A QUALITATIVE MODEL OF FACTORS INFLUENCING BEEF TENDERNESS

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SUMMARY

A conceptual model is presented in which the effects of both pre- and post-slaughter factors on tenderness were considered. The pre-slaughter factors were plane of nutrition, breed type and target carcase weight. Post-slaughter factors considered were carcase weight, fatness and cooling rate, the use of effective electrical stimulation, muscle ultimate pH and ageing the meat. Generally, 2 extreme, but commercial, levels of each factor were considered. The relative importance of the contributions of the myofibrillar and connective tissue components to toughness were illustrated by predicting Instron Compression (IC), an index of the connective tissue contribution, and calculated tenderness values; the latter are calculated using IC values and Warner-Bratzler (WB) peak force (PF) values, which are more of an index of the myofibrillar contribution. The modelling was simplistic in that values were predicted by extrapolation and interpolation from a number of experiments involving many animals. Advantages were that the same procedure was used to determine the objective tenderness of muscles of all of these animals and there were at least 40 animals per treatment in the base data.

Keywords: model, tenderness, beef, electrical stimulation

INTRODUCTION

There have been a number of models produced to account for the wide variation in tenderness found in a muscle, across animals within a species (Dransfield 1992). Unfortunately, data used were often from experiments in which only one muscle, ***M.longissimus** dorsi* (LD), was used from animals slaughtered to meet car-case specifications for 1 market and with carcases and cuts being processed in 1 way. This approach is not sufficiently complete to be of maximum benefit in predicting variations in tenderness of muscles of beef animals slaughtered in Australia for export to a large number of countries. Generally, extremes have been chosen and predicted numbers are relative, and not absolute, values. Objective measurements of tenderness will be used; these are the Warner Bratzler (WB) peak shear force (PF) and Instron Compression (IC) values, which can be used together to account for about 80% of the variation in mean tenderness scores of trained taste panels (Shorthose and Harris 1990). WB values are more influenced by contractile proteins and IC values by connective tissue. The "tenderness" (T) values reported were calculated (T= 1.16 WBPF + 3.24 IC -1.04, Shorthose and Harris 1990) using predicted WBPF and IC values.

THE MODEL

The outcomes of interpolation and extrapolation of data from a number of experiments, on the effects of a number of treatments on the tenderness of 4 muscles, are presented in tabular form.

Limits of the variables in the model

The limits were animals of light (LMW) or heavy mature weight breeds (HMW), grown on planes of nutrition either average for Central Queensland pasture (NAP) or average for feedlots in Queensland (NAFL) and slaughtered at either domestic, supermarket (190 kg) or Japanese trade (320 kg) carcase weights. It was presumed that carcases were chilled at either prescribed (PC) (Meat Order 250 = deep butt temperature of 20°C at 20 hours postmortem), or slower (AC), chilling rates after either effective electrical stimulation (EES) or no stimulation (NES).

Muscles

The 4 muscles chosen were 2 muscles restrained (R) from shortening postmortem by their muscle attachments and 2 muscles free to shorten (F). Within the 2 groups (R and F), 1 muscle had a high connective tissue content (HC) and the other a low connective tissue content (LC).

The muscles considered were:-

	Free to shorten	Restrained from shortening
Low Connective	*M. longissimus dorsi* (LD) = FLC	*M. psoas major* (PM) = RLC
High Connective	*M. semimembranosus* (SM) = FHC	*M. semitendinosus* (ST) = RHC

The muscles were presumed to have an ultimate pH of 5.6 (except in Table 6) and to have been cooked "well-done" at either 1 day postmortem (no ageing (NA) or after ageing for 4 weeks at 0°C (A4).

RESULTS

Age at slaughter

Age at slaughter (at a target carcase weight) is determined by the interaction of breed type (LMW v HMW) and plane of nutrition (NAP v NAFL). The data (Table 1) are derived from Loxton (1992).

Table 1. Age (days) at slaughter of steers of either light mature (LMW) or heavy mature weight (HMW) breeds produced either off pasture (NAP) or after 100 days in a feedlot (NAF)

Carcase weight (kg)	190		320	
Breed type	LMW	HMW	LMW	HMW
Pasture	500	440	1180	1060
Feedlot	380	340	740	660

Influences of the interaction of carcase weight and carcase processing conditions (chilling rate and electrical stimulation) and animal age on "tenderness" of 4 muscles

Chilling rate affects the toughness of muscles free to shorten; the faster the chilling rate the more the muscle shortens and toughens. Carcase weight, therefore, affects toughening in these muscles, as heavier car-cases cool more slowly with consequent less muscle shortening and toughening; subcutaneous fat (related to carcase weight) has an independent, insulating effect. Changes in muscle shortening affect PF values more than IC values and animal age differences affect IC values more than PF values, particularly in muscles with a high connective tissue content. IC and calculated tenderness (T) values of the 4 muscles of the groups of animals described in Table 1 are shown in Tables 2 and 3; results in Table 2 are when carcases are effectively electrically stimulated and in Table 3 with no ES.

Table 2. Effects of age differences on tenderness (IC [kg] and T[A] values in parentheses) of 4 unaged muscles of effectively electrically stimulated steer carcases chilled at an average rate (deep butt temperature of 140 kg side, 20°C at 20 hours postmortem)

Carcase weight (kg)		190				320			
Breed type		LMW		HMW		LMW		HMW	
	Muscle	IC	T	IC	T	IC	T	IC	T
Pasture	LD	1.4	(9)	1.3	(9)	1.7	(11)	1.6	(10)
	PM	1.0	(7)	1.0	(7)	1.0	(7)	1.0	(7)
	SM	1.7	(10)	1.6	(10)	2.4	(14)	2.3	(13)
	ST	2.0	(12)	1.9	(11)	2.8	(16)	2.4	(14)
Feedlot	LD	1.2	(8)	1.1	(8)	1.5	(10)	1.4	(10)
	PM	1.0	(7)	1.0	(7)	1.0	(7)	1.0	(7)
	SM	1.6	(10)	1.5	(9)	2.1	(12)	2.0	(11)
	ST	1.7	(10)	1.6	(10)	2.3	(13)	2.2	(13)

[A] = Values rounded to nearest whole number. 1 = extremely tender and 25 = extremely tough; values of >11 are considered undesirable.

Note that: the 2 muscles free to shorten (LD and SM) did not shorten due to EES and the PM was always tender (as it cannot shorten and has a low CT content). The SM and ST muscles of the heavier car-cases were tough because of increased animal ages, even though shortening was inhibited (by EES) in the SM and the

ST cannot shorten. Without EES, the LD and SM would be expected to shorten and toughen; the effect would be least in LD and SM muscles from heavier carcases and less in the SM, a deep muscle, than the LD.

The effects of animal age, carcase weight and fatness differences on the tenderness of the 4 unaged muscles chilled at an average rate without EES are shown in Table 3.

Table 3. Effects of animal age differences on tenderness (IC [kg] and T values in parentheses) of 4 unaged muscles of non-electrically stimulated carcases chilled at an average rate

Carcase weight (kg)		190				320			
Breed type		LMW		HMW		LMW		HMW	
	Muscle	IC	T	IC	T	IC	T	IC	T
	LD	1.5	(17)	1.5	(17)	1.8	(11)	1.7	(11)
Pasture	PM	1.0	(7)	1.0	(7)	1.0	(7)	1.0	(7)
	SM	1.9	(16)	1.8	(16)	2.4	(18)	2.3	(17)
	ST	2.0	(12)	1.9	(11)	2.8	(16)	2.4	(14)
	LD	1.4	(17)	1.4	(17)	1.6	(10)	1.6	(10)
Feedlot	PM	1.0	(7)	1.0	(7)	1.0	(7)	1.0	(7)
	SM	1.8	(15)	1.7	(15)	2.1	(16)	2.1	(17)
	ST	1.7	(10)	1.6	(10)	2.3	(13)	2.2	(13)

Faster than average chilling (AC) exacerbates differences in WBPF of muscles free to shorten, especially in superficial muscles of light, lean carcases. Faster chilling has no effect on WBPF or IC values of restrained muscles, therefore only the tenderness of muscles free to shorten (LD and SM) are shown in Table 4 to demonstrate the effects of faster chilling (PC) in non-stimulated carcases.

Table 4. Effect of 2 chilling regimes (PC v AC) on tenderness of 2 unaged muscles free to shorten (LD or SM) of non-stimulated carcases of pasture-fed steers of 2 weights (190 or 320 kg)

Carcase weight (kg)		190				320			
Breed type		LMW		HMW		LMW		HMW	
	Muscle	IC	T	IC	T	IC	T	IC	T
Fast (PC)	LD	1.5	(21)	1.5	(22)	1.8	(13)	1.7	(13)
	SM	1.9	(17)	1.8	(18)	2.4	(18)	2.3	(18)
Average (AC)	LD	1.5	(17)	1.5	(17)	1.8	(11)	1.7	(11)
	SM	1.9	(16)	1.8	(16)	2.4	(18)	2.3	(17)

Although the HMW animals have the same carcase weight they would be leaner and their loin muscles would be expected to cool more quickly at any carcase weight or in either chilling regime. In contrast they would be younger; the age difference would increase with increasing target carcase weight.

Effects of handling primal cuts (ageing)

Ageing rates Muscles that have shortened excessively, by about 40 per cent, do not age, ie WBPF values do not change with the duration of ageing and they remain tough. Similarly, stretched muscles (eg PM) are very tender at 1 day postmortem and do not age much. There is, thus, an apparent curvilinear relationship between the extent of ageing (reduction in WBPF) and the contraction state of the muscle (Bouton *et al.* 1973). The tenderness of EES muscles with LC does not change much with time (they are already quite tender), and ageing does not influence the connective tissue component of toughness. Therefore, in Table 5, the effect of ageing on the tenderness of a muscle free to shorten (LD) of car-cases chilled PC or AC after EES is shown.

Table 5. The tenderness (IC and T values) of loin (LD) muscles of carcases, of pasture-fed steers of an average mature weight breed, chilled PC or AC, with or without EES, unaged or aged for 4 weeks at 0°C

Carcase weight (kg)	190				320			
	Unaged		Aged		Unaged		Aged	
	IC	T	IC	T	IC	T	IC	T
Fast (PC) (NES)	1.5	(21)	1.5	(14)	1.8	(13)	1.8	(11)
Average (AC) (NES)	1.5	(17)	1.5	(11)	1.8	(12)	1.8	(10)
Stimulated (EES)	1.5	(9)	1.5	(8)	1.8	(10)	1.8	(10)

Effects of preslaughter stress

Preslaughter stress influences meat tenderness by affecting the final or ultimate pH of the muscles. Ultimate pH has a marked effect on tenderness, particularly the myofibrillar component of toughness. For example, as the ultimate pH of beef LD muscles increases from 5.4 to 6.0 the meat goes from being tender to being very tough; WBPF values increase from 4 to 15 kg. The influence of ultimate pH on the tenderness of the LD muscles of carcases treated as described in Table 5 is shown in Table 6; two ultimate pH values (5.4 or 6.0) are considered and the average chilling regime is excluded.

Table 6. The tenderness (IC [kg] and T values) of loin muscles with ultimate pH values of 5.4 or 6.0 of carcases of pasture-fed steers, of an average mature weight breed, chilled fast (PC) with or without EES, and unaged or aged for 4 weeks at 0°C

Carcase Weight (kg)		190				320			
	Ultimate pH	Unaged		Aged		Unaged		Aged	
		IC	T	IC	T	IC	T	IC	T
Fast chill (PC) (NES)	5.4	1.5	(21)	1.5	(14)	1.8	(13)	1.8	(11)
	6.0	1.5	(24)	1.5	(21)	1.8	(18)	1.8	(16)
Fast chill (PC) (EES)	5.4	1.5	(9)	1.5	(8)	1.8	(10)	1.8	(10)
	6.0	1.5	(24)	1.5	(21)	1.8	(18)	1.8	(16)

DISCUSSION

The model presented is only a conceptual model and has not been validated. The tenderness of muscles free to shorten can vary more than that of muscles that are restrained from shortening. In muscles free to shorten, preslaughter stress, car-case processing and meat ageing conditions can have large effects on tenderness over and above the effects of connective tissue toughness. The tenderness of muscles restrained from shortening is largely dependent on the amount and nature of their connective tissue; as a result their tenderness is primarily dependent on animal age. These influences on tenderness mean that, depending on processing conditions, some muscles get tougher with increasing animal age, others become more tender and the toughness of others changes little (Bouton *et al.* 1978).

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