Effects of age, pasture- and feedlot conditions on energy metabolism and meat quality

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Abstract

Feeding regime and breed type on the energy status of the *post-slaughter* muscle and meat tenderness were investigated. The age groups consisted of A-age (zero permanent incisors) AB-age (one-two incisors) and B-age (three - six permanent incisors) of beef breed crosses. Feedlot animals were raised until required age-classes (A- and AB-age). The pasture animals were introduced to pasture after weaning until required age-classes (A-, AB- and B-age). The animals were slaughtered according to normal South African slaughter procedures and the carcasses were electrically stimulated. Loin samples were analysed at 24 hours *post mortem* for the content of glycogen, glucose, glucose-6-phosphate, lactate, adenosine-triphosphate (ATP) and phosphocreatine (CP). The pH, sarcomere length (SL) and Warner-Bratzler shear force (WBSF) were measured. The results showed that the A-age (pasture) loins were the toughest and AB-age (feedlot) loins the most tender at 1-, 7-, and 14 days *post mortem* compared to the other age-groups. Feedlot carcasses (A- and AB-age) had higher lactate content and the lowest ultimate pH values compared to A-, AB- and B-age pasture carcasses. This is of primary interest because ultimate pH plays a vital role in the overall meat quality.

Introduction

The exact mechanisms involved in the *post mortem* meat tenderisation process and the nature of changes associated with improvement of meat tenderness is complex and not fully understood (Ouali, 1990). The main energy supply to muscles *post mortem* is glycogen deposits. However, the content of CP also contributes to the metabolism of ATP shortly after exsanguinations. Shortly after commencement of *post mortem* phase anaerobic metabolism of glycogen into ATP takes over, and the waste product from this process is lactate. The glycogenolysis continues and pH continues to fall until the stores of glycogen are used up or the metabolic processes stop due to enzymatic arrest cause by low pH (Bendall, 1973). The accumulation of lactate in muscles causes the pH to fall *post mortem*, and the stores of glycogen in the muscles at slaughter will determine the level of ultimate pH (Bendall, 1973). Glucose and glucose-6-phospate are intermediates produced during the transformation of glycogen to lactate. The glycolytic potential (GP) has been used to express the energy level of the entire animal prior to slaughter (Maribo *et al,* 1999). Age of bovine animals has been used in South Africa since 1936 as a characteristic to grade their carcasses, presumably because carcasses of younger cattle were considered to be of "better" quality than those of older cattle (Government Notice No. 1548 of 1936). The objective of this study is to determine if feeding regime has an influence on *post mortem* glycolysis, and if the resultant energy status has an effect on sarcomere length and shear force (tenderness).

Materials and methods

Each test group consisted of 30 cross breed animals. Feedlot animals were raised until required age-classes (A- (zero permanent incisors) and AB-age (one-two incisors)). The pasture animals were introduced to pasture after weaning until required age-classes (A-, AB- and B-age (three - six permanent incisor)). The animals were slaughtered according to normal South African slaughter procedures and the carcasses were electrically stimulated for 15 seconds (400 V peak, 5 ms pulses at 15 pulses per second). Carcasses were chilled directly after dressing at room temperature before loading at 0 - 4°C. Sampling of the *M.longissimus* (LD) for measurement of WBSF, SL and energy status took place 24 hours *post mortem.* LD of both sides was sampled. The position of sampling for each test was consistent. Samples destined for WBSF were vacuum packaged and aged at 2°C ± 2ºC for 1 day, 7- and 14 days *post mortem.* The sarcomere lengths were measured at 1 and 3 days *post mortem* and WBSF was measured as described by Strydom and Frylinck (2005). A muscle sample (3g) was frozen in liquid nitrogen until analysis of the concentrations of ATP, glucose-6-phospate, lactate, CP, glycogen and glucose. The extraction from the frozen sample was done according to Dalrymple and Hamm (1973). The glycogen concentration was determined as glycosyl units after hydrolysis with α-amyloglycosidase according to Keppler and Decker (1974). The glucose in the perchloric acid extract filtrate was also determined and the glycogen concentration corrected. ATP, glucose-

6-phosphate and CP were determined in the perchloric acid extract according to the method of Lamprecht, Stein, Heinz and Weisser (1974), and the lactate concentration according to the method of Gutmann and Wahlefeld (1974). The glycolytic potential (GP) was calculated as the sum of: 2(glycogen, glucose, glucose-6-phosphate) plus lactate (Monin & Sellier, 1985). The data were subjected to a three way analysis of variance. Means for the main effects were separated using Fisher's protected t-test least significant difference (LSD) at the 5% level (Snedecor & Cochran, 1980).

Results and discussion

The energy status and pH at 24 hours *post mortem* are presented in Table 1 for the different age groups (pasture and feedlot) studied.

Table 1. Energy status and pH for the different age groups

	pH	**G6P**	**Glu**	**Gly**	**Lac**	**ATP**	**CP**	**GP**
24 hours *post mortem*								
AF	5.475^{a}	7.400	4.319^{b}	15.24^{a}	84.46^{b}	2.958	5.689^{a}	138.37^{ab}
ABF	5.633^{b}	7.873	4.043^{ab}	21.92^{bc}	77.09^{a}	3.312	5.912^{ab}	144.76^{abc}
AP	5.673^{b}	8.247	4.339^{b}	25.90^{c}	75.68^{a}	3.333	5.204^{a}	152.65^{c}
ABP	5.654^{b}	8.379	3.783^{a}	24.64^{c}	72.29^{a}	3.045	5.932^{ab}	145.90^{bc}
BP	5.643^{b}	7.529	3.643^{a}	18.08^{ab}	73.18^{a}	3.112	6.601^{b}	131.69^{a}
P value	**<.001**	**=.624**	**<.022**	**<.001**	**<.001**	**=.788**	**<.015**	**<.024**

Significant differences were found for pH, glucose, glycogen, lactate, CP and GP considering the various age groups (pasture and feedlot). At 24 hours *post mortem* the AF, ABF and BP carcasses were similar for the GP levels but differed from the AP and ABP carcasses. When considering all the carcasses, the BP carcasses had the lowest GP levels compared to the other carcasses, thus lower energy levels for the muscle prior to slaughter (Maribo *et al*, 1999).

Glycolysis occurs in *post mortem* muscle and produces lactic acid that accumulates because the circulatory system is not functioning and causes a decline in muscle pH from approximately 7.0 at the time of death to 5.4 to 5.6 in normal beef (Wulf *et al*, 2002). The results from Table 1 indicate that normal carcass conditions and events occurred during the study, because the pH decline in the muscle was normal, thus occurrence of DFD (dark, firm and dry) were limited. According to Wulf *et al* (2002) dark cutting beef results from lower than normal muscle glycogen stores at the time of slaughter, which causes lower than normal lactic acid production after slaughter and a higher than normal ultimate meat pH. The lactate production at 24 hours *post mortem* indicates that the AF carcasses were significantly different from the other carcasses and this corresponds with the ultimate pH values. According to Henckel *et al,* (2000) the pH decrease is determined by the physiological conditions of muscles at the time of stunning and can be related to lactate production, or to the capacity of the muscle to produce energy in the form of ATP. No significant differences were found for ATP levels in the study, but the AF carcasses had significant higher lactate production compared to the other carcasses and this could explain the lower ultimate pH value. At 24 hours *post mortem* AF and BP carcasses had similar glycogen levels (lower) compared to the other carcasses. The BP carcasses were similar to the AF and ABF carcasses where the ABF, AP and ABP carcasses were similar.

The ABP, ABF and BP carcasses were similar for glucose levels. The ABF carcasses were also similar to the AF and AP carcasses for glucose levels 24 hours *post mortem*. For CP levels the ABF and ABP carcasses don't differ from all the other carcasses and the BP carcasses only differ from the AF and AP carcasses.

The results in Table 2 indicate that significant differences for WBSF (1, 7 and 14 days *post mortem*) and SL were found for the various age groups. At 1 day *post mortem* the WBSF values and SL (shorter, thus less tender) for the AP carcasses differed significantly from all the other carcasses studied. At 7 and 14 days *post mortem* the WBSF values of the AP carcasses were similar to the ABP carcasses. The higher WBSF values of the AP and ABP carcasses indicate the carcasses were less tender compared to the other carcasses studied. The ABF carcasses had the lower WBSF values at 1, 7 and 14 days *post mortem* (more tender) and was similar to the AF and BP carcasses. This also corresponds to the GP levels 24 hours *post mortem* (Table 1). The ABF carcasses at 3 days *post mortem* also had the longer SL (more tender) that differed significantly from the other carcasses studied and this could support the lower WBSF values at 1, 7 and 14 days *post mortem*.

Table 2. Warner-Bratzler shear force and sarcomere lengths for the different age groups

Age Groups	WBSF 1	WBSF 7	WBSF 14	SL 1	SL 3
AF	6.559^{ab}	5.290^{ab}	4.227^{ab}	1.727^{b}	1.747^{b}
ABF	6.037^{a}	4.826^{a}	3.872^{a}	1.753^{b}	1.800^{c}
AP	7.611^{c}	5.969^{c}	4.999^{c}	1.673^{a}	1.701^{a}
ABP	6.826^{b}	5.587^{bc}	4.643^{bc}	1.746^{b}	1.746^{ab}
BP	6.103^{a}	4.950^{ab}	3.935^{a}	1.723^{b}	1.735^{ab}
P value	**<.001**	**<.007**	**<.001**	**<.001**	**<.001**

Conclusions

The regulation of glycogen content in muscle is complex. Results from this study suggest with a decreasing glycolytic potential, decreased glycogen levels, higher lactate production that is associated with lower pH values (not reported) could result in lower tenderness values. Studies that should be considered is the role of different breed types, feeding practices, management practices (i.e. different implant strategies) on the process of glycolysis and if it will influence the end product in terms of meat tenderness.

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