

## THE STRESS SYNDROME AND MEAT QUALITY

## METHODS FOR PREDICTION OF PALE, SOFT, EXUDATIVE PORK.

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The condition of pale, soft and exudative (PSE) pork has long been considered to be simply a post mortem phenomenon. Now there is substantial evidence that these pigs are suffering from a myopathy which predisposes them to an abnormal postmortem metabolism. Conditions such as the Porcine Malignant Hyperthermia Syndrome and Acute Back Muscle Degeneration and Necrosis which occur in the live animal, seem to be closely related to this myopathy.

Genetic studies on PSE indicate a moderate heritability for various post mortem muscle quality traits. With the aid of reliable methods to determine the abnormal condition in the live animal, it would theoretically be possible to select more effectively and economically against stress- and PSE-susceptibility.

Sofar three methods have been developed:

- Analysis of blood serum for CPK, Aldolase, GOT or other enzyme activities.
- Muscle biopsy analysis for glucose-6-phosphate, lactate or energy-rich phosphates.
- Non-destructive testing of young pigs for sensitivity to the Malignant Hyperthermia Syndrome by allowing them to inhale the anaesthetic halothane (Fluothane) for a 5 minute period. The development of muscular rigidity and stiffness indicates a susceptibility to stress and a potential for PSE meat.

The relationship of the various methods with ultimate muscle- and carcass quality as well as the problems inherent with each method are discussed.

It is concluded that the third test seems to be the most promising one for application in breeding of pigs for optimal stress resistance and muscle quality.

## METHODEN ZUR VORAUSSAGE VON BLASSEM, WEICHEM, WAESSRIGEM SCHWEINEFLEISCH.

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Das Merkmal blasses, weiches, wässriges (PSE) Schweinefleisch ist schon lange betrachtet worden als ausschliesslich ein post mortem Phänomen. Mehr und mehr wird es deutlich dass es sich hier handelt um eine Muskelabweichung die nach der Schlachtung ein abnormales Metabolismus hervorruft.

Akute Muskeldegeneration und Nekrosis und das Maligne Hyperthermia Syndrome, welche während des Lebens des Tieres stattfinden sind aetiologisch sehr eng mit dieser Abweichung verbunden.

Genetische Studien über PSE haben gezeigt dass verschiedene Fleischqualitätseigenschaften einigermaßen erblich festgelegt sind. Es würde möglich sein zu selektieren gegen PSE- und Stressempfindlichkeit wenn während des Lebens der Tiere mit Hilfe geeigneter Methoden diese Abweichung festzustellen ist. Bis jetzt sind die folgenden Methoden in dieser Hinsicht entwickelt worden:

- Bestimmungen von CPK, Aldolase, GOT oder andere Enzyme im Blutserum.
- Bestimmung von Glucose-6-phosphat, Laktat oder energiereiches Phosphat in Muskelproben.
- Eine nicht-destructive Ueberprüfung von Ferkeln auf spezielle Anfälligkeit für das Maligne Hyperthermia Syndrome durch eine fünfminuten Respiration mit dem Narcoticum Halothane.

Die Beziehung zwischen die Resultate der verschiedenen Methoden und die Fleischqualität, aber auch die Probleme verbunden mit jeder Methode werden diskutiert.

Es wird konkludiert dass die dritte Methode meistversprechend ist für eine zielgerichtete Selektion auf Stress Resistenz und Fleischqualität.

## DES METHODES POUR PREDIRE LA CONDITION PALE, MOLLE ET EXUDATIVE DE LA VIANDE DE PORC.

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La condition pale, molle et exudative (PSE) de la viande de porc a été considérée pendant longtemps comme un simple phénomène post mortel. En ce moment il y a une évidence substantielle que ces porcs souffrent d'une myopathie qui les prédispose à une abération du métabolisme post mortel. Des conditions comme le syndrome porcin d'hyperthermie maligne ainsi que la dégénération aigue et la nécrose des muscles dorsaux qui se présentent dans l'animal vivant semblent avoir des relations étroites avec cette myopathie.

Des études génétiques concernant la condition PSE indiquent une héritabilité modérée. A l'aide de méthodes pour déterminer la condition aberrante dans l'animal vivant, il serait possible en théorie de sélectionner de façon plus efficace contre la sensibilité pour le stress et la condition PSE.

Jusqu'à maintenant trois méthodes ont été développées:

- l'analyse du serum sanguin pour CPK, Aldolase, GOT et autres activités d'enzymes
- l'analyse d'un échantillon (de tissu) musculaire pour G6P, lactate, ATP ou CP
- un test dans lequel on fait inhaler le narcotique halothane (Fluothane) à des porcelets pendant une période de 5 minutes. Si une rigidité musculaire se développe ceci indique une sensibilité pour le stress et une prédisposition pour la viande PSE.

La relation des différentes méthodes avec la qualité finale des muscles et la qualité de la carcasse est discutée, ainsi que les problèmes inhérentes à chaque méthode. La troisième méthode semble le plus prometteur pour être appliquée dans la sélection de porcs pour une résistance optimale contre le stress et une qualité optimale des muscles.

БЛЕДНУЮ, МЯГКУЮ И ПОКРУЮ СВИНИНУ (pale, soft and exudative, PSE) В ТЕЧЕНИЕ ДОЛГОГО ВРЕМЕНИ ПРИНЯТО РАССМАТРИВАТЬ КАК ВСТРЕЧАЮЩЕЕСЯ ИСКЛЮЧИТЕЛЬНО ПОСЛЕ СМЕРТИ ЖИВОТНОГО ЯВЛЕНИЕ.

МЕСТО ИМЕЮТ, ОДНАКО, ОПРЕДЕЛЕННЫЕ ПРИЗНАКИ, УКАЗЫВАЮЩИЕ НА ТО, ЧТО ЭТИ СВИНКИ СТРАДАЮТ ОТ ОТЛИЧТЕЛЬНОГО ОБМЕНА МУСКУЛЬНОЙ ТКАНИ (Myopathie) В ПЕРИОД СВОЕЙ ЖИЗНИ, ЧТО ПРЕДПОРЕДЕЛЯЕТ ИХ ДЛЯ PSE. СИНДРОМ Maligne Hyperthermia (MH) И ОСТРЫЙ НЕКРОЗ СПИННОЙ МУСКУЛАТУРЫ СВИНЕЙ УКАЗЫВАЮТ НА ТЕСНОЕ РОДСТВО С PSE ЧУВСТВИТЕЛЬНОСТЬЮ К НАПРЯЖЕННОСТИ.

ПРИЕМЫ, КОТОРЫЕ НА ПРОТЯЖЕНИИ ВСЕГО ПЕРИОДА ЖИЗНИ В СОСТОЯНИИ БЫЛИ БЫ ПОДАВАТЬ ИНФОРМАЦИИ ОБ ОТЛИЧТЕЛЬНОМ ПОЛОЖЕНИИ МУСКУЛАТУРЫ, БЫЛИ БЫ, ВЕРОЯТНО, В СОСТОЯНИИ СОЗДАВАТЬ БОЛЕЕ ЭФФЕКТИВНУЮ ВОЗМОЖНОСТЬ ОТБОРА.

К ЧИСЛУ ЭТИХ ПРИЕМОВ ОТНОСЯТСЯ:

- ОПРЕДЕЛЕНИЕ АКТИВНОСТИ ВАЖНЫХ ЭНЗИМОВ ДЛЯ ЭНЗИМОВ ТАК СРК, Aldolase, GOT.
- ОПРЕДЕЛЕНИЕ РАЗЛИЧНЫХ МЕТАБОЛИТОВ В БИОПСИЯХ МУСКУЛЬНОЙ ТКАНИ КАК ГЛЮКОЗА-6-ФОСФАТ, МОЛЧЯНАЯ КИСЛОТА ИЛИ ЭНЕРГЕТИЧЕСКИЕ ФОСФАТЫ.
- ПОДВЕРГАНИЕ МОЛОДЫХ ПОРОСЯТ ИСПЫТАНИИ НА ЧУВСТВИТЕЛЬНОСТЬ НА MH, ПОДАВАЯ ИМ НАРКОТИК ГАЛОФАН НА ПРОТЯЖЕНИИ ПЯТИ МИНУТ.

ОБСУЖДАЕТСЯ ЗНАЧЕНИЕ ОТДЕЛЬНЫХ МЕТОДОВ ДЛЯ ДАННОЙ ЦЕЛИ, Т.Е. ДЛЯ ОТБОРА В ПЕРИОД ЖИЗНИ И ВСТРЕЧАЮЩИЕСЯ ПРИ ЭТОМ ЗАТРУДНЕНИЯ.

ПРИХОДЯТ К ЗАКЛЮЧЕНИЮ, ЧТО ПОСЛЕДНИЙ ПРИЕМ ПРЕДСТАВЛЯЕТ САМЫЕ ЛУЧШИЕ ПЕРСПЕКТИВЫ ОТНОСИТЕЛЬНО ЕГО ПРИМЕНЕНИЯ В ОТДЕЛЬНЫХ ПРОГРАММАХ ПО ПЛЕМЕННОЙ РАБОТЕ, НАПРАВЛЕННЫХ НА РАЗВЕДЕНИЕ К НАПРЯЖЕННОСТИ НЕЧУВСТВИТЕЛЬНЫХ ЖИВОТНЫХ С МЯСОМ ХОРОШЕГО КАЧЕСТВА.

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## Introduction

The condition of pale, soft, exudative (PSE) muscle has long been considered to be a post mortem phenomenon, which occurred predominantly in the lean meaty type of pig as a consequence of the stress applied by transportation and slaughter. Recent studies, reviewed by Cassens et al. (1974), indicate that there is in these pigs an abnormal condition in the musculature in vivo.

It is likely that in addition to PSE and the Porcine Stress Syndrome (Topel et al., 1968) also Acute Back Muscle Degeneration and Necrosis (Bickhardt, 1972) and hypersensitivity to halothane (Malignant Hyperthermia Syndrome; Sybesma and Eikelenboom, 1969) are expressions of the same abnormal condition.

Genetic studies on the inheritance of abnormal muscle quality indicate a moderate coefficient of heritability of 0.3 for various post mortem muscle quality characteristics (Weniger et al., 1970; Jonsson, 1971; Walstra et al., 1971). This paper reviews recent research on methods for diagnosing the abnormal condition in the live animal, which can possibly be used as selection criteria in a breeding program directed towards optimal muscle quality.

## I Serum enzyme analysis

In 1967 Sybesma and Hessel-de Heer first reported the observation of elevated serum lactate dehydrogenase (LDH) activity, due to increase of the muscle specific isoenzyme, in stress-susceptible Piétrain pigs as compared with stress-resistant Yorkshire pigs. This observation has been confirmed by several others (Addis and Kallweit, 1969; Merkel, 1971; Reddy et al., 1971) while in addition other serum enzyme levels such as glutamic-oxalacetic-transaminase (GOT), creatine phosphokinase (CPK), malate dehydrogenase (MDH), glutamic-pyruvic transaminase (GPT) and

has been recommended by Richter et al. (1973) further research needs to be done in order to increase the accuracy of the test and to improve the relationship with ultimate quality.

## II Muscle biopsy analysis

Sair et al. (1970) and Lister et al. (1970) found considerable differences in energy rich phosphate and lactate levels between muscle samples taken at the time of death from anaesthetized stress-susceptible and stress-resistant pigs. Bickhardt et al. (1972), using an in vivo freezing technique, found higher levels of lactate and lower levels of pyruvate and several glycolytic intermediates in the longissimus muscle of a strain of German Landrace with a high incidence of PSE as compared with a strain from the same breed with a low incidence of PSE.

Schmidt et al. (1971, 1972) designed a muscle biopsy technique whereby 200 mg samples of the longissimus muscle were obtained without the use of a general anaesthetic. Lactate, but particularly glucose-6-phosphate (G6P) determined in samples taken 6 or 12 days ante mortem, predicted, as well ultimate quality characteristics as did post mortem pH and rigor measurements.

Sybesma et al. (1972) repeated the experiment on a larger number of pigs and found lower, although significant, relationships between G6P or lactate and ultimate quality (Table 1).

Traits	Norwegian Dutch Dutch Piétrain Belgian L.S.D						
	N	Landrace	Landr.	Yorksh.	Landrace		
biopsy G6P		3.65	3.69	2.24	5.80	5.13	0.62
Lactate		10.95	11.31	7.48	18.28	14.04	1.86
	N	80	112	96	92	80	
45 min. post mortem							
pH(M. semimem.)		6.64	6.51	6.69	6.22	6.17	0.13
(M. long. dorsi)		6.55	6.41	6.71	6.21	6.22	0.15
rigor		4.6	5.7	5.1	8.8	8.9	1.0
24 h post mortem							
transmission %		30.6	31.1	16.4	50.3	49.8	9.6

Table 1. TWO WEEKS ANTE MORTEM BIOPSY AND POST MORTEM MUSCLE QUALITY RESULTS IN FIVE BREEDS OF PIGS (WALSTRA, DATA TO BE PUBLISHED)

1, 6, diphospho-fructoaldolase have been reported to be increased in stress-susceptible pigs (Eikelenboom et al., 1970; Bickhardt, 1971; Schmidt et al., 1971).

The decreased selective permeability of the muscle fiber membranes as evidenced by the leakage of large protein molecules suggests that these pigs are suffering from a myopathic condition. Since, unlike the other enzymes CPK only occurs in muscle tissue, it is the most specific indicator of this condition.

Most of the studies mentioned above have shown differences in mean serum enzyme activities between breeds with different degrees of stress-susceptibility. In a relatively few number of studies the direct relationship between serum enzyme levels and post mortem muscle quality within a breed has been investigated. Schmidt et al. (1971) found CPK, determined in samples taken 6 or 12 days ante mortem from Dutch Landrace pigs, significantly related to muscle protein solubility and subjective evaluation at 24 hrs post mortem. CPK was also significantly related to G6P and lactate levels in muscle biopsies taken immediately prior to bloodsampling.

The results of Allen and Patterson (1971) indicate that enzyme activities are related to the method of sampling. Puncture of the vena cava gave elevated readings as compared with samples obtained from the ear vein, which is probably due to contamination of the serum with muscular tissue. Bickhardt (1971) found differences in mean serum enzyme activity to increase between groups of stress resistant and stress-susceptible pigs after short term exercise.

Richter et al. (1973) demonstrated the logarithm of CPK activity, determined in blood samples taken after certain "standardized" stress conditions, to be related to meat: fat ratio ( $r = -0.33$ ), meat percentage ( $r = 0.31$ ), G6P ( $r = -0.32$ ) and pH<sub>1</sub> value ( $r = -0.41$ ). Considerable variation in mean CPK value with large standard deviations were found between the various days of sampling, representing possibly environmental influences. Correlations of enzyme activity determined twice in one sample and in two samples taken in succession with an interval of one week, were 0.81 and 0.68, respectively.

Before the CPK test can be used in a pig performance testing scheme as

Measurements of pH at 45 minutes post mortem were a better predictor than G6P or lactate. No substantial difference in predictive quality could be shown between G6P and lactate. Sampling at 14 and 6 weeks ante mortem did not show a significant relationship between both metabolites and ultimate muscle quality. Calculations on heritability coefficients suggested a rather high heritability for the criteria measured. In further research (Pieterse et al., 1973) no effect of site of sampling or exercise was found on muscle biopsy metabolite level. Incubation of the biopsy for a longer period and under different temperature conditions as in the original procedure of Schmidt et al. (1972) resulted in increased lactate levels and decreased levels of energy rich phosphates and G6P.

Recently Walstra (1974) compared results of muscle biopsies taken two weeks ante mortem from pigs of five European breeds with muscle quality post mortem. Table 1, which contains some of his preliminary data, clearly demonstrates similar trends between the breeds in muscle biopsy results and post mortem muscle quality characteristics. Pooled correlations for G6P and lactate with meat percentage, pH<sub>1</sub> and percent transmission were 0.08, -0.20, 0.20 and 0.15, -0.18, 0.12, respectively. For the Dutch Landrace pigs these values were 0.04, -0.34, 0.39 and 0.18, -0.35, 0.18, respectively.

Yet, these correlations are too low to be useful in selection. Sybesma et al. (1971) suggested that improvement of the correlations could probably be achieved by further standardization of sampling technique, transport and slaughter circumstances.

Although the biopsy technique allows direct observation on the tissue which is primarily affected in PSE-susceptible pigs, the parameters which have been developed so far are not yet suitable as a selection criterion.

## III Testing for hypersensitivity to halothane

Previous studies from our laboratory have shown that stress-susceptible Piétrain pigs are hypersensitive to halothane (Fluothane, ICI) anaesthesia (Sybesma and Eikelenboom, 1969). The symptoms these pigs develop when they are subjected to this type of anaesthesia closely resemble those which may occur in these pigs during conditions of physiological stress or exercise. The condition, characterized by severe muscle rigidity, progressive hyperthermia and a metabolic acidosis, has been defined as

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Malignant Hyperthermia Syndrome (MHS) (Sybesma and Eikelenboom, 1969; Allen et al., 1970).

Recent aetiological studies suggest that the syndrome provoked by halothane is non-lethal in 6-8 week old piglets, provided that appropriate measures are taken immediately (Rapacz, 1972; Hall et al., 1972).

Eikelenboom and Minkema (1974) evaluated the relationship between the reaction of young Dutch Landrace pigs to halothane anaesthesia and the occurrence of PSE muscle upon normal slaughter at 100 kg. At an average age of 15 weeks, 231 Dutch Landrace pigs were subjected to anaesthesia in random order with a mixture of oxygen and 2-4% halothane supplied through a facemask for 5 minutes. Thirteen percent of the pigs showed signs of the MHS: muscular spasm with extreme extension of fore and hind legs. As soon as the first positive signs developed treatment was immediately stopped and the pig's reaction to halothane challenge was qualified as either positive (MHS-susceptible) or negative (non-susceptible). Considerable differences in growth and carcass composition traits between susceptible and non-susceptible pigs were found (Eikelenboom and Minkema, 1974). These results indicate that the susceptible pigs were of a leaner meatier type than the others, an observation which has also been made by Christian (1973) in American Yorkshire pigs.

Ham and loin muscle quality of susceptible pigs 45 min. post mortem had significantly lower pH and significantly higher temperature and rigor scores, while protein solubility and subjective evaluation at 24 hrs post mortem were significantly inferior only in the susceptible gilts (Table 2). No significant differences in 24 hr post mortem characteristics were found between susceptible and non-susceptible barrows. However, since 45 min. post mortem measurements did not differ significantly between susceptible gilts and barrows, it was suggested that the sarcoplasmic proteins in barrows are less sensitive early post mortem to denaturation causing factors than in gilts (Eikelenboom and Minkema, 1974).

This non-destructive test for the Malignant Hyperthermia Syndrome is less expensive but easier to perform and interpret than the two methods discussed before and hence seems to be more promising. Further research will determine whether this test is suitable application in commercial pig testing and breeding schemes for optimal stress resistance and muscle quality.

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Table 2. RESULTS OF MUSCLE QUALITY MEASUREMENTS IN DUTCH LANDRACE GILTS AND BARROWS WITH DIFFERENT REACTIONS UPON CHALLENGE WITH HALOTHANE.

Traits	Gilts		Barrows	
	+	-	+	-
N	15	90	14	111
45 min. post mortem				
pH(M.semimem.)	5.93±0.29	6.32±0.29***	5.87±0.28	6.41±0.28***
(M.long.dorsi)	5.86±0.22	6.34±0.37***	5.88±0.36	6.40±0.29***
temperature (°C)				
(M.semimem.)	40.82±0.59	40.06±0.65***	40.79±0.51	39.70±0.74***
(M.long.dorsi)	41.00±0.82	40.42±0.72*	41.28±0.66	40.26±0.77***
rigor	7.07±2.59	4.13±2.32***	6.50±1.70	2.79±2.21***
24 h post mortem				
transmission %	73.1±19.2	44.7±25.1***	46.3±26.6	37.8±22.0
subj.qual.score	3.43±0.76	2.34±0.90***	2.29±0.83	2.13±0.92

+ MHS-susceptible

- non-susceptible

\* P ≤ 0.05

\*\*\* P ≤ 0.001

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