectations while optimising oxidative status, it is recommended to prioritise a grass-based diet rich in antioxidants and fibre. This approach helps reduce the risk of diseases related to oxidative stress, such as cardiovascular diseases, while improving the tenderness and flavour of the meat. The sedentary system, which produces more tender and highly appreciated meat, should be encouraged, particularly by reducing pre-slaughter stress to preserve organoleptic qualities. Diversifying the offer by promoting meat from both grass-fed and concentrate-fed animals could thus contribute to better food security and enhanced public health in sub-Saharan Africa.

REFERENCES

AFNOR 1994. French Association for Standardization T90000.

Bauchart D, Chantelot F, Gandemer G. 2008. Nutritional qualities of beef and offal: recent data on the main constituents of nutritional interest. Cahiers de Nutrition et de Diététique 43:1S29-1S39.

Blagna S, Koté B, Tellah M, Djalal AK, Ouédraogo J, Mopaté LY, Boly H. 2020. Survival and abilities of calves from crossbreeding between Brown Swiss and Fulani Zebus in the Cascades region of Burkina Faso. Revue d'élevage et de médecine vétérinaire des pays tropicaux., 73: 239-246. doi: 10.19182/remvt.31942.

Bonnet M, Gruffat D, Hocquette JF. 2010. Lipid metabolism in adipose muscle tissues. In: Bauchard D., Picard B. (editors). Muscle et viande de ruminant. Paris: QUAE, pp. 79-88.

Boulefrek FZ. 2016. Nutritional characteristics, effect of feeding, and meat preservation abilities of local and imported bovine meat. Master's thesis, Abdelhamid Ibn Badis University–Mostaganem. Agronomy. Food Biotechnology Option. 62p.

Cassignol V. 2018. Factors determining the sensory quality of beef: the importance of breed? Viandes et Produits carnés. VPC-2018-34-1-5, Paris. 10: 3-4. https://www.viandesetproduitscarnes.fr/index.php/fr/processtechnologies/904-facteursdeterminant-la-qualite-sensorielle-de-la-viande-bovine-quelle-importance-de-la-race.

De Barmon AN, Legrand I, Normand J, Cos I, Madrange P, Denoyelle C. 2022. What farming factors influence marbling in beef? Viandes et Produits Carnés. p11.

Dransfield E, Ngapo TM, Nielsen NA. 2005. Consumer choice and suggested price for pork as influenced by its appearance, taste and information concerning country of origin and organic pig production. Meat Science. 69: 61-70.

Ferguson DM, and Warner RD. 2008. "Have we underestimated the impact of pre-slaughter stress on meat quality in ruminants?" Meat Science. 80:12. https://doi.org/10.1016/j.meatsci.2008.05.004.

Folch J, Lees M, Stanley GHS. 1957. Une méthode simple pour l'isolement et la purification des lipides totaux des tissus animaux. Journal of Biological Chemistry. 226: 497-509.

Geay Y, Bauchart D, Hocquette JF, Culioli J. 2002. Nutritional value and sensory qualities of ruminant meats. Influence of animal feeding. INRAE Productions Animales. 15: 37-52.

Gobert M., Damon M., Durand D. 2013. Oxidative stress and nutritional qualities of animal products. Cahiers de Nutrition et de Diététique. 48: 225–232. doi: 10.1016/j.cnd.2013.04.006.

Hafid 2015. Effect of age at slaughter on carcass characteristics and meat quality of ISA strain spent laying hens (F15). Thesis submitted to the University of the Institute of Nutrition. Food. and Agro-Food Technologies. Food Science Option: Food Technology. 127p.

Hanekon 2010. The effect of extensive and intensive production systems on the meat quality and carcass characteristics of Dohne Merino lambs, Thesis for the degree of Master of Science in Food Science at Stellenbosch University, Department of Food Science Faculty of AgriSciences. pp 155.

Hocquette JF, Cassar-Malek I, Jurie C, Bauchart D, Picard B, Renand G. 2015. Muscle characteristics of cattle selected for muscle growth. Viandes et Produits carnés. VPC-2015-31-4-2 https://www.viandesetproduitscarnes.fr/index.php/fr/processtechnologies/678-caracteristiques-musculaires-des-bovinsselectionnes-pour-la-croissance-musculaire.

Huang X, and Ahn DU. 2019. Lipid oxidation and its implications for meat quality and human health. Food Science and Biotechnology. DOI: 10.1007/s10068-019-00631-7.

Labonne M, Magrong P, Oustalet Y. 2003. The livestock sector in Cameroon and the provinces of the Far North: current situation, constraints, challenges, and prospects. Hal Open Archives. 12p.

Lanari MC, Brewster M, Yang A, Tume RK. 2002. Grazing and finishing grain affect beef color stability. Journal of Food Science. 67: 2467–2473.

Lebret B, and Picard B. 2015. The main quality components of carcasses and meat in different animal species. INRA Animals Productions. 28: 93-98.

Listrat A, Lebret B, Louveau I. 2015. How the structure and composition of muscle determine the quality of meat or flesh," Special Issue. Muscle and Meat. INRA Animals Productions. 28: 125-136.

Livestock Institute 2007. Overview of... The quality of carcasses and beef in large cattle. Study report n° 17 05 32 022. Department of Livestock Techniques and Quality. Meat Quality Service. 72p.

López-Pedrouso M, Rodríguez-Vázquez R, Purriños L. 2020. "Sensory and physicochemical analysis of meat from different bovine breeds in various animal production systems, pre-slaughter handling conditions, and aging time". Foods. 9: 1-18. doi:10.3390/foods9020176.

Lyons TJ, Liu H, Goto JJ, Nersissian A, Roe JA, Graden JA, Café C, Ellerby LM, Bredesen DE, Gralla EB, Valentine JS. 1996. Mutations in copper-zinc superoxide dismutase that cause amyotrophic lateral sclerosis alter the zinc binding site and the redox behavior of the protein. Proceedings of the National Academy of Sciences of the United States of America. 93: 12240-12244.

Maraval I, Bugaud C, Forestier-Chiron N. 2018. Guide RTBFoods. Montpellier (France). Guide RTBfoods Project. 50 p.

Misra and Fridovich. 1972. Détermination du niveau de superoxyde dismutase dans le sang total. Yale University Press New Haven. 101-109.

Murat M. 2009. Human nutrition and food security. 1st edition. Tec & doc Lavoisier. France. p 678.

Normand J, Moevi I, Lucbert J, Pottier E. 2005. Overview of cattle and sheep feeding and meat quality.

Olleta JL, Sañudo C, Monsón F. 2008. Sensory evaluation of several European cattle breeds in Olaizola A. (ed.), Boutonnet JP (ed.), Bernués A. (ed.). Mediterranean livestock production: uncertainties and opportunities Zaragoza: CIHEAM / CITA / CITA Mediterranean Options: Series A. Mediterranean Seminars. 78: 297-300.

Oury MP, Picard BB., Istasse I, Micol DD, Dumont R. 2007. Mode de conduite en élevage et tendreté de la viande bovine. Productions Animales. 20 : 309-326. ffhal-02663759f.

Oyaizu M. 1986. Études sur les produits des réactions de brunissement : activités antioxydantes des produits de réaction de brunissement préparés à partir de la glucosamine. Japanese Journal of Nutrition and Dietetics. 44: 307-15.

Pastsart U., De Boever M., Claeys E. 2013. De Smet S, Effect of post-mortem muscle pH and temperature drop on antioxidant enzyme activities in bovine meat. Meat Science. 93: 681-686.

Pietrzak M, Greaser ML, Sosnicki, A.A., 1997. Effect of rapid rigor mortis processes on protein functionality in pectoralis major muscle of domestic turkeys. Journal of Animal Science 75: 2106-2116.

Prieto P, Pineda M, Aguilar M. 1999. Quantification spectrophotométrique de la capacité antioxydante par la formation d'un complexe de phosphomolybdène: application spécifique à la détermination de la vitamine E. Analytical Biochemistry. 269:337-341.

Priolo A, Micola D, Agabriela J, Prachea S, Dransfield E. 2002. Effect of grass or concentrate feeding systems on lamb carcass and meat quality. Meat Science. 62: 179-185.

Promeyrat A. 2018. Post-mortem muscle evolution and Meat Science. Mémento viandes et charcuteries. 1: 12.

Realini CE, Duckett SK, Brito GW, Dalla RM, De Mattos D. 2004. Effect of pasture vs concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. Meat Science. 66: 567-577.

Ritz P, Sallé A, Berrut G. 2004. Variation in the water balance of the elderly. Nutrition Clinique et Métabolisme. 18: 205-211. doi: 10.1016/j.nupar.2004.09.006

Sadaka C. 2011. Chemical composition and nutritional interest of beef based on the INRA 2007 data analysis for the Meat Information Center. Alimentation et Nutrition. ffdumas-01076976.

Sinha AK. 1972. Dosage colorimétrique de la catalase. Analytical Biochemistry, 47:389–394. doi:10.1016/0003-2697(72)90132-7 10.1016/0003-2697(72)90132-7.

Soro S, Assi YA., Traore B, Fantodji A. 2020. Some organoleptic characteristics and nutritional values of Thryonomys swinderianus (Temminck, 1827) meat raised in captivity and fed two types of feed. International Journal of Biological and Chemical Sciences, 14: 1576-1584.

Sottero B., Leonarduzzi G., Testa G., Gargiulo S., Poli G., Biasi F. 2019. Lipid oxidation derived aldehydes and oxysterols between health and disease. Eur J Lipid Sci Technol, 15,12. doi: 10.1002/ejlt.201700047.

Sounon AKLS, Ickowicz A, Lesnoff M, Messad S, Valls-Fox H, Houinato, MRB. 2019. Impact of sedentarization of livestock breeders on bovine production in northern Benin. Livestock and Veterinary Medicine Journal of Tropical Countries. 72: 93–99. doi: 10.19182/remvt.31778.

Terlouw EMC, Arnould C, Auperin B, Berri C, Le Bihan-Duval E, Deiss V, Lefèvre F., Lensink, B.J., Mounier, L. 2008. Preslaughter conditions, animal stress and welfare: current status and possible future research. Animal. 2: 1501-1517.

Van Soest P, Robertson J., Lewis BA. 1991. Methods for dietary fiber, detergent fiber, and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science. 74 : 3583-3597.

Wilbur KM, Bernheim F, Shafiro OW. 1949. Détermination de la peroxydation lipidique. Archives of Biochemistry. 24:305-3