A comparison of some meat quality parameters in two breeds of cattle

P.G. VAN DER WAL[1], B.J. TINBERGEN[2] and P.L. BERGSTRÖM[1]

[1]Research Institute for Animal Husbandry "Schoonoord", Zeist, the Netherlands

[2]Netherlands Centre for Meat Technology, Dept. of Central Institute for Nutrition and Food Research-TNO, Zeist, the Netherlands

Meat quality of Dutch Friesian (FH) and Dutch red and white (Meuse-Rhine-Yssel = MRY) bulls has been compared. The meat quality measurements were performed on three different muscles, viz. M. longissimus dorsi, M. pectoralis profundus and M. triceps brachii. It was found that muscular tissue of the MRY-bulls contained more expressible water, while cooking losses were higher. The animals were slaughtered at three different weights, viz. 380, 440 and 500 kg live-weight; the weight groups have been compared. This comparison showed differences in the amounts of haematin, which increased with higher slaughter weight, and which was correlated positively with Göfo-values. Warner-Bratzler shear force values also rose in connection with the weight.
At 380 kg MRY-bulls had less haematin, more expressible water and higher cooking losses, compared with FH-bulls. In the other weight groups, expressible water and cooking losses also were higher in the MRY-breed; while haematin was higher in the MRY-bulls at 440 kg and neary equal to that of the FH-bulls at 500 kg.
With most of the meat quality parameters, differences were observed between the muscles that have been measured.

Ein Vergleich einiger Fleischparameter von zwei Rinderrassen

P.G. VAN DER WAL[1], B.J. TINBERGEN[2] und P.L. BERGSTRÖM[1]

[1]Institut für Tierzuchtforschung "Schoonoord", Zeist, Niederlande

[2]Niederländisches Zentrum für Fleischtechnologie, Abteilung des Zentralinstituts für Ernährungsforschung-TNO, Zeist, Niederlande

Die Qualität des Fleisches von niederländischen schwarzbunten (FH) und niederländischen rotbunten (Maas-Rhein-IJssel = MRY) Bullen ist verglichen worden. Von drei verschiedenen Muskeln, M. longissimus dorsi, M. pectoralis profundus und M. triceps brachii, wurde die Fleischqualität gemessen. Dabei wurde festgestellt, dass das Muskelgewebe der MRY-Bullen mehr freies Wasser enthält, während die Kochverluste grösser waren. Weil die Tiere geschlachtet wurden bei drei verschiedenen Gewichten, nämlich 380, 440 und 500 kg Lebendgewicht, konnten auch die Gewichtsgruppen verglichen worden. Dieser Vergleich zeigte Unterschiede für die Haematingehalte, welche stiegen mit ansteigendem Gewicht. Die Haematinspiegel waren positiv korreliert mit den Göfo-Werten. Die Warner-Bratzler Scherwerte stiegen ebenfalls an bei Zunahme des Lebendgewichtes der Tiere.
Mit 380 kg hatten die MRY-Bullen weniger Haematin, mehr freies Wasser und höhere Kochverluste als die FH-Bullen. Die anderen Gewichtsgruppen der MRY-Rasse hatten ebenfalls mehr freies Wasser und höhere Kochverluste im Vergleich mit der FH-Rasse. Haematin war bei MRY-Bullen von 440 kg erhöht, während der Haematingehalt bei 500 kg von gleicher Höhe war wie bei den FH-Bullen.
Unterschiede zwischen den gemessenen Muskeln wurden beobachtet für die meisten der Fleischqualitätskriterien.

I.6

Une comparaison de quelques paramètres de la viande de deux races bovines

P.G. VAN DER WAL[1], B.J. TINBERGEN[2] et P.L. BERGSTRÖM[1]

[1]Institut de Recherches Zootechniques "Schoonoord", Zeist, Pays-Bas

[2]Centre Néerlandais pour la Technologie de viande, Dépt. de l'Institut Central de la Nutrition et de l'Alimentation-TNO, Zeist, Pays-Bas

La qualité de la viande de taureaux des races Néerlandaises pie noire (FH) et pie rouge (Meuse Rhine Yssel = MRY) a été comparée. Les mesurages de la qualité de la viande ont été réalisés sur trois muscles différents: M. longissimus dorsi, M. pectoralis profundus et M. triceps brachii. Le tissu musculaire des taureaux MRY se caractérise par un pouvoir de rétention d'eau inférieur et par plus de pertes à la cuisson. Les animaux étant abattus à trois poids différents (380, 440 et 500 kg de poids vif), ces groupes ont été comparés. Cette comparaison démontrait des différences dans les quantités d'hématine, lesquelles augmentaient avec un poids plus élevé à l'abattage. La quantité d'hématine était correlée positivement avec la valeur Göfo. Les valeurs trouvées avec l'appareil de Warner-Bratzler (shear force values) augmentaient aussi avec les poids vif des taureaux.
À 380 kg les taureaux MRY avaient moins d'hématine, un pouvoir de rétention d'eau inférieur et plus de pertes à la cuisson que les taureaux FH du même poids. Dans les deux autres groupes (440 et 500 kg) le pouvoir de rétention d'eau et les pertes à la cuisson étaient comparables. A 440 kg la quantité d'hématine dans la race MRY était plus basse, et à 500 kg à peu près égale comparée avec les taureaux FH.
Des différences entre les trois muscles mesurés, ont été observées pour la plupart des paramètres de la viande.

Сравнение некоторых параметров мяса двух пород скота.

П.Г. фан дер ВАЛЬ[1], Б.Й. ТИНБЕРГЕН[2] и П.Л. БЕРГСТРЕМ[1]

[1]Нии Животноводства "Схооноорд", г. Зейст, Голландия
[2]Отдел"Нидерландский Центр Мяной Технологий" Центрального Нии Пнтания и Пищи, г. Зейст, Голландия

Произведено сравнение качества мяса быков нидерландской чернопестрой породы (FH) и нидерландской краснопестрой породы (Maas-Rijn-IJssel = MRY). Для выявления качества мяса было произведено измерение мышцы трех различных видов, а именно,M. longissimus dorsi, M. pectoralis profundus и M. triceps brachii.В связи с этим было установлено, что мышечная ткань быков MRY содержит больше свободной воды, между тем как потери варки увеличились. так как производили убой быков трех различных весов, а именно, 380, 440 и 500 кг живой массы, то можно было осуществить также сравнение весовых категорий в отдельности. Из этого сравнения вытекают разницы в отношении содержания гематина, которое с повышением веса увеличивается, и в положительном отношении их уровень соответствует значениям Göfo. Коэффициенты резания по Warner-Bratzler(у) в соответствии с повышением живой массы также увеличились.
По сравнению с быками FH быки MRY в условиях веса в 380 кг характеризовались меньшим содержанием гематина, более высоким содержанием свободной воды,а также более высокими потерями в процессе варения. Остальные весовые категории быков породы MRY по сравнению с быками FH отличаются также более высоким содержанием свободной воды и более значительными потерями варения. Содержание гематина быков MRY весом в 440 кг повысилось, между тем как в весовой категории 500 кг в условиях одинаковой высоты оно характеризовалось таким же самым значением как у быков FH.
Обследованию были подвержены также разницы между измеряемой мышцей по большинству критерий, имеющих отношение к качеству мяса.

A comparison of some meat quality parameters in two breeds of cattle

P.G. VAN DER WAL[1], B.J. TINBERGEN[2] and P.L. BERGSTRÖM

1 Research Institute for Animal Husbandry "Schoonoord", Zeist, The Netherlands

2 Netherlands Centre for Meat Technology, Dept. of Central Institute for Nutrition and Food Research-T.N.O., Zeist, The Netherlands

Introduction

It is known that differences in meat quality parameters and biochemical meat characteristics exist between breeds of cattle (LAWRIE, 1974). In a comparison of black-pied cattle and beef crossbreds, the latter ones produce meat with higher shear force values (OTTO and STANG, 1975). The same authors found that beef of the heavier animals was more tender. This observation may be in contrast to REAGAN et al. (1976) who stated that increases in actual age were significantly associated with decreases in beef tenderness, provided that the animals were of older age. Together with an increase in age, higher myoglobin levels could be determined in bovine muscular tissue (BOWLING et al., 1978). That muscular characteristics are not identical for all muscles in the same animal was pointed out by HUNT and HEDRICK (1977), who indicated significant differences among muscles for e.g. visual colour, percent reflectance, myoglobin and hemoglobin content, water holding capacity, etc. Similar observations in connection with tenderness have already been described by RAMSBOTTOM et al. (1945), who gave tenderness values for a great number of bovine muscles.
However, we still need more information about breed differences, especially when it concerns meat quality characteristics of different muscles in relation to slaughter weight and feeding level. Therefore, in this report a comparison between bulls belonging to two breeds of cattle (FH and MRY) is given; the animals differ significantly in fatness when fed ad libitum (BERGSTRÖM, 1965). As an additional factor, for further information, the animals were slaughtered at three different weights. In this way we were informed about breed differences as well as the influence of slaughter weight on meat quality characteristics.

Material and methods

On 90 bulls meat quality measurements have been performed. The breeds were Dutch Friesian (FH) and Dutch red and white (Meuse Rhine Issel = MRY), with 45 animals each. The bulls were slaughtered at three different weights, viz. 380, 440 and 500 kg live-weight, with equal numbers in the weight groups.
Three different muscles of each animal have been measured at varying times (2 to 5 days) post mortem, connected with the lapse of time between slaughter and dissection. The beef samples have been collected from the longissimus dorsi (at the level of the last rib = LD), the pectoralis profundus (cranial half = PP) and the triceps brachii (distal part of the caput longum = TB) muscles. These muscles were chosen because they are large, homogeneous muscles, in order to obtain samples of sufficient weight for the physical and chemical analyses. The analyses comprised:

a. pH (Electrofact pH-meter, type 36100; Philips pH-electrode type C 64/1; 0-12 pH, 0-70^{o}C),
b. water binding capacity (water holding capacity = WHC) according to GRAU and HAMM (1953). A 300 mg muscle sample is pressed on a filter paper (S&S 2040b) between plexiglass plates for 5 minutes at 115 Newton (N) per sq. cm pressure,
c. haematin content (mg haematin per kg muscle tissue), which was determined according to the method of HORNSEY (1956),
d. meat colour by means of a Göfo-apparatus, (type 2, Ernst Schütt jun. Laborgerätebau, 34 Göttingen).

After these measurements, the muscle samples were vacuum packed into plastic bags to prevent dehydration, and stored at 4^{o}C during 10 days. It may be accepted that during the storage period full ageing was achieved. After 10 days ageing the samples were prepared and repacked, heated at 70^{o}C during 90 minutes, and subsequently cooled (about 18^{o}C). Then cooking loss (percentage weight loss) and Warner-Bratzler shear force values were determined. The latter estimations were performed, using 12 cores (1.26 cm in diameter). Each core was sheared with a Warner-Bratzler blade, attached to the Instron Universal Testing Instrument. The mean values of 12 cores are reported as max. force in Newtons, required to shear the cores (TINBERGEN, 1979).

Results

Beef quality characteristics in relation to live-weight groups

The data obtained in the study about the quality of the meat of young bulls can be ranked according to different principles. A very important factor is the influence of live-weight on beef quality, which is correlated to a certain extent to the animal's age. Some reservation regarding this statement may be made, which is caused by the fact that, besides different slaughter weights, three different feeding levels (ad libitum, 80 % and 60 % of ad libitum) were used in the experiment. Therefore, it is better to take into consideration the bulls' live-weights. The results of the measurements of the three weight groups are given in Table 1.

Table 1. Mean values (in round numbers) and standard deviations of the beef quality measurements, performed on the bulls of three different live-weight groups (n = 30 bulls per group; lower numbers are indicated in parenthesis).

Live-weight	Muscle	WHC %		Haematin (mg/kg)		Göfo		Cooking loss %		W-B shear force (N)	
		x̄	Sx	x̄	Sx	x̄	Sx	x̄	Sx	x̄	Sx
380 kg	LD[1)]	34	3	110	24	65	8(18)	27	3	37	11
	PP	35	3	118	21	62	5(18)	30	4	42	8
	TB	38	4	157	42	70	6(18)	28	3	33	5
440 kg	LD	34	3	121	22	72	9(27)	28	2	37	14
	PP	36	4	133	26	66	6(27)	33	2	47	6
	TB	38	3(29)	181	33(29)	75	5(26)	30	2(29)	38	5(29)
500 kg	LD	35	2	146	30	74	6	28	2	39	14
	PP	36	4	150	22	70	6	32	2	49	9
	TB	38	3	187	35	75	6	30	2	39	8

1) LD = M. longissimus dorsi
PP = M. pectoralis profundus
TB = M. triceps brachii

The table shows that the WHC of the same muscles belonging to the three weight groups does not differ. The amount of haematin, on the contrary increases significantly (.05 > P > .01) with weight, when the groups of 380 and 440 kg live-weight are compared. A similar comparison between 440 and 500 kg, shows that the increase of the haematin content of the LD (P < .001) and the PP (.01 > P > .001) is significant, while also the level of haematin of the TB still increases (NS; t-test according to STUDENT). The Göfo values also increase significantly (LD: .05 > P > .01; PP: .05 > P > .01; TB: .01 > P >.001) with increasing weight from 380 kg to 440 kg, implying that the meat gets a darker colour. Further increases were observed with heavier animals, but these were only significant in the PP (.01 > P > .001). Also cooking losses were higher at 440 kg in comparison with 380 kg (LD: NS; PP: .01 > P > .001; TB: .05 > P > .01). This tendency continued (NS) in the next weight group. The Warner-Bratzler shear force values demonstrated an increase in force, required to shear the samples, with increasing weight of the animals. The increases were even significant for the PP and TB (.01 > P > .001 and P < .001, resp.) in the comparison of the two lower weight groups. This means that the meat gets tougher with increasing weight.
Between the three live-weight groups differences, sometimes very significant ones, are present. Although the calculations have been performed for the whole population, the data obtained from the individual breeds were mainly comparable.

Quality of beef from two different breeds

The meat quality parameters of bulls, belonging to the two breeds, have been compared. This was done by comparing the breed groups, each consisting of the three weight classes. The results of these comparisons are given in Table 2.

Table 2. Mean values (in round numbers) and standard deviations of the beef quality measurements, performed on the bulls of two breeds (n = 45 bulls per breed; lower numbers are indicated in parenthesis).

Breed	Muscle	WHC (%)		Haematin (mg/kg)		Göfo		Cooking loss (%)		W-B shear force (N)	
		x̄	Sx	x̄	Sx	x̄	Sx	x̄	Sx	x̄	Sx
FH[2)]	LD[1)]	33	4	124	28	71	8(39)	27	3	35	13
	PP	35	3	132	23	67	7(39)	31	3	46	8
	TB	37	3	176	38	74	5(39)	29	3	36	7
MRY	LD	35	2	127	30	72	9(36)	29	2	40	12
	PP	36	3	136	29	66	6(36)	33	2	45	8
	TB	39	4(44)	174	40(44)	73	6(35)	30	2(44)	37	7(44)

1) LD = M. longissimus dorsi
PP = M. pectoralis profundus
TB = M. triceps brachii

2) FH = Dutch Friesian
MRY = Dutch red and white

From the table it can become clear that in this comparison the two breeds only differ significantly in WHC (LD: .01 > P > .001; PP: .01 > P > .001; TB: .05 > P > .01) and cooking losses (LD: P < .001; PP .01 > P > .001; TB: .05 > P > .01). The Göfo values, the haematin levels and the Warner-Bratzler shear force values are of the same order. A comparison of the two breeds per weight group gave even less significant differences per group than the number which was found per breed. Remarkable, however, was the fact that the pH of the TB muscle of the FH-breed was significantly (.05 > P > .01) higher (pH 5.5) in the group of 380 kg live-weight, in contrast to the other pH values which were in the range of pH 5.3 - 5.4. Furthermore, attention should be given to differences in meat quality parameters that certainly will be found between individual muscles within the same carcass.

A comparison of the meat quality parameters of three different bovine muscles

The three different muscles, on which the meat quality measurements were performed, have been compared. The mean values and standard deviations of each of the meat quality parameters per muscle are given in Table 3.

Table 3. Mean values (in round numbers) and standard deviations of the meat quality measurements of three different muscles, belonging to two breeds of cattle (n = 90 samples per muscle; lower numbers are indicated in parenthesis).

Muscle	WHC (%) $\bar{x}$	WHC (%) Sx	Haematin (mg/kg) $\bar{x}$	Haematin (mg/kg) Sx	Göfo $\bar{x}$	Göfo Sx	Cooking loss (%) $\bar{x}$	Cooking loss (%) Sx	W-B-shear force (N) $\bar{x}$	W-B-shear force (N) Sx
LD[1]	34	3	126	29	71	8(75)	28	2	38	13
PP	35	3	134	26	67	7(75)	32	3	46	8
TB	38	3([illegible]	175	39(89)	73	10(74)	30	3(89)	37	7(89)

1) LD = M. longissimus dorsi
PP = M. pectoralis profundus
TB = M. triceps brachii

The table shows that rather important differences exist between the three muscles that have been measured, with an exception for the Göfo- and Warner-Bratzler shear force values. In a comparison of the LD and the TB muscles, the two parameters do not differ significantly. Both muscles, however, are significantly different ($P < .001$) from the M. pectoralis profundus. The Göfo values of the PP are lower, while the Warner-Bratzler shear force values are higher, which means that the PP is tougher. The water holding capacity, cooking losses and haematin levels differ significant, from $.05 > P > .01$ to $P < .001$, when the three muscles are compared. The order is such that the LD has the highest WHC in constrast to the TB which has a rather low water binding capacity. For cooking losses the TB takes an intermediate position between the LD and the PP, while the LD has a rather low cooking loss. The haematin content of the TB and the Göfo value are the highest, compared with the other muscles. While the heamatin level of the LD is low, the Göfo values of the PP were observed to be lowest. The significances, which were calculated for the whole population, were also present in the individual breeds, however, often on a lower level of significance.

As a discrepancy seems to be present between e.g. the haematin levels and the Göfo values, and WHC and cooking losses, we decided to calculate the coefficients of correlation between several meat quality parameters. The results of these calculations are given in Table 4.

The table shows that the muscular haematin concentrations are correlated significantly with the Göfo values. Furthermore, significant correlations between haematin on the one side and other meat quality parameters on the other, are not present, with an exception for the Warner-Bratzler shear force values. Göfo values are of the same magnitude as the haematin concentrations correlated with cooking losses and WHC.

WHC and cooking losses are non-significantly correlated; this is also valid for WHC and Warner-Bratzler shear force values. These shear force values on the contrary, are highly significantly correlated with cooking losses in the PP as well as the TB muscles. This might be due to the fact that meat gets tougher with a higher cooking loss. Furthermore, the two parameters connected with colour, are correlated with the meat's tenderness in some of the muscles.

Table 4. The coefficients of correlation and their levels of significance, which are calculated between the meat quality parameters of three different bovine muscles (two-tailed test).

	LD[1] r	LD d.f.[2]	PP r	PP d.f.	TB r	TB d.f.
Haematin - Göfo[4]	.48***	73	.31**	73	.26*	72[3]
Haematin - WHC	.06	88	-.08	88	.01	87
Haematin - cooking loss	-.03	88	.06	88	.03	87
Haematin - W-B shear force	.26**	88	.20*	88	.13	87
Göfo - WHC	-.17	73	-.09	73	-.33**	72
Göfo - cooking loss	-.08	73	.10	73	.02	72
Göfo - W-B shear force	.45***	73	.15	73	.37**	72
WHC - cooking loss	.20	88	.06	88	.08	87
WHC - W-B shear force	-.11	88	.06	88	-.13	87
Cooking loss - W-B shear force	-.01	88	.43***	88	.40***	87

1) LD = M. longissimus dorsi
PP = M. pectoralis profundus
TB = M. triceps brachii

2) d.f. = degrees of freedom

3) * = $.05 > P > .01$
** = $.01 > P > .001$
*** = $P < .001$

4) WHC = water holding capacity

Discussion

The meat quality measurements, which have been performed on muscular tissue of bulls belonging to two breeds, proved that the live-weight of the animal is a very important factor, accordingly to literature (LAWRIE, 1974). With increasing weight, from 380 to 500 kg, the amounts of haematin in the tissue increased significantly. Similar observations have been made by BOWLING et al.(1978), who found that the muscular (M. longissimus dorsi) myoglobin concentration rose in older steers. Therfore, it might be expected that the Göfo values develop similarly, but here the increases were less abvious. Higher reflection values correspond with a darker meat colour, which is related to higher amounts of muscle pigments (GOUTEFONGEA, 1969). This latter finding could be confirmed with the high level of significance which was calculated for the coefficients of correlation between Göfo values and haematin concentrations.

In contrast to the water holding capacity, which did not change in the three weight groups, cooking losses increased in the animals of the higher weight classes. Besides, a tendency is found that the Warner-Bratzler shear forces, required to shear the individual muscle samples, increase in the heavier animals. This is specially present in a comparison of the two groups with the lower weights (380 versus 440 kg live-weight). Our data may correspond with those of REAGAN et al.(1976), who found on bovine longissimus dorsi muscles that increases in actual age were significantly associated with decreases in tenderness. It must be noted in connection with this, that the weight groups in our experiment are not identical with age groups, because three different feeding

levels were used per group. Therefore, an interaction may be expected between live-weight and chronological age, caused by the feeding level. A comparison of the two breeds, with which the experiments were performed, demonstrated that significant differences only occurred in water holding capacity and cooking losses. Both estimations showed lower values in meat of Dutch Friesian bulls. Although, Warner-Bratzler shear force values were not different in the two breeds, they appeared to be significantly correlated with cooking losses in the pectoralis profundus as well as the triceps brachii muscles. Breed differences between Dutch Friesians and Dutch red and whites, which might be expected on account of findings on cows by OTTO and STANG (1975), could only be observed in a very limited non-significant way. These authors stated that beef crossbreds in contrast to pure milk breeds produced meat with higher shear force values, i.e. less tender meat. In this case our observations, performed on bulls, agree with the data of the German research workers, as far as breed differences are concerned.
A comparison of the three muscles gave no significant differences in Göfo and Warner-Bratzler shear force values between the LD and TB. These two muscles were significantly more tender than the PP, which was comparable to the findings of RAMBSBOTTOM et al.(1945). The colour of the LD and TB was darker in comparison to the PP when measured with the Göfo apparatus. The water holding capacity, cooking losses and haematin concentrations of the three muscles differed significantly.Whereas the TB had the lowest WHC in contrast to the LD. This latter muscle had next to the highest WHC the lowest cooking losses. In spite of these facts, WHC and cooking losses appeared not to be correlated. The cooking loss on the contrary is correlated, at a high level of significance, with the meat's tenderness of the PP as well as the TB muscles. This phenomenon might possibly be explained by the fact that drier muscles, due to the cooking process, possess a higher resistance against the shearing device of the Warner-Bratzler apparatus. The positive correlation between Göfo values and haematin concentrations on the one side and Warner-Bratzler shear force values on the other can be explained by the fact that muscular tissue of the heavier bulls is darker in colour and has an increased toughness in comparison with the animals of the lower weight classes. These correlations must be explained by the age interaction.

Concluded remarks

- In muscular tissue of bulls, the amounts of haematin rise with increasing (from 380 to 500 kg) live-weight.
- The Göfo values, which represent the light reflection of the meat, also increase in heavier animals.
- Göfo values and muscular haematin concentrations are significantly correlated.
- Increases in cooking losses and Warner-Bratzler shear force values occur in the bulls of the higher weight classes.
- The differences between Dutch Friesian (FH) and Dutch red and white (MRY) bulls only exist in water holding capacity (WHC) and cooking losses. The WHC is lower, while cooking losses are higher in the MRY breed.
- In a comparison of the longissimus dorsi (LD), pectoralis profundus (PP) and triceps brachii (TB) muscles, the PPhas the highest Warner-Bratzler shear force values, i.e. less tender. The TB has a rather low WHC and the highest haematin concentration.

Final conclusions

- A higher live-weight, which is not directly due to a higher age, corresponds with darker meat.
- Cooking loss as well as toughness after cooking, increases with heavier animals.
- Breed differences are not obvious with an exception to WHC and cooking losses.
- The M. pectoralis profundus has the highest light reflection (lowest Göfo values) together with the highest shear force resistance, when compared with the longissimus dorsi and triceps brachii muscles.

References

BERGSTROM, P.L., 1965. Erfelijke verschillen bij de produktie van rundvlees. Veeteelt en Zuivelberichten 8(3): 113-123.

BOWLING, R.A., J.K.RIGGS, G.C.SMITH, Z.L.CARPENTER, R.L.REDDISH & O.D.BUTLER, 1978. Production, carcass and palatability characteristics of steers produced by different management systems. J.Animal Sci. 46(2): 333-340.

GOUTEFONGEA, R., 1969. Relations between water-binding capacity of pork and the evolution of Ca and MG-linked fractions during the occurrence of rigor mortis. In: W.SYBESMA, P.G.VAN DER WAL & P.WALSTRA (eds).Recent points of view on the condition and meat quality of pigs for slaughter. Proc.int. Symp. IVO, Zeist, 1968. pp. 227-236.

GRAU, R. & R.HAMM, 1953. Eine einfache Methode zur Bestimmung der Wasserbindung in Fleisch. Naturwissenschaften 40: 29-30.

HORNSEY, H.C., 1956. The colour of cooked cured pork. I. Estimation of the nitric oxide-Haem pigments. J. Sci Fd Agric. 7: 534-540.

HUNT, M.C. & H.B. HEDRICK, 1977. Profile of fiber types and related properties of five bovine muscles. J.Fd Sci. 42(2): 513-517.

LAWRIE, R.A., 1974. Meat Science. 2nd edition. Pergamon Press, Oxford.

OTTO, E. & N.STANG, 1975. Grundlagenuntersuchungen zur Messung der Zartheit von Rindfleisch. 2. Mitteilung.Einflussfaktoren auf die Fleischzartheit. Arch. Tierzucht, Berlin 18(6): 367-377.

RAMSBOTTOM, J.M., E.J.Strandine & C.H.Koonz, 1945. Comparative tenderness of representive beef muscles. Food Res. 10: 497-509.

REAGAN, J.O., Z.L.CARPENTER & G.C.SMITH, 1976. Age-related traits affecting the tenderness of the bovine longissimus dorsi muscle. J. Animal Sci. 43(6): 1198-1205.

TINBERGEN, B.J., 1979. Objective measurements for the quality of beef. CIVO-Report No R 6021 (March, 1979).

Acknowledgement

Thanks are due to Mr. G. van Essen, Mr. H.L. van Boxtel and Mr. H.G.Hulshof from IVO and Miss M. van Biert and Mr. R.Delpeut from CIVO for their technical assistance.