Relationship between fat content, connective tissue and objective tenderness measurement in porcine longissimus dorsi.

E. KIRKEGAARD, A.J. MØLLER and J. WISMER-PEDERSEN.

Royal Vet. - and Agricultural University, Department of Meat Science and Technology.
Copenhagen, Denmark.

Heat-induced changes in tenderness parameters in pork loins with differing intramuscular fat content were studied in relation to some qualitative characters of collagen. The meat was heated to 55°C, 65°C and 75°C. Objective tenderness measurements by an Instron Universal Testing apparatus were performed including Warner-Bratzler shear and compression. Parameters derived from the force-deformation curves were correlated with the chemical analyses.

The intramuscular fat content in the samples varied between 1,5 percent - 5,5 percent and significant negative correlations between percent fat and the percentage of cooking loss were found. The tenderness parameters reflecting the connective tissue component in the heat treated meat were most strongly correlated to the percent intramuscular fat. However the correlations between percent fat an analyses of pepsin-soluble collagen and also the amount of collagentype I and III were generally low. The effect of percent fat on the studied tenderness parameters was mainly pronounced, when the fat content was below 2,5 percent.

Beziehungen zwischen Fettgehalt, Bindegewebe und Objektiven Konsistenzmessungen in Porcine Longissimus Dorsi.

E. KIRKEGAARD, A.J. MØLLER und J. WISMER-PEDERSEN.

Royal Vet. - and Agricultural University, Department of Meat Science and Technology.
Copenhagen, Denmark.

Erwärmungsbedingte änderungen der Konsistenzparameter im Schweinekamm mit varierendem intramuskulärem Fettgehalt wurden in Relation zu einigen qualitativen Kollageneigenschaften untersucht. Das Fleisch wurde bei 55°C, 65°C und 75°C wärmebehandelt. Objektive Konsistenzmessungen einbegriffen Warner-Bratzler Überschneidung und Kompression wurden ausgeführt. Unterschiedliche Parameter vom Kraft-deformations Kurven wurden mit den chemischen Analysen korreliert.

Der Fettgehalt in den Proben varierte zwischen 1,5 - 5,5 prozenten und signifikante negative Korrelationen zwischen prozent Fett und prozent Schwund bei Wärmebehandlung wurden erwiesen. Die Konsistenzparameter,die die Bindegewebe-komponenten im wärmebehandelten Fleisch wiedergeben waren am meisten mit den prozentualen intramuskulären Fettgehalt Korreliert. Die Korrelationen zwischen prozent Fett und Analysen für pepsinlöslichem Kollagen samt für gehalt vom Kollagentypus I und III waren jedoch generel niedrig. Die Wirkung von prozent Fett der untersuchten Konsistenzparameter war hauptsächlich nur zugegen, wenn der Fettgehalt $<$ 2,5 prozent war.

5.10

Relations entre contenus de matières grasses caractéristiques des tissus connectifs, et mesures de tendreté dans longissimus dorsi du porc.

E. KIRKEGAARD, A.J. MØLLER et J. WISMER-PEDERSEN.

Royal Vet. - and Agricultural University, Department of Meat Science and Technology. Copenhagen, Denmark.

Les changements des paramètres de consistance produits par chauffage de filets de porc ont été etudiés et mis en rapport avec des qualités caractéristiques des collagenes dans les tissus connectifs des filets. Echantillons à differentes pourcentages de matières grasses intramusculaires ont été traitées à 55°C, à 65°C et à 75°C. Mesures de tendreté étaient obtenues avec un appareil Instron par Warner-Bratzler coupages et compressions. Les paramètres de consistance étaient calculées de graphes des forces appliqués contre les déformations réalisées.

Les contenus de matières grasses intramusculaires dans les échantillons ont varié dé 1,5% à 5,5%. La corrélation entre ces pourcentages et les pertes de poids pendant les traitements se trouve signifiante et négative. Les pourcentages de matières grasses intramusculaires et les paramètres de consistance, qui dépendent des qualités des tissus connectifs, sont parmi les plus corrélés. Les corrélations des pourcentages de matières grasses avec les contenus de collagenes soluble à pépsine, avec les contenus de collagenes de type I et avec de type III, sont moins prononçées. C'est seulement pour les contenus de matières grasses moins de 2,5%, qu'il se trouve une corrélation entre les pourcentages de matières grasses et les paramètres etudiées de consistance.

Отношение между содержанием жира, соединительной тканью и объективными измерениями мягкости в свинине (лопаточной части).

Е.КИРКЕГААРД, А.Й.МЁЛЛЕР и Й.ВИСМЕР-ПЕДЕРЗЕН.

Королевский Университет ветеренарии и сельского хозяйства, отдел технологии и исследования мяса. Копенгаген, Дания.

Были исследованы условные нагреванием изменения в параметрах мягкости в свинине (лопаточной части) с варьирующим процентом интрамышечного жира по отношению с некоторыми качественными коллаген-свойствами. Мясо было нагрето до соответственно 55°C, 65°C и 75°C. Объективные измерения мягкости выполнялись на Инстрон-аппарате для измерения мягкости учитывая Варнер-Братцлер перерезание и сжатие. Разные параметры силодеформационных кривых коррелировались с химическими анализами.
Содержание жира в опытах колебалось в пределах от I,5 до 5,5% и было указано на характерные отрицательные корреляции между процентом жира и процентом убыли во время нагревания. Параметры, которые отражают компонент соединительной ткани в нагреваемом мясе, были сильнее всего коррелированы с процентом интрамышечного жира. Корреляции между процентом жира и анализами пепсин-растворимого коллагена а также между процентом жира и количеством коллагена-типа I и коллагена III были однако вообще низкие. Действие процента жира на исследованные параметры мягкости присутствовало главным образом только тогда, когда содержание жира было ниже 2,5%.

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E. Kirkegaard, A.J. Møller and J. Wismer-Pedersen.

Royal Vet.- and Agricultural University, Department of Meat Science and Technology.
Copenhagen, Denmark.

Introduction.

Reducing the fat content of carcasses is a prime objective in swine improvement programmes and selection for this trait has increased the lean/fat ratio . Against this, however, there is a widespread belief that a certain amount of external and intramuscular fat is essential to ensure satisfactory cooked flavour and tenderness. Comprehensive studies have been conducted about the correlation between the fat content and factors relating to eating quality of meat (Bray 1966, Parrish 1974). Inconsistent results about the importance of percent intramuscular fat have arised in ealier reports, but more recently significant correlations between measurements of fatness and tenderness have been found (Davis et al. 1975, Martin and Fredeen 1974).

In some breeds which are superior in carcass muscling it seems that the content of intramuscular fat are of increasing importance for the sensoric properties (Buchter and Zeuthen 1971). The fat content in muscles is mainly located in the perimysium and it has been suggested that this may aid in the ultimate alteration of the collagen during cookery (Carpenter et al. 1963). Culler et al. 1978 found a significant correlation between myofibril fragmentation index and marbling in beef which may indicate that the fat content may be associated with factors modifying the myofibril proteins as well.

The purpose of this experiment is to study the effect of heat induced changes in objective tenderness measurements and relating these to the content of intramuscular fat and characteristics of collagen including pepsin-soluble collagen and the amount of collagen type I and III. Studies have proved that the latter reflects different degrees of cross-linking of collagen (Bailey and Sims 1977).

Materials and methods.

Carcasses from 10 pigs of Danish Landrace and 10 pigs of Duroc were slaughtered at approximately 90 kg liveweight. After a 24 hr. chill the loin sections were excised and aged at 2-4°C for a period of 7 days. All animals had ultimate pH value around 5.5 - 5.7.

Intramuscular fat was determined by a physical and a chemical method. The physical evaluation of fat was made on slices of both endsections of the loins. A grid 0.5 x 0.5 cm was used to quantitate the amount of fat present in the sections of m. longissimus dorsi. The fat measure was expressed as the percent of intersections falling on fat tissue. A representative sample of the two sections was analysed for percent intramuscular fat by a refractometrical method (Rudischer 1965)

The total amount of collagen was determined as percent hydroxyprolin (Wyler 1972). The connective tissue was isolated from the samples after homogenization and extraction procedure using 0.9 percent NaCl and 1 M KCl. The collagenous tissues were separated into collagen type I and type III by fractional precipitation from the pepsin solubilised collagen essentially as Bailey and Sims (1977). In addition to this the percent of collagen made soluble by the pepsin treatment was calculated as well as contained in the procedure to fractionate collagen. Subsamples of the longissimus dorsi muscle from each animal were cooked for 20 minutes in glass tubes containing 0.9 percent NaCl at 55°C, 65°C and 75°C. Samples were weighed before and after cooking to determine cooking losses.

An Instron Universal Testing machine table model 1140 was used to measure Warner-Bratzler (W-B) shear and compression with the following operation parameters: Crosshead speed 100 mm pr. minute and chart speed 100 mm pr. minute. The raw meat subsamples for heat treatment were 6 cm along the muscle fibre x 1 cm x 1 cm for shear measurements and 3 cm along the muscle fibre x 3 cm x 1 cm for compression measurements. From the W-B shear deformation curve two parameters were taken: (a) peak shear value, (b) slope of yield defined as x 2 - x 1 kg/s, where s is the distance travelled by the shear blade between x 1 = 0.5 kg and x 2 = 1.5 kg.

For the purpose of the compression measurement a 2.5 diameter flat plunger was driven vertically 70 percent through the samples of the cooked meat. The meat samples were cut and presented so that the fibres were perpendicular to the direction of the plunger movement. The plunger was driven into the meat twice in each sample and the work and force penetration curve for each cycle recorded. Four parameters were determined : (a) "elasticity" defined as the difference between the force required to achieve the first and second penetration, (b) "hardness" defined as the force required to achieve the first (Hardness 1) resp. the second (Hardness 2) penetration divided by the distance travelled by the plunger at the fist resp. the second penetration, (c) "cohesiveness" defined as the ratio of the work done during the second penetration to that performed during the first penetration.

The data were analyzed by simple correlation based upon the total material as no difference between the main effects of intramuscular fat and breed were found.

Results and discussions.

The content of intramuscular fat varied between 1.5 and 2.8 percent in the group of animals belonging to the Danish Landrace, whereas for Duroc it varied between 2.6 and 5.5 percent. The high level of intramuscular fat in the Duroc breed is in agreement of other authors (Hiner et al.1965, Allen et al.1966, Jensen et al.1967 and Kauftman et al. 1968). The physically determined intramuscular fat varied between 1.2 and 2.7 percent in Danish Landrace and between 3.4 and 5.2 percent in Duroc. The correlation between the physical and chemical determination of fat was very high significant ($r= .83$ $P < .001$). Mainly for the Duroc group the physical determination of fat resultet in higher values than the chemical determined fat. This is probably caused, that an increase in the content of intramuscular fat not only results in an increase in the total amount and size of fat cells but the fat is also located in greater, more visible groups (Moody and Cassens 1968).

The correlation coefficients between fat content and cooking losses at the three heating temperatures are shown in Table 1. An increased content of intramuscular fat resulted in significant lower cooking losses ($P < .01$). This effect was independent by the applied cooking temperatures. The intramuscular fat level had no effect on the differences in cooking losses arised from the different cooking temperatures (Fig. 1). The cooking losses varied between 20 and 30 percent and were mainly due to release of water. The observed effect of percent intramuscular fat on the cooking losses may probably indicate that the free water due to decreased waterbinding capacity after heat treatment is somewhat more inhibited from release when the surrounding perimysium contains higher levels of fat. Another reason could be that the amount of incorporated fat is related to factors effecting the heat induçed denaturation of the myofibrillar proteins. While it is well known that increased juiciness of meat is associated with the amount of intramuscular fat, this experiment shows that it also may be caused by a fat related effect on the waterbinding characteristics of meat.

The results obtained by calculation of correlation coefficients between the tenderness parameters and percent intramuscular fat are shown in Table 2. Most of the coefficients were found significant. When the fat was determined by the physical method the correlation coefficients were slightly higher.

The W-B peak shear values were found to correlate most significantly with the content of intramuscular fat when the meat was cooked at $55^{o}C$ ($r= -.65$ $P < .01$). Heat treatment at $65^{o}C$ and $75^{o}C$ also revealed that a decreasing amount of percent intramuscular fat resulted in higher W-B peak shear values although the correlation coefficients were smaller. Incorporation of fat in the perimysium reduces the physical resistence of meat, and this effect must be most pronounced at $55^{o}C$ where the connective tissue component mainly contributes to the shear value.

The W-B slope of yield represents the rate of change of initial force and was calculated from the force deformation curve as a measure of hardness. As shown in Table 2 the correlation coefficients between the W-B slope of yield and percent intramuscular fat were highly significant at all three cooking temperatures. This means that a decreasing amount of intramuscular fat causes a more rigid structure of the cooked meat.

Parameters derived or calculated from the compression curves have been used as a measurement of hardness, elasticity and cohesiveness of meat (Friedmann et al. 1963). In a study comparing different methods for determining meat tenderness, Bouton and Harris (1972) found that the compression measurements account mainly for the variation in tenderness caused by the connective tissue component.

In this experiment the difference between the force required to achieve the first and second curve produced by the plunger was taken as a measurement of elasticity. When differences were small, this was taken as an indication of higher elasticity. As shown in Table 2, highly significant correlation were found between percent intramuscular fat and the amount of elasticity at cooking temperatures at 55°C and 65°C ($P < .01$). Also the derived parameters concerning hardness were highly correlated with percent intramuscular fat at all cooking temperatures. Samples containing a decreasing amount of fat therefore have a decreasing elasticity but increasing hardness compared to the more fatty samples. When the cooking temperature was raised to 75°C the correlation between elasticity and percent intramuscular fat decreased. This is probably caused by the higher degree of coagulation of the myofibrillar proteins assuming that the main effect of fat is connected to the connective tissue component.

The cohesiveness of meat after heat treatment is related to the gelatinization of collagen as shown by the higher correlations between cohesivness and percent intramuscular fat at cooking temperature at 75°C. Carpenter et al. (1963) suggested, that increasing amount of intramuscular fat may aid in the alteration of collagen during cooking. According to this the effect of fat on cohesiviness may be more pronounced by cooking at 75°C.

Splitting the total material into three subgroups based upon the percentage of intramuscular fat, the relationship between fat levels and W-B peak shear as well as W-B slope of yield is shown in Fig. 2. The effect of percent intramuscular fat on the tenderness parameters appeared to be more pronounced at decreased level of fat in the samples. Increasing amount of fat beyond 2.5 percent had no further effect on the W-B peak shear or the W-B slope of yield as seen from Fig. 2.
In Table 3 the correlation coefficients between the different tenderness parameters are presented. The highest correlations were found between the W-B slope of yield and the compression parameters. Most probably both of these parameters measure the same characteristics of meat namely the connective tissue component. Therefore it is assumed that the effect of intramuscular fat on the tenderness of meat is mainly manifested through an effect on the connective tissue component.

Total collagen contents calculated from hydroxyprolin analyses varied between .88 and 1.32 percent in the group of animals belonging to the Danish Landrace and between .85 and 1.04 percent in the group of Duroc. The amount of pepsin soluble collagen was determined from the isolated and freeze dried connective tissue after removal of the saltsoluble fraction. A negative correlation was found between percent intramuscular fat and the amount of non-pepsin-soluble collagen ($r = -.33$ and $r = -.56$ $P < .05$ for resp. the chemical and physical determination of fat). Therefore, an increasing content of fat in the samples was related to higher amount of pepsin soluble collagen. A higher degree of cross-linking in the telopeptid region of the tropocollagen reduces the solubility effect of pepsin. However, the correlation coefficients between percent pepsin soluble collagen and the various tenderness parameters were in general low and not significant. The amount of collagen type I and III was resp. c. 5 and c. 26 percent, the latter amount in accordance with results found by Bailey and Sims (1976). The analyses of collagen types were, however, not related to the variation in the fat content nor the variation in the tenderness parameters studied.

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Table 1. Simple correlation coefficients between percent intramuscular fat and percent cooking loss at different cooking temperatures.

Percent cooking loss	Percent intramuscular fat	
	Chemical	Physical
55°C	-.56[xx]	-.75[xxx]
65°C	-.48[x]	-.70[xxx]
75°C	-.57[xx]	-.67[xx]

x = P< .05 , xx = P< .01 , xxx = P< .001 , n = 20

Table 2. Simple correlation coefficients among tenderness parameters and percent intramuscular fat at different cooking temperatures.

	Cooking temperature					
	55°C		65°C		75°C	
	Percent intramuscular fat					
	chemical	physical	chemical	physical	chemical	physical
Warner-Bratzler shear.						
Peak shear value	$-.65^{xx}$	$-.67^{xx}$	$-.24$	$-.38$	$-.32$	$-.61^{xx}$
Slope of yield	$-.54^{x}$	$-.73^{xxx}$	$-.60^{xx}$	$-.77^{xxx}$	$-.65^{xx}$	$-.74^{xxx}$
Instron compression.						
Elasticity	$-.61^{xx}$	$-.78^{xxx}$	$-.63^{xx}$	$-.75^{xxx}$	$-.27$	$-.41$
Hardness I	$-.46^{x}$	$-.74^{xxx}$	$-.20$	$-.50^{x}$	$-.46$	$-.64^{xx}$
Hardness II	$-.62^{xx}$	$-.73^{xxx}$	$-.24$	$-.50^{x}$	$-.33$	$-.52^{x}$
Cohesiveness	$-.35$	$-.60^{xx}$	$-.36$	$-.45$	$-.73^{xxx}$	$-.63^{xx}$

x = P< .05 , xx = P< .01 , xxx = P< .001 , n = 20

Table 3. Simple correlation coefficients between tenderness parameters at different cooking temperatures.

		W-B peak shear value			W-B slope of yield		
Compression parameters		55°C	65°C	75°C	55°C	65°C	75°C
Elasticity	55	$.59^{xx}$	$.39$	$.58^{xx}$	$.70^{xxx}$	$.80^{xxx}$	$.64^{xx}$
	65	$.58^{xx}$	$.28$	$.49^{x}$	$.62^{xx}$	$.76^{xxx}$	$.75^{xxx}$
	75	$.29$	$.65^{xx}$	$.60^{xx}$	$.47^{x}$	$.57^{xx}$	$.35$
Hardness I	55	$.42$	$.24$	$.55^{x}$	$.61^{xx}$	$.71^{xxx}$	$.77^{xxx}$
	65	$.33$	$.52^{x}$	$.73^{xxx}$	$.63^{xx}$	$.55^{x}$	$.49^{x}$
	75	$.45^{x}$	$.58^{xx}$	$.66^{xx}$	$.65^{xx}$	$.75^{xxx}$	$.56^{xx}$
Hardness II	55	$.52^{x}$	$.27$	$.49^{x}$	$.63^{xx}$	$.74^{xxx}$	$.78^{xxx}$
	65	$.39$	$.46^{x}$	$.74^{xxx}$	$.60^{xx}$	$.57^{xx}$	$.52^{x}$
	75	$.25$	$.22$	$.48^{x}$	$.55^{x}$	$.57^{xx}$	$.55^{x}$
Cohesiveness	55	$.40$	$.25$	$.49^{x}$	$.51^{x}$	$.45^{x}$	$.54^{x}$
	65	$.52^{x}$	$.45^{x}$	$.57^{xx}$	$.49^{x}$	$.41$	$.35$
	75	$.45^{x}$	$.07$	$.21$	$.41$	$.47^{x}$	$.54^{x}$

x = P< 0.05 , xx = P< 0.01 , xxx = P< 0.001 n = 20

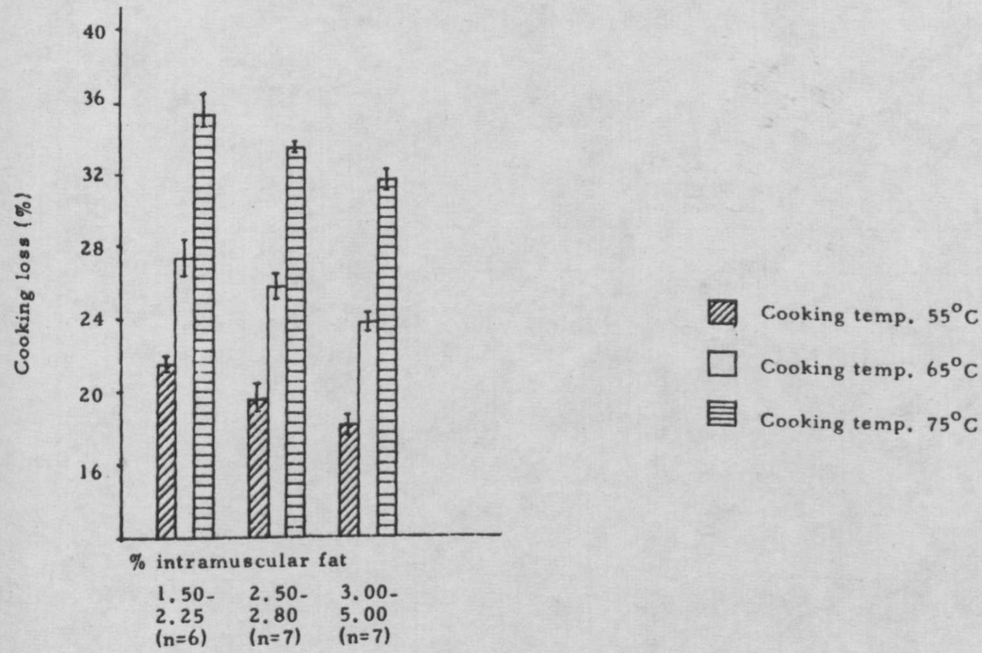

Fig. 1. Cooking loss in pork loins with different intramuscular fat content after heating to 55°C, 65°C and 75°C. (The vertical bars are the 95% confidence limits).

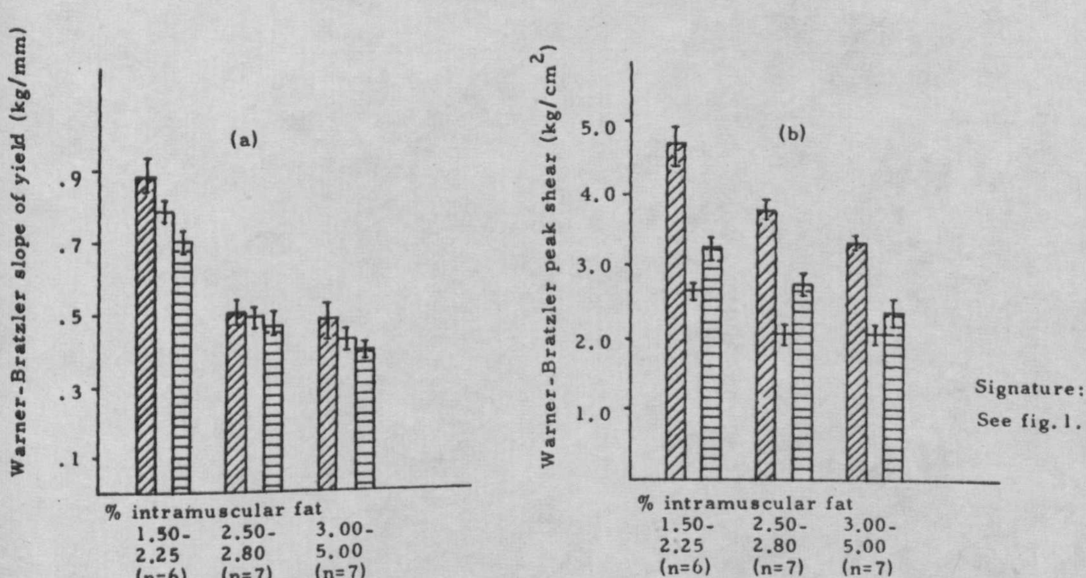

Fig. 2. Warner-Bratzler slope of yield (a) and peak shear (b) in pork loins with different intramuscular fat content after heating to 55°C, 65°C and 75°C (The vertical bars are the 95% confidence limits).