# The Effect of Postmortem Myotomy on Glycolysis and Ultimate Qualitative Characteristics of Porcine Rectus Femoris Muscles

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Samples of the rectus femoris muscles of 22 pigs were excised according to a postmortem schedule. The rates of postmortem pH decline, levels of some glycolytic metabolites, and qualitative properties of the rectus femoris muscles were determined as well as the effects of postmortem muscle temperature upon the glycolytic metabolites. Rapid chilling of the rectus femoris at early postmortem time periods (0 to 15 min) markedly decreased the effects of the contractile response that accompanied myotomy in the longissimus muscle. The effects of rapid chilling were greater among low quality than in normal quality muscles.

The "redness" or "whiteness" of a muscle has been shown to be due to the varying proportion of red and white muscle fibers (Blanchaer *et al.*, 1963; Brooke, 1966; Dubowitz and Pearse, 1961; Van Wijhe *et al.*, 1963). These authors reported that aerobic metabolism predominates in red fibers and anaerobic metabolism is predominant in white fibers. Red fibers are also characterized by a slow and sustained contractile activity, whereas white fibers contract more rapidly but for a shorter duration. Barany *et al.* (1965); Seidel and Gergely (1963), Seidel *et al.* (1964), and Sreter *et al.* (1966) observed that myosin of red muscle has a lower ATPase activity than that of white muscle.

The rectus femoris is a "red" muscle, while the longissimus is classified as "white" (Beecher *et al.*, 1965). The paleness associated with low qualitative properties is not manifested in the rectus femoris, hence it has been implicated as being more resistant to the development of rapid postmortem pH declines and low qualitative characteristics than the longissimus muscle (Beecher *et al.*, 1965; Briskey, 1964; Briskey *et al.*, 1960). Thus, this study was conducted to determine the effects of myotomy at the time of exsanguination on glycolysis and qualitative properties of the rectus femoris muscle.

## EXPERIMENTAL PROCEDURE

The pigs used for this phase of the study were the same as those previously described for the longissimus muscle (Koch *et al.*, 1970). The postmortem sampling schedule followed for the rectus femoris (RF) muscle is shown in Table I. The 0-hr and 15 min samples were excised as cross-sectional slices (approximately 100 g and 1.5 cm in thickness) of the RF muscle from the proximal (position relative to insertion) one-third of the muscle. The medial third of the muscle was sampled at 45 min and 2 hr, and the distal portion was sampled at 24 hr. Essentially the entire muscle was exposed when the subcutaneous fat was removed to facilitate its identification prior to sampling. The RF muscle samples were prepared, stored, and analyzed as described for the longissimus muscle (Koch *et al.*, 1970); however, the RF was not scored for qualitative characteristics. Muscle temperatures of the pigs in the 15–2 sampling group were recorded at 2 hr postmortem.

## RESULTS AND DISCUSSION

The RF muscle pH values, glycogen, and some glycolytic metabolites are presented in Table II. The differences between means were not considered significant if the probability level was $>0.05$. Analyses of variance were determined on the data within sampling groups and Duncan's Multiple Range test was applied when significant differences were observed. The 0–45 group showed no differences in 0-hr or 45 min pH values between sides (R–RF *vs.* L–RF). In both the 0–2 and 15–2 groups the 2 hr pH values of the L–RF were lower than the 2 hr pH of the R–RF muscles. Since the 24 hr pH values of all samples were similar, the rate and not extent of pH decline was affected. These data indicate that the RF muscles responded differently than the longissimus muscles (Koch *et al.*, 1970); *i.e.*, sample excision at the time of exsanguination appeared to inhibit rather than enhance postmortem glycolysis. The differences in response between the two muscles were unexpected since the RF muscles appeared to contract just as violently as the longissimus muscles following 0 hr myotomy.

Muscle temperatures of the pigs in the 15–2 sampling group at 2 hr (34.2° C, and 38.4° C for R–RF and L–RF, respectively) were statistically different. The removal of skin and subcutaneous fat to facilitate excision of the R–RF muscle samples at 0 hr and 15 min resulted in more rapid heat dissipation from the remaining portion of the incised R–RF muscles than the L–RF which were not exposed until 2 hr postmortem. Consequently the L–RF muscles maintained near normal *in vivo* temperature during this time period (carcasses were not placed in the chill room until 2 hr). A temperature differential between the right (RL) and left (LL) longissimus muscles (Koch *et al.*, 1970) was not observed since the skin and subcutaneous fat were left attached to the

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**Table I. Postmortem Sampling Schedule of the Right and Left Rectus Femoris Muscles**

| Sampling group[a] | No. of pigs | Side | Postmortem sampling times[b] 0 hr | 15 min | 45 min | 2 hr | 24 hr |
|---|---|---|---|---|---|---|---|
| 0–45 | 10 | Right | X | | X | | X |
| | | Left | | | X | | X |
| 0–2 | 5 | Right | X | | | X | X |
| | | Left | | | | X | X |
| 15–2 | 6 | Right | | X | | X | X |
| | | Left | | | | X | X |

[a] Group designation refers to the initial sampling time for the right and left rectus femoris muscle, respectively. [b] X indicates the time of postmortem myotomy.

remaining portion of the longissimus muscle following sample excision. Temperatures of the right and left normal and low quality longissimus muscles at 45 min were 39.5, 39.5, 40.0, and 39.9° C, respectively. Muscle temperatures of the longissimus (both right and left sides) at 2 hr were similar to those of the L–RF muscles, all of which had no skin or subcutaneous fat removed until sample excision at this time period.

Despite the differences in pH decline, no differences in transmission values were noted among the RF muscles. Transmission values for the 0–45, 0–2, and 15–2 sampling groups were 15.6 and 18.4, 11.3 and 9.9, and 11.2 and 12.4, for the R–RF and L–RF muscles, respectively.

Glycogen and lactate levels (Table II) are consistent with

**Table II. The Effect of Myotomy (0 hour) on Postmortem pH Decline and Some Glycolytic Metabolites of the Rectus Femoris Muscle[a]**

| Sampling group | No. of pigs | Side | Postmortem sampling times 0 hr | 15 min | 45 min | 2 hr | 24 hr |
|---|---|---|---|---|---|---|---|
| | | | pH Decline | | | | |
| 0–45 | 10 | Right | $6.44^{d} \pm 0.04$ | | $6.39^{d} \pm 0.08$ | | $5.44^{e} \pm 0.07$ |
| | | Left | | | $6.41^{d} \pm 0.08$ | | $5.43^{e} \pm 0.06$ |
| 0–2 | 5 | Right | $6.55^{d} \pm 0.07$ | | | $6.32^{d} \pm 0.11$ | $5.48^{f} \pm 0.03$ |
| | | Left | | | | $5.84^{e} \pm 0.17$ | $5.39^{f} \pm 0.03$ |
| 15–2 | 6 | Right | | $6.62^{d} \pm 0.07$ | | $6.32^{e} \pm 0.08$ | $5.56^{g} \pm 0.05$ |
| | | Left | | | | $5.90^{f} \pm 0.18$ | $5.47^{g} \pm 0.06$ |
| | | | Glycogen[b] | | | | |
| 0–45 | 10 | Right | $30.5^{d} \pm 4.36$ | | $33.7^{d} \pm 5.93$ | | $6.6^{e} \pm 0.33$ |
| | | Left | | | $35.8^{d} \pm 4.89$ | | $5.1^{e} \pm 0.22$ |
| 0–2 | 5 | Right | $36.4^{d} \pm 5.31$ | | | $30.8^{d} \pm 6.31$ | $4.9^{f} \pm 0.83$ |
| | | Left | | | | $15.2^{e} \pm 4.41$ | $3.8^{f} \pm 0.94$ |
| 15–2 | 6 | Right | | $39.2^{d} \pm 4.03$ | | $32.9^{d} \pm 3.86$ | $5.1^{f} \pm 1.27$ |
| | | Left | | | | $17.8^{e} \pm 4.19$ | $3.5^{f} \pm 0.85$ |
| | | | Lactate[c] | | | | |
| 0–45 | 10 | Right | $27.2^{e} \pm 3.44$ | | $34.2^{e} \pm 7.25$ | | $73.2^{d} \pm 3.16$ |
| | | Left | | | $32.2^{e} \pm 5.73$ | | $76.8^{d} \pm 3.83$ |
| 0–2 | 5 | Right | $19.8^{e} \pm 4.98$ | | | $34.6^{e} \pm 6.13$ | $68.8^{d} \pm 6.09$ |
| | | Left | | | | $69.3^{d} \pm 11.08$ | $77.6^{d} \pm 2.88$ |
| 15–2 | 6 | Right | | $18.5^{f} \pm 3.68$ | | $34.6^{e} \pm 5.01$ | $71.2^{d} \pm 3.20$ |
| | | Left | | | | $67.2^{d} \pm 12.50$ | $74.2^{d} \pm 5.36$ |
| | | | Glucose 6-Phosphate[c] | | | | |
| 0–45 | 10 | Right | $4.07^{e} \pm 0.69$ | | $0.91^{f} \pm 0.30$ | | $7.02^{d} \pm 1.84$ |
| | | Left | | | $0.91^{f} \pm 0.46$ | | $6.04^{d} \pm 1.85$ |
| 0–2 | 5 | Right | $3.12^{e} \pm 0.97$ | | | $1.12^{e} \pm 0.63$ | $7.02^{d} \pm 0.45$ |
| | | Left | | | | $2.94^{e} \pm 1.05$ | $5.70^{d} \pm 1.23$ |
| 15–2 | 6 | Right | | $1.74^{f} \pm 0.72$ | | $1.12^{f} \pm 0.38$ | $8.24^{d} \pm 2.10$ |
| | | Left | | | | $2.66^{f} \pm 0.57$ | $5.78^{e} \pm 1.06$ |
| | | | ATP[c] | | | | |
| 0–45 | 10 | Right | $2.73^{d} \pm 0.36$ | | $2.50^{d} \pm 0.49$ | | $0.12^{e} \pm 0.12$ |
| | | Left | | | $2.64^{d} \pm 0.58$ | | $0.08^{e} \pm 0.06$ |
| 0–2 | 5 | Right | $3.72^{d} \pm 0.25$ | | | $2.51^{e} \pm 0.74$ | $0.20^{f} \pm 0.07$ |
| | | Left | | | | $0.72^{f} \pm 0.51$ | $0.13^{f} \pm 0.08$ |
| 15–2 | 6 | Right | | $3.60^{d} \pm 0.36$ | | $2.49^{e} \pm 0.42$ | $0.19^{f,g} \pm 0.12$ |
| | | Left | | | | $0.76^{f} \pm 0.37$ | $0.10^{g} \pm 0.06$ |
| | | | Creatine Phosphate[c] | | | | |
| 0–45 | 10 | Right | $0.80^{d} \pm 0.29$ | | $0.84^{d} \pm 0.64$ | | $0.07^{e} \pm 0.07$ |
| | | Left | | | $0.45^{d,e} \pm 0.18$ | | $0.06^{e} \pm 0.06$ |
| 0–2 | 5 | Right | $2.32^{d} \pm 1.94$ | | | $0.39^{e} \pm 0.23$ | $0.09^{e} \pm 0.08$ |
| | | Left | | | | $0.19^{e} \pm 0.10$ | $0.11^{e} \pm 0.12$ |
| 15–2 | 6 | Right | | $2.13^{d} \pm 2.04$ | | $0.18^{e} \pm 0.16$ | $0.14^{e} \pm 0.13$ |
| | | Left | | | | $0.14^{e} \pm 0.10$ | $0.09^{e} \pm 0.06$ |

[a] Mean values ± standard error of the mean. Means within a sampling group with the same superscripts do not differ significantly ($P > 0.05$). [b] Levels are expressed as micromoles glucose equivalents/g muscle. [c] Levels are expressed as micromoles/g muscle.

Table III. The Effect of Myotomy (0 Hr) on Certain Qualitative Assessments for Normal and Low Quality Rectus Femoris Muscles[a]

| Quality assessment | Normal quality | | Low quality | |
|---|---|---|---|---|
| | R-RF | L-RF | R-RF | L-RF |
| Transmission value | $10.7^{b,c} \pm 0.33$ | $10.1^{c} \pm 0.31$ | $10.9^{b,c} \pm 0.47$ | $19.2^{b} \pm 0.52$ |
| pH, 45 min postmortem | $6.48^{b} \pm 0.04$ | $6.57^{b} \pm 0.04$ | $6.16^{c} \pm 0.04$ | $6.21^{c} \pm 0.05$ |
| pH, 2 hr postmortem | $6.47^{b} \pm 0.05$ | $6.26^{c} \pm 0.06$ | $6.12^{c} \pm 0.05$ | $5.46^{d} \pm 0.06$ |

[a] Means with the same superscripts do not differ significantly ($P > 0.05$). Mean values ± standard error of the means.

the pH patterns. In the 0–45 group, neither glycogen nor lactate levels were different among 0 hr R-RF or 45 min R-RF and L-RF muscles. Less glycogen and more lactate were found at 2 hr in the L-RF compared to the R-RF muscles in both the 0–2 and 15–2 groups. No marked differences in 24 hr glycogen or lactate levels were apparent between sides (R-RF *vs.* L-RF) among any of the sampling groups. Thus, the rate rather than the extent of glycolysis was affected by 0 hr myotomy in the RF muscle which concurs with the observations of the longissimus.

The glucose 6-phosphate (G-6-P) levels (Table II) of the RF were comparable to and followed a postmortem pattern similar to that observed for the longissimus muscle (Koch *et al.*, 1970). The G-6-P levels were relatively high initially, dropped to low levels between 15 min and 2 hr, and then reached higher levels at 24 hr than those found initially. No differences in G-6-P levels at 45 min (0–45 group) or 2 hr (0–2 and 15–2 groups) were noted between R-RF or L-RF muscles, even though in both the 0–2 and 15–2 groups the L-RF muscles had more than twice as much G-6-P as the R-RF muscles at 2 hr.

No differences in ATP or CP levels (Table II) were found between 0 hr and 45 min values, as well as between the R-RF and L-RF muscles of the 0–45 group at 45 min. ATP levels of the R-RF were higher than L-RF muscles in the 0–2 and 15–2 groups at 2 hr. Levels of CP roughly paralleled the ATP concentrations. These results and the other glycolytic metabolite data indicate that stimulation of the contractile machinery by myotomy did not diminish ATP or enhance glycolytic rate of the RF muscles, as observed in the longissimus. If myofibrillar ATPase was stimulated to any extent, then either the maintenance of ATP was very efficient or the chilling effects accompanying RF excision negated the stimulatory effects of myotomy. The faster glycolytic rates of the L-RF apparently reflected the lower ATP levels (Scrutton and Utter, 1968; Wood, 1966) and higher muscle temperatures (Lawrie, 1966) than observed in the R-RF.

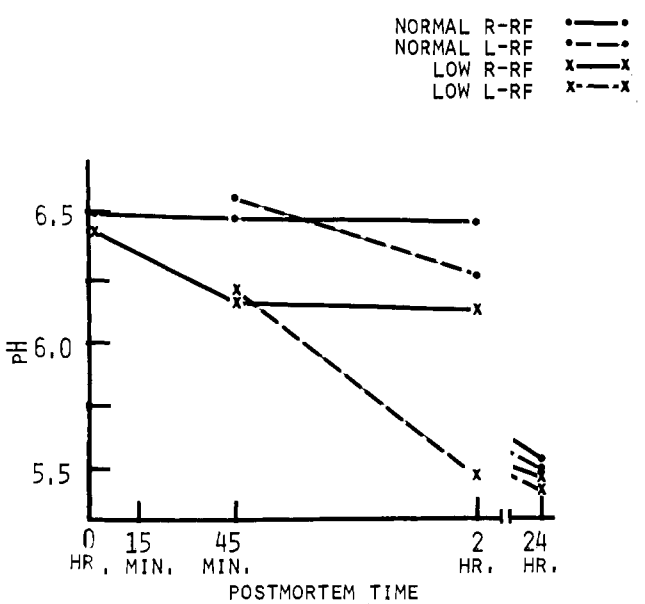


**Figure 1. Postmortem pH patterns of normal and low quality rectus femoris muscles as affected by myotomy at 0 hr**

A comparison of the glycolytic metabolites already discussed, together with levels of glucose-1-phosphate (G-1-P) fructose-6-phosphate (F-6-P), glucose, ADP, and AMP was made of the RF muscles between "normal" and "low" quality groups based on the categorization of the longissimus muscles (Koch *et al.*, 1970). In both the normal and low quality groups, the same three carcasses included in the longissimus muscle data plus one additional carcass were used. The 0 hr values represent the same three carcasses used for the longissimus muscle; 45 min values included two of the three carcasses; 2 hr values included the remaining carcass of these three, plus the additional carcass (indicated above); and the 24 hr values included all four carcasses. This approach was followed because 45 min and 2 hr RF samples were not obtained from each carcass. Thus, the data between sides (R-RF *vs.* L-RF) and quality groups (normal *vs.* low quality) can be directly compared within time periods, but comparison of glycolytic metabolites between time periods is limited by this sampling procedure.

Table III shows that low quality L-RF had higher transmission values than normal L-RF muscles. Low quality R-RF and L-RF had lower 45 min pH values than normal R-RF and L-RF muscles. The R-RF muscles had higher pH values at 2 hr than the L-RF within both the normal and low quality groups. Likewise, low quality RF muscles had lower pH values than corresponding normal RF muscles. These data indicate that the RF muscles from carcasses with normal longissimus muscles had different ultimate qualitative properties than those with low quality longissimus muscles. This observation concurs with the results of Koch (1969), who found that transmission values and 2 hr pH of the biceps femoris, supraspinatus, and RF muscles were significantly and positively correlated with transmission values and pH (2 hr) of the longissimus.

Figure 1 shows that the pH decline of low quality RF muscles was faster than that of normal muscles. While 2 hr pH values of the L-RF muscles were lower than the R-RF, they were lowest among low quality muscles. Thus, the more rapid heat dissipation accompanying myotomy at 0 hr had a greater effect (inhibitory) on the rate of pH decline of low quality muscles. Glycogen and lactate levels (Figure 2) roughly paralleled the pH patterns. Normal RF muscles maintained higher glycogen levels and accumulated less lactate than low quality muscles through 2 hr. While L-RF muscles had slightly more glycogen and less lactate at 45 min than R-RF samples, the R-RF had more glycogen and less lactate at 2 hr than the L-RF muscles. The differences

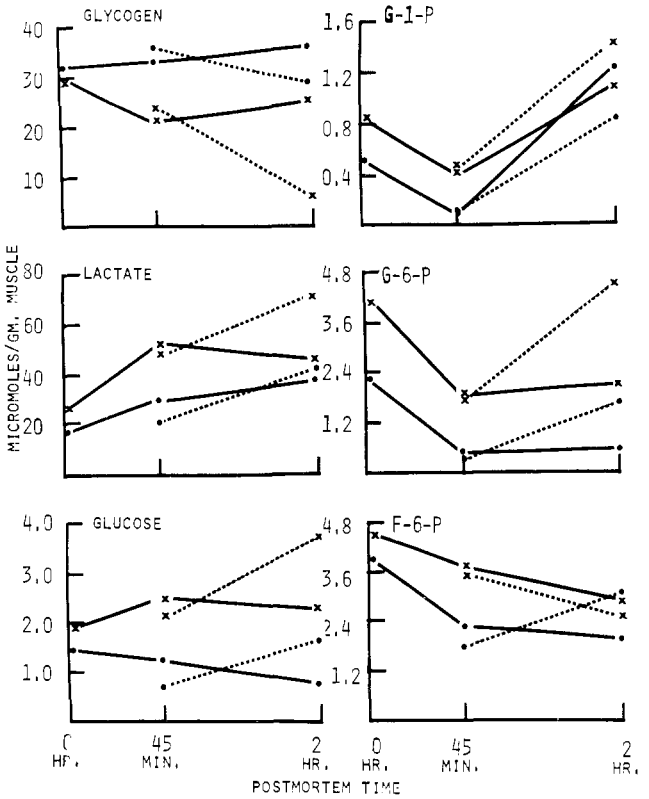


**Figure 2. The effect of myotomy (0 hr) on postmortem levels of glycogen, lactic acid, glucose, glucose 1-phosphate, glucose 6-phosphate, and fructose 6-phosphate between normal (solid circles) and low quality (x's) rectus femoris muscles (right side = solid line and left side = broken line)**

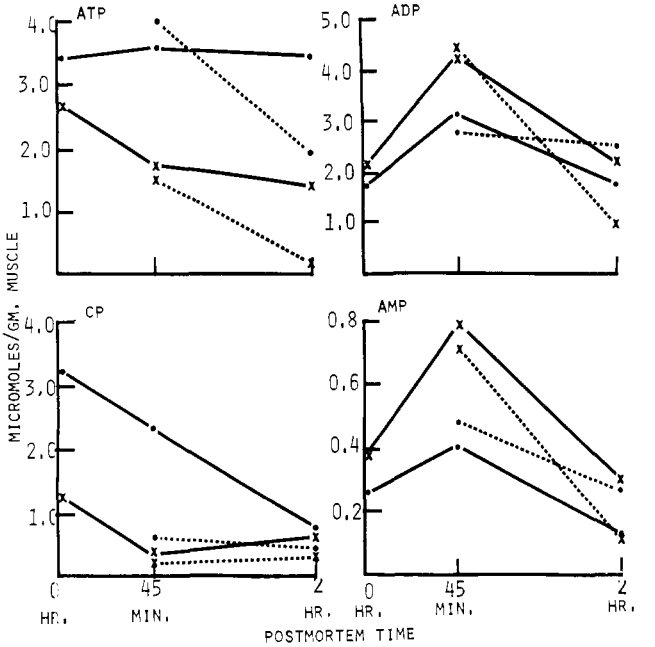


**Figure 3. The effect of myotomy (0 hr) on postmortem levels of ATP, ADP, AMP, and creatine phosphate between normal (solid circles) and low quality (x's) rectus femoris muscles (right side = solid line and left side = broken line)**

between sides (R–RF *vs.* L–RF) was especially marked among low quality muscles.

The G-1-P levels (Figure 2) decreased from 0 hr to 45 min and then increased markedly from 45 min to 2 hr among all muscles. Normal muscles had lower G-1-P and G-6-P levels than low quality muscles at corresponding time periods. Low quality muscles had consistently more glucose than normal muscles. The R–RF muscles had higher glucose levels than the L–RF at 45 min; whereas, L–RF muscles had more glucose than the R–RF at 2 hr. The difference between sides was greatest among low quality muscles at 2 hr.

Normal RF muscles contained higher ATP and CP levels (Figure 3) than low quality muscles at all time periods. The L–RF had more ATP at 45 min than the R–RF among normal muscles, while low quality R–RF muscles had slightly higher ATP levels than the L–RF. The R–RF had more ATP at 2 hr than the L–RF muscles among both quality groups. The R–RF had higher CP levels than the L–RF muscles at both 45 min and 2 hr. ATP levels of the low quality L–RF muscles were nearly depleted at 2 hr. Low quality R–RF had higher ADP and AMP levels (Figure 3) than normal muscles.

The R–RF muscles of both quality groups had lower pH values and glycogen levels, and more lactate, G-6-P, F-6-P and glucose than the L–RF at 45 min. These data indicate that much of the difference in glycolytic rate, as observed between sides in the longissimus, were negated by more rapid heat dissipation in the R–RF in contrast to that of the L–RF muscles. Figures 1 and 2 show that the differences in pH, glycogen, lactate, G-6-P, and glucose levels between R–RF and L–RF muscles were greater in the low quality group at 2 hr than among normal muscles. Thus, it appears that the temperature effects accompanying myotomy of the RF at 0 hr had a greater influence upon low quality than the normal muscles.

## CONCLUSION

Low quality muscle is characterized by a more rapid rate of postmortem glycolysis than normal muscle. Muscle contraction, stimulated by myotomy particularly in the excised sample, resulted in rapid diminution of ATP and CP which, in turn, appears to have contributed to the observed differences in glycolytic rate. An activating mechanism of this nature would not be expected to be as effective on a process that is already rapid as on one which is relatively slow. Thus, muscle contraction resulting from myotomy was more effective in increasing glycolytic rate of normal longissimus muscles than those of lower quality (inherent rapid glycolyzing). Also, since low temperatures (2 to 4° C) are normally used to chill pork carcasses and are known to exert an inhibitory effect upon glycolytic rate, the inhibition would be expected to have a greater effect on the faster process. Thus, the rapid heat dissipation in the RF muscles decreased glycolytic rate to a greater extent among low quality than normal muscles. Consequently, what appeared to be a discrepancy in response between the two muscles (longissimus and rectus femoris) was in actuality a natural physiological response to differences in experimental procedure.

These data show that myotomy at or shortly after exsanguination altered the glycolytic rate, and that the degree of response differed between normal and low quality muscle. These results also indicate that muscle contraction and the cooling effects accompanying myotomy must be considered when attempting to study the postmortem changes of muscle. This applies equally to studies involving the nature and rate of a particular reaction as well as comparisons of postmortem changes between muscles of varying degrees of quality.

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