PORCINE PHYSIOLOGY AS RELATED TO POST-MORTEM MUSCLE PROPERTIES

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The importance of many of the manifestations of ante-mortem physiological factors have been recognized for several years---particularly those which are associated with environment and stress.

Some of the early work with the problem of dark cutting beef conducted here at Kansas State by Professor Mackintosh and Dr. Hall,(Hall et al. 1944), provided a basis for believing that ante-mortem physiology was influenced by ante-mortem environment and was important in affecting post-mortem muscle properties. These early observations were further substantiated by Lawrie (1958) and Hedrick (1959). Workers at Missouri (Hedrick et al. 1961) Purdue, Judge et al. (1963) and Kansas (Forrest et al. 1964) have shown that ante-mortem stress is also important in lambs.

Some of the first evidence of the profound effect which ante-mortem physiological factors had on ultimate porcine muscle was presented by Briskey et al. (1959[a,b]) when they demonstrated the effect of diet and exercise on the occurrence of pale, soft, exudative pork.

The influence of environment on the post-mortem muscle properties has been established in reports by Ludvigsen (1954), Judge et al. (1959). Sayre et al. (1961) (1963) Forrest et al. (1963), Kastenschmidt et al. (1964) (1965) and Addis (1965).

Since the term physiology encompasses the entire gamit of biological function, it becomes necessary to define the limits for discussion in this paper. We will be concerned primarily with some of the physiological parameters which permit an animal to cope with its immediate environment. Specifically, we will be concerned with heart rate, respiration rate and two blood gases O_2 and CO_2 as well as blood pH.

The influence of environment on the physiological parameters mentioned is complex and as yet only limited work has been reported on large laboratory animals. Robinson and Lee (1941) and Ingram (1964) demonstrated that heart and respiration rates increase as rectal temperature increases in the pig.

In a recent study (Forrest et al. 1965), we observed that in untreated animals, heart and respiration rates determined immediately prior to slaughter tended to be higher in those animals which ultimately became PSE. This result has been further substantiated in another group of 33 Poland China and Chester White pigs.

In studying the influence of a warm environment, we observed that some animals increased in heart rates while others decreased in heart rate as

a result of the warm treatment. It was observed however that the pre-treatment heart rates were considerably higher than the normal resting rates in a pig which may explain why some animals decreased in heart rate upon exposure to the warm environment. The most interesting point of this observation is shown in the next slide, which illustrates the fact that the animals which already had high heart rates and responded to the warm treatment by increasing heart rate, produced PSE muscles, while those which decreased in heart rate when placed in the warm environment chamber had normal muscle.

To further elucidate some of the changes which occur during the warm environmental treatment an experiment was designed to study heart and respiration rate and the characteristics of venous blood in two breeds of pigs subjected to a warm environmental treatment.

Resting heart and respiration rates were determined on 6 Poland China and 6 Chester White pigs at least 12 hr. prior to experimentation. Resting rates were determined by placing a leather belt around the body of the pig to hold two needle electrodes which were inserted dorsally to the left of center line and posterior to the scapula and ventrally to the left of center line and posterior to the fore limbs. The animals were allowed to become accustomed to the apparatus. Rates were determined only after the animal had remained in a prone position for at least 30 min.

Three pigs of each breed were designated as controls and placed in the controlled environment temperature chamber for 30 min. at room temperature (22°C.). The other three pigs of each breed were subjected to a warm environment (50°C.) in the same chamber for 30 min. All other conditions were held constant (as much as possible and practical for all 12 animals).

A blood sample was collected anaerobically from the jugular vein of each animal before and after the 30 min. period in the environmental chamber. PCO_2, PO_2 and pH of these samples were determined using the Beckman Model 160 Physiological Gas Analyzer shown in the next slide.

Heart and respiration rates were determined before the animals were placed in the chamber and at 5 min. intervals during the time the animal was in the chamber. The controlled environment chamber and Cardiopan electrocardiograph which was used for determining heart and respiration rates are shown in the next slide.

The animals were exsanguinated immediately after collection of the last blood sample. A muscle sample was excised from the right longissimus doral muscle in an area posterior to the last thoracic vertebra immediately after exsanguination. pH, time course of rigor mortis and response to electrical stimulation were determined on this sample. The next slide shows the apparatus used for electrical stimulation. The stimulation procedure per se will be discussed more fully in the next paper. The rate of pH decline was determined by measuring muscle pH on the freshly cut muscle surface at 0, 15, 30, 45, 60, 120, 180 min. post exsanguination.

Samples of the longissimus dorsi and gluteus medius muscle were also scored subjectively for color-morphology at 24 hr. post-mortem.

Results

The next slide shows that in the control group, longissimus dorsi muscle from animals of both breeds were nearly normal with the exception of one Poland China which became pale, soft and exudative. On the average muscle gross morphology ratings from the Chester Whites were slightly lower than those from the Poland Chinas (2.2 compared to 2.3).

The next slide shows that in the warm treatment group all the Poland Chinas had longissimus dorsi muscles which were extremely pale, soft and exudative at 24 hr. post-mortem. All the Chester Whites had normal longissimus dorsi muscles at 24 hr. post-mortem. Similar results were observed in the gluteus medius muscles.

These subjective color-morphology ratings were further substantiated by the observation that all animals in the central group, with the exception of the PSE Poland China, had a slow rate of post-mortem pH decline, long time course of rigor mortis and strong response to electrical stimulation. Conversely the Poland Chinas in the warm treatment group had a fast rate of post-mortem pH decline (5.8 at 30 min.), reached the onset of rigor mortis in less than 15 min., and did not respond to electrical stimulation. The Chester Whites from the warm treatment group had a slow rate of post-mortem pH decline (5.8 at 2 hr.), average onset of rigor mortis at 113 min. post-mortem, and responded strongly to electrical stimulation.

In agreement with previous observations resting heart and respiration rates were considerably lower than the rates observed on standing animals immediately prior to treatment. Resting heart and respiration rates were not observed to be significantly different between breeds.

The next slide shows the influence of treatment on mean heart rate for the two breeds. During the control period in the environmental chamber the heart rates decreased slightly in both breeds. In general rates tended to be slightly higher in the Poland Chinas, this higher average rate was due to the animal which was observed to be ultimately pale, soft and exudative.

The Poland Chinas which were subjected to this warm environment exhibited a sharp increase in heart rate reaching an average of 268 beats/min. Ten min. after the beginning of treatment all three Poland Chinas were removed from the chamber and exsanguinated after 20 min. or less.

Animals from the Chester White breed which were subjected to the warm treatment, had heart rate which dropped below the pre-treatment level and at the end of the treatment period the rates were only slightly higher than the pre-treatment levels.

The next slide shows the influence of treatment on respiration rates. During the control period in the chamber respiration rates in both breeds did not appear to be significantly different. The respiration rates tended to increase during the first 15 min. treatment and then decreased toward the end of 30 min. treatment period.

In the warm treatment group the Poland Chinas exhibited a sharp rise and subsequently showed a fast decline in respiration rate. This change in respiration rate was one to respiratory arrest and was the reason the animals had to be removed from the chamber and exsanguinated before the end of the treatment period.

Respiration rates in the Chester Whites showed continuous increases during the warm treatment period. Blood gas and blood pH data characterize some of the breed differences previously described.

The control Poland China pigs exhibited no change in PCO_2 or pH during the time that they were in the chamber. The Chester Whites exhibited only a small decrease in PCO_2 and retained similar pH values.

The Poland China pigs which were subjected to warm treatment showed significant increases in PCO_2 during treatment, however the PO_2 values decreased drastically during the same time period. In one case no free O_2 was detected in the blood after treatment. pH of the blood also dropped significantly from 7.4 to 6.8.

Conversely the Chester Whites decreased in blood PCO_2 during the warm treatment and showed a slight increase in PO_2 (not significant). Data from another study (Judge et al. 1965) indicates that physiological adjustments made by Chester White pigs during the stress of restraint may be governed more closely by endocrine factors than those adjustments made by Poland Chinas.

From these results it appears that circulatory and respiratory difficulties leading to increased blood PCO_2 and decreased PO_2 can be major contributors to the production of pale, soft, exudative muscle, particularly in animals which are subjected to warm temperature and stress such as would be encountered in trucking animals to market.

In summary, the limited evidence now available indicates that the physiological response of an animal to its ante-mortem environment has a strong influence on changes which occur in its post-mortem muscle. As techniques and facilities for large animal physiological research become available more intensive studies may elucidate the causes and controls of the complex reactions of an animal to its environment, and lead the way to producing and marketing animals which will yield uniformly high quality meat products.

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V. R. CAHILL: Thank you John, for those very stimulating remarks. I can see many ramifications of some of these ideas whether it be in the carcass contest story we are going to hear later or in the food which we eat each day, even for breakfast in Kansas. As we move now to the more Specific Biological Features of Post-Mortem Change in Porcine Muscle we are calling on our good friend J. D. Sink who has seen fit to direct his post-doctorate effort in this particular area, so, John, we will turn the mike to you.

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