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January 2001

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The Effects of Post-Harvest Time and Temperature on Glycolytic Potential of Beef Muscle.

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Chris Calkins[1]

Post mortem temperature has little effect on the extent of glycolysis in beef muscle. The time of post mortem sampling can impact glycolytic potential values in beef longissimus muscle.

Summary

The objectives of this study were to determine if post mortem temperature affects extent of glycogen metabolism and if sampling time influences glycolytic potential values in muscle. Beef longissimus muscles entered rigor mortis at two different temperatures and were sampled at 45 minutes post mortem, rigor mortis and 24 hours post mortem to determine the glycolytic potential of the muscle. Post mortem temperature had little effect on the glycolytic potential of beef muscle. Glycolytic potential values from samples removed early post mortem were underestimated when compared to samples taken at 24 hours post mortem.

Introduction

Glycolytic potential is a procedure that is commonly used to estimate the ability of muscle to generate lactic acid. Ante-mortem muscle glycogen levels can also be estimated. Knowledge of a muscle's glycolytic potential can help studies on dark cutting beef and other quality defects. It often is assumed that sampling time is not an important consideration, because the glycolytic potential procedure measures glycogen and some of its degradation products; glucose-6-phosphate and lactic acid. There are a number of intermediate products of glycolysis that are not quantified; their omission might influence the glycolytic potential value.

Temperature also may have an impact on the extent of glycogen breakdown, post mortem. This may affect the overall quantities of lactic acid and residual glycogen in muscle used to determine glycolytic potential. The objective of this study was to determine if temperature and time of muscle sampling affects glycolytic potential values of beef longissimus muscle.

Procedure

The right and left sides from 10 steers were randomly assigned to warm (86°F) or cold (32°F) temperature treatments. For the warm temperature treatment, full, bone-in strip loins were removed immediately after slaughter and held at 86°F until rigor (ca. 6 h); then these samples were moved to 32°F. Cold-temperature loins remained within the carcasses, which were stored at 32°F. Longissimus muscle pH was measured every hour to determine rigor (defined as two consecutive pH readings within 0.1 unit). Samples for lactic acid, glycogen and glycolytic potential (mmol/kg) were removed 45 minutes post mortem, at rigor, and 24 hours post mortem. Glycolytic potential is a procedure that measures the potential for lactic acid production by the muscle. Knowledge of glycogen, glucose-6-phosphate, and lactic acid concentrations (determined enzymatically) allows glycogen levels to be calculated because each molecule of glycogen generates two molecules of lactic acid. These sample were frozen in liquid nitrogen and stored at -112°F until further analysis. Three, 1-inch thick steaks were cut from each loin section to be used for Warner-Bratzler shear determination after one, seven and 14 days of aging. Steaks were cooked on table-top broilers to 158°F prior to cooling for removal of 1/2-inch cores.

Results

Longissimus muscle pH did not differ between hot- and cold-treated muscle at 24 hours ($P<.05$). The rate of pH decline was different among the temperature treatments, but this had no effect on the final values. These pH data are summarized in Table 1.

With the exception of lactic acid levels ($P< .05$) at 24 h, temperature at storage (warm vs cold) had no significant effects on lactic acid, glycogen and glycolytic potential at 45 minutes post-mortem (Table 2), at the point of rigor development (Table 3), or 24 hours post mortem (Table 4). Clearly storage

(Continued on next page)

Table 1. Mean pH values at three different times post mortem for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
45 min post mortem	6.6 ± .21	6.8 ± .13	.02
Estimated rigor [c]	5.3 ± .05	5.5 ± .19	< .01
24 h post mortem	5.4 ± .04	5.4 ± .09	.43

[a] Warm = 86ºF.
[b] Cold = 32ºF.
[c] Estimated rigor = the time when consecutive, hourly pH readings were within 0.1 unit.

Table 2. Pre-rigor glycogen, lactate, and glycolytic potential values for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
Glycogen [c], mmol/kg	58.6 ± 7.0	62.6 ± 8.7	.35
Lactate, mmol/kg	48.2 ± 11.4	46.1 ± 5.3	.64
Glycolytic potential [d]	165.4 ± 16.8	171.3 ± 15.4	.40

[a]Warm = 86ºF.
[b]Cold = 32ºF.
[c]Glycogen = ([glycogen] + [glucose] + [glucose-6-phosphate]).
[d]Glycolytic Potential (mmol of lactate equivalents / kg of wet tissue). This is determined as (2 x glycogen) + lactate concentrations.

Table 3. Glycogen, lactate, and glycolytic potential values at rigor onset for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
Glycogen [c], mmol/kg	42.1 ± 9.7	43.8 ± 7.3	.41
Lactate, mmol/kg	128.1 ± 5.7	130.2 ± 8.3	.54
Glycolytic potential [d]	212.3 ± 21.2	217.8 ± 21.4	.37

[a]Warm = 86ºF.
[b]Cold = 32ºF.
[c]Glycogen = ([glycogen] + [glucose] + [glucose-6-phosphate]).
[d]Glycolytic Potential (mmol of lactate equivalents / kg of wet tissue). This is determined as (2 x glycogen) + lactate concentrations.

Table 4. Post mortem (24 h) glycogen, lactate, and glycolytic potential values for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
Glycogen [c], mmol/kg	42.3 ± 10.0	39.8 ± 9.9	.19
Lactate, mmol/kg	134.0 ± 6.6	140.6 ± 7.0	.05
Glycolytic potential [d]	221.6 ± 19.8	220.1 ± 18.9	.86

[a]Warm = 86ºF.
[b]Cold = 32ºF.
[c]Glycogen = ([glycogen] + [glucose] + [glucose-6-phosphate]).
[d]Glycolytic Potential (mmol of lactate equivalents / kg of wet tissue). This is determined as (2 x glycogen) + lactate concentrations.

Table 5. Warner-Bratzler shear (lb) values at three different aging times for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
1 day of aging	11.5 ± 1.3	10.6 ± 1.5	.03
7 days of aging	9.9 ± 1.2	8.2 ± .84	< .01
14 days of aging	9.9 ± 1.3	7.5 ± 1.2	< .01

[a] Warm = 86ºF.
[b] Cold = 32ºF.

temperature (or temperature at rigor) has little influence on the extent of post mortem glycolysis.

Time of storage altered the calculated glycolytic potential in this study. These values increased from 165.4 to 221.6 mmol/kg over a 24-hour period (P< .05) in warm-treated muscle and from 171.3 to 220.1 in cold-treated muscle. Values at 24 hours for warm versus cold muscle were not different (P = .86). These data suggest that glycolytic potential will be underestimated if muscle samples are taken at 45 minutes post mortem. It is likely that substrate (glycogen) is caught in the various stages of glycolysis. These intermediate products of glycolysis are not measured by the glycolytic potential assay. It appears that pre-rigor muscle samples intended for determination of glycolytic potential should be allowed to fully metabolize prior to measurement.

In this study, warm treatment was associated with elevated (P< .05) shear force values at one, seven and 14 days of aging compared to cold-treated muscle. Perhaps the more rapid rate of pH decline in warm-treated muscle did not allow sufficient time for proteolytic enzymes to break down the muscle ultra structure before the ultimate pH was achieved. The mean pH values after six hours post mortem for cold-treated muscle were higher (P<.01) than the warm treated-muscle, 5.54 vs 5.33, respectively. The proteolytic enzymes may have been irreversibly denatured by the low pH, high temperature condition, which would explain the lack of tenderness improvement on days 7 and 14 for the warm-treated muscle.

It can be concluded that temperature has little effect on the extent of post mortem glycolysis in muscle. Measuring glycolytic potential prior to rigor mortis underestimates glycogen by 10-15%. This may be due to the concentration of intermediate products of glycolysis. Muscle samples for determination of glycolytic potential should be taken after rigor to avoid underestimation of glycogen in beef longissimus muscle.

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