BLOOD GLUCOSE, CORTISOL AND SOME MEAT QUALITY CHARACTERISTICS OF COWS FROM BEEF AND DAIRY PRODUCTION SYSTEMS

Yonela Z. Njisane and Voster Muchenje*

Department of Livestock and Pasture Science, University of Fort Hare, P. Bag X1314, Alice 5700, South Africa

*vmuchenje@ufh.ac.za

Abstract – The objective of the study was to assess blood glucose and cortisol, pH_{24}, colour (L*, a*, b*), thawing-drip-cooking losses and Warner Bratzler Shear Force (WBSF) of slaughter cows from a dairy and a beef production system. Forty four cows from two different breeds (19 Friesland and 25 Bonsmara) were used for the study. Animal behavior was observed during lairaging. Two exsanguination blood samples were obtained from each cow for glucose and cortisol analysis. Furthermore, 44 meat samples were harvested from the shoulder muscle for measurements of pH_{24}, colour (L*, a*, b*), thawing loss (TL), drip loss (DL), cooking loss (CL) and WBSF. Glucose levels did not differ (P>0.05) between breeds, while Cortisol was higher in Bonsmara (273.7±18.0) than Friesland (104.9±20.7). Colour variable b* and TL did not differ (P>0.05) between breeds. The Friesland had higher pH24 (5.9±0.6), CL (37.8±1.1) and WBSF (54.1±2.2) than the Bonsmara (5.7±0.5, 33.6±0.9 and 45.8±1.9, respectively). Variables L*, a* and DL were higher in Bonsmara samples than in Friesland samples. Even though the Friesland breed seemed generally more social towards humans in the lairages and had lower cortisol levels compared to the agitated Bonsmara, it produced meat of lower quality with regard to tenderness, colour and cooking properties than the latter.

Key Words – Production system, Lairage behaviour, Meat Classification.

I. INTRODUCTION

Different cattle breeds are kept in a wide range of production systems according to their specific traits. Nevertheless, at the end of their production cycle, they are culled, sometimes fattened and slaughtered for meat production regardless of their initial function. Due to different management systems, the meat quality from these cattle is expected to differ. However, the red meat classification system post dressing does not cater for the differences caused by selection and production system, it only addresses what is observed on the carcass. The South African red meat classification criterion includes classes like sex, age, conformation, fat and bruising. The purpose served by this is to allow the consumers to select meat according to their partialities (1). Nonetheless, not all details that could influence the choices are made available.

This practice also occurs for dairy producing cows. Bazzoli *et al*. (2) listed the major reasons for culling dairy cows as reproductive failure, mastitis and udder problems, low milk production, and old age. Rogers *et al*. (3) reported that one of the options dairy farmers have when culling non-productive or diseased cows is to sell them at a salvage value to slaughter plants. Generally, in South Africa, beef producing cattle breeds are kept extensively in either natural or cultivated pastures with the aim of increasing muscle growth as well as meat quality and quantity; while dairy producing cattle breeds are mostly fed supplemental diets to primarily enhance milk production, quality and quantity. Soji *et al*. (4) reported that this practice can influence the carcass (lean-to-fat ratio, dressing percentage and conformation) and meat (taste, colour and texture) quality traits.

Apart from the nutrition differences of the two systems, dairy cattle are more exposed to human interactions on a daily basis during milking and feeding and this may be favourable prior to slaughter by allowing ease during handling. Unlike dairy cows, beef cattle only have minimal contact with humans, mostly during management procedures like weighing, vaccination, regrouping and dipping. Cattle mostly perceive these rare interactions as being hostile (5) thus sometimes resulting to fear of humans (6; 7). In addition, exposure to unfamiliar human beings either at the farm or abattoir is likely to frighten slaughter animals (8; 5). Grandin (9) reported that cattle perceive the abattoir environment in the same way as at the farm during procedures like vaccination and other managerial processes that involve moving animals through the race.

Blood cortisol and glucose levels have been used to determine short-term stress due to handling and pre-slaughter activities in general. Both cortisol and glucose were reported to increase with handling and transportation, and was also observed more on temperamental cattle than on calm ones (10; 11). These biochemical changes in the animal's system, mainly due to stress, then affect the quality of meat produced (12; 13). An increase in blood glucose and cortisol in the muscle results in glycolysis, and thus in the formation of lactic acid and also in decreased meat pH, increased WBSF, cooking loss, drip loss and lightness of the meat (14; 15). The aim of this study was then to assess blood glucose and cortisol, pH_{24}, colour (L*, a*, b* values), thawing loss, drip loss, cooking loss and WBSF of slaughter cows from dairy and beef production systems.

II. MATERIALS AND METHODS

Ethical clearance and study site

Consent to carry out the study was approved and issued by the University of Fort Hare Ethical Clearance committee (Reference Number: MUC03S1NJI01). The data was collected from the East London abattoir. The abattoir is a typical high throughput commercial operation, equipped with modern technology to enhance production efficiency. It operates according to the standard laws and regulations governing abattoirs, under "The Meat Act, 2000, the Animal Protection Act, 1962 and 1935 for animal welfare maintenance" to ensure public health safety.

Animal Description, Lairaging and Slaughter

Two groups of cows of the same age group (class C) from a dairy and beef production systems were selected at the abattoir lairages. The dairy system was represented by 19 Friesland culls and the beef production by 25 Bonsmara cows. Information on the animals' background was accessed through the abattoir manager. These cows were kept in groups of 7-9 animals in a 5.3 m × 5.3 m area space per lairage pen overnight with ad lib access to water.

On the day of slaughter, they were partially observed for their general responses to the presence of humans around the lairage aisles. The Friesland group seemed to be more social towards humans, curious and not bothered by the presence of humans around the lairages. This was not the case for the Bonsmara group: they kept their distance from humans at least 2-3 m away, limited by the enclosure of the lairage.

When moved towards the slaughter floor, there was minimal animal-human interaction as the animals directions were led by the narrow crush connecting the holding pens and restraining or stunning areas. A gun stunner was used to terminate the cattle's consciousness before exsanguination was initiated using a sharp knife to cut the jugular vein across the animals neck. A Horizontal bleeding method was used for all cows.

Blood & Meat Sampling & analysis measurements

Two sets of blood samples were obtained from each animal into two vacutainer tubes during the process of exsanguination after the stunning processes for glucose and cortisol analysis. This was done to determine the stress levels of the two breeds. The samples were kept in ice until separation of serum through centrifuging at 21°C for 10 min at 3000 rpm.

After carcass dressing, forty four meat samples of 100-200 g were collected from the shoulder muscle of each cow. This muscle was made available for sampling by the abattoir, but not the usual *longissimus dorsi* muscle to protect their production quality, quantity and profit. The samples were analysed for pH_{24} and colour (L*, a*, b* values). Further measurements for thawing loss (TL), drip loss (DL), cooking loss (CL) and Warner Bratzler Shear Force (WBSF) were done and analysed.

Statistical analysis

The data obtained was analysed using SAS (16) statistical package. The effect of the breed/background on Glucose and Cortisol, Meat pH, Colour, Thawing, Drip and Cooking Losses and WBSF was analysed by ANOVA using Proc GLM for. Pearson's correlation coefficients between the variables were also determined (16). The model used was: $Y_i = \mu + \alpha_i + e_i$

III. RESULTS AND DISCUSSION

Blood Cortisol and Glucose results

Table 1 shows results that glucose levels did not differ (P>0.05) between breeds. However cortisol was higher in Bonsmara (273.7±18.0) than in Friesland (104.9±20.7). Cortisol was reported to increase with handling and transportation more on temperamental cattle than on calm ones (10; 11). This may have been the case with the Bonsmara breed which was observed to keep their distance from human beings at the lairages compared to the more social Friesland breed. Additionally, these observations could be linked to the previous exposures of these animals to handling at the farm, allowing the group from a dairy farm to exhibit better results than the other group.

Table 1: The effect of breed on glucose, cortisol, Meat pH_{24}, colour (L*, a*, b*), TL, DL, CL and WBSF

Parameter	*Bonsmara*	*Friesland*	*P.Value*
Glucose	5.6±0.1	5.4±0.2	NS
Cortisol	273.7±18.0^a	104.9±20.7^b	P <0.001
pH_{24}	5.7±0.5^b	5.9±0.6^a	P <0.05
L*	28.9±0.5^a	26.8±0.6^b	P <0.05
a*	18.8±0.4^a	17.4±0.5^b	P <0.05
b*	13.9±0.4	13.1±0.5	NS
TL (in %)	5.4±0.4	5.3±0.5	NS
DL (in %)	5.8±0.2^a	4.9±0.2^b	P <0.05
CL (in %)	33.6±0.9^b	37.8±1.1^a	P <0.05
WBSF (in N)	45.8±1.9^b	54.1±2.2^a	P <0.05

Means in the same row with different superscripts are significantly different at P<0.05, P<0.001, NS-Not significant, TL-thawing loss, DL-drip loss, CL-cooking loss and WBSF-Warner Bratzler Shear Force.

Meat pH, Colour, TL, DL, CL and WBSF

Table 1 also reveals that the b* value and TL did not differ (P>0.05) between breeds. However, even though behavior in the lairages and exsanguination blood parameters looked better for the Friesland breed, these animals produced meat with higher pH_{24} (5.9±0.6), CL (37.8±1.1) and WBSF (54.1±2.2) compared to the Bonsmara which had lower values (5.7±0.5, 33.6±0.9 and 45.8±1.9, respectively).

The higher WBSF and cooking loss values for the Friesland could be attributed to the fact that for a greater part of the cows' developmental cycle, feeding was focused on enhancing milk production rather than muscle quality. Additionally, dairy animals are normally selected for strong and well attached suspensory ligament in favor of udders. Therefore, the tough muscle is within their genetic makeup. In contrast, Jurie *et al*. (17) found no breed differences on meat tenderness of Holtein (dairy) and Salers (beef) cull cows slaughtered at the same age and fattening level.

The Bonsmara cows produced meat of significantly lower pH_{24} despite their high cortisol levels. This is in contrast with results reported that high cortisol levels in the blood result to glycogen depletion and increase meat pH_{24} thus inducing DFD meat (18). Okeudo and Moss (19) associated cortisol increase with decreased initial mutton pH. In addition, the Bonsmara cows produced meat that is lighter (28.9±0.5), redder (18.8±0.4) and tender (45.8±1.9) than the Friesland cows. These results confirm those that were observed by Wulf *et al*. (20) and Hayes *et al*. (21) that lighter, more red and yellow meat is more tender.

Correlations between the studied variables

Table 2 shows a positive correlation (P<0.05) between blood glucose and cortisol levels. Both these blood parameters are determinants of short term stress such as handling and transportation. Tarrant *et al*. (10) and Hulbert *et al*. (11) reported that cortisol and glucose increase more with handling and transportation. Cortisol is also correlated negatively (P<0.01) with CL. These results confirm those reported by Okeudo and Moss (19) on a study on sheep and mutton quality. Increased meat pH resulted in elevated glycogen depletion thus Dark-Firm-Dry meat (18).

This is in agreement with the current results that

Table 2: Correlations between blood parameters and some meat quality variables

Variables	*Cortisol*	*pH_{24}*	*L**	*a**	*b**	*TL*	*DL*	*CL*	*WBSF*
Glucose	0.34*	-0.19	-0.15	-0.74	-0.03	0.15	0.34	-0.16	-0.03
Cortisol		-0.29	0.07	0.08	-0.01	0.07	0.28	-0.37**	-0.21
pH_{24}			-0.49***	-0.26	-0.34*	-0.13	-0.48***	0.11	-0.001
Lightness (L*)				0.23	0.45**	0.04	0.24	-0.01	0.02
Redness (a*)					0.81***	-0.16	0.20	-0.32*	-0.09
Yellowness (b*)						-0.03	0.24	-0.14	-0.01
TL (in %)							-0.12	0.29	-0.04
DL (in %)								-0.30*	-0.18
CL (in %)									0.24

Significantly correlated at *P<0.05, **P < 0.01, ***P <0.001, thawing loss (TL), drip loss (DL), cooking loss (CL) and Warner Bratzler Shear Force (WBSF) showed a negative correlation between pH_{24} and L* (P<0.001); a* (P<0.05); and DL (P<0.001). Furthermore, DL negatively correlated (P<0.05) with CL. The more water and nutrients lost during thawing, the less there will be available to lose at cooking.

IV. CONCLUSION

The Friesland dairy breed seemed generally more calm and social towards humans in the lairages and had lower blood cortisol levels after slaughter. However, compared to the more agitated Bonsmara beef breed, the meat harvested from Friesland carcasses was of lower quality with regard to tenderness, colour and cooking properties. Additionally, these two groups may have been classified under the same C age class; however they produced meat of different quality.

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REFERENCES

1. KZN DAEA, 2005. The beef carcass classification system. Retrieved on 04 March 2014 fromwww.agriculture.kzntl.gov
2. Bazzoli, I., De Marchi, M., Cecchinato, A., Berry, D.P. & Bittante, G. (2014). Factors associated with age at slaughter and carcass weight, price, and value of dairy cull cows. Journal of Dairy Science 97:1082-1091.
3. Rogers, C. A., Fitzgerald, A. C., Carr, M. A., Covey, B. R., Thomas, J. D., & Looper, M. L. (2004). On-farm management decisions to improve beef quality of market dairy cows. Journal of Dairy Science 87: 1558–1564.
4. Soji, Z., Mabusela, S. P. & Muchenje, V. Association between animal traits, carcass traits and carcass classification in a selected abattoir in the Eastern Cape Province, South Africa. South African Journal for Animal Science. **In Press**.
5. Probst, J. K., Hillmann, E., Leiber, F., Kreuzer, M. & Neff, A. S. (2013). Influence of gentle touching applied few weeks before slaughter on avoidance distance and slaughter stress in finishing cattle. Applied Animal Behaviour Science 144: 14-21.
6. Boissy, A. 1998. Fear and fearfulness in determining behaviour. In: Grandin T. (Ed.), Genetics and behaviour of domestic animals (pp. 67-111). San Diego, USA: Academic Press.
7. Raussi, S. (2003). Human-Cattle interactions in group housing. Applied Animal Behaviour Science 80: 245-262.
8. Hemsworth, P. H. & Coleman, G. J. (1998). Human-Livestock interactions. In: The stockperson and the productivity of intensively farmed animals. Wallingford: CAB International.
9. Grandin, T. (2006). Progress and challenges in animal handling and slaughter in the U.S.: Sentience in animals. Applied Animal Behaviour Science 100: 129-139.
10. Tarrant, P. V., Kenny, F. J., Harrington, D. & Murphy, M. (1992). Long distance transportation of steers to slaughter: effect of stocking density on physiology, behaviour, and carcass quality. Livestock Production Science 30: 223-238.
11. Hulbert, L. E., Carroll, J. A., Burdick, N. C., Randel, R. D., Brown, M. S. & Balloua, M. A. (2011). Innate immune responses of temperamental and calm cattle after transportation. Veterinary Immunology and Immunopathology 143: 66-74.
12. Ferguson, D. M. & Warner, R. D. (2008). Have we underestimated the impact of pre-slaughter stress on meat in ruminants? Meat Science 80: 12-19.
13. Hemsworth, P. H., Rice, M., Karlen, M. G., Calleja, L., Barnett, J. L., Nash, J. & Coleman G. J. (2011). Human–animal interactions at abattoirs: Relationships between handling and animal stress in sheep and cattle. Applied Animal Behaviour Science 135: 24-33.
14. Choe, J. H., Choi, Y. M., Lee, S. H., Nam, Y. J., Jung, Y. C., Park, H. C., Kim, Y. Y. & Kim, B. C. (2009). The relation of blood glucose level to muscle fiber characteristics and pork quality traits. Meat Science 83: 62-67.
15. Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P. E. & Raats, J. G. (2009). Relationship between pre-slaughter stress responsive and beef quality in three cattle breeds. Meat Science 81: 653-657.
16. SAS. (2003). SAS/STAT Software Release 6.12. SAS Institute Inc., Cary, NC, USA.
17. Jurie, C., Picard, B., Hocquette, J. F., Dransfield, E., Micol, D. & Listrat, A. (2007). Muscle and meat quality characteristics of Holstein and Salers cull cows. Meat Science 77:459-466.
18. Muchenje, V., Dzama, K., Chimonyo, M., Raats, J. G. & Strydom, P. E. (2008). Meat quality of Nguni, Bonsmara and Aberdeen Angus steers raised on natural pasture in the Eastern Cape, South Africa. Meat Science 79: 20-28.
19. Okeudo, N. J. & Moss B. W. (2005). Serum Cortisol Concentration in Different Sex-Types and Slaughter Weights, and its Relationship with Meat

Quality and Intramuscular Fatty Acid Profile. Pakistan Journal of Nutrition 4:64-68.

20. Wulf, D. M., O'Connor, S. F., Tatum, J. D., & Smith, G. C. (1997). Using objective measures of muscle color to predict beef longissimus tenderness. Journal of Animal Science 75:684-692.
21. Hayes, N. S., Schwartz, C. A., Phelps, K. J., Borowicz, P., Maddock-Carlin, K. R. & Maddock , R.J. (2015). The relationship between pre-harvest stress and the carcass characteristics of beef heifers that qualified for kosher designation. Meat Science 100:134-138.