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EARLY POSTMORTEM MEASUREMENT OF MEAT QUALITY[1]

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Summary

pH and temperature were measured in the ham and loin, rigor was estimated on the ham and subjective scores for color and muscling were made at 45 min postmortem on 95 pig carcasses in a commercial packing plant. Carcass length, weight, backfat thickness and loin eye area were measured at 24 hr postmortem and scores for marbling and firmness as well as measurement of pH, reflectance, expressible juice and protein solubility (transmission value) were made on a sample of the loin.

All objective measurements made at 45 min postmortem were highly significantly correlated ($P < .01$) among each other as were all measurements of quality at 24 hr postmortem. Of all measurements made at 24 hr postmortem, transmission value showed the highest relationship with pH, temperature and rigor measurement at 45 min postmortem. Initial pH of the loin was more highly related with ultimate quality, as determined by transmission value, than was ultimate pH of the loin ($r = -.69$ vs $r = -.51$). When a stepwise multiple regression analysis was used for prediction of transmission value, the variables added in order of importance were 24 hr firmness score, initial pH of the loin,

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expressible juice, initial temperature of the loin, ultimate color score and ultimate pH of the loin. Initial pH and temperature of the loin accounted for 52% of the variation in transmission value.

Fat thickness, loin eye area and carcass weight were not found to be related with any of the quality measurements taken at 45 min and 24 hr postmortem. Only carcass length and subjective muscling score were related with transmission value ($r = -.26$ and $r = -.31$, respectively). However, it is suggested that visual score of muscling might be influenced by degree of onset of rigor mortis.

Introduction

It is generally accepted that the occurrence of pale, soft, exudative (PSE) porcine muscle (Briskey, 1964) results from a combination of low pH and high temperature in the early postmortem period; this causes a denaturation of the muscle proteins (Wismer-Pedersen, 1959; Bendall and Wismer-Pedersen, 1963). Consequently, the solubility of the sarcoplasmic proteins decreases, a phenomenon which served as the basis for Hart's (1962) transmission value method for determination of ultimate muscle quality.

Sybesma (1966) designed an apparatus for measurement of the degree of onset of rigor mortis at 40-45 min postmortem and demonstrated that this method, in combination with 45 min pH and temperature measurements, carried out under practical conditions in a commercial abattoir, were useful parameters for identification of potential PSE muscle. Verdijk (1972) suggested that rigor measurement is of more value than initial pH, while Herring, Haggard and Hansen (1971) found that ultimate pH was more related to water holding capacity and subjective color score than 45 min pH, temperature or rigor status.

The purpose of the present study was to evaluate in a commercial plant, the relationship between muscle quality measurements at 45 min and at 24 hr postmortem as well as the relationship between these measurements and traits for muscling and other compositional traits. Early postmortem detection of potentially abnormal muscle quality is important because it allows the processor to subject these carcasses to a different postmortem treatment, to penalize such carcasses in a grading system, and to identify herds which yield a high incidence of PSE meat and possibly stress-susceptible animals. Special emphasis was placed, therefore, on examining the ability of the various parameters measured at 45 min postmortem to predict ultimate quality.

Materials and Methods

Certain objective and subjective measurements were recorded from 95 porcine carcasses, which were randomly selected 45 min after carbon dioxide stunning from the slaughterline of a commercial meat packing plant. Both pH and temperature of the ham (M. semimembranosus) and loin (M. longissimus) were determined. pH was measured with a pocket-pH meter (Beckman, model 180) and temperature with a Tele-thermometer (model 43TF, Yellow Springs Instrument Company) using a thermistor hypodermic probe (nr. 418). The rigor reading was determined according to the method of Sybesma (1966). Subjective muscling scores (USDA, 1970) and Wisconsin color scores (Anonymous, 1963) were assigned to each carcass.

Carcasses were cooled for 24 hr and then carcass length was determined and the left side of each carcass was sectioned at the 10th rib and loin eye area and color, firmness and marbling scores of the

M. longissimus muscle were assigned, using the Wisconsin System (Anonymous, 1963).

A muscle sample (50-100 g) was removed from the M. longissimus. The ultimate pH was measured on this slice using a Radiometer (type PHM26) pH meter. As an objective measure of color, reflectance was determined at 640 mμ with a Bausch and Lomb "Spectronic 20" colorimeter adapted for reflectance monitoring on a 3 cm disk of muscle sectioned from the slice and expressed as a percentage of the reflectance of a magnesium carbonate block. Expressible juice was determined on duplicate samples from each slice by the technique of Grau and Hamm (1953) as modified by Briskey et al. (1960) and was expressed as a ratio of the total area divided by the meat sample area.

Percent transmission was determined according to a slight modification of Hart's procedure (1962). Five grams of muscle were homogenized with a Polytron (Type PT_{10}) homogenizer and left at 4C for 15 hours. After rehomogenization the samples were centrifuged (2000 r/min for 15 min) and filtered. One ml of the filtrate was added to one colorimeter tube containing 5 ml citrate phosphate buffer (0.2 M Na_2HPO_4; 0.1 M $C_6H_8O_7$) adjusted to pH 4.58 and one blank containing distilled water. After exactly 30 min in a waterbath at 20C turbidity was measured in a Bausch and Lomb "Spectronic 20" colorimeter at 600 mμ.

Simple correlations were computed and a stepwise multiple regression analysis was employed to select which variables best predicted ultimate meat quality as indicated by percent transmission values. The program allowed selection of the variables in the order of their significance and rejected any independent variable having a level of significance $> .05$. The multiple correlation coefficient (R) and

coefficient of determination (R^2) for each variable entering the equation are expressed accumulatively.

Results and Discussion

Table 1 includes simple correlations among and between 45 min and 24 hr postmortem measurements. All objective 45 min postmortem measurements of pH, temperature and rigor were highly significantly ($P < .01$) correlated among each other as were all measurements of quality at 24 hr postmortem. In general, transmission value showed relatively the highest relationship with other objective parameters, measured at 45 min and 24 hr postmortem. Initial pH of the loin was significantly ($P < .01$) related with all objective 45 min and both subjective and objective 24 hr postmortem measurements. Ultimate pH of the loin, when related with 45 min postmortem measurements, showed only a significant relationship with initial loin pH ($r = 0.27$; $p < .01$). Yet correlations with all postmortem measurements were significant ($p < .01$).

Briskey (1964, 1968) reported that it is the rate and not the extent of pH fall that is associated with low quality pork. However, Herring, Haggard and Hansen (1971) found final pH of greater significance than initial pH measured at 45 min postmortem, in predicting water holding capacity and color score. In our study, both initial pH and ultimate pH were found to be related with ultimate quality, although initial pH showed a higher relationship than ultimate pH when related with transmission value ($r = -.69$ and $r = -.51$, respectively). The correlation of rigor value and initial ham pH agrees with the finding of Sybesma (1966), who reported a correlation coefficient of -.40 between measurements taken at 40 min postmortem.

Subjective color score at 45 min postmortem was not significantly related with any of the objective 45 min measurements, and although significant correlations with some of the 24 hr characteristics were obtained, it did not appear to be of great practical value in predicting ultimate quality. Muscling score showed a similar relationship as rigor value to all 45 min measurements. When both these parameters are related to ultimate quality the correlations are of the same magnitude, an observation which can possibly be explained from the relatively high correlation between muscling score and rigor value ($r = 0.67$; $p < .01$). This observation, that muscling score might be influenced by degree of onset of rigor mortis, is in our opinion of interest since many grading systems include a visual appraisal of ham size and shape. A possible overevaluation of certain carcasses in these systems for these reasons should be considered as serious because of the negative relationship with qualitative traits.

Of all the carcass composition measurements, only carcass length was related with 45 min and 24 hr postmortem qualitative measurements such as transmission value ($r = -.26$; $p < .05$) and expressible juice ($r = -.20$; $p < .05$). Carcass traits such as fat thickness, loin eye area and carcass weight were not found to be significantly related with any of the quality measurements taken at either 45 min or 24 hr postmortem. Many reports in the literature suggest a negative relationship between muscularity and muscle quality. Recently, Johnsson et al. (1971) found color score to be related with loin eye area ($r = 0.29$) and carcass length (0.26). The fact that the carcasses in our study varied widely in weight (54 to 101 kg), fat thickness and probably age might have

influenced our estimates of the relationship between qualitative measurements and traits for absolute muscling as expressed by simple correlation coefficients.

In the stepwise multiple regression analysis for identification of those traits which predict the best ultimate quality, we selected transmission value as the most appropriate dependent variable because of its objectivity and reliability in assessing the degree of PSE. Accepting a 5% significance level, the variables added in order of importance were firmness score ($R = 0.73$; $R^2 = 0.54$), plus initial loin pH ($R = 0.80$; $R^2 = 0.65$), plus expressible juice ($R = 0.85$; $R^2 = 0.73$), plus initial loin temperature ($R = 0.87$; $R^2 = 0.75$), plus ultimate color score ($R = 0.88$; $R^2 = 0.78$) and ultimate loin pH ($R = 0.89$; $R^2 = 0.79$). If only the 45 min measurements were the independent variables, then loin pH ($R = 0.69$; $R^2 = 0.48$), plus temperature ($R = 0.73$; $R^2 = 0.52$) were the only ones selected. Loin temperature alone accounted for 22% of the variation in transmission value ($R = 0.47$). Early postmortem detection methods for potential PSE muscle should therefore include at least one of both objective measurements with preference, although more complicated, for the pH measurement.

TABLE 1. SIMPLE CORRELATION COEFFICIENTS AMONG CERTAIN OBJECTIVE AND SUBJECTIVE TRAITS OF PORK MUSCLE QUALITY DETERMINED AT 45 MIN AND 24 HR POSTMORTEM

	45 min postmortem						
Trait	Muscling score	Color score	Rigor	Ham pH	Ham T	Loin pH	Loin T
Muscling score	--						
Color score	0.10	--					
Rigor	-.67**	-.12	--				
Ham pH	0.33**	0.14	-.42**	--			
Ham T	-.52**	0.15	0.40**	-.51**	--		
Loin pH	0.33**	0.15	-.38**	0.76**	-.44**	--	
Loin T	-.55**	-.09	0.44**	-.44**	0.73**	-.36**	--
Marbling score	0.29**	0.00	-.27**	0.32**	-.15	0.43**	-.20*
Color score	0.19	0.29**	-.19	0.37**	0.00	0.54**	-.19
Firmness score	0.21*	0.23*	-.20*	0.52**	-.15	0.57**	-.32**
Reflect. (640 mμ)	-.10	-.25*	-.17	-.34**	0.03	-.46**	0.18
Ultimate pH	-.02	-.02	-.03	0.19	0.13	0.27**	-.04
Exp. juice	-.06	-.04	0.08	-.31**	0.08	-.34**	0.21*
Percent transm.	-.31**	-.21*	0.32**	-.62**	0.36**	-.69**	0.47**

	24 hr postmortem						
Trait	Marbling score	Color score	Firmness score	Reflect. (640 mμ)	Ultimate pH	Exp. juice	Percent transm.
Marbling score	--						
Color score	0.50**	--					
Firmness score	0.59**	0.76**	--				
Reflect. (640 mμ)	-.34**	-.75**	-.72**	--			
Ultimate pH	0.32**	0.62**	0.56**	-.60**	--		
Exp. juice	-.45**	-.54**	-.52**	0.48**	-.35**	--	
Percent transm.	-.45**	-.73**	-.73**	0.64**	-.51**	0.64**	--

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FRÜHE POST-MORTEM MESSUNGEN DER FLEISCHQUALITÄT

ZUSAMMENFASSUNG

Der pH-Wert und die Temperatur wurden im Schinken und im Kotelett gemessen, das Eintreten der Todesstarre (rigor mortis) wurde festgestellt und eine subjektive Punktbewertung für Farbe und Bemuskelung wurde 45 Min. post-mortem an 95 Schweineschlachtkörpern in einer Verpackungsfabrik durchgeführt. Schlachtkörperlänge, Gewicht, Rückenspeckdicke und Fleischfläche am Kotelettschnitt wurden 24 Std. post-mortem gemessen, und an einem Kotelettmuster wurde eine Punktbenotung für Marmorierung und Festigkeit gegeben, wie auch Messungen des pH-Wertes, des Reflexionswertes, des Wasseraustritts (Presswert) und der Proteinlöslichkeit (Transmissionswert) erhoben wurden.

Alle objektiven Messungen, welche 45 Min. post-mortem stattfanden, zeigten eine hoch signifikante Korrelation ($P < .01$) untereinander, wie dies auch der Fall für die 24 Std. post-mortem ausgeführten Qualitätsmessungen war. Von allen Messungen, die 24 Std. post-mortem stattfanden, zeigte der Transmissionnswert die höchste Beziehung zu des 45 Min. post-mortem gemessenen Werten für pH, Temperatur und rigor mortis. Der anfängliche pH-Wert des Koteletts hatte eine höhere Beziehung zur Endqualität, welche mit Hilfe des Transmissionswertes festgestellt wurde, als der End-pH-Wert des Koteletts ($r = -.69$ gegen $r=-.51$). Wenn man eine stufenweise multiple Regressionsanalyse für die Vorhersage des Transmissionswertes benutzte, waren die nach Wichtigkeit geordneten hinzugefügten Variablen : Festigkeitsbenotung 24 Std. post-mortem, Anfangs-pH des Koteletts, auspressbares Wasser, Anfangstemperatur des Koteletts, Endbenotung der Farbe und End-pH des Koteletts. Anfangs-pH und Anfangstemperatur des Koteletts stellten 52% der Variation des Transmissionswertes dar.

Es wurde festgestellt, dass Fettdicke, Fleischfläche am Kotelettschnitt und Schlachtkörpergewicht keine Beziehung zu den Qualitätsmessungen zeigten, die 45 Min. und 24 Std. post-mortem durchgeführt wurden. Nur die Schlachtkörperlänge und die subjektive Bemuskelungsnote hatten ein Verhältnis zum Transmissionswert ($r = -.26$ bzw. $r = -.31$). Man nimmt jedoch an, dass eine visuelle Benotung der Bemuskelung vom Grad des Todesstarreeintritts beeinflusst sein kann.

APPRECIATION DE LA QUALITE DE LA VIANDE

IMMEDIATEMENT POST MORTEM

Résumé :

Le pH et la température ont été mesurés dans le jambon et la longe, la rigor mortis a été estimée pour le jambon et une notation subjective par points pour la couleur et la musculature a été effectuée 45 minutes post mortem sur 95 carcasses de porcs en usine. La longueur de la carcasse, le poids, l'épaisseur du lard dorsal et la surface de noix de côtelette ont été mesurés 24 heures post mortem, et une notation par points pour le persillé et la fermeté, ainsi que des mesures du pH, de la réflectance de l'eau extractible par pression et de la solubilité des protéines sarcoplasmiques (valeur de transmission) ont été effectuées sur un échantillon de longe.

Toutes les mesures objectives effectuées 45 min. post mortem avaient une corrélation hautement significative ($P < .01$) entre elles : il en était de même pour toutes les mesures de qualité prises 24 h post mortem. De l'ensemble des mesures prises 24h post mortem, la valeur de transmission montrait la plus grande relation avec les mesures du pH, de la température et de la rigor mortis 45 min. post mortem. Le pH initial de la longe avait une relation plus élevée avec la qualité finale déterminée par la valeur de transmission que le pH final de la longe ($r = -.69$ contre $r = -.51$). Lorsqu'une analyse de régression multiple progressive était utilisée pour la prédiction de la valeur de transmission, les variables ajoutées étaient par ordre d'importance : note pour la fermeté 24 h post mortem, pH initial de la longe, eau extractible par pression, température initiale de la longe, note pour la couleur finale et pH final de la longe. Le pH initial et la température de la longe comptaient pour 52% de la variation de la valeur de transmission.

L'épaisseur du lard, la surface de noix de côtelette et le poids de carcasse ne montraient aucune relation avec les mesures de qualité prises 45 min. et 24 h post mortem. Seules la longueur de carcasse et la notation subjective de la musculature avaient une relation avec la valeur de transmission ($r = -.26$ et $r = -.31$, respectivement). Cependant, on suppose que la notation visuelle de la musculature peut être influencée par le degré de l'établissement de la rigor mortis.