Influence of Age, Sex, and Feeding Regimes of Cattle on Biochemical Changes post mortem, Sarcomere Length and Water-Holding Capacity of Various Muscles

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SUMMARY

The post mortem changes of energyrich compounds like glycogen and ATP with its metabolites in the muscles of a carcass are of paramount importance for quality characteristics of the meat. Shelflife, tenderness, colour, flavour and water-holding capacity are affected. In this paper the effect of age (150 to 650 days old), sex (bulls, steers, heifers), feeding (ad libitum and restricted) on post mortem changes in 130 to 150 animals of the breed "Deutsches Fleckvieh" and in 4 muscles (longissimus dorsi, psoas major, semitendinosus, supraspinam) are reported.

Age does not influence the velocity nor the extent of post mortem biochemical changes; Sex of the animals has no influence on post mortem changes and rarely any influence on the the quality characteristics measured. There exists also no influence on the characteristics studied by feeding regimes used. The main differences exist between muscles. M. psoas major has the fastest post mortem changes in all age groups and sexes, M. longissimus dorsi the slowest post mortem changes. The glycogen concentration of M. supraspinam is about half of the concentration of that of M. longissimus dorsi. In both muscles, however, the pH values at 1 hour and 48 hours post mortem are similar.

The drip losses of M. supraspinam are in general lower than those of the other 3 muscles. Psoas major muscles with pH values of 5.8 and lower at 1 hour post mortem exhibit no sign of PSE characteristics. Various methods for the determination of water-holding capacity have been employed. Drip losses at 1, 3, 6, 8 and 14 days correlate rather close with each other, with centrifugation loss and capillary volumeter measurements, however, the relationships are rather poor.

INTRODUCTION

The velocity and the extent of post mortem changes are of paramount importance for quality characteristics of meat. Chilling regime, ageing conditions are other factors which influence meat quality. The breed and especially in beef the age effect the eating quality like toughness, juiciness and flavour. Furthermore it is reported that feeding may change flavour and meat composition (e.g. ASHGAR and PEARSON, 1980) and also the sex of the animal is hold responsible for composition, flavour and toughness of beef. We took the rare opportunity to study most of these questions in a collective of animals up to 150 individuals of the breed "Deutsches Fleckvieh" which were 150 to 650 days old. Bulls, heifers and steers were divided into two feeding groups with ad libitum and restricted feeding. So except one group (steers with resticted feeding) we obtained in each group data from about 30 animals. Four important muscles were chosen for the investigation: longissimus dorsi, psoas major, semitendinosus and supraspinam. We studied the changes of ATP and its metabolites post mortem, the breakdown of glycogen and the fall of pH, measured the sarcomere length and applied three methods of water-holding capacity determination: the capillary volumeter method and the centrifugation loss at 48 h post mortem and drip loss measurements at 1, 3, 6, 8, and 14 days post mortem in all 4 muscles, 3 sexes and 2 feeding regimes over the whole range of age. With the results we wanted to learn how the changes post mortem influence meat quality characteristics. About the characteristic, water holding capacity in this paper is reported.

MATERIALS and METHODS

Nucleotides and nucleosides were determined with HPLC after the precipitation of a meat homogenate with trichloro acetic acid. An anion exchange resin (Ionospher A of Crompack) was used with elution of a linear gradient of 10 - 95% buffer B within 25 min. Buffer A: 0.006 M phosphate pH 3; buffer B: 0.3 M phosphate pH 6.

Glycogen was hydrolyzed with acid to glucose which was detected with anthrone and thiourea (CARROLL and LONGLEY, 1956).

Sarcomere lengths were measured according to VOYLE (1971).

Drip loss was determined as described by HONIKEL (1987). Centrifucation loss was measured by using 10 g of meat and centrifugation for 20 min at 16 000 rpm in rotor JA-20 or Beckman (28.000 xg). The exudated fluid in % of original weight is presented as centrifugation loss. Capillary volumeter readings were obtained according to FISCHER et al. (1976).

RESULTS and DISCUSSION

1) Biochemical changes post mortem

a) Influence of sex and age

All animals used in this study were offsprings of one father and we were able to investigate intact muscles from about 200 days to about 650 days of age. The results are presented in table 1.

Table 1: ATP- and glycogen concentration in bull meat in dependence of slaughterweight (age) in M. long dorsi and M. psoas major at 1 h post mortem in comparison with the same muscles of heifers and steers

slaughter weight (kg) of bulls	N	ATP concentration (µMol/g) M.long.dorsi $\bar{x} \pm s$	ATP concentration (µMol/g) M.psoas major $\bar{x} \pm s$	Glycogen concentration (mg/g) M.long.dorsi $\bar{x} \pm s$	Glycogen concentration (mg/g) M.psoas major $\bar{x} \pm s$	pH_1 M.long.dorsi $\bar{x} \pm s$	pH_1 M.psoas major $\bar{x} \pm s$
ca. 200	7	4.5 ± 0.7	1.9 ± 1.3	9.7 ± 1.0	4.8 ± 1.9		
ca. 340	4	4.6 ± 1.8	0.95± 0.15	9.8 ± 0.7	5.4 ± 1.5		
ca. 480	6	4.6 ± 0.95	2.0 ± 1.6	8.4 ± 1.9	4.0 ± 1.0		
ca. 550	8	4.8 ± 1.45	1.4 ± 1.4	9.2± 1.3	3.9 ± 1.4		
ca. 625	7	4.2 ± 1.85	2.6 ± 2.2	9.9± 3.0	3.9 ± 1.9		
overall bulls	32	4.5 ± 1.15	1.95 ± 1.6	9.2 ± 2.2	4.0 ± 1.8	6.75± 0.3	5.7 ± 0.25
heifers	28	4.8 ± 0.8	1.50 ± 0.9	8.1 ± 3.5	3.5 ± 2.1	6.6 ± 0.35	5.8 ± 0.25
steers	30	4.8 ± 1.2	2.05 ± 1.2	9.6 ± 2.2	3.8 ± 2.7	6.75± 0.35	5.8 ± 0.25

With the ATP concentration measured at one hour post mortem no influence of age can be seen in M. long. dorsi. In M. psoas major there seems to be a minimum at about 340 kg slaughter weight. As can be seen in table 1 the standard deviation of this weight group (4 animals) is very small. In the other four groups the wide variation causes an increase of deviation which exaggerates the difference of the mean values. The glycogen concentration at 1 hour post mortem is rather uninfluenced by weight. With M. psoas major there is a tendency to lower mean values with increasing weight. Due to the large standard deviation this decrease is not significant. In conclusion: in M. long. dorsi weight (age) does not play a role in post mortem concentrations of ATP and glycogen, in M. psoas major there exists some variation. But the variations within psoas major muscles are small compared to the difference to the concentration of M. longissimus dorsi.

These results in bulls proved to be similar in heifers and steers. As table 1 shows in an overall view, the ATP and glycogen concentrations at 1 hour post mortem between the different sexes are rather small. Heifers show slightly reduced glycogen concentrations. This can be due to a faster pH fall at least in M. longissimus dorsi as the pH_1 in heifers is with 6.6 lower than with 6.75 in steers and bulls. In conclusion: neither sex nor age has a remarkable influence on post mortem changes.

Tabelle 2: ATP-, glycogen concentration and pH at 4 different muscles in bulls, heifers and steers at different times post mortem (N = 28 - 32)

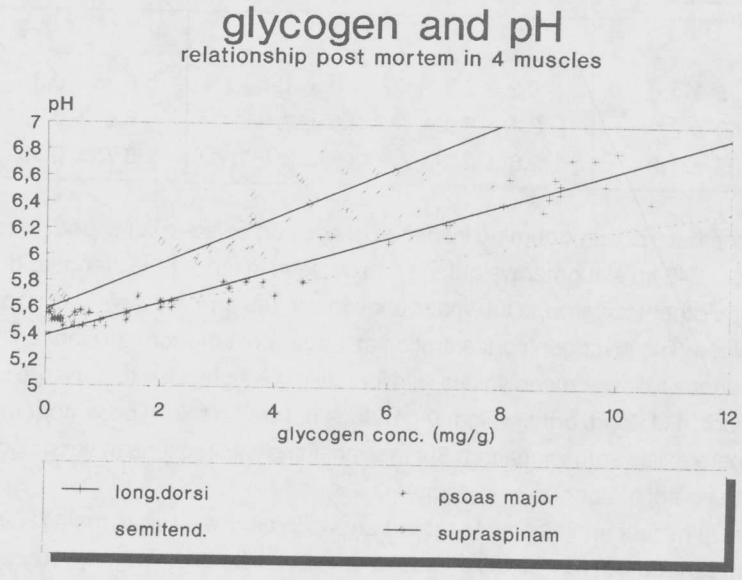
muscle	sex	ATP-concentration (µ Mol/g) $\bar{x} \pm s$ 1 h	3 h	48 h	Glycogen concentration (mg/g) $\bar{x} \pm s$ 1 h	3 h	pH $\bar{x}$ 1 h	3 h	48 h
long. dorsi	bulls	4.5 ± 1.15	3.9 ± 1.65	0.08 ± 0.07	9.2 ± 2.2	8.8 ± 2.3	6.75	6.45	5.4
psoas major	"	1.95 ± 1.6	0.45± 0.5	0.1 ± 0.15	4.0 ± 1.8	2.2 ± 1.8	5.7	5.6	5.4
semitendinosus	"	4.2 ± 1,0	3.7 ± 1.2	0.1 ± 0.08	7.8 ± 2.5	7.1 ± 3.1	6.55	6.25	5.45
supraspinam	"	4.0 ± 1.1	3.5 ± 0.2	0.1 ± 0.1	6.1 ± 1.95	5.2 ± 1.2	6.65	6.35	5.5
long. dorsi	heifers	4.8 ± 0.8	4.15± 1.4	0.1 ± 0.1	8.1 ± 3.5	8.0 ± 3.6	6.6	6.4	5.45
psoas major	"	1.5 ± 0.9	0.7 ± 0.4	0.1 ± 0.1	3.5 ± 2.1	2.2 ± 1.8	5.8	5.65	5.5
semitendinosus	"	4.4 ± 0.8	3.9 ± 1.3	0.1 ± 0.1	5.8 ± 2.5	5.4 ± 3.2	6.5	6.3	5.5
supraspinam	"	4.2 ± 0.8	3.6 ± 1.2	0.1 ± 0.08	4.4 ± 2.7	3.6 ± 2.6	6.6	6.3	5.55
long. dorsi	steers	4.8 ± 1.2	4.15± 1.1	0.1 ± 0.1	9.6 ± 2.2	9.0 ± 1.8	6.75	6.45	5.45
psoas major	"	2.05 ± 1.2	0.4 ± 0.5	0.1 ± 0.05	3.8 ± 2.7	3.2 ± 2.0	5.8	5.65	5.55
semitendinosus	"	4.4 ± 1.0	3.7 ± 1.1	0.1 ± 0.08	5.8 ± 2.7	5.3 ± 2.4	6.5	6.2	5.55
supraspinam	"	4.1 ± 0.5	3.8 ± 1.4	0.1 ± 0.1	5.5 ± 2.0	5.3 ± 1.6	6.6	6.35	5.6

b) Differences between muscles

In table 2 the post mortem changes of ATP-, glycogen concentration and pH are shown for the four muscles studied divided into the three sex groups. It becomes obvious that with ATP concentrations M. psoas major behaves different to the other three

muscles in all sexes. In glycogen concentrations there exists a clear graduation. Long. dorsi muscles have at 1 hour post mortem the highest concentration, followed by semitendinosus, supraspinam and psoas major. Remarkable, however, is the fact that the pH_1 and also pH_{48} values differ with the exception of psoas major much less than the glycogen concentrations. This means that there is not only a different early postmortem glycogen concentration in the living muscles or various rates of pH fall, there exist also various buffering capacities in the muscles. Fig. 1 shows this. Extrapolated at pH 7 (muscle in live animal) supraspinam would have about 8 mg glycogen/g muscle, semitendinosus 10 mg/g, longissimus dorsi about 13 mg/g, psoas major about 20 mg/g. As all four muscles have a final pH of 5.45 to 5.6, the slope varies and this is an expression of the buffering capacity of muscle. This is an astonishing result and needs further investigations. In conclusion: Muscle differences in post mortem changes are larger than those of age or sex. Not shown here but also studied were the feeding influences. There is also no significant influence of feeding on biochemical changes post mortem.

Fig. 1:



2) Changes of sarcomere length

There are no large differences in the sarcomere length of the four muscles which were excised in the prerigor state. The mean value at 1 - 1,5 hours post mortem for all muscles, sexes, ages and feeding regimes is 1.90 ± 0.07 µm. The small standard deviation expresses the uniformity. Minimum values were at 1.78 µm, maximum values at 2.1 µm. At 48 hours the mean value was 1.56 ± 0.13 µm, with minimum values at 1.3 µm and maximum values at 1.8 µm. An explanation for this average shortening of 18% post mortem in the excised muscle cannot be given. Due to the lowering of the temperature 8 - 10% would be expected.

3) Changes in water-holding capacity

Despite the slower pH fall of long. dorsi muscles and pH_1 of 5.7 - 5.8 in M. psoas major (table 2) the drip losses of psoas major muscles at 6 and 14 days post mortem are equal or slightly smaller than in longissimus dorsi muscles (table 3). There is again no influence of sex and age (not shown). Semitendinosus muscles of bulls have the highest drip loss, in between lie longissimus dorsi and psoas major muscles. The lowest drip losses exhibit in M. supraspinam samples. There is an influence of feeding. Muscles of animals fed ad libitum have a tendency to higher drip losses than muscles of animals fed restrictively. At the moment an explanation for this is a pure hypothesis. Collagen variations in crosslinking may cause this.

Table 3: Influence of sex and muscle type on drip loss of beef
(M. long. dorsi $pH_1 > 6.6$, $pH_{24} < 5.65$; M. psoas major $pH_1 < 5.95$, $pH_{24} < 5.5$)

sex	N	drip loss (%) in M. long. dorsi 6 days	14 days	drip loss (%) in M. psoas major 6 days	14 days
bulls	32	5.8 ± 0.7	8.9 ± 2.4	5.6 ± 2.1	9.0 ± 2.3
heifers	28	5.6 ± 1.5	9.2 ± 2.1	5.7 ± 1.7	8.4 ± 2.3
steers	30	6.8 ± 1.5	9.25± 1.6	5.2 ± 1.8	8.4 ± 2.0

Whereas, as table 4 shows, the drip losses measured at various days are closely related to each other, its relationship to centrifugation loss (linear r: 0.12 - 0.50) and capillary volumeter (linear r: 0.29 - 0.37) are rather poor. Centrifugation loss and capillary

volumeter at 48 hours correlate with r = 0.38. There is also a poor correlation to sarcomere length but to centrifugation loss the pH_{48} has a correlationcoefficient of r = 0.48.

Centrifugation loss and capillary volumeter readings show an extreme influence of muscle. M. long. dorsi has 16 - 18% centrifugation loss (48 hours) and 32 - 36 µl capillary volumeter readings (48 hours). M. psoas major 12 - 17% resp. 29 - 36 µl, M. semitendinosus 11 to 13% and 26 - 31 µl supraspinam 6 - 9% resp. 25 - 29 µl. Again as a pure hypothesis variations in collagen tissue may be responsible for the differences.

Table 4: Linear correlation coefficients between water-holding capacity methods, sarcomere length and pH at 48 hours. All animals and muscles are put together in one pool (N = 500 - 600)

	drip 1. day	drip 3. day	drip 6. day	drip 8. day	drip 14.day	ZV 48 h	SL 48 h	pH 48 h
drip 14. day	0.57 a)	0.82 d)	0.93 a)	0.96 a)	-			
ZV 48 h	0.12 c)	0.34 c)	0.46 a)	0.47 a)	0.50 a)	-	0.11 c)	- 0.48 a)
CV 48 h	0.29 b)	0.37	0.35 a)	0.33 a)	0.30 a)	0.38 a)	0.05 c)	- 0.10 c)

a) linear
b) non linear; curve at low drip
c) graphically no dependency recognizable
d) non linear at high drip
ZV = centrifugation loss; CV = capillary volumeter readings; SL = sarcomere length

In conclusion: There are variations in water-holding capacity of the four muscles which cannot be explained with the changes post mortem. The comparability of methods is rather poor.

CONCLUSION

Neither age, sex nor feeding regimes have a remarkable influence on post mortem changes. Different muscles in a carcass vary much wider. This applies also to water-holding capacity measurements. The methods are difficult to compare i.e. measurements obtained with one method do not allow predictions for other variations of water-holding capacity measurement.

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