P4. **REFRIGERATION, FREEZING AND THAWING**

BEEF QUALITY RESULTING FROM MUSCLE BONING THE UNCHILLED CARCASS

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Fabrication of the bovine carcass prior to chilling has several potential advantages. The economy of this process is reflected by the removal of waste fat and bone prior to chilling, thereby reducing the amount of chilling space by 25 to 30 percent per carcass. A hanging carcass requires 86,400 cu. in. of refrigerated space. The space wasted above and below the hanging carcass is equal to 34,000 cu. in. making a total space requirement per carcass equal to 120,400 cu. in. The actual space required to chill the edible portion of a 600 lb. carcass is 26,000 cu. in. or a saving of 75 to 78%. Boneless meat would have a more rapid and uniform cooling rate. Refrigerated space now wasted above and below the carcass would be saved and the output increased. Conveyorized cooling of boneless meat may become the most efficient method of handling slaughtered beef. A boneless, closely trimmed beef muscle or muscle system would lend itself well to portion control and marketability.

Muscle boning and fabricating of the choice bovine carcass prior to chilling is of commercial interest. Although little research has been reported on beef, extensive investigations have been conducted using the porcine carcass.

Forty commercial 1000 pound Angus steers were used. One side of each carcass was randomly assigned to a 3, 5, or 7 hour conditioning period at 16 degrees C (hot boned). Muscles were excised at the end of the conditioning period, placed in Cryovac bags, and chilled at 1.1 degree C for the remaining part of the 48 hr. period. The opposite intact side (cold boned) was chilled 48 hours at 1.1 degrees C and then the muscles were excised. The change in the fall of pH was measured in the Psoas Major muscle and muscle temperature was recorded for the Longissimus doris, Semimembranosus, and Semitendinosus muscles. Yield of salable meat for each treatment was determined and the aerobic microbial total count was made on the ground trimmings from each control and treatment side. Detailed studies of three individual muscles for each treatment were made. These studies included fiber diameter, kinkiness, sarcomere length, panel tenderness, panel colour, press fluid,and shear tests.

Colour of the various muscles was recorded using the photovolt reflectometer. Initial colour measurements were recorded 48 hours after death and daily for 5 days.

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LA QUALITÉ DE BOEUF Ā LA SUITE DE L'EXCISION DES OS ET DES MUSCLES DANS UNE CARCASSE NON-REFROIDIE

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La préparation intensive d'une carcasse bovine avant le refroidissement offre des avantages potentiels. En enlevant toute graisse supplémentaire et tous les os, le processus envisagé réduit l'espace refrigéré nécessaire de 25 à 30%. Une carcasse suspendue exige à peu près 2 m^3 d'espace refrigéré. L'espace non-utilisé au-dessous et au-dessus de la carcasse s'élève à presque 2/3 m^3 ou, au total, à plus de 2-1/2 m^3. Par contre, le stockage nécessaire pour refrigérer la partie comestible d'une carcasse de 450 kg. est à peu près 1/2 m^3, ou 75 à 78% de moins. De plus, une viande sans os est plus susceptible à un refroidissement uniforme. L'espace non-utilisé au-dessus et au-dessous de la carcasse pourrait ainsi être réservé à d'autre chose et le stockage total peu être augmenté. Il se peut bien que le processus de refroidissement de viande, sans os et en gros, puisse devenir la méthode la plus efficace pour conserver du boeuf. Il va sans dire qu'un système de muscles bien taillé et dépouillé de graisse et d'os inutiles facilite la coupe et augmente la qualité du produit du point de vue de sa rentabilité commerciale.

Bien qu'il n'y ait presque pas, à l'heure actuelle, de recherches de ce genre se rapportant sur le boeuf, on emploie déjà des méthodes semblables dans l'industrie porcine.

Pour nos expériences, on a employé 40 boeufs du type Angus, à un poids de 450 kg chacun. Un côté de chaque carcasse (sans os) fut exposé à des périodes de conditionnement de 3, 5, ou 7 heures, à une température de 16° C. Les muscles furent coupés à la fin de la période de conditionnement, mis dans des sac de celloïde et refroidis à une température de 1,1° C pour le restant de la période de 48 heures. L'autre côté (laissé intacte) fut refroidi à 1,1° C pendant 48 heures, puis les muscles furent excisés. La chute de la valeur pH fut mesurée dans le psoas majeur, et la température musculaire établie pour le longissimus dorsi et les muscles semimembraneux et semitendineux. On a ensuite établi la quantité de viande commerciale (et prête à être vendue) pour chaque côté, ainsi que le compte des microbes aérobiques total de quelques échantillons pris dans la masse et du côté d'observation. Des études détaillées se rapportent sur trois muscles individuels pour chaque expérience. On a ensuite mesuré le diamètre des fibres, la texture, la longueur des sarcomères, le tissue fibreux, la couleur, la fluidité sous pression et la résistance à l'abrasion de la viande ainsi préparée.

La couleur des divers muscles a été établie à l'aide d'un réflectomètre photopile. La coloration fut enrégistrée 48 heures après le décès des animaux et, ensuite, une fois par jour cinq jours durant.

ERHÖHTE RINDFLEISCHQUALITÄT DURCH TOTALE AUSSCHLACHTUNG DER SCHLACHTWARMEN KARKASSE

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Die Verarbeitung von Rinderkarkassen vor dem Einfrieren bietet gewisse potentielle Vorteile. Ökonomisch vorteilhafte Ergebnisse können erzielt werden, wenn überschüssige Fettmassen und Knochen vor dem Einfrierungsverfahren erfernt werden, wodurch der erforderliche Gefrierraum um 25-30% pro Karkasse herabgesetzt und eingespart werden kann. Eine abhängende Karkasse erfordert etwa 2 m^3 Gefrierraum. Der beanspruchte Lagerraum über und unter der Karkasse beträgt nicht ganz 2/3 m^3, sodaß sich ein Gesamtlagerraum von mehr als 2-1/2 m^3 ergibt. Dagegen erfordert die Gefrierlagerung einer voll verwendungsfähigen Karkasse von 225 kg. nur ca. 1/2 m^3, oder 75-78% weniger Raumfläche. Außerdem ist knochenloses Fleisch schneller und gleichförmiger einzufrieren. Der bisher unausgenützte Gefrierraum über und unter der Karkasse könnte auf diese Weise eingespart und dessen Kapazität erhöht werden. Automatisiertes Gefrieren knochenlosen Fleisches sollte als die beste Lagerungsmethode für Schlachtvieh angesehen werden, da ein knochenloses und gut verarbeitetes Muskelsystem leichter aufbewahrt und kommerziell auswertbar ist.

Die restlose Ausschlachtung einer qualitätsmäßig guten Rinderkarkasse vor dem Einfrieren ist deshalb von ökonimischem Interesse. Eine entsprechende Auswertung von Schweinekarkassen wurde bereits vorgeschlagen.

Zu experimentellen Zwecken wurden 40 Angus-Stiere im Lebendgewicht von je 450 kg. verwendet. Je eine Seite der Karkasse wurde nach Knochenentfernung im Warmzustand und ohne besondere Auswahl 3, 5 oder 7 Stunden lang in Kühllagerung bei 16°C gegeben. Muskelsysteme wurden nach dieser Einlagerungsperiode ausgeschnitten, in Cryovachüllen überführt undbbei einer Temperatur von 1, 1°C bis zu einer Zeitspanne von 48 Stunden überlassen. Die andere Seite, deren Knochen in kaltem Zustand entfernt wurden, wurde erst 48 Stunden lang bei einer Temperatur von 1, 1°C abgekuhlt bevor das Muskelgewebe entfernt wurde. Der Abfall des pH Wertes im Psoas Major Muskel, sowie Muskeltemperaturen im Longissimus dorsi, in semimembranen und semitendinösen Muskeln wurden sodann ermittelt. Schließlich wurde das Endprodukt der verkauffertigen Fleischmengen ermittelt und der aerobischmikrobische Zahlwert an Hand von geschabten Fleischproben an Kontroll-und Testseiten festgestellt. Genaue Untersuchungen erstreckten sich auf drei spezielle Muskelsysteme. Die Untersuchungen schlossen auch Diameterbemessungen von Fasern, sowie Grobheitsgrad, Sarkomerlänge, Gewebegrad und -farbe, Pressflüssigkeitswerte und Abschertests ein.

Die Farbe verschiedener Muskeln wurde mit Hilfe eines Photovoltreflektometers festgehalten. Ursprüngliche Messungen wurden 48 Stunden nach Schlachtung und 5 Tage täglich danach vorgenommen.

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Introduction

Concern for the conservation of energy and the spiraling price of food throughout the world has resulted in a search by Industry for more efficient methods of providing quality beef at reasonable prices. Improving the efficiency of beef processing is one of the major goals of boning the unchilled carcass. Such a procedure must provide a product of comparable, if not improved quality, to the conventional method of fabricating the chilled carcass. Although muscle boning has for many years been accomplished using cow, and other low value beef for comminuted meat products, limited attention has been given to adapting this method to block beef. (prime, choice, good). Ample evidence has been available since 1939 to demonstrate that muscle excised before the onset phase of rigor mortis, will shorten. Furthermore, the data points out that the extent to which a muscle shortens, has a great influence upon the ultimate product tenderness. Various attempts have been made to reduce the shortening phenomenon by controlling muscle tension.

Classical papers by Bate - Smith (1939) and Bate - Smith and Bendall (1949) showed the importance of the time course of rigor mortis upon shortening and muscle tenderness. Investigations by Locker (1960) and Herring et al. (1965) provided evidence that bovine muscle excised immediately after death would shorten. Furthermore, Locker (1960), Herring et al. (1965), Herring et al. (1967), Gillis and Henrickson (1968), and Hostetler et al. (1972) indicated that the amount of stretch upon muscles by various methods of suspension could greatly influence their tenderness. Equally important, Marsh (1954), de Fremery and Pool (1960), Briskey et al. (1962) and Cassens and Newbold (1967) showed that the time course of rigor mortis was dramatically influenced by temperature and that the shortening of bovine muscle was minimized at 16°C. By using these facts and those of Henrickson (1968) and Kastner and Henrickson (1969) as guidelines, the investigation of boning the unchilled bovine carcass was initiated.

A study by Brasington and Hammons, (1971) gave support to on-the-rail boning by suggesting that the method would use more semi-skilled labourers. Further advantages such as shorter chill time, less refrigeration space, and increased yield of boneless beef of the desired fat content would allow maximum utilization of the refrigeration space. Savings in the fat rendering operation would also result in decreased use of heat energy. Bone from the proposed method could be sold at a premium price for soup stock. In addition, boneless closely trimmed meat would lend itself well to forming and shaping for portion control and marketability. The shelf life of the final product could be enhanced, benefiting all segments of the distribution chain.

This investigation was formulated to evaluate the quality of beef resulting from boning the unchilled carcass.

Materials and Methods

Thirty Angus steers of approximately the same weight (45 kg.) and market grade (choice) were randomly designated to be used in one of three (three, five, and seven hour) holding periods for the unchilled side. Extreme care was taken in handling the animals to avoid any adverse effect upon post-mortem metabolic reasctions and ultimate product quality. Each animal was stunned, raised from the floor by both legs, bled, and dressed in the conventional slaughterhouse manner. Dressing of the carcass proceeded rapidly so that Federal Inspection of the washed sides was made within 45 minutes post-mortem. Either the right or left side of each carcass was utilized in one of the two treatments: 1) removing the muscles from the unchilled side three, five, or seven hours after death while at 16°C or 2) removing the muscles from the chilled side after a 48 hour holding period at 1.1°C. Each side was suspended from a rail via a roller and hook through the Achilles tendon. Thermocouples connected to a recording potentiometer were inserted into three test muscles, namely, the longissimus dorsi (LD), semimembranosus (SM), and semitendinosus (ST) to follow the decline in temperature. Fall in pH of the psoas major was followed utilizing a section of the muscle at 30 minute intervals one through five hours post-mortem and again at 24 and 48 hour post-mortem. At the end of the treatment holding period (3, 5, or 7 hour) at 16°C., the longissimus dorsi muscle was excised, placed in a moisture barrier bag and removed to a 1.1°C. cooler along with the paired hanging side for the remaining portion of the 48 hour period. At the end of the 48 hour period, the LD from the intact chilled side (control) was excised. When the excision was complete, muscles from both sides were divided into sections. Duplicate steaks were packaged, labelled, and frozen at -10°C. As work schedules permitted, analyses were made for colour, press fluid, percent moisture, percent fat, histological observation, organoleptic evaluation, percent cooking loss, and shear force.

The SAS computer programming system, Service (1972) was used to analyse the data.

Results and Discussion

Holding the beef side immediately post-mortem at 16°C for three hours before removal of the longissimus dorsi muscle was effective in reducing muscle shortening resulting from rigor mortis. As shown in Table I, and Figure 1, no significant difference ($P < .05$) in shear force occurred between the three hour boned LD and its corresponding 48 hour control. Although not practically important, when the shear values were compared after a five hour post-mortem holding period it was noted that the difference was significant ($P - .05$). Similar results were reported by Kastner (1972). Although the LD boned unchilled had a slightly higher shear force than the chilled boned control, when held for seven hours post-mortem, little difference was noted. Steaks sampled from the origin and inserting ends of the LD muscle responded similarly regardless of the period held prior to excision as evidenced by the nonsignificant ($P < .05$) boning x steak interaction which occurred in all three holding periods (Figure 1). Further examination of these data revealed that steaks excised near the posterior portion of LD were not influenced by boning the unchilled muscle as much as, steaks cut from near the origin. Variation in the response within a given muscle to boning may be due, in part, to connective tissue content, mode of attachment, and/or the amount of muscle tension at a specific location. The difference in shear force between steaks, regardless of boning time, was nonsignificant ($P > .05$) in all holding periods. Similar variation in shear force of chilled LD muscle with respect to within muscle location was also observed by Weir (1953), Cover et al., (1962), Kastner (1972), and Hansen (1973).

When a muscle shortens, sarcomere length, fiber length, and tenderness each decrease, while shear force increases. A microscopic examination of the LD muscle indicated that the difference in sarcomere length between the chilled and unchilled excised muscle was nonsignificant ($P > .05$) for each of the three holding periods. However, as shown in Table 2, and Figures 2 and 3, the sarcomere length of the chilled muscle was always greater (0.13 um) than those from muscle boned before chilling. This supports the shear data in that muscle excised from the carcass at three, five, or seven hours post-mortem did undergo a slightly greater amount of shortening when compared to muscles removed after 48 hours post-mortem. This also agreed with the work of Herring et al., (1966; 1967) who found that shear force increased curvilinearly with decreased sarcomere length.

Further evidence of shortening was illustrated by an increased fiber diameter, as well as, increased fiber kinkiness score for the LD excised unchilled as compared to muscle excised from the chilled carcass (Table 3 & 4). Differences in fiber diameter between the five and seven hour holding periods and the corresponding 48 hour control were nonsignificant ($P > .05$), however, the difference at five hours did approach significance. Fibers from the three hour holding period muscle were significantly ($P < .05$) larger than the chilled control. This observation agreed well with both the shear force and sarcomere length, as well as, with Herring et al. (1967) who showed that shear force and sarcomere length changed with increased fiber diameter. In addition, the relationship of fiber diameter to muscle shortening and tenderness was also demonstrated by Buck and Black (1967), Gillis and Henrickson (1970), and Cagle and Henrickson (1970).

Evaluation of fibers for kinkiness was shown by Gillis and Henrickson (1970) to be another estimate of the contraction state of muscle. A muscle in severe contraction will have a greater percentage of kinky fibers, a higher shear value and be less tender. An analysis of variance revealed that muscle excised before being chilled had a significantly higher ($P < .05$) kinkiness score than the corresponding 48 hour chilled muscle. When one practically evaluates all three parameters, the largest difference in fiber diameter between the chilled and unchilled muscle was 6.12 microns. The kinkiness scores for both treatments were in the range of three to five, meaning that the contraction state of the fibers ranged from wavy to twisted. If severe shortening had occurred in the unchilled excised muscle one would expect the fibers to show kinkiness scores in the range from six to seven, that is, from twisted to kinky.

The duo - trio test revealed that panelists were significantly ($P < .05$) able to distinguish differences in tenderness between the chilled and unchilled excised LD at the seven hour holding period. (Table 5). Difference in preference between the two treatments were nonsignificant ($P > .05$) at three and seven hour holding period, but a significant difference ($P < .05$) was indicated at the five hour period. (Table 6). Steaks removed from the unchilled muscle were slightly preferred to the 48 hour control at the seven hour holding period. Practical differences in tenderness were small as the panelists evaluated both treatments using the hedonic scale (Table 6). Acceptability values were in the range of slightly acceptable for all holding periods.

The importance of meat colour to consumer acceptability was demonstrated by Danner (1959) and Dunsing (1959) who showed that physical appearance of a retail cut was the most important factor used in meat selection. The consumer selects a meat cut primarily on leanness, and then for appearance, and freshness with the latter judgement based primarily on brightness of colour (Rhodes et al., 1955; Seltzer 1955).

Colour evaluation by the duo - trio test for the chilled versus unchilled LD indicated that the panelists could significantly ($P < .05$) distinguish differences between the two processes at the three hour holding period. (Table 7). A colour preference was given to the cold boned muscle when compared to either the three or five hour excised product. (Table 8). Differences in acceptability of the unchilled excised muscle versus the 48 hour control was also found to be non-significant ($P > .05$) at all holding periods. Both the products from unchilled muscles and those from the chilled side were scored in the range of slightly acceptable at all holding periods. Thus, indicating that the product excised from the unchilled carcass would have colour pleasing to the consumer.

No significant ($P > .05$) difference in psychrophilic bacterial populations occurred between the chilled versus unchilled excised muscle at any of the holding periods. Differences in the mesophilic count were also small and practically nonsignificant. Mean log numbers for the psychrophilic were in the range of 10^2 to 10^3 per gram, where as mesophiles ranged from 10^3 to 10^4 per gram for both treatments. These low bacterial counts illustrate that on-the-rail boning is more sanitary than the conventional method of fabrication where the carcass is exposed to the air for a greater period.

Difference in press fluid ratios, percent cooking loss, percent moisture and percent fat between steaks from the two methods of handling meat were small and nonsignificant ($P > .05$).

The data from this investigation indicates that one may excise the LD muscle from the carcass, as early as, three hours post-mortem without a large discernable loss in the major quality attributes of beef. Because the tissues are still warm and pliable, fabrication time is decreased, which further lends support for on-the-rail boning.

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TABLE I

MEAN SHEAR VALUES OF 'HOT' AND 'COLD' BONED LONGISSIMUS DORSI

[a]Holding Period (Hr.)	'Cold' Shear Force (lb)	'Hot' Shear Force (lb)	Std. Error of Treatment Mean (lb)
3	15.14	16.44 NS	0.47
5	13.47	15.25*	0.45
7	14.33	14.60 NS	0.47

[a]Post-mortem holding period for 'hot' boned side.
NS = Nonsignificant
* = Significant difference ($P < .05$) between 'hot' and 'cold' boned steaks.

TABLE 2

ANALYSIS OF SARCOMERE LENGTH IN 'HOT' VERSUS 'COLD' BONED LONGISSIMUS DORSI

[a]Holding Period (Hr)	Mean 'Cold' Sarcomere Length (μm)	Mean 'Hot' Sarcomere Length (μm)	Std. Error of Treatment Mean (μm)
3	2.58	2.45 NS	0.05
5	2.48	2.40 NS	0.02
7	2.70	2.57 NS	0.03

[a]Post-mortem holding period for 'hot' side.
NS = Nonsignificant.

TABLE 3

ANALYSIS OF FIBER DIAMETER IN 'HOT' VERSUS 'COLD' BONED LONGISSIMUS DORSI

[a]Holding Period (Hr)	Mean 'Cold' Fiber Diameter (μm)	Mean 'Hot' Fiber Diameter (μm)	Std. Error of Treatment Mean (μm)
3	63.72	69.84*	1.52
5	63.52	67.16 NS	1.34
7	64.48	66.04 NS	1.88

[a]Post-mortem holding period for 'hot' side. NS = Nonsignificant.
* = Significant difference ($P < .05$) between 'hot' and 'cold' boned sides.

TABLE 4

ANALYSIS OF KINKINESS SCORE IN 'HOT' VERSUS 'COLD BONED LONGISSIMUS DORSI

[a]Holding Period (Hr.)	Mean 'Cold' Kinkiness Score	Mean 'Hot' Kinkiness Score	Std. Error of Treatment Mean
3	3.54	4.90*	0.35
5	3.52	5.16*	0.33
7	3.18	4.46*	0.28

[a]Post-mortem holding period for 'hot' side.
* Significant difference ($P < .05$) between 'hot' and 'cold' boned sides.

TABLE 5

PAIRED COMPARISON ANALYSIS FOR THE LONGISSIMUS DORSI

[a]Holding Period (Hr.)	Total Number Paired Comparisons	Total Number Identifying Pair
3	120	63 NS
5	120	62 NS
7	120	73*

[a]Post-mortem holding period for 'hot' boned side.
NS = Nonsignificant.
* = Significant difference ($P < .05$) between 'hot' and 'cold' boned steaks.

TABLE 6

PREFERENCE RANK ANALYSIS FOR TENDERNESS OF THE LONGISSIMUS DORSI MUSCLE

[a]Holding Period (Hr.)	Mean Rank of 'Cold' Boned Steaks	Mean Rank of 'Hot' Boned Steaks
3	1.60	1.40 NS
5	1.62	1.38 *
7	1.48	1.52 NS

[a]Post-mortem holding period for 'hot' boned side.
[b]Larger value denotes increased preference.
NS = Nonsignificant.
* = Significant difference ($P < .05$) between 'hot' and 'cold' boned steaks.

HEDONIC SCALE RANK ANALYSIS FOR TENDERNESS OF THE LONGISSIMUS DORSI

[a]Holding Period (Hr.)	Mean 'Cold' Hedonic Score	Mean 'Hot' Hedonic Score	Mean 'Cold' Ranked Score	Mean 'Hot' Ranked Score
3	4.42	4.14	1.59	1.41*
5	4.68	4.42	1.59	1.41 NS
7	4.41	4.47	1.48	1.52 NS

[a]Post-mortem holding period for 'hot' boned side.
[b]Larger value denotes higher acceptability.
NS = Nonsignificant.
* Significant difference ($P < .05$) between 'hot' and 'cold' boned steaks.

TABLE 7

PAIRED COMPARISON ANALYSIS OF THE COLOUR OF 'HOT' & 'COLD' LONGISSIMUS DORSI

[a]Holding Period (Hr)	Total Number of Paired Comparisons	Total Number Identifying Pair
3	60	44*
5	60	36 NS
7	60	32 NS

[a]Post-mortem holding period for 'hot' boned side.
NS = Nonsignificant.
* = Significant difference ($P < .05$) between 'hot' and 'cold' boned steaks.

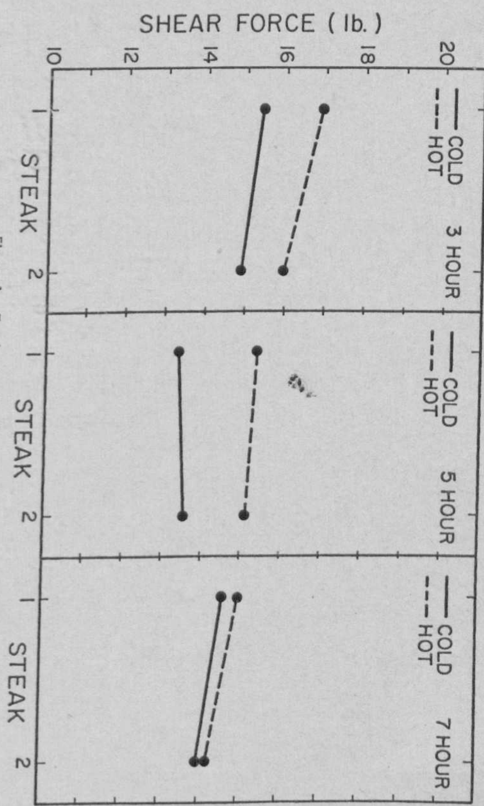

Figure 1. Tenderness Evaluation of Longissimus Dorsi: by Warner-Bratzler Shear

TABLE 8

PREFERENCE RANK ANALYSIS OF THE COLOUR OF 'HOT' AND 'COLD' BONED LONGISSIMUS DORSI

[a]Holding Period (Hr)	[b]Mean Rank of 'Cold' Boned Steaks	[b]Mean Rank of 'Hot' Boned Steaks
3	1.63	1.37*
5	1.58	1.42 NS
7	1.45	1.55 NS

[a]Post-mortem holding period for 'hot' boned side.
[b]Larger value denotes increased preference.
NS = Nonsignificant.
* = Significant difference ($P < .05$)

HEDONIC SCALE SCORE RANK ANALYSIS OF THE COLOUR OF 'HOT' AND 'COLD' BONED LONGISSIMUS DORSI

[a]Holding Period (Hr)	[b]Mean 'Cold' Hedonic Score	[b]Mean 'Hot' Hedonic Score	[b]Mean 'Cold' Ranked Score	[b]Mean 'Hot' Ranked Score
3	4.30	4.30	1.56	1.44 NS
5	4.63	4.53	1.54	1.46 NS
7	4.45	4.51	1.50	1.50 NS

[a]Post-mortem holding period.
[b]Larger value denotes higher acceptability.
NS = Nonsignificant.

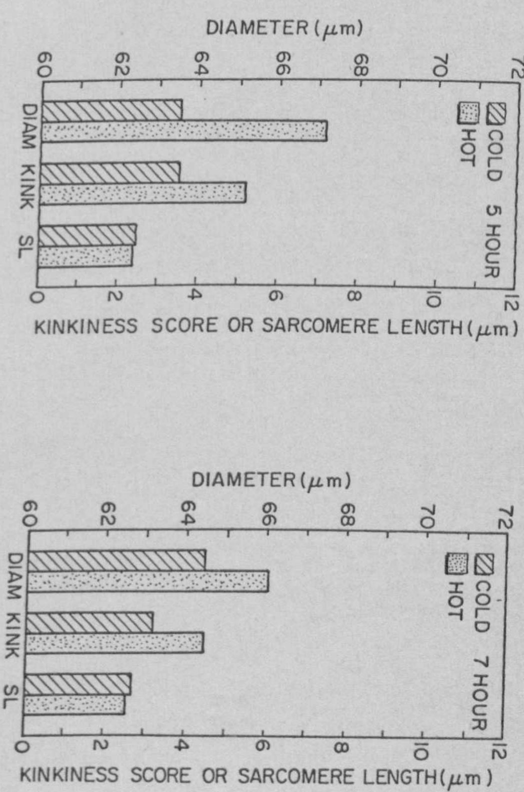

Figure 3. Fiber Characteristics of Bovine Longissimus Dorsi: Excised "Hot" and "Cold"

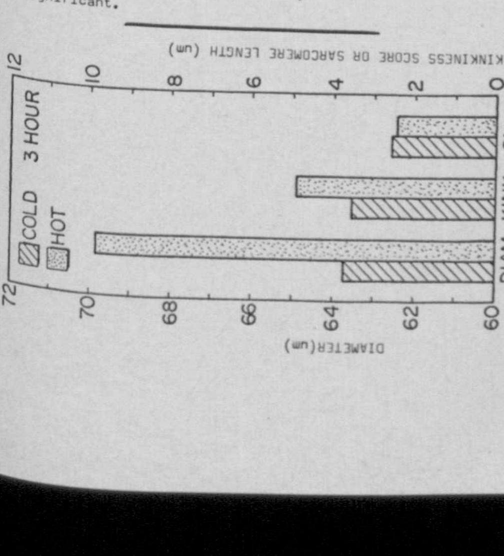

Figure 2. Fiber Characteristics of Bovine Longissimus Dorsi ; Excised 'Hot' and 'Cold'