J. agric. Sci., Camb. (1976), **86**, 435–442
Printed in Great Britain

Muscle weight distribution in four breeds of cattle with reference to individual muscles, anatomical groups and wholesale cuts

BY D. D. CHARLES AND E. R. JOHNSON*
Veterinary School, University of Queensland, St Lucia, Australia

(*Received* 13 *May* 1975)

SUMMARY

One side of each of 51 carcasses of Hereford, Angus, Friesian and Charolais cross-bred steers was dissected and the weights of individual muscles and total carcass muscle were obtained. The percentage distribution of total carcass muscle weight in muscles and in standard groups of muscles was determined. In addition, the percentage distribution of total carcass muscle weight in wholesale cuts was determined from the weights of whole and part muscles specified as comprising the respective cuts.

Minor breed differences only were found in muscle weight distribution among muscles, groups of muscles and wholesale cuts. Similarity of muscle weight distribution in the different types of carcasses studied shows that carcass shape is not associated with differences in the distribution of muscle weight in wholesale cuts.

INTRODUCTION

Distribution of muscle weight in beef carcasses is similar among cattle differing in conformation (Butterfield, 1963*b*). Conflicting views are evident in the literature, however, regarding the role of conformation on differences in commercial yield among carcasses. Martin, Walters & Whiteman (1966) found that although total muscle was relatively constant over a range of carcass shapes there were consistent and significant advantages for 'Choice' conformation in the yield of thick high value muscles. However, Hedrick, Stringer & Krause (1969) reported that 'Choice' conformation carcasses had a higher yield of thin retail cuts and a lower yield of thick muscle cuts than carcasses of 'Good' conformation. Cole *et al.* (1964) found differences in yield associated with breed but emphasized the role of fat in depressing the percentage of carcass muscle and yield of untrimmed wholesale cuts. Hedrick *et al.* (1969) also reported that differences in fat thickness had a more consistent effect on weight and percentage of retail cuts than conformation. Carroll, Clegg & Kroger (1964) reported a positive association between carcass conformation and percentage yield of retail and boneless cuts, but Branaman *et al.* (1962) observed no advantage of beef type carcasses for carcass cut-out. Tyler *et al.* (1964) also found no significant difference in yield of boneless retail cuts from carcasses varying widely in conformation. The conflict in the literature may result from different cutting procedures or differing proportions of muscle and fat in cuts.

Excess fat is trimmed from commercial boneless beef cuts to produce a cut with sufficient fat to meet market requirements. Superior yield of a particular cut or cuts infers that a higher percentage of the weight of carcass muscle is present in the cut or cuts. There is a need to establish if muscle weight distribution differences among carcasses are responsible for differences in yield of beef cuts.

In this study carcasses of four breeds of cattle varying widely in conformation were dissected to determine the muscle weight distribution of (*a*) individual muscles, (*b*) standard muscle groups, (*c*) wholesale cuts.

MATERIALS AND METHODS

Fifty-one Hereford, Angus, Friesian, Charolais × Friesian and Charolais × Australian Illawara Shorthorn steers were fed a pelleted diet (12 % crude protein) *ad libitum* from approximately 8 months old. Age at slaughter, live weight and carcass details are shown in Table 1.

After slaughter the carcasses were chilled for 72 h at 4 °C and then each right side was totally dissected into its 96 individual muscles using the technique described by Butterfield (1963*a*). With this method each muscle is trimmed of fat, coarse

* Present address: School of Veterinary Studies, Murdoch University, Murdoch, Western Australia.

Table 1. *Live weight and carcass details of 51 steers used to study muscle distribution*

Breed	Number	Slaughter age range (days)	Mean slaughter age (days)	Mean live weight at slaughter (kg)	Mean carcass weight (kg)	Carcass composition: Muscle (%)	Bone (%)	Fat (%)
Hereford	11	360–630	510	332	189	58·7	14·9	23·9
Angus	20	250–1260	510	337	192	57·7	15·6	24·7
Friesian	10	450–630	540	424	247	59·0	17·4	21·4
Charolais cross-breds	10	360–540	450	445	271	59·0	14·0	24·9

Table 2. *Description of standard muscle groups*

Standard muscle group (SMG)	No. of muscles	Description	Approximate wholesale cuts
1	21	Proximal pelvic limb	Inside, outside, knuckle, rump
2	10	Distal pelvic limb	Shank
3	8	Surrounding spinal column	Loin, cube roll, tenderloin
4	8	Abdominal wall	Thin flank
5	13	Proximal thoracic limb	Shoulder, blade
6	10	Distal thoracic limb	Shin
7	5	Thorax to thoracic limb	Set of ribs, brisket
8	5	Neck to thoracic limb	Chuck
9	16	Intrinsic of neck and thorax	Chuck

connective tissue and tendon at the musculotendinous junction.

Individual muscle weights and the weight of each standard muscle group (Butterfield, 1963*b*) were obtained directly by carcass dissection. Muscle weights in the wholesale cuts were determined from the muscles and proportions of muscles in each cut, as specified by Butterfield & May (1966). All weights are expressed as a percentage of total carcass muscle. The nomenclature used for muscles is in accordance with the World Association of Veterinary Anatomists (N.A.V. 1968).

A brief description of the standard muscle groups (SMG) and the wholesale cuts to which they belong is set out in Table 2. Breed differences between individual muscles, standard muscle groups and the muscle in wholesale cuts (all expressed as percentage of total muscle) were tested by analyses of variance and significant differences are shown.

RESULTS

Individual muscles

Breed differences in the weight of each muscle in the carcass relative to side muscle weight were not significant in 74 of the 96 muscles (Table 3). Of the 22 muscles (constituting about 36 % of total muscle weight) which were significantly different between breeds, nine were hindquarter muscles and 13 were from the forequarter. Each of the four breeds had muscles which were relatively heavier than the same muscles in the other breeds but the differences were quite small. M. biceps femoris, for example, showed a range of 7·08 % to 7·45 % of total muscle weight among breeds while m. semimembranosus ranged from 5·06 % to 5·49 %. Consistent differences in favour of a breed were not obvious in either the fore or hindquarter. The low standard errors showed that individual muscle weight distribution was remarkably consistent among breeds despite the wide variation in carcass weight and conformation.

It is possible that small and non-significant differences between individual muscles, together with the significant differences evident in 22 muscles, could summate to larger differences between groups of muscles and contribute to the difference in conformation among breeds. Therefore, the distribution of muscle weight in the standard muscle groups (Table 4) and in wholesale cuts (Table 5) was examined for breed differences.

Standard muscle groups

There were no significant breed differences for seven (SMG 1–3, 6–9) of the nine muscle groups (Table 4). The Friesians had less SMG 4 than the Angus whilst their proportion of SMG 5 was greater than in the Hereford, Angus or Charolais. All differences, however, were minor. There were no significant breed differences for SMG 1+3+5. These groups contain the higher-priced meat cuts so that any variation in them as a whole could be of economic importance.

Table 3. *Muscle percentage of total muscle weight in Hereford, Angus, Friesian and Charolais cross-bred steer carcasses*

Muscle	Standard muscle group no.	Hereford (H) $n = 11$ Percentage of total muscle	S.E.	Angus (A) $n = 20$ Percentage of total muscle	S.E.	Friesian (F) $n = 10$ Percentage of total muscle	S.E.	Charolais cross-breds (CH×) $n = 10$ Percentage of total muscle	S.E.	Significance
M. cutaneous trunci	4	1·77	0·062	1·71	0·046	1·56	0·065	1·67	0·065	NS
M. *tensor fasciae latae*	1	1·30	0·026	1·27	0·020	1·33	0·028	1·34	0·028	NS
M. biceps femoris	1	7·23	0·089	7·45	0·066	7·26	0·094	7·08	0·094	A > CH× *
M. glutaeus medius	1	3·77	0·061	3·72	0·046	3·75	0·064	3·94	0·064	NS
M. vastus lateralis	1	2·44	0·046	2·46	0·034	2·51	0·048	2·41	0·048	NS
M. glutaeus accessorius	1	0·28	0·010	0·29	0·007	0·29	0·011	0·25	0·011	A > CH× *
M. glutaeus profundus	1	0·38	0·010	0·36	0·007	0·38	0·010	0·38	0·010	NS
M. rectus femoris	1	2·07	0·038	2·08	0·028	2·23	0·040	2·01	0·040	F > A*, CH× **
M. semitendinosus	1	2·39	0·050	2·58	0·037	2·49	0·053	2·36	0·053	A > CH× *
M. gracilis	1	1·31	0·044	1·38	0·033	1·37	0·046	1·36	0·046	NS
M. semimembranosus	1	5·06	0·097	5·25	0·072	5·13	0·102	5·49	0·102	CH× > H *
M. adductor	1	1·78	0·052	1·85	0·039	1·80	0·055	1·90	0·055	NS
M. triceps surae (Mm. gastrocnemius et soleus)	2	2·00	0·068	2·11	0·050	1·98	0·071	1·87	0·071	NS
M. flexor digitorum superficialis	2	0·45	0·017	0·47	0·013	0·47	0·018	0·42	0·018	NS
M. pectineus	1	0·60	0·019	0·55	0·014	0·54	0·020	0·56	0·020	NS
M. sartorius	1	0·33	0·018	0·36	0·013	0·37	0·018	0·35	0·018	NS
M. gemellus	1	0·08	0·004	0·08	0·003	0·07	0·005	0·07	0·005	H > CH× *
M. quadratus femoris	1	0·07	0·004	0·06	0·003	0·06	0·003	0·06	0·004	H > F *
Mm. obturatorii internus et externus	1	0·53	0·014	0·53	0·011	0·60	0·016	0·54	0·016	F > H*, CH× *, A**
M. vastus medialis	1	0·73	0·018	0·77	0·014	0·77	0·019	0·73	0·019	NS
M. vastus intermedius	1	0·71	0·030	0·69	0·022	0·79	0·031	0·76	0·031	NS
M. articularis genu	1	0·08	0·007	0·06	0·005	0·07	0·007	0·07	0·007	NS
Extensor group	2	0·71	0·021	0·64	0·015	0·66	0·022	0·68	0·022	NS
M. peronaeus longus	2	0·11	0·005	0·11	0·004	0·10	0·005	0·11	0·005	NS
M. extensor digitorum lateralis	2	0·24	0·008	0·22	0·006	0·21	0·009	0·21	0·009	NS
M. tibialis cranialis	2	0·13	0·015	0·14	0·011	0·12	0·016	0·12	0·016	NS
M. tibialis caudalis	2	0·11	0·005	0·09	0·004	0·11	0·006	0·11	0·006	F > A *
M. popliteus	2	0·29	0·010	0·27	0·007	0·28	0·011	0·28	0·011	NS
M. flexor digitorum longus	2	0·20	0·008	0·21	0·006	0·18	0·009	0·19	0·009	NS
M. flexor hallucis longus	2	0·62	0·019	0·66	0·014	0·63	0·020	0·59	0·020	NS
M. psoas minor	3	0·32	0·023	0·29	0·017	0·30	0·024	0·29	0·024	NS
M. psoas major	3	1·57	0·059	1·55	0·043	1·60	0·061	1·59	0·061	NS
M. quadratus lumborum	3	0·16	0·008	0·16	0·006	0·17	0·008	0·16	0·008	NS
M. iliacus	1	0·87	0·026	0·82	0·019	0·91	0·027	0·91	0·027	NS
M. latissimus dorsi	7	2·26	0·039	2·17	0·029	2·19	0·041	2·21	0·041	NS

Table 3 (*cont.*)

Muscle	Standard muscle group no.	Hereford (H) $n = 11$ Percentage of total muscle	Hereford (H) S.E.	Angus (A) $n = 20$ Percentage of total muscle	Angus (A) S.E.	Friesian (F) $n = 10$ Percentage of total muscle	Friesian (F) S.E.	Charolais cross-breds (CH×) $n = 10$ Percentage of total muscle	Charolais cross-breds (CH×) S.E.	Significance
M. serratus dorsalis caudalis	4	0·15	0·009	0·17	0·007	0·15	0·009	0·16	0·009	NS
M. iliocostalis	3	0·47	0·015	0·44	0·011	0·47	0·016	0·45	0·016	NS
Mm. longissimi thoracis et lumborum	3	6·97	0·182	6·59	0·135	6·84	0·191	6·71	0·191	NS
Mm. spinalis	3	1·80	0·051	1·67	0·038	1·73	0·054	1·74	0·054	NS
Mm. multifidi thoracis et lumborum	3	0·93	0·052	0·90	0·039	1·02	0·055	0·92	0·055	NS
M. obliquus externus abdominis	4	2·29	0·080	2·44	0·060	2·27	0·084	2·25	0·084	NS
M. retractor costae	4	0·05	0·007	0·05	0·005	0·04	0·007	0·04	0·007	NS
M. obliquus internus abdominis	4	1·82	0·048	1·95	0·036	1·85	0·050	1·90	0·050	NS
M. transversus abdominis	4	1·20	0·047	1·28	0·035	1·24	0·049	1·24	0·049	NS
M. rectus abdominis	4	2·29	0·076	2·19	0·057	2·27	0·081	2·37	0·081	NS
M. diaphragma, pars costalis	4	0·54	0·054	0·54	0·040	0·51	0·057	0·62	0·057	NS
Mm. sacrococcygis	1	0·12	0·007	0·11	0·006	0·11	0·009	0·13	0·009	NS
Mm. intercostales externi et interni	9	2·78	0·078	2·62	0·058	2·77	0·820	2·74	0·082	NS
M. trapezius, pars cervicalis	8	0·53	0·026	0·47	0·020	0·49	0·028	0·50	0·028	NS
M. trapezius, pars thoracica	7	0·73	0·031	0·69	0·023	0·65	0·032	0·64	0·032	NS
M. deltoideus	5	0·52	0·011	0·47	0·008	0·47	0·012	0·49	0·012	H > A**, F*
M. infraspinatus	5	2·02	0·052	2·13	0·039	2·27	0·055	1·98	0·055	F > H*, CH× **
M. triceps brachii (caput lateralis)	5	0·68	0·020	0·67	0·014	0·68	0·021	0·65	0·021	NS
M. teres minor	5	0·20	0·006	0·18	0·004	0·19	0·006	0·17	0·006	H > CH× *
M. triceps brachii (caput longum)	5	3·14	0·043	3·20	0·032	3·12	0·045	2·94	0·045	H*, A*** > CH×
M. tensor fasciae antibrachii	5	0·15	0·008	0·16	0·006	0·14	0·008	0·14	0·008	NS
M. extensor carpi radialis	6	0·74	0·017	0·71	0·013	0·74	0·018	0·70	0·018	NS
M. extensor digitorum communis	6	0·20	0·008	0·20	0·006	0·20	0·009	0·22	0·009	NS
M. extensor digitorum lateralis	6	0·14	0·005	0·13	0·004	0·12	0·005	0·13	0·005	NS
M. extensor carpi ulnaris	6	0·30	0·013	0·27	0·009	0·29	0·013	0·29	0·013	NS
M. abductor pollicis longus	6	0·30	0·002	0·03	0·001	0·03	0·002	0·03	0·002	NS
M. omotransversarius	8	0·55	0·024	0·51	0·018	0·51	0·025	0·55	0·025	NS
Mm. rhomboidii thoracis et cervicis	8	1·23	0·056	1·22	0·041	1·20	0·059	1·24	0·059	NS
M. serratus ventralis cervicis	8	3·10	0·062	3·03	0·046	3·12	0·065	2·88	0·065	NS
M. serratus ventralis thoracis	7	1·50	0·046	1·56	0·034	1·51	0·049	1·46	0·049	NS
M. pectorales profundi	7	3·91	0·067	3·73	0·050	3·62	0·070	3·90	0·070	H > F*
M. pectorales superficiales	7	1·52	0·059	1·49	0·043	1·57	0·061	1·76	0·061	CH× > A**
M. supraspinatus	5	1·54	0·023	1·53	0·017	1·64	0·024	1·53	0·024	F > H*, CH× *, A**
M. biceps brachii	5	0·60	0·013	0·62	0·010	0·66	0·014	0·60	0·014	F > H*
M. teres major	5	0·43	0·014	0·41	0·010	0·43	0·014	0·43	0·014	NS
M. coracobrachialis	5	0·13	0·005	0·12	0·003	0·13	0·005	0·13	0·005	NS
M. subscapularis	5	1·11	0·064	1·03	0·047	1·18	0·067	1·08	0·067	NS

Table 3 (*cont.*)

Muscle	Standard muscle group no.	Hereford (H) $n = 11$ Percentage of total muscle	S.E.	Angus (A) $n = 20$ Percentage of total muscle	S.E.	Friesian (F) $n = 10$ Percentage of total muscle	S.E.	Charolais cross-breds (CH×) $n = 10$ Percentage of total muscle	S.E.	Significance
M. brachialis	5	0·46	0·009	0·44	0·007	0·46	0·009	0·43	0·009	NS
M. brachiocephalicus	8	1·54	0·054	1·39	0·040	1·42	0·057	1·54	0·057	NS
M. triceps brachii (caput mediale)	5	0·10	0·006	0·10	0·005	0·10	0·007	0·10	0·007	NS
M. flexor carpi radialis	6	0·12	0·005	0·10	0·004	0·11	0·005	0·11	0·005	NS
M. flexor carpi ulnaris	6	0·14	0·005	0·13	0·003	0·12	0·005	0·13	0·005	NS
M. flexor digitorum superficialis	6	0·32	0·011	0·33	0·008	0·34	0·011	0·30	0·011	NS
M. flexor digitorum profundus	6	0·57	0·027	0·65	0·020	0·61	0·028	0·58	0·028	NS
M. anconaeus	6	0·10	0·005	0·10	0·004	0·10	0·006	0·10	0·006	NS
M. serratus dorsalis cranialis	9	0·13	0·007	0·13	0·005	0·13	0·007	0·11	0·007	NS
M. scalenus dorsalis	9	0·23	0·013	0·27	0·010	0·25	0·014	0·21	0·014	A > CH×**
M. omohyoideus	9	0·02	0·004	0·02	0·003	0·02	0·005	0·03	0·005	NS
M. longissimus cervicis	3	0·38	0·016	0·39	0·012	0·35	0·017	0·35	0·017	NS
M. splenius	9	0·69	0·042	0·74	0·031	0·68	0·044	0·65	0·044	NS
M. scalenus ventralis	9	0·45	0·016	0·43	0·012	0·38	0·017	0·48	0·017	CH× > F**
M. longus capitis	9	0·19	0·013	0·18	0·009	0·18	0·013	0·14	0·013	NS
Mm. longissimi capitis et atlantis	9	0·29	0·015	0·31	0·011	0·31	0·016	0·30	0·016	NS
Mm. intertransversarii cervici	9	0·89	0·034	0·87	0·025	0·94	0·035	0·87	0·035	NS
M. semispinalis capitis	9	1·63	0·031	1·72	0·023	1·61	0·033	1·58	0·033	A > CH×*
M. rectus capitis dorsalis major	9	0·12	0·009	0·12	0·006	0·11	0·009	0·16	0·009	CH× > H**, A**, F**
M. obliquus capitis caudalis	9	0·34	0·011	0·32	0·008	0·34	0·009	0·34	0·009	NS
M. rectus thoracis	9	0·13	0·004	0·12	0·003	0·11	0·005	0·10	0·005	H**, A* > CH×
M. transversus thoracis	9	0·22	0·009	0·23	0·007	0·23	0·010	0·21	0·010	NS
M. longus colli	9	0·70	0·029	0·71	0·022	0·81	0·030	0·78	0·030	NS
Mm. multifidi cervicis	9	0·27	0·012	0·27	0·009	0·27	0·012	0·30	0·012	NS

* $P > 0{\cdot}05$; ** $P > 0{\cdot}01$; *** $P > 0{\cdot}001$; NS, $P > 0{\cdot}05$.

Table 4. *Percentage of total carcass muscle in standard muscle groups of Hereford, Angus, Friesian and Charolais cross-bred steer carcasses*

Standard muscle group	Percentage of total muscle: Hereford (H), $n = 11$	Angus (A), $n = 20$	Friesian (F), $n = 10$	Charolais cross-breds (CH×) $n = 10$	Significance
1	32·15	32·74	32·81	32·59	NS
2	4·84	4·89	4·73	4·58	NS
3	12·61	12·32	12·44	12·49	NS
4	10·10	10·50	9·86	10·24	A > F*
5	11·13	11·13	11·46	10·65	F > H*, A*, CH×**
6	2·69	2·65	2·66	2·58	NS
7	9·91	9·62	9·53	9·98	NS
8	6·95	6·59	6·84	6·71	NS
9	9·05	9·05	9·13	8·98	NS
Groups 1+3+5	55·89	56·19	56·71	55·73	NS

* $P < 0·05$; ** $P < 0·01$; NS, $P > 0·05$.

Table 5. *Percentage of total carcass muscle in wholesale cuts and quarters of Hereford, Angus, Friesian and Charolais cross-bred steer carcasses*

Cut	Percentage of total muscle: Hereford (H) $n = 11$	Angus (A) $n = 20$	Friesian (F) $n = 10$	Charolais cross-breds (CH×) $n = 10$	Significance
Loin	5·48	5·38	5·43	5·43	NS
Rump	6·57	6·51	6·55	6·72	CH× > A*
Inside	8·74	9·02	8·84	9·32	CH× > H*
Outside	10·69	11·19	10·89	10·39	A > H* A > CH×***
Knuckle	6·32	6·25	6·56	6·19	NS
Tenderloin	2·67	2·63	2·71	2·70	NS
Flank	6·06	5·05	4·79	6·10	H > A*** H > F*** CH× > A*** CH× > F***
Set of ribs	8·01	7·66	7·82	7·79	H > A*
Chuck and blade	26·44	26·20	26·64	25·58	NS
Brisket	9·64	9·56	9·41	9·86	NS
Hindquarter	52·84	53·87	53·01	53·13	NS
Forequarter	47·16	46·13	46·99	46·87	NS

* $P < 0·05$; *** $P < 0·001$; NS, $P > 0·05$.

Wholesale cuts

Minor breed differences only were found in the distribution of muscle weight in wholesale cuts. There were significant breed differences in four of the seven wholesale cuts in the hindquarter and one of the three cuts in the forequarter. However, with the exception of the flank, differences between cuts were considerably less than 1 % of total muscle and therefore were probably of no real commercial significance. In addition, the nett result of the differences did not favour any one breed. A summation of percentage muscle in the cuts cancelled out the minor differences, leaving no significant breed differences in percentage muscle in either the fore or hindquarter.

DISCUSSION

The results obtained for the proportion of total carcass muscle distributed as individual muscles and standard muscle groups support the sions of Butterfield (1963*b*), Butterfield & Johnson (1971), Kellaway (1971) and Kauffman *et al.* (1973) that muscle-weight distribution does not vary greatly between breeds.

Most studies of the association between carcass conformation and carcass yield are based on the weights of commercial beef cuts (Carpenter *et al.* 1961; Carroll *et al.* 1964; Cole *et al.* 1964; Tyler *et al.* 1964; Martin *et al.* 1966). A disadvantage of the commercial cut technique is that the proportions of muscle and fat in each cut are unknown. In addition it is extremely difficult to replicate anatomical boundaries of cuts, or the prescribed trim.

The use of Butterfield & May's (1966) specifications of the muscles and proportions of muscles present in each wholesale boneless cut enables the distribution of muscle weight in the cuts to be related directly to basic dissection data. The finding that there were minor between-breed differences only in the proportion of total muscle in any wholesale cut indicates that differences in commercial yield must be due to fat and not to muscle. At a certain stage of maturity in cattle, fat grows with a high impetus (Suess, Tyler & Brungardt, 1969; Waldman, Tyler & Brungardt, 1971; Johnson, 1972) and its deposition is likely to cause differences in animal or carcass shape (Callow, 1961; Butterfield, 1966). Mukhoty & Berg (1973) found small but significant differences between Friesian and Hereford steer carcasses in SMG 4 and 9. They found that the Herefords had significantly more muscle in SMG 9 and less in SMG 4. In the present study (Table 3) there was no significant difference in SMG 4 or SMG 9 between the two breeds but the Herefords had slightly more muscle in SMG 4. The minor differences in results between the two studies may indicate very small true breed differences or it may simply reflect allometric growth differences within the musculature brought about by the stage of growth reached by two breeds of cattle of differing maturity type.

Results of this study indicate that carcass conformation is not associated with a superior yield or distribution of carcass lean.

This study was assisted by a grant from the Australian Meat Research Committee. We thank Mrs P. Macdonald, Mr D. A. Baker and Mr M. A. Fisher for valuable technical assistance and Mr R. Sheard for advice on statistical methods.

REFERENCES

Branaman, G. A., Pearson, A. M., Magee, W. T., Griswold, R. M. & Brown, G. A. (1962). Comparison of the cutability and eatability of beef- and dairy-type cattle. *Journal of Animal Science* **21**, 321–6.

Butterfield, R. M. (1963*a*). Estimation of carcase composition: the anatomical approach. In *Symposium on Carcase Composition and Appraisal of Meat Animals* (ed. D. E. Tribe), paper 4–1. Melbourne, Australia: C.S.I.R.O.

Butterfield, R. M. (1963*b*). Relative growth of the musculature of the ox. In *Symposium on Carcase Composition and Appraisal of Meat Animals* (ed. D. E. Tribe), paper 7–1. Melbourne, Australia: C.S.I.R.O.

Butterfield, R. M. (1966). The effect of nutritional stress and recovery on the body composition of cattle. *Research in Veterinary Science* **7**, 168–79.

Butterfield, R. M. & May, N. D. S. (1966). *Muscles of the Ox.* University of Queensland Press.

Butterfield, R. M. & Johnson, E. R. (1971). A study of growth in calves. II. Relative growth in muscles. *Journal of Agricultural Science, Cambridge* **76**, 457–8.

Callow, E. H. (1961). Comparative studies of meat. VII. A comparison between Hereford, Dairy Shorthorn and Friesian steers on four levels of nutrition. *Journal of Agricultural Science, Cambridge* **56**, 265–82.

Carpenter, J. W., Palmer, A. Z., Kirk, W. G., Peacock, F. M. & Koger, M. (1961). Slaughter and carcass characteristics of Brahman and Brahman-Shorthorn crossbred steers. *Journal of Animal Science* **20**, 336–40.

Carroll, F. D., Clegg, M. T. & Kroger, D. (1964) Carcass characteristics of Holstein and Hereford steers. *Journal of Agricultural Science, Cambridge* **62**, 1–6.

Cole, J. W., Ramsey, C. B., Hobbs, C. S. & Temple, R.S. (1964). Effect of type and breed of British, Zebu, and dairy cattle on production, palatability, and composition. III. Percent wholesale cuts and yield of edible portion as determined by physical and chemical analysis. *Journal of Animal Science* **23**, 71–7.

Hedrick, H. B., Stringer, W. C. & Krause, G. F. (1969). Retail yield comparison of average Good and average Choice conformation beef carcasses. *Journal of Animal Science* **28**, 187–91.

Johnson, E. R. (1972). Ph.D. Thesis, University of Queensland.

Kauffman, R. G., Grummer, R. H., Smith, R. E., Long, R. A. & Shook, G. (1973). Does live-animal and carcass shape influence gross composition? *Journal of Animal Science* **37**, 1112–19.

Kellaway, R. C. (1971). Breeds and breeding of beef cattle. Part 1. Production and fitness characters of straightbred cattle. *Australian Meat Research Committee*, review no. 1, 1–17.

Martin, E. L., Walters, L. E. & Whiteman, J. V. (1966). Association of beef carcass conformation with thick and thin muscle yields. *Journal of Animal Science* **25**, 682–7.

Mukhoty, H. & Berg, R. T. (1973). Influence of breed and sex on muscle weight distribution of cattle. *Journal of Agricultural Science, Cambridge* **81**, 317–26.

Nomina Anatomica Veterinaria (N.A.V. 1968). International Committee on Veterinary Anatomical Nomenclature of the World Association of Veterinary Anatomists. Distributed Department of Anatomy, New York State Veterinary College, Ithaca, N.Y.

Suess, G. G., Tyler, W. J. & Brungardt, V. H. (1969). Influence of weight and nutrition upon muscle growth and intramuscular fat deposition in Holstein steers. *Journal of Animal Science* **29**, 410–16.

Tyler, W. E., Hallett, D. K., Murphey, C. E., Hoke, K. E. & Breidenstein, B. C. (1964). Effects of variation in conformation on cutability and palatability of beef. *Journal of Animal Science* **23**, 864 (Abstract).

Waldman, R. C., Tyler, W. J. & Brungardt, V. H. (1971). Changes in the carcass composition of Holstein steers associated with ration energy levels and growth. *Journal of Animal Science* **32**, 611–19.