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The Role of Muscle Glycogen in Dark Cutting Beef.

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Pre- slaughter glycogen levels need to be greater than 80 mmol/kg to prevent the dark cutting beef condition.

Summary

Dark cutting beef occurs when muscle glycogen levels are depleted prior to slaughter. Without glycogen, lactic acid is not produced in post-mortem muscle, causing a higher than normal muscle pH. This research was conducted to identify the threshold level of glycogen where the dark cutting condition is likely to occur. These data from muscles varying widely in pH suggest that muscle glycogen levels need to be at or above 80 mmol/kg to prevent the dark cutting beef condition.

Introduction

Carbohydrates are stored as glycogen in muscle. Glycogen provides energy for the muscle cell to function. This carbohydrate, through conversion to lactic acid, facilitates the normal pH drop that occurs when muscle is converted to meat after slaughter. Glycogen that has been stored in the muscle continues to be metabolized post mortem. This degradation of glycogen produces lactic acid and causes the pH of the muscle to drop.

Normally, muscle glycogen concentrations are sufficient to drive the pH of the muscle to approximately 5.6. If the animal has been exposed to a large amount of stress (harsh weather, excessive exercise, lack of water or feed, mixing with unfamiliar animals, or estrus) prior to slaughter, the amount of glycogen in the muscle can be severely reduced. In this case, dark cutting beef can occur. This is due to the lack of glycogen needed to facilitate a drop in muscle pH after death. Dark cutting beef has a pH greater than 5.8 and can be as high as 6.9. This muscle is dark in color, undesirable in flavor, and more susceptible to microbial spoilage. As a result, prices paid to producers are severely reduced when this condition occurs.

There are limited data regarding muscle glycogen concentrations needed to prevent the dark cutting beef condition. The objective of this study was to determine the level of pre-slaughter glycogen that is required to prevent dark cutting beef. This information may be helpful in designing strategies to reduce the occurrence of this condition.

Procedure

Dark cutting and normal colored muscle samples (n=180) were collected from two major packers in the state of Nebraska. These sample were obtained by removing approximately 100 g from the 12th rib region of beef carcasses 2 - 4 days post mortem. Color scores (L*, measures the relative lightness and darkness of a color; a*, measures the relative greenness to redness color of a sample; b*, measures the relative yellowness to blueness of a color) were also taken just prior to removal of the sample. Samples with high fat content (> 6.0 %) were removed from the original data set. It was concluded that high fat samples cause an overestimation of L* value due to the amount of white color provided by the fat in the sample. A visual color scale was used to classify samples (n=121) based on the dark to normal color range of the muscle. A score of 1 represented a normal-appearing muscle and 5 represented extremely dark muscle. Samples were frozen on dry ice and stored at - 22 F before analysis for glycolytic potential (glycogen content) and pH. Glycolytic potential is a procedure that measures the total amount of lactic acid produced by the muscle as well as the glycogen remaining in the system. The lactic acid values can be converted to glycogen because each molecule of glycogen generates two molecules of lactic acid. These data essentially indicate the amount of glycogen that was present in the muscle system before death. Regression analysis was used to determine the relationship between glycogen concentration and pH. The characteristics for each color score were evaluated by analysis of variance. Means were then separated using t-tests.

Results

The data collected revealed a significant quadratic relationship (Figure 1) between pre-slaughter glycogen levels and pH (R^2 = .83, root mean square error = 8.6.), where ultimate pH decreased with increasing glycogen level. Figure 1 also shows the relationship of residual glycogen to pH (R^2 = .63, root mean square error = 7.7). A very strong linear relationship exists between muscle glycogen concentration and pH for pH values above 5.6. In this pH range, residual glycogen levels appear to consistently reach about 12 mmol/kg. For this part of the curve, post-mortem conversion of muscle glycogen to lactic acid seems to continue until this baseline level of glycogen remains. The result is a steady decline in pH with increasing levels of muscle glycogen at slaughter.

Below pH 5.6, however, the relationship of ante-mortem muscle glycogen to pH is dramatically different. In this

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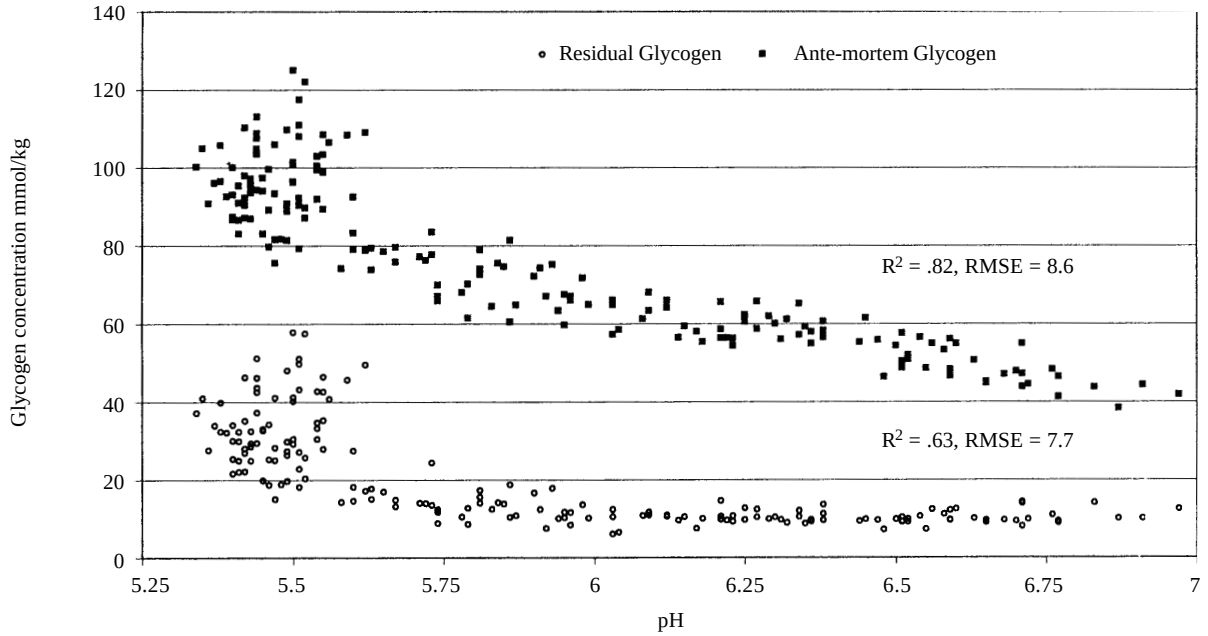

Figure 1. Comparison of estimated and residual glycogen in a population of normal and dark cutting beef.

Table 1. Mean values for pH, L*, a*, b*, residual glycogen, and ante-mortem glycogen separated by visual color score [a].

	Visual Color Score				
	1	2	3	4	5
n	59	5	26	26	5
Ultimate muscle pH	5.47[a]	5.73[b]	6.05[c]	6.31[d]	6.72[e]
L* [b]	34.63[a]	34.40[a]	34.09[a]	31.39[b]	25.41[c]
a* [c]	33.97[a]	29.09[b]	28.41[b]	27.11[b]	26.58[b]
b* [d]	29.02[a]	24.94[b]	23.79[b]	22.13[bc]	20.04[c]
Residual glycogen, mmol/kg	33.01[a]	22.93[b]	14.36[c]	12.01[c]	11.74[c]
Ante-mortem glycogen, mmol/kg	96.35[a]	80.17[b]	66.94[c]	58.82[d]	48.48[d]

[abcd]Means within a row with unlike superscripts differ (P<.05).
[a]Color score, 1 = normal muscle color ; 5 = extreme dark cutting beef color.
[b]Lightness: 0 = black, 100 = white.
[c]Red to green: - 60 = green, + 60 = red.
[d]Blue to yellow: - 60 = blue, + 60 = yellow.

situation, glycogen levels above 80 mmol/kg do not result in consistently lower pH values. In fact, residual glycogen levels in post mortem muscle increase. These values are not lowered to the 12 mmol/kg level noted at pH values above 5.6. The apparent reason is that pH values below 5.6 seem to inactivate the enzymes responsible for glycogen degradation. Thus, muscle glycogen levels at death of 80 mmol/kg or more are sufficient to reduce ultimate pH levels in post-mortem muscle and avoid the dark cutting condition.

Muscle L*, a* and b* values had significant curvilinear relationships (data not shown) to pH (R^2=.34, .64 and .60, respectively). These relationships were lower than expected. The L*, a* and b* readings represent a point in a three-dimensional color system. For example, two samples may have identical L* and a* readings yet one sample may appear to have an orange hue while the other appears purple. Each color occupies a certain point within the 3-D color space. Drawing conclusions from a single parameter (L*, a*, b*) should be made with caution. Visual color scores in this study proved to be a more effective means in which to segregate carcasses based on their overall color.

Means from the visual color scale are presented in Table 1. The visual color scale was used to classify beef carcasses based on the perceived severity of dark cutting. Significant differences (P<.05) among visual categories were noted for pH. All glycogen levels were significantly different from each other (P<.05), except those for scores 4 and 5 (P = .08). These data suggest that visual assessment of color can be effective in classifying dark cutting beef. Currently, the USDA grading system uses this type of subjective measure of color to classify dark cutters. These data suggest that this approach is viable.

Results from this study indicate that the dark cutting condition is more likely to occur when muscle glycogen levels are below 80 mmol/kg. With this information, management strategies prior to slaughter could be developed to reduce the incidence of dark cutting beef.

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